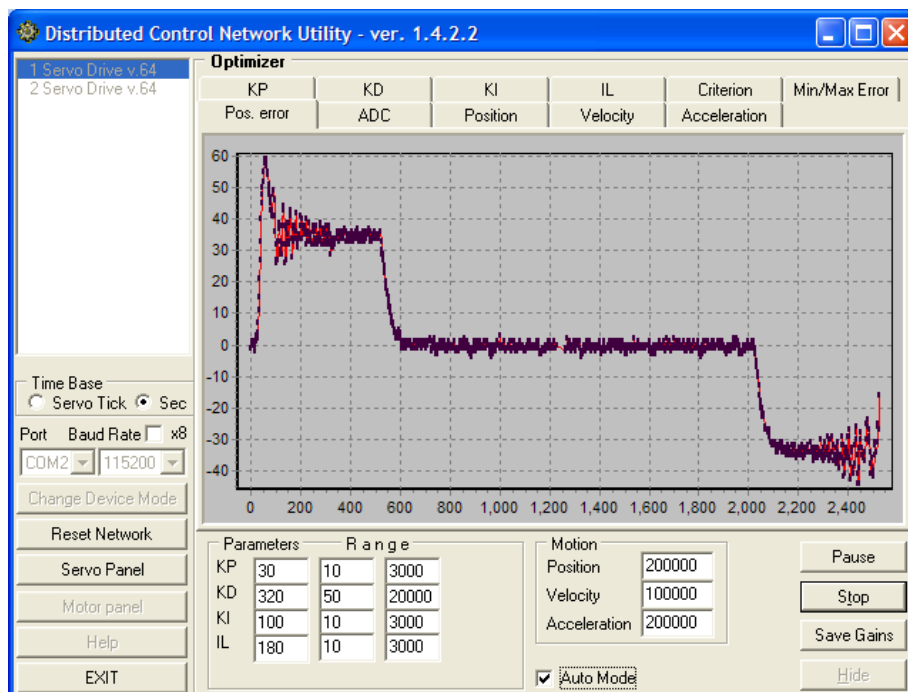


FLASHCUT CNC

Control Made Simple

Servo System Setup



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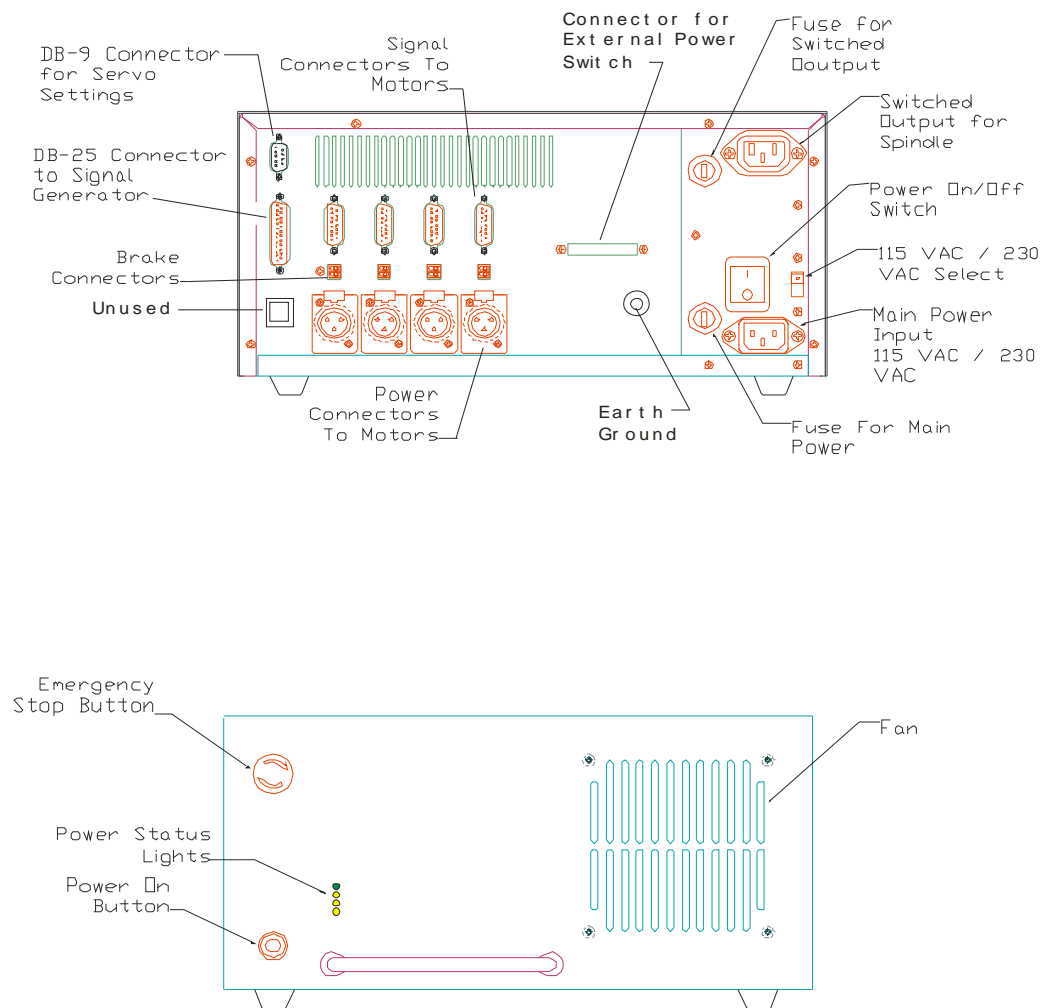
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1. Cable Connections



Power On/Off Switch – This is the main power switch for the unit.

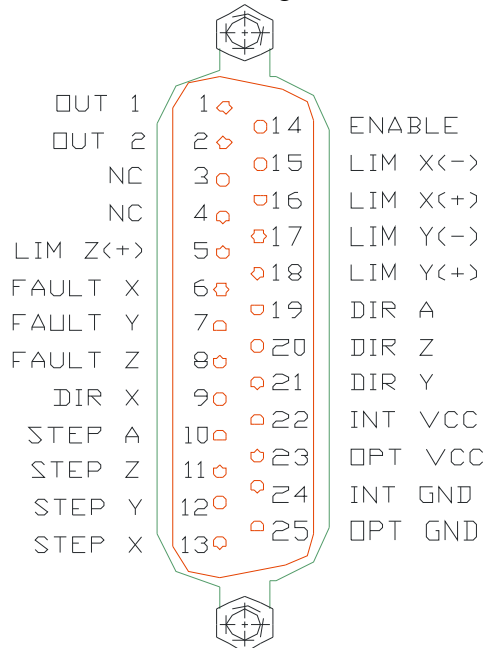
115 VAC / 230 VAC Select – This switch allows you to choose the type of power going into the Main Power Input.

DB-9 Connector for Servo Settings – This connects to an open serial port on the PC using a 9-pin serial cable. The servo settings are factory preset for your motor type. There is no need to connect this cable unless you are changing the settings using the “DCN” Program.

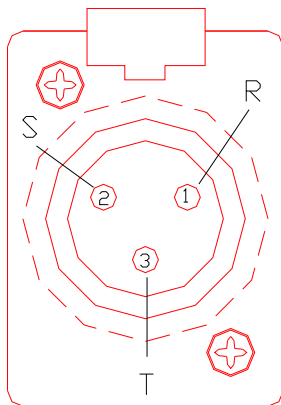
Main Power Input – This uses a standard power cord connected to 115VAC or 230VAC. Make sure the 115VAC / 230VAC Selector switch is set properly for your power.

Fuse for Main Power – In here is a 6 A fuse. This should be no more than 7A. You can use a coin to open it. If you have chronic fuse problems, please call FlashCut for assistance. Note that this fuse should be sized for your total current draw for each motor axis. For example, if you have a 4 axis system with 200 W servo motors on each axis, you will need $4 \times 200W / 115V = 7A$.

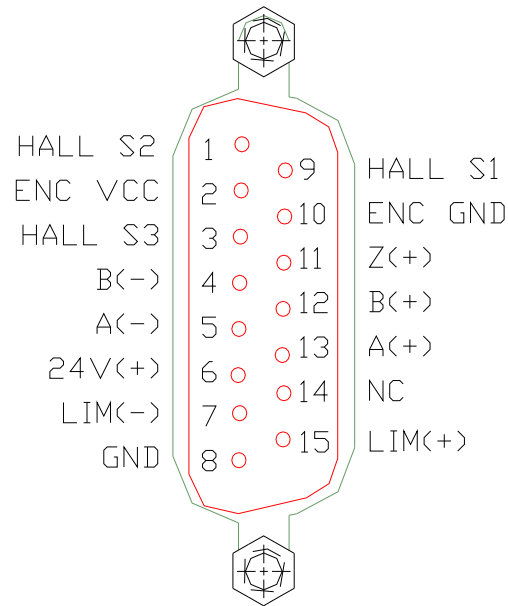
DB-25 Connector to Signal Generator – This uses a DB-25 Cable to receive signals from the FlashCut CNC Signal Generator.



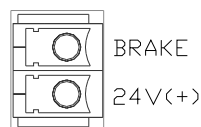
Power Connector to Motors –The power lines for motors 1-4 plug into these female audio connectors. The motor lines 1-4 are correlated to X, Y, Z and A axis in the motor signal settings in FlashCut. All four motor connectors are available only if you ordered the 4-Axis version. If you did not order a 4 axis system, a dummy plug is placed in the 4th axis position.



DB15 Signal Connector to Motors – The encoder and hall sensor signal lines and in some cases the limit switch lines for motors 1-4 plug into these female DB15 connectors. The motor lines 1-4 are correlated to X, Y, Z and A axis in the motor signal settings in FlashCut. All four motor connectors are available only if you ordered the 4-Axis version. If you did not order a 4 axis system, a dummy plug is placed in the 4th axis position.



Brake Connector–Ground and 24 Volts are provided to switch on and off a brake connected to your servo motor. A brake is not necessary on all axes and is most commonly found on a Z axis where gravity will pull the axis down when un-powered.



Switched Output Line–This is a 115 or 230 volt output (dependant on how the 115VAC / 230VAC Select switch is set). It is controlled through output line 1 in the FlashCut CNC Software. It is most commonly used to turn a spindle motor on and off. It can also be turned off when the Emergency Stop Button is hit. It can control up to 9Amps, however, the fuse for it is only 6 Amps. A mating connector is provided with the unit.

Fuse for Switched Output– In here is a 6 A fuse. You can use a coin to open it. This can be a maximum of 9A. If you have chronic fuse problems, please call FlashCut for assistance. Note that this fuse should be sized for your device that is connected to this switched output line. For example, if you have a 900W spindle and connected to

115VAC, then the current draw would be $900/115 = 7.8$ amps. This would need at least an 8 or 9 amp fuse.

Power Status Lights—There are four LED lights that indicate the status of the servo drive box.

- 1. The top LED is green when everything is running properly. It is red when the main power of the unit is on, but the unit has not been reset using the Emergency Power button and the Power On button in the front. If it will never go on, then you should check the fuse inside of the unit on the main power board. This fuse is shipped as 10A and if replaced, should be no more than 15A.
- 2. The second LED is on (yellow) if the motor power is OK and off if there is a blown 10A fuse on the power board inside the drive box. Later models have an automatically resettable fuse that resets after 5-10 minutes.
- 3. The third LED is on (yellow) if the E-Stop circuit is closed and off if the E-Stop circuit is open. For the E-Stop circuit to be closed, the red mushroom button on the drive box must be in the “out” position
- 4. The fourth (bottom) LED is on (yellow) if the optional watch dog is OK and off if the watch dog is activated (THIS SHOULD ALWAYS BE ON)

Emergency Stop Button— This “Mushroom” switch needs to be pulled out for the power to be fully on. Depressing this switch will turn the power off to the servo motors and will turn off any device connected to the Switched Output Line. To reset this button, turn the knob clockwise until it clicks up.

Power On Button (Reset Button)—This button resets the unit after the power has been shut off by the Emergency Power Button or the main power switch in the back of the unit.

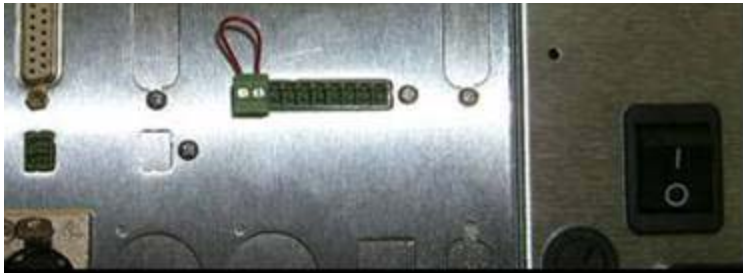
Earth Ground – This is a stud that can be used to electrically connect the chassis to Earth Ground. Note that the chassis is also connected to Earth Ground via the third prong on the main power input.

Connector to External Power Switch—This is a 10-pin Phoenix connector that can be used to connect an external Emergency Stop Button and Power Reset Button. To connect a switch between either one of these, you simply place the switch between the two leads marked A and B. It also has a 24VDC connections for general use.



Pin assignments (from left to right in the photo):

1. Emergency Stop A (+24VDC)
2. Emergency Stop B
3. +24VDC
4. GND for 24VDC
5. Stop (Input)
6. GND
7. Enable (Input)
8. Power Reset Button A
9. Power Reset Button B
10. Shield / GND



If there is no Emergency Stop control cable connected to the machine via pins 1 and 2 then it is necessary to have a jumper installed between pins 1 and 2 as shown.

The mating connectors for this are:

Mfg: Phoenix Contact

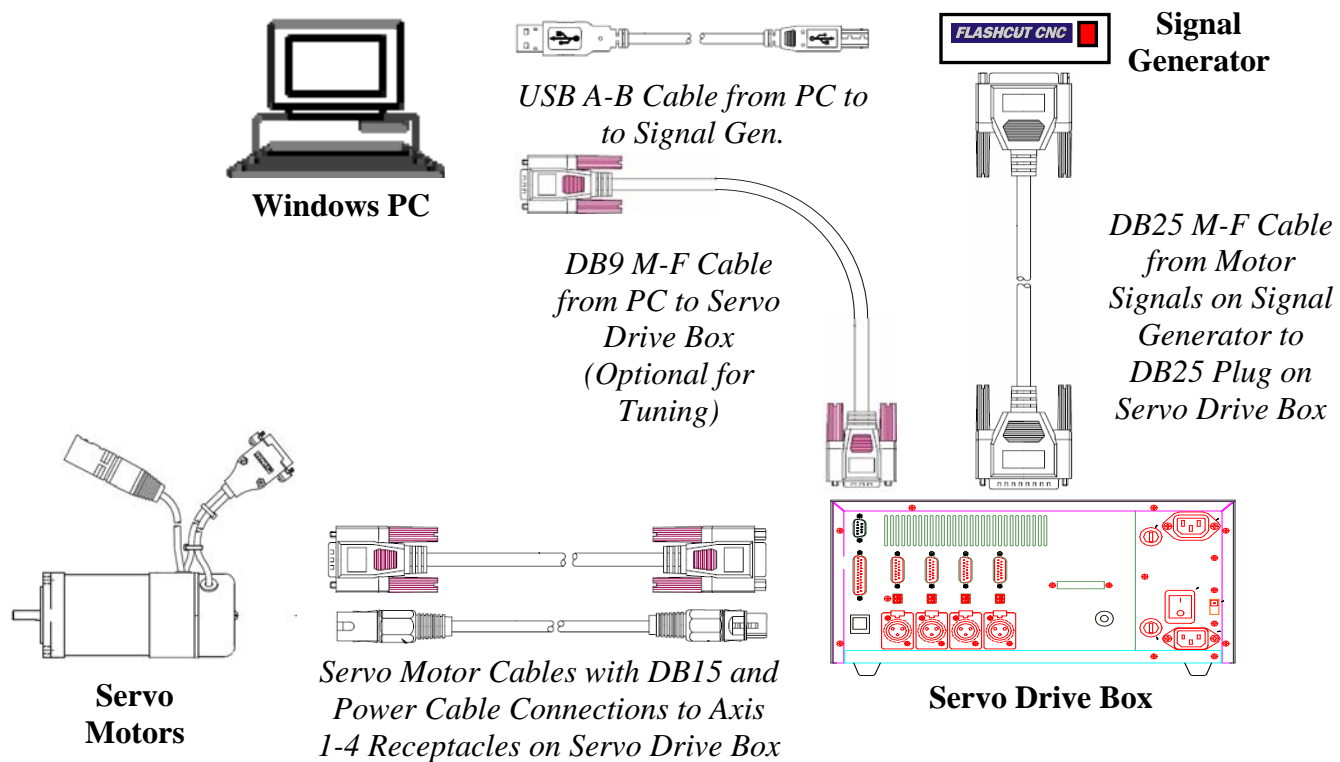
10 pin:

Description: Pluggable Mini Terminal Blocks 3.81mm 10POS PLUG 180DEG
Part Number: 1803659

2 pin:

Description: Pluggable Mini Terminal Blocks 3.81mm 2POS PLUG 180DEG
Part Number: 1803578

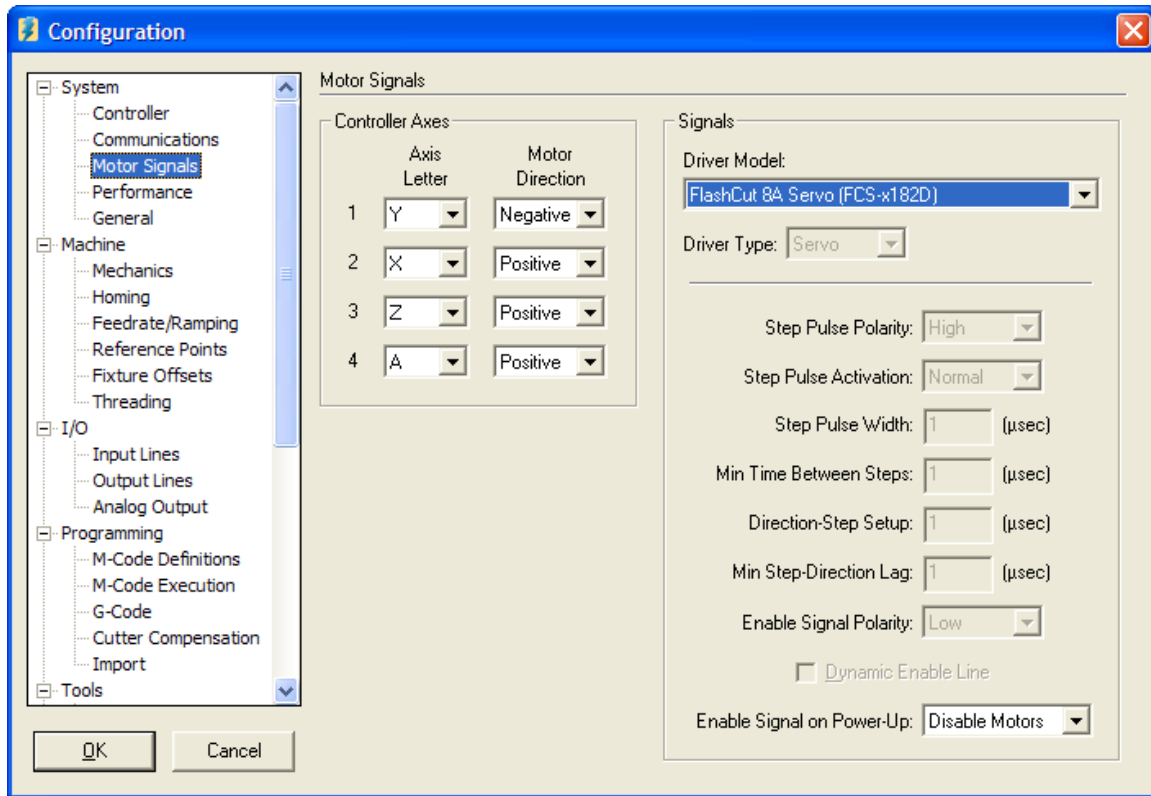
2. System Hook Up Diagram



3. FlashCut Software Settings

Motor Signal Setup:

In FlashCut CNC go to Configuration...System...Motor Signals and choose the appropriate servo box that you have:



Input Lines Setup:

If you overdrive the servomotors, they will get out of position beyond their programmed tolerance. If this occurs a fault signal will be sent from the servo box to the signal generator through one of the above input lines.

This signal is automatically routed to the Signal Generator via the DB-25 cable. There is no need to connect wires to lines 5-8 of the input line connector on the back of the Signal Generator.

Configuration

I/O

- Input Lines (selected)
- Output Lines
- Analog Output

Programming

- M-Code Definitions
- M-Code Execution
- G-Code
- Cutter Compensation
- Import

Tools

- Tool Library
- Tool Change
- Tools in Changer

Sensing

- Tool Length Sensing
- Program Zero Sensing
- Touch Probe

Preferences

- Viewports
- Point List
- Jogging
- Pendant
- Files

Input Lines

Line #	Function	Location	Description	Wiring	Sensing Debounce (inches)
1	Unused	N/A		N.C.	0.0040
2	Unused	N/A		N.C.	0.0040
3	Unused	N/A		N.C.	0.0040
4	Unused	N/A		N.C.	0.0040
5	Safety	N/A	Axis 4 Servo Fault	N.C.	0.0040
6	Safety	N/A	Axis 1 Servo Fault	N.C.	0.0040
7	Safety	N/A	Axis 2 Servo Fault	N.C.	0.0040
8	Safety	N/A	Axis 3 Servo Fault	N.C.	0.0040
9	Unused	N/A		N.C.	0.0040
10	Unused	N/A		N.C.	0.0040
11	Unused	N/A		N.C.	0.0040
12	Unused	N/A		N.C.	0.0040
13	Unused	N/A		N.C.	0.0040
14	Unused	N/A		N.C.	0.0040
15	Unused	N/A		N.C.	0.0040
16	Unused	N/A		N.C.	0.0040

Debounce Factor: 8

Debounce During Motion: 5 (msec)

Debounce When Idle: 0.250 (sec)

Set All Wiring:

Normally Closed

Normally Open

OK Cancel

Please note that if you are using the FlashCut CNC Limit Switch Kit with 5 switches and you have a 4 Axis controller, the Z+ limit switch and the Axis 4 Servo Fault would share the same line. In this case it is best to disconnect the Axis 4 Servo Fault by disconnecting the wire connected to Pin 5 of the DB-25 connector inside of the Servo Drive box.

Also, make sure the wires closing the signals for lines 6, 7 and 8 are cut leaving an open connection. In this case, (and the case where you have a 3 axis controller and limit switches) the input lines should be set up like this:

Configuration

I/O

Input Lines

Line #	Function	Location	Description	Wiring	Sensing Debounce (inches)
1	Home / Limit	X-	X- Home / Limit	N.C.	0.0040
2	Home / Limit	X+	X+ Home / Limit	N.C.	0.0040
3	Home / Limit	Y-	Y- Home / Limit	N.C.	0.0040
4	Home / Limit	Y+	Y+ Home / Limit	N.C.	0.0040
5	Home / Limit	Z+	Z+ Home / Limit	N.C.	0.0040
6	Safety	N/A	Axis 1 Servo Fault	N.C.	0.0040
7	Safety	N/A	Axis 2 Servo Fault	N.C.	0.0040
8	Safety	N/A	Axis 3 Servo Fault	N.C.	0.0040
9	Unused	N/A		N.C.	0.0040
10	Unused	N/A		N.C.	0.0040
11	Unused	N/A		N.C.	0.0040
12	Unused	N/A		N.C.	0.0040
13	Unused	N/A		N.C.	0.0040
14	Unused	N/A		N.C.	0.0040
15	Unused	N/A		N.C.	0.0040
16	Unused	N/A		N.C.	0.0040

Debounce Factor: 8

Debounce During Motion: 5 (msec)

Debounce When Idle: 0.250 (sec)

Set All Wiring: Normally Closed

Normally Open

OK Cancel

4. Signal Generator Settings

For all USB Signal Generators and Serial Port Signal Generators with serial numbers above 102000:

There is no need to configure the signal strength of the motor signals or output signals.

For Serial Port Signal Generators with Serial Numbers below 102000:

RP4 and RP6

There are two resistors in the Signal Generator that control the strength of the Step and Direction signals interfacing with the driver box. These two resistors (RP4 and RP6) may need to be changed to 4.7Kohm for proper use with the servo driver box. To change these resistors:

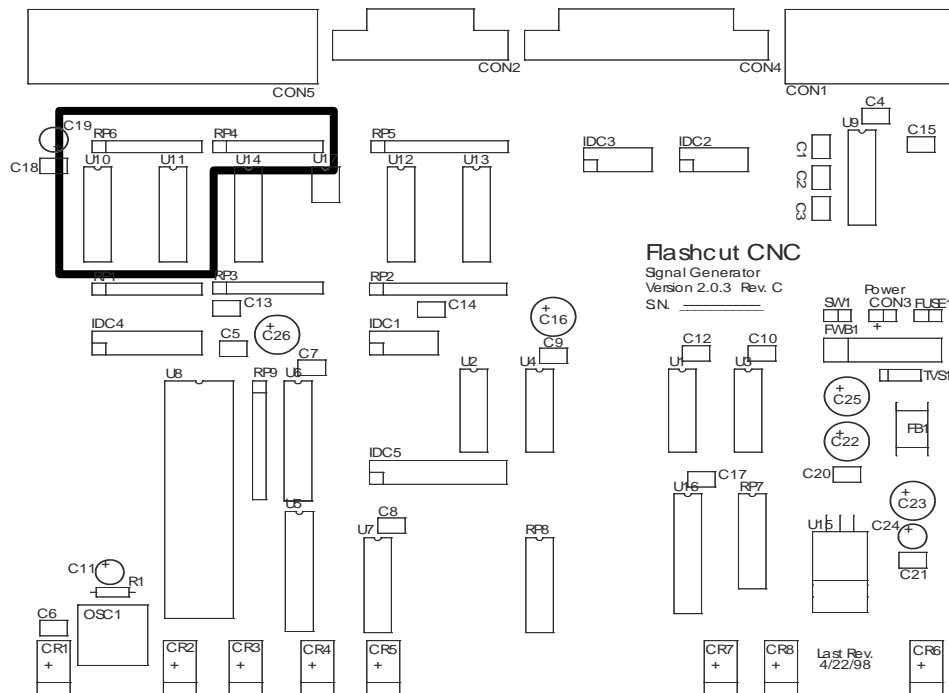
Remove the two Phillips screws on the bottom of the signal generator.

Remove the cover and locate the two 9 pin resistor packs RP4 and RP6. Carefully remove these resistors from their sockets.

Replace the resistors with the proper value if necessary. Please note that these resistors are not symmetrical. Pin 1 on the resistor is noted with a dot or a line and should coincide with the white square silk screened on the circuit board under the socket.

U10 and U11

Some drivers, such as our Servo Driver need a very fast, sharp signal coming out of the Signal Generator. For these drivers you will need to replace the optical couplers (PS2501-4) in U10 and U11 with a bank 3906 PNP transistors. The wiring diagram of how to do this is shown in the Wiring Diagrams Appendix of the Hardware Guide.



4. Resetting Your Servo Drive

1. If a Servo Fault occurs you must reset the Servo Module. To reset the module, you can turn the Servo Drive Unit off using the E-Stop button in the front, wait 30 seconds then pull the E-Stop button back out and push the Power Reset button.
2. Check your feedrate/ramping settings to make sure they are not too aggressive.
3. Resume movement. You may need to re-home the axes as they have most likely lost position.

Note that a servo fault might show up by a message that says, “A limit switch has briefly been tripped and reset...” In this case the error will not show up if you check the input status.

5. Replacing or Adding a Servo Drive Module

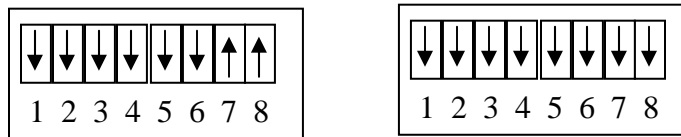
The servo box comes complete with wiring for up to 4 servo drive modules. If you want to add a drive module or you need to replace a servo drive module, follow these instructions:

1. Remove the screws from the cover of the drive box chassis. There are 13 screws in all.
2. Carefully remove the cover by sliding it back.
3. If you are replacing a drive, carefully remove all of the cabling from the drive that you are replacing.
4. Remove the two screws that fasten the bottom flange of the servo drive to the Servo Box Chassis. It is actually easiest if you remove one of the screws and loosen the other.

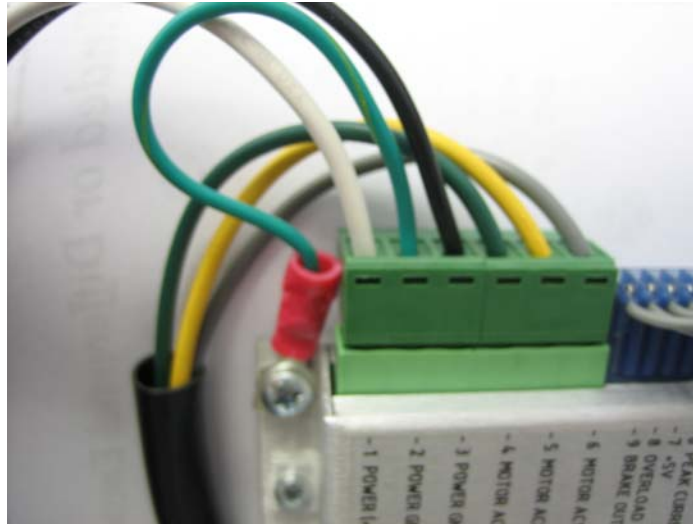


5. Remove the drive module.
6. Make sure that the dip switch settings are set properly on the new drive module. Inside of the servo box, there is one drive module for each axis. These modules

have a set of 8 dip switches on the side next to the RJ-45 receptacles. Switches 1-6 should be towards the numbers on the switch bank (Towards the front panel of the drive module). Switches 7 and 8 should be away from the numbers on the switch bank **for all of the drive modules except the last one in line**. The last drive module in line should have switches 7 and 8 towards the numbers. For example, for a 3 axis system, the switch bank in the modules for axes 1 and 2 should look like the figure on the left, while the last module (axis 3) should have switch settings like the figure on the right. In a 4 axis system, the switch bank in modules 1-3 should look like the figure on the left and module 4 should look like the figure on the right.



7. For noise immunity, it is good to install a grounding wire from Pin 2 of CN1 to the chassis of the drive module.



8. Install the new drive module and secure it with the two screws to the bottom of the chassis.
9. Install all of the connectors of the cabling onto the drive module. **In some Models CN1 (6 pin connector) is divided into two 3 pin connectors. Make sure that you do not mix these up or damage will result.**
10. There are two RJ-45 connections on the end of each drive module (CN5 and CN6). The first RJ-45 cable goes from the communications card on the main servo box to CN6 of the first drive. The next cable goes from CN5 of the first module to CN6 of the following module. This continues up to the last drive module which only has CN6 connected from the preceding drive module.



11. Do a final check on all of the connections
12. Replace the cover and the 13 screws.

6. Servo Gain Settings

There are mathematical parameters for the servo system that need to be tuned to account for the differing mechanical behavior of a given machine tool and a given motor. We have already pre-tuned these settings in your system given some assumptions that were made about the dynamics of your machine and motors. Sometimes these settings need to be adjusted for better performance. The main parameters that need to be adjusted are the Servo Gain, the Dead Band Compensation, and the Error Limit.

The Servo Gain is the stiffness of the motors. The higher the servo gain, the tighter the motor will follow the toolpath, however, the tighter the system, the more susceptible the motors will be to high frequency vibration when at rest.

The dead band compensation negates the “dead band” zone of the motors, when they have very little stiffness. The higher the dead band compensation, the smaller this zone is. However, the larger this number, the more susceptible the motors will be to high frequency vibration when at rest.

Since a servo system is a feedback system, it moves to a position, compares the actual position with the desired position, and then physically corrects itself. The amount that the actual position can differ from the desired position at any time is the Error Limit. If the Error Limit is exceeded, an error signal is sent to the signal generator, and the Servo System needs to be reset. The higher the Error Limit, the less susceptible you will be to getting a servo error.

To change these settings, we have provided a program called Distributed Control Network Facility (DCN).

To install DCN:

1. DCN is automatically installed on your hard drive if you have FlashCut CNC version 3.0.6 or later. It is located by default under:
C:\Program Files\FlashCut CNC 3\Servo Software
2. If you do not have DCN installed, you can either find it on the FlashCut CNC Installation CD or on the Downloads portion of the www.flashcutcnc.com website. Please copy the entire contents of the Servo Software folder onto your hard drive in the C:\Program Files\FlashCut CNC 3 directory.

To Use DCN:

1. If you are using a model 501A (USB) signal generator :

Connect the Servo Box to an available serial port on your computer. If you do not have a serial port, it is OK to use an off-the shelf USB-Serial adapter that you can find at most computer stores (Note that this connection will only work for the serial connection on the servo box. It will not work with serial signal generators) Make sure that FlashCut is online. This will allow you to change parameters using DCN and interactively test the new parameters using FlashCut.

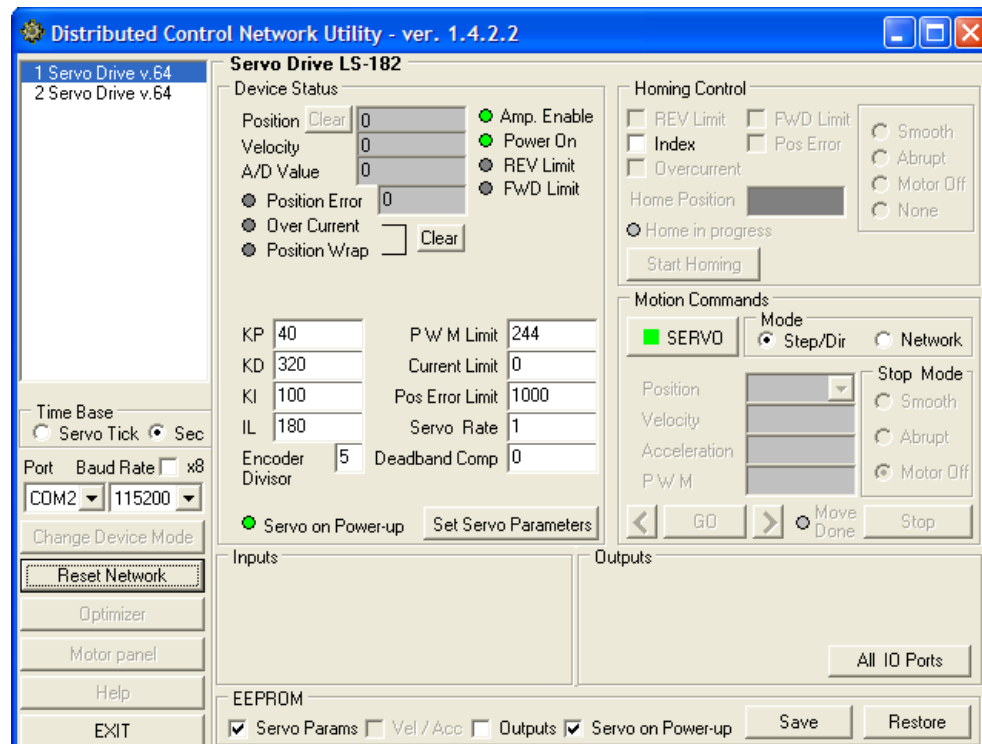
2. If you are using a model 401A (serial) signal generator and you have 2 available serial ports, or 2 computers:

Connect the Signal Generator to one serial port and connect the Servo Box to the other. Make sure that FlashCut is online. This will allow you to change parameters using DCN and interactively test the new parameters using FlashCut.

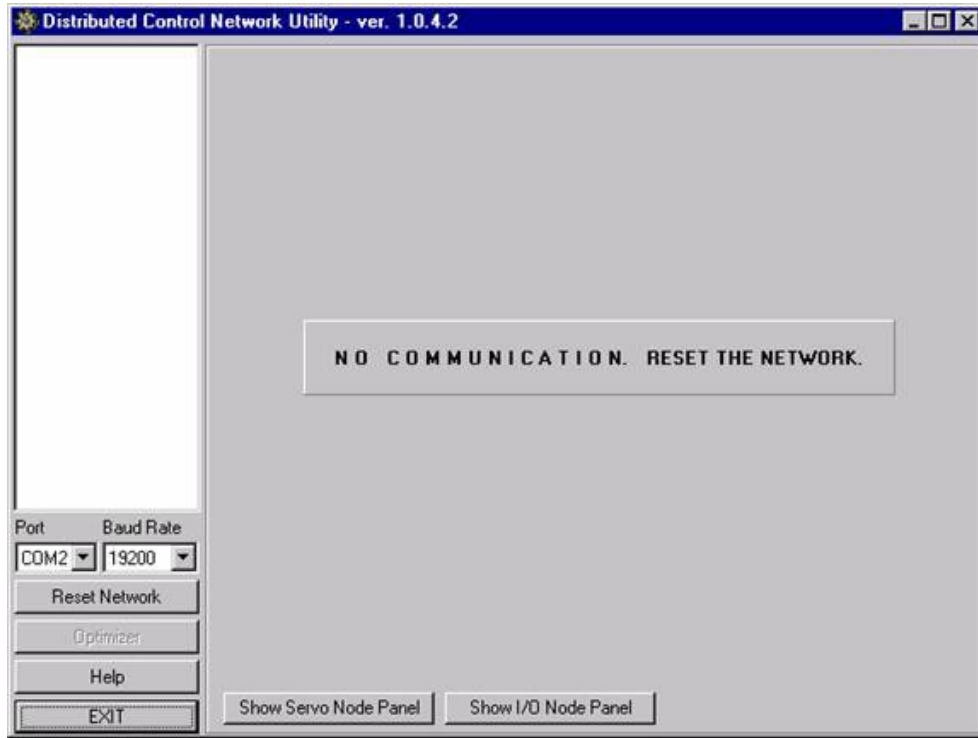
If you are using a model 401A (serial) signal generator and you have only one serial port available:

If FlashCut is active, set the Signal Generator Offline in the Controller Menu in FlashCut. Unplug the DB-9 Cable from the Signal Generator and Plug it into the DB-9 Connector of the Servo Box. Follow the directions below to set the servo parameters. Each time you have a set of servo parameters you would like to test to see how they perform on your machine, you will need to exit DCN then plug the Serial Cable into the Signal Generator then bring FlashCut online.

3. Launch the Program (DCN.exe) (for example, from the Start menu choose Run.. then type "C:\Flashcut Servo Software\DCN.exe"). A screen should appear that looks like this:



If instead you get a screen that looks like this:



Then you need to check your Com Port settings and your baud rate (lower left of screen), check your cabling to make sure you have a good connection between your Com Port on the PC and the DB-9 Connector on the Servo Box. Once this all has been verified, choose the Reset Network button.

The upper left corner of the screen shows a list of the drive modules that you have:



To change the servo parameters for a particular drive

1. Choose that drive from the module list.
2. Change the servo parameters you need to change for the drive. (See Servo Parameters in Appendix I.)
3. Turn the servo off by choosing the Servo button in the Motion Commands area of the window. When the servo is on it will have a little green square in the button, when it is off the square will be gray.
4. Choose the Set Servo Parameters button. This will set the servo parameters in the drive, but they will be lost when you turn the power off to the servo unit.
5. To permanently save the servo parameters, make sure the servo params check box is checked in the EEPROM section of the window and choose the Save button

with your left mouse button. If you right mouse click on the Save button, you can save the parameters to a file on your computer also. The default extension is .led.

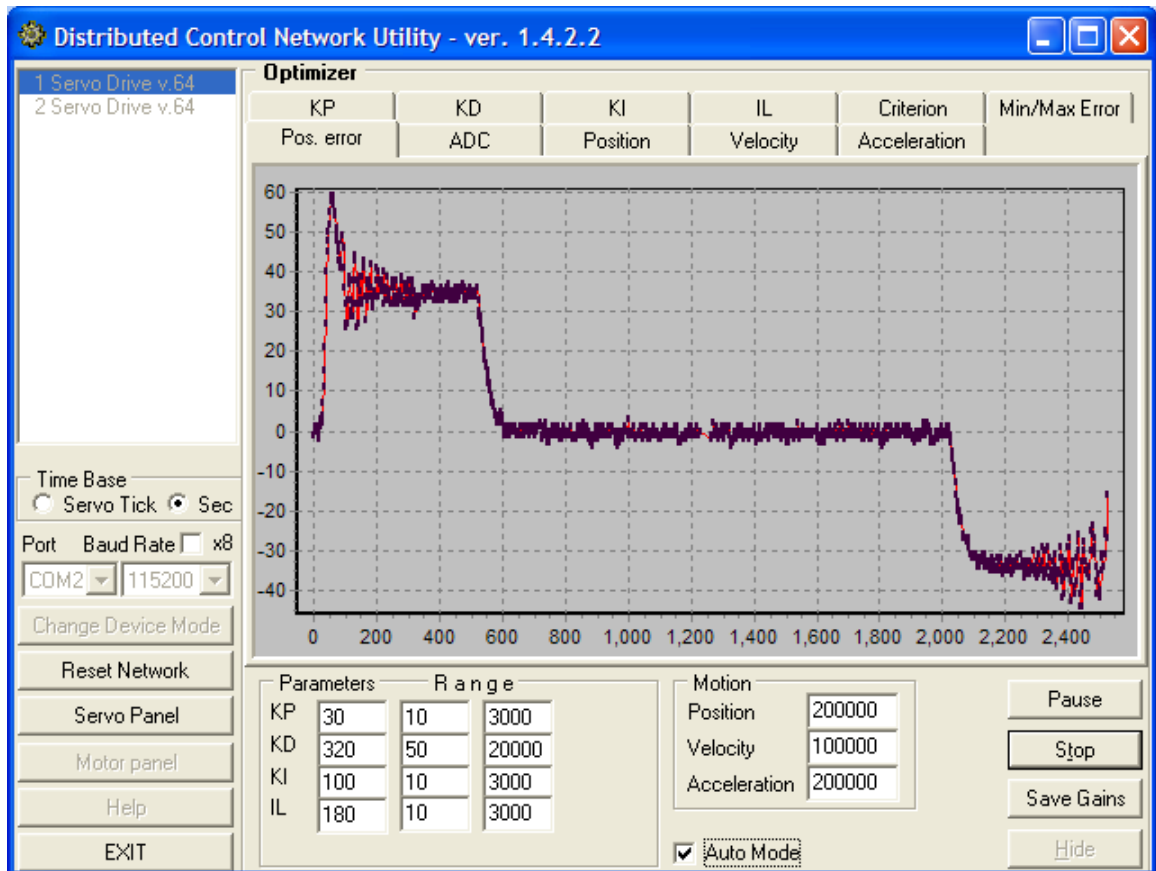
6. You can also load servo parameters from a .led file by clicking Restore with the right mouse button, and then clicking Set Servo Parameters and the Save Button.
7. Repeat the above for all of the drive modules that you have.
8. Turn the unit off and disconnect the serial cable. It is now ready to be used with the new settings.

Optimizing your Servo Settings:

There is also a very useful feature that will help you automatically tune your motors while they are connected to your system. This can be done using the Optimizer button on the left side of the screen. Please note that the optimizer is an automated program that will go through an algorithm to find a local optimum for servo values. In many cases, this local optimum may not be the best values for your machine. Therefore, the optimizer is best used by watching your machine while it runs and writing down the parameters that look smooth and have a low position error. When the optimizer is finished, you then have the option of using the parameters that it found, or the ones that you found to be best during the test. You also have the option of using the optimizer to view the physical effects of servo parameters that you enter manually.

To try the optimizer, each drive must be taken out of STEP mode.

1. To take the servo box out of STEP mode simply click the radio button that says Network in the DCN software.
2. The unit is not in Step and Direction mode any more. You will only be able to use DCN to move the motors.
3. Make sure you position the each axis to the middle of their travel, as they will move back and forth during the tuning process. You can move the motors by typing in a position and velocity in the respective fields. They are in quadrature encoder counts and quadrature encoder counts/servo tick. $\text{Quadrature encoder counts} = \text{Encoder counts} \times 4$.
4. Open the DCN Utility and choose the Optimizer button.



5. The first column of Servo Parameters is a starting point for the optimizer, the second column is the low limit for each parameter and the third column is the high limit. Fill in amounts for each field. Sometimes, it is best to increase the upper ranges by 2 or 3 times their current values. Make sure that the Auto Mode box is checked. The optimizer will increment each of the parameters within the given range and find a local optimum value. If you want to test different parameters manually, make sure that Auto Mode is not checked.
6. Choose a position, velocity and acceleration that seem appropriate for typical movement of your machine. The distance chosen should be just large enough for the motors to get up to speed and have room to decelerate to a stop. (Usually on the order of 0.25 to 2 inches of travel on your machine. (Remember, the distance is based on quadrature encoder counts and is independent of the encoder divisor).
7. Hit the Start button and let the system run for a few minutes until it stabilizes on a set of servo parameters. You can view the position error (shown above) as it is doing the test. The criterion is to minimize the position error. When it has reached a stable value hit the Stop button.
8. Save the new servo parameters (if you choose) by hitting the Save Gains button. You can exit the Optimizer by hitting the Hide button. (Make sure you follow the directions on saving the servo parameters above).
9. Repeat the above process for each axis.
10. Once you have finished you need to set the reset the module or reset the network to place the unit back into step and direction mode.
11. You will now be able to use the system with FlashCut.

7. Motor Wiring:

The motor connectors contain all of the drive and encoder signals going out to the motors. The motors can be either brush or brushless and the encoder signals can be either differential or single ended. See the Appendix with the Schematics at the end of this manual for details.

8. Support:

FlashCut CNC Midwest Office
444 Lake-Cook Road Suite 17
Deerfield, IL 60015
(847) 940-9305
(847) 940-9315 Fax
support@flashcutcnc.com - e-mail

Appendix I. Servo Parameters

The Servo Parameters panel allows the user to modify the eight servo control parameters, or gains. The "Set Servo Parameters" button will apply the gains to the selected controller. Here is a brief explanation of the servo algorithm and the associated parameters:

PID Servo Control

In general, in position or velocity mode, the motor is controlled by a servo loop which once every servo tick (1953 times/sec) looks at the current position of the motor, compares it to where the motor should be, and then uses a "control filter" to calculate an output which will cause the difference in positions, or the "position error" to become smaller. Two sets of parameters will govern the motion of the motor: the desired trajectory parameters (goal position, velocity, acceleration) which are described in the next section, and the control filter parameters discussed here.

The control filter is a "proportional-integral-derivative", or PID filter. The output to the motor amplifier is the sum of three components: one proportional to the position error providing most of the error correction, one proportional the *change* in the position error which provides a stabilizing damping effect, and one proportional to the accumulated position error which helps to cancel out any long-term error, or "steady state error".

The PID control filter, operating on the command position and the actual position each servo tick, produces an output calculated as follows:

$$\text{output} = K_p(\text{pos_error}) - K_d(\text{pos_error} - \text{prev_pos_error}) + K_i(\text{integral_error})$$

The term `pos_error` is simply the current command position minus the actual position. The `prev_pos_error` is the position error from the previous servo tick. `Kp`, `Ki` and `Kd` are the servo gains which will be programmed to optimize performance for your particular motor.

The `integral_error` is the running sum of `pos_error` divided by 256. To keep from growing a potentially huge `integral_error`, the running sum is bounded by a user specified integration limit. (Note that some other controllers will bound the value of the `integral_error`, but leave the actual running sum to grow unbounded, causing greater integral error windup.) By temporarily setting the integration limit to 0, the user can zero out the accumulated running sum.

The actual PWM output value (0-255) and direction bit are given by:

$$\text{PWM} = \min(\text{abs}(\text{output}/256), \text{output_limit}) - \text{current_limit_adjustment}$$

$$\text{Dir} = 0 \text{ if } \text{output} > 0, \text{ Dir} = 1 \text{ if } \text{output} < 0$$

First note that the scaled PWM output is limited by a user defined `output_limit`. For example, if you are using a 12v motor powered by 24v, you would want to set the `output_limit` to 255/2, or 127. Also note that the final PWM value is reduced by a `current_limit_adjustment`. Under normal operation, `current_limit_adjustment` = 0. If the motor current, as indicated by the A/D value, exceeds a user specified limit, `current_limit_adjustment` is incremented by 1 each servo tick, up to a maximum value of $\min(\text{abs}(\text{output}/256), \text{output_limit})$. If the motor current is below the specified limit,

current_limit_adjustment is decremented by 1, down to a minimum value of zero. This incremental adjustment is used rather than a proportional adjustment due to the non-linearity of many current sensing schemes, and in fact can be used with external amplifiers which provide only a binary current threshold value.

The PWM signal is a 19.53 KHz square wave of varying duty cycle with a PWM value of 255 corresponding to 100% and a value of 0 corresponding to 0%.

One last control parameter is the user specified position error limit. If $\text{abs}(\text{pos_error})$ becomes larger than this limit, the position servo will be disabled. This is useful for disabling the servo automatically upon a collision or stall condition. (This condition can also be used for homing the motor by intentionally running it up against a limit stop.)

Selection of the optimal PID control parameters can be done analytically, but more typically, they are chosen through experimentation. As a first cut, the following procedure may be used:

1. First set the position gain, K_p , and the integral gain, K_i , to 0. Keep increasing the derivative gain, K_d , until the motor starts to hum, and then back off a little bit. The motor shaft should feel more sluggish as the value for K_d is increased.
2. With K_d set at this maximal value, start increasing K_p and commanding test motions until the motor starts to overshoot the goal, then back off a little. Test motions should be small motions with very large acceleration and velocity. This will cause the trapezoidal profiling to jump to goal position in a single tick, giving the true step response of the motor.
3. Depending on the dynamics of your system, the motor may have a steady state error with K_p and K_d set as above. If this is the case, first set a value for IL of 16000 and then start increasing the value of K_i until the steady state error is reduced to an acceptable level within an acceptable time. Increasing K_i will typically introduce some overshoot in the position. The best value for K_p will be some compromise between overshoot and settling time.
4. Finally, reduce the value of IL to the minimum value which will still cancel out any steady state error.

The default (and maximum) servo rate is approximately 2 KHz (1.953 KHz, to be more exact). For systems with a combination of a large inertia, little inherent damping and limited encoder resolution, it may be difficult to get sufficient damping at low speeds because the digitization noise with very large values of K_d will cause the servo to hum or vibrate. Fortunately, such systems typically have a rather slow response and the servo rate can be decreased considerably. For example, switching from 2 KHz to 200 Hz will allow you to achieve the same level of damping with a value of $K_d/10$. The minimum possible servo rate is 7.6 Hz.

In summary, we have a total of eight control filter parameters: Position Gain (K_p), Derivative Gain (K_d), Integral Gain (K_i), Integration Limit (IL), Output Limit (OL), Current Limit (CL), Position Error Limit (EL) and the Servo Rate

Parameter Ranges

KP, KI, KD

KP, KI, and KD are the primary control parameters used by the PID control filter. They must all be positive values in the range between 0 and 32,767.

Integration Limit (IL)

The integration limit limits the absolute value of the integral of the position error. The integration limit must be between 0 and 32,767. The limit value used internally is the limit value x 256. Limiting the integration term is useful for preventing huge sums from accumulating in that case of a locked rotor. Temporarily setting this value to zero can be used to zero out any accumulated integral error term.

Encoder Divisor

The Encoder Divisor divides the effective resolution of the encoder. This is especially useful if you want to get more speed out of your motor in exchange for increased encoder resolution. For example, if you have a 1000 line encoder which has 4000 quadrature counts per revolution, and you have an encoder divisor of 5, then your effective resolution would be 800 quadrature counts per revolution. The encoder divisor in DCN must match the encoder divisor in FlashCut CNC.

PWM Limit

The PWM limit sets the maximum PWM output value. If the control algorithm produces a larger value, the actual value will be clipped to the PWM limit value. The PWM limit must be between 0 and 255.

Current Limit

A/D value and CCL (continuous current limit parameter of Set Gain command) may be used for current limit control. A/D value is proportional to the motor current. CCL is compared each servo tick with A/D value. If the A/D input is connected to a voltage signal proportional to the motor current, the current limit can be used to adjust the PWM output to prevent the motor current from exceeding the limit. If a current limit between 1 and 127 is used, the PWM output will be reduced if the A/D value exceeds the current limit. The Over current flag will be set whenever an over current condition occurs. A current limit value of 0 effectively disables current limiting.

Position Error Limit

The position error limit is used to detect locked rotor conditions or other situations where the motor is not tracking as accurately as it should. If the absolute value of the position error ever becomes greater than the position error limit, the position servo will be disabled and the PWM output value will be set to 0. The position error flag will also be set. The position error limit is in units of quadrature encoder counts, and must be between 0 and 16,383. For example a 1000 line encoder will have 4000 quadrature encoder counts.

Servo Rate

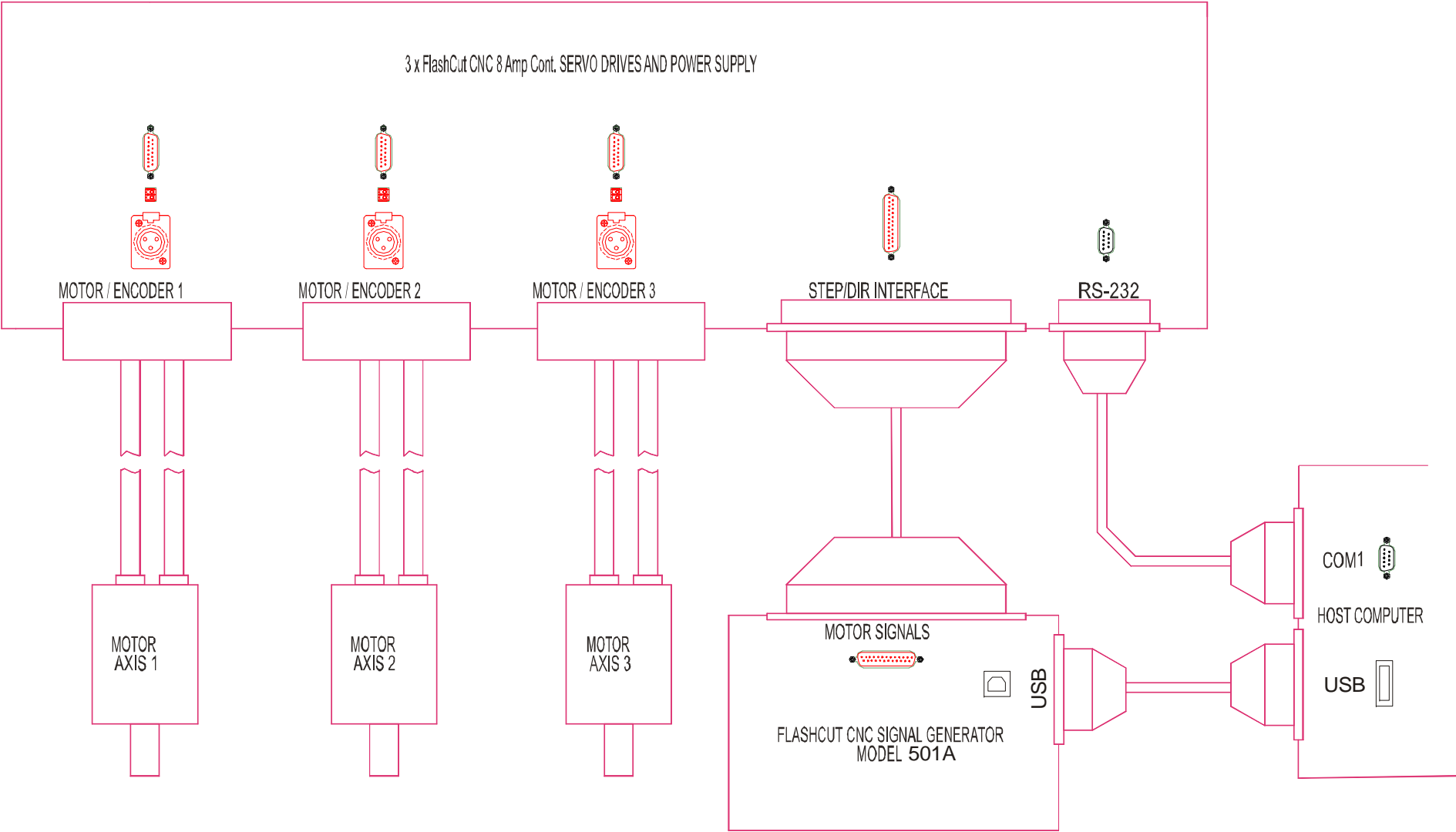
The servo rate is a clock divisor, which determines the length of a servo tick. The servo tick time is equal to 0.512 milliseconds multiplied by the servo rate divisor value. This value must be between 1 and 255. In general, this value may be left at the default value of 1, but for systems with a large inertia and/or low encoder resolution, it may be desirable to increase the tick time to improve the servo's damping characteristics.

Deadband Compensation

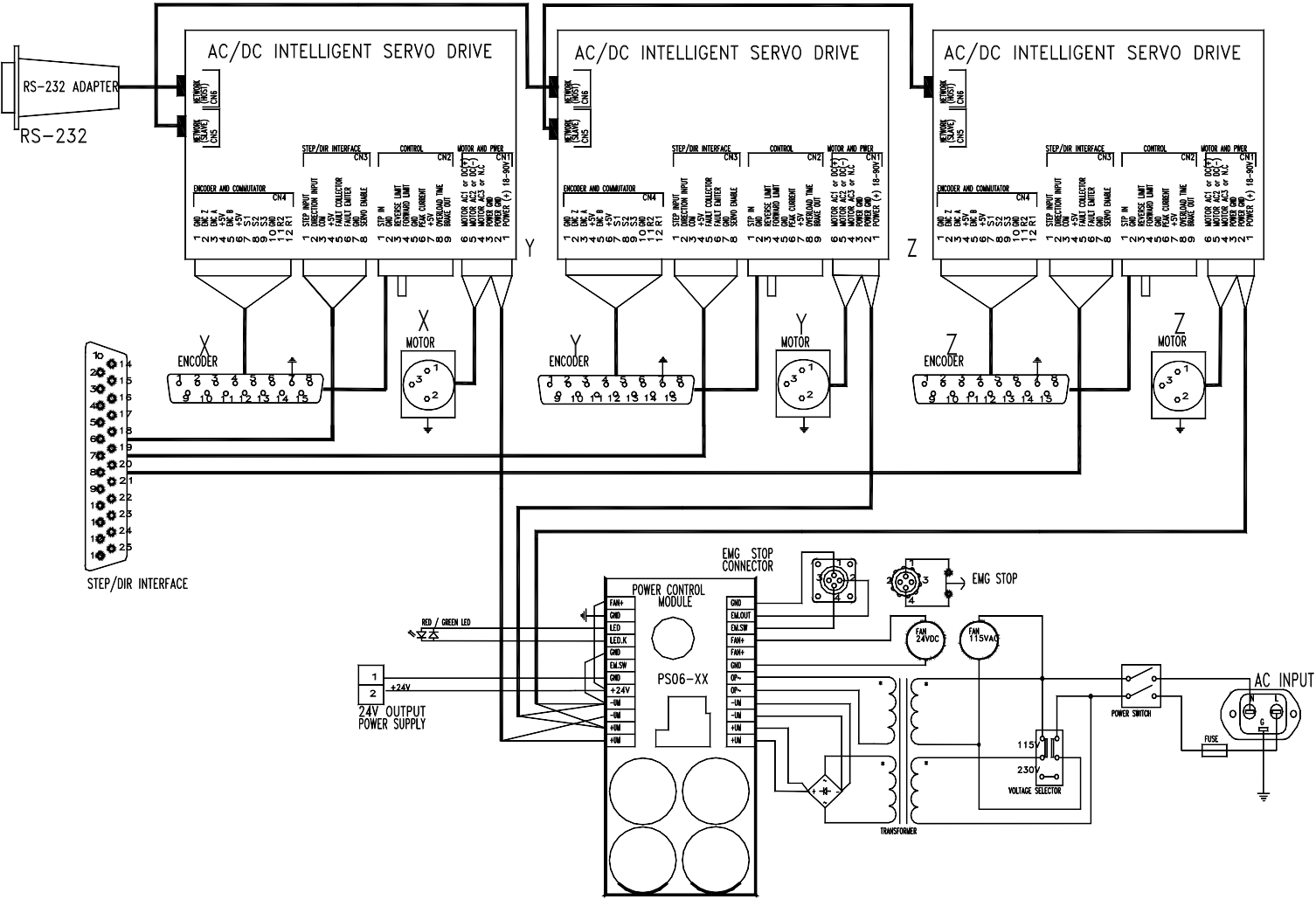
Some amplifier/motor combinations will exhibit a deadband around a zero PWM output. That is, small PWM values will have no visible effect on driving the motor. While servoing, the deadband compensation value will be added to the magnitude of the PWM output, thus boosting the control signal into the active region outside the deadband. This has the gain settings for Axis 1 in your servo controller. You can change the gain settings using the following guidelines:

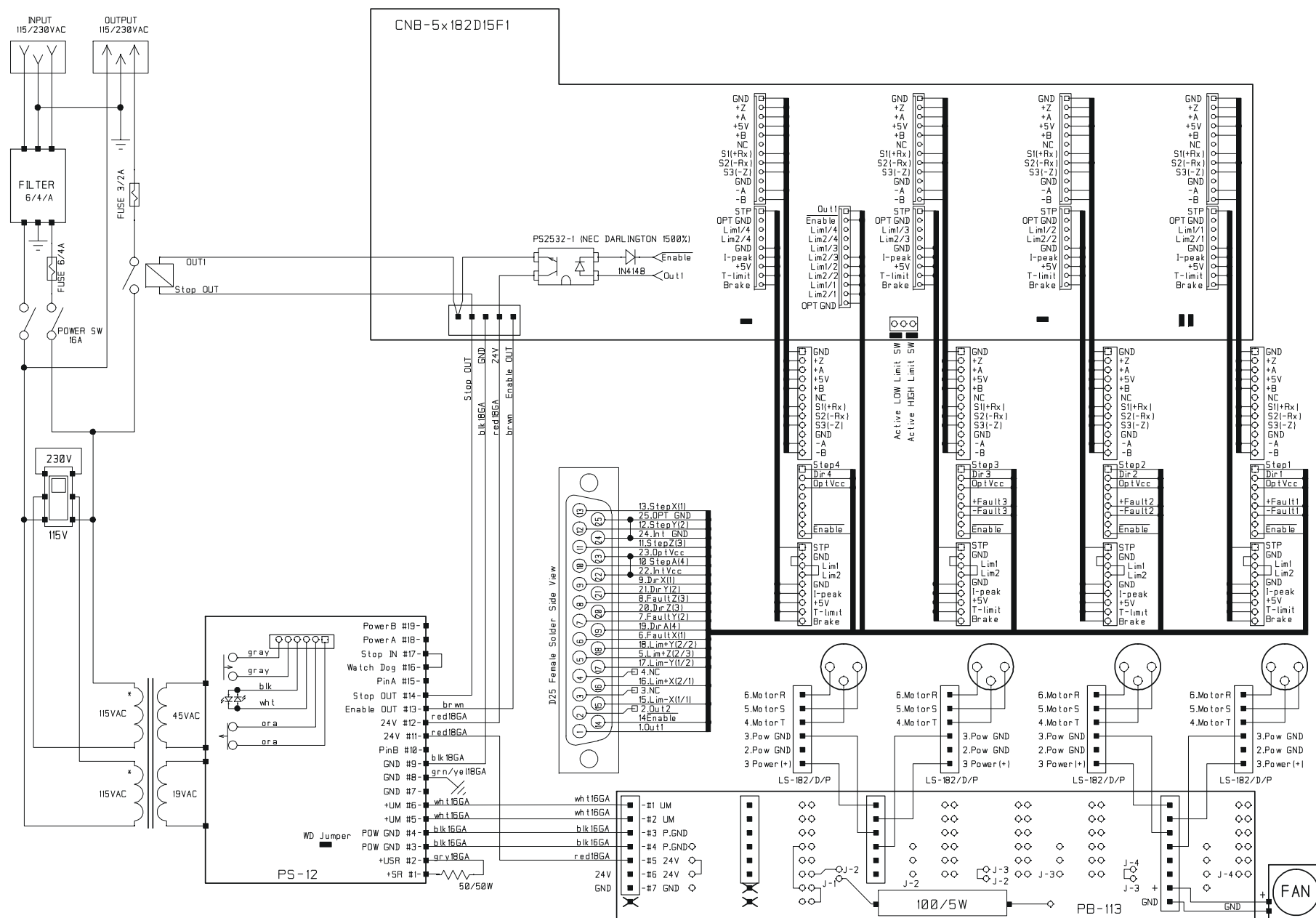
Appendix II. Schematics:

FlashCut CNC - THREE AXES CNC SERVO CONTROL SYSTEM

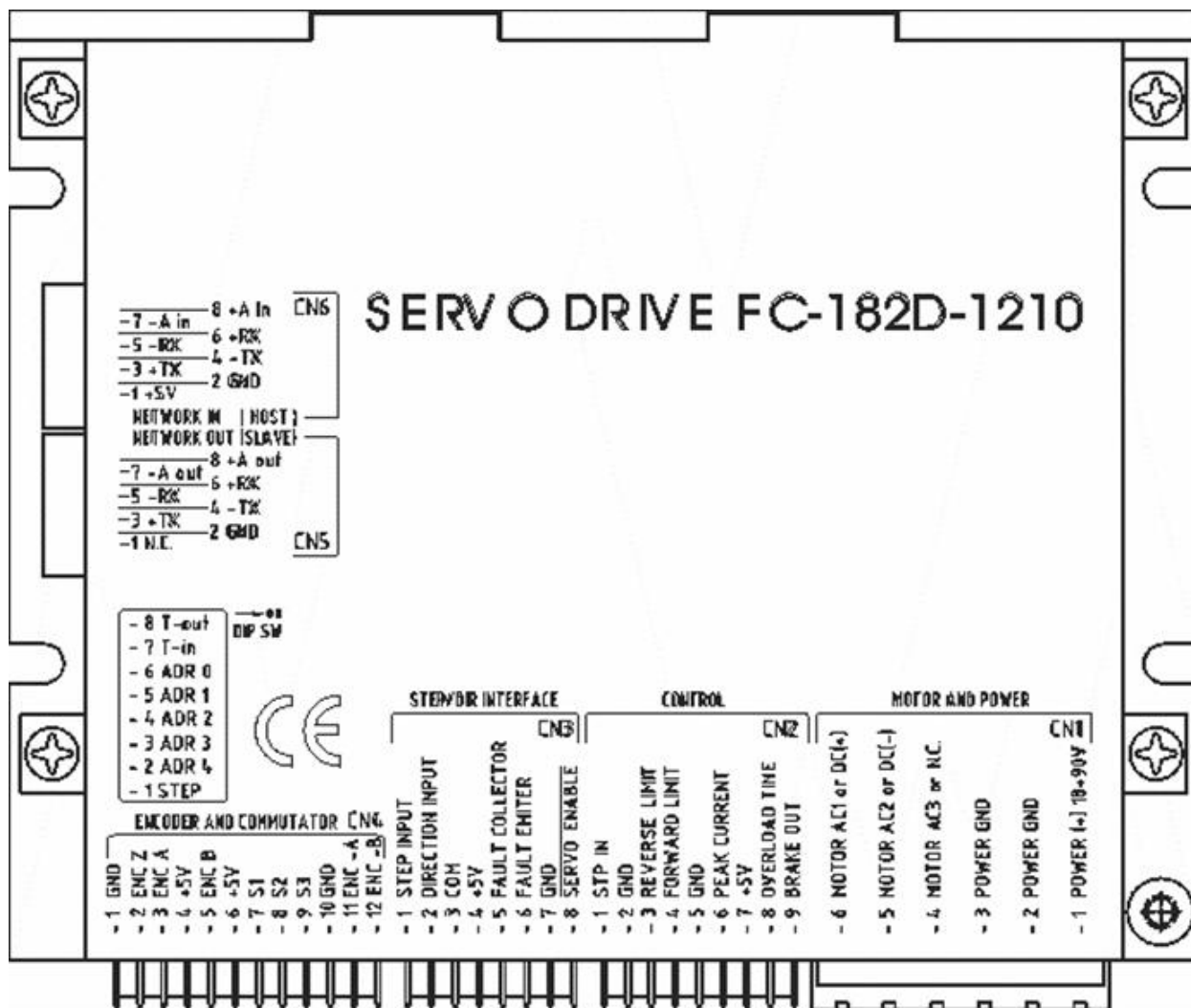


FlashCut CNC- THREE AXES CNC SERVO CONTROL SYSTEM

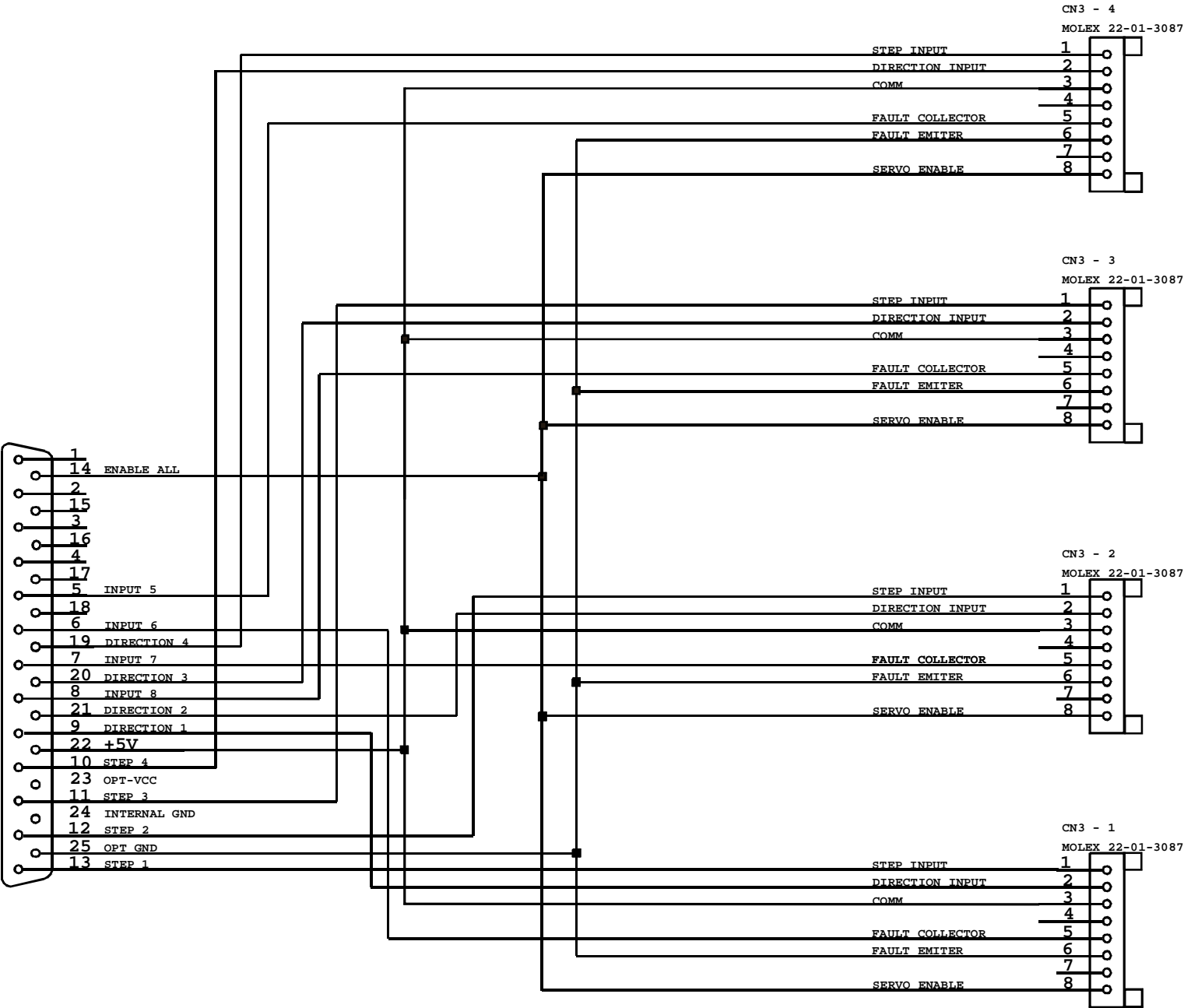


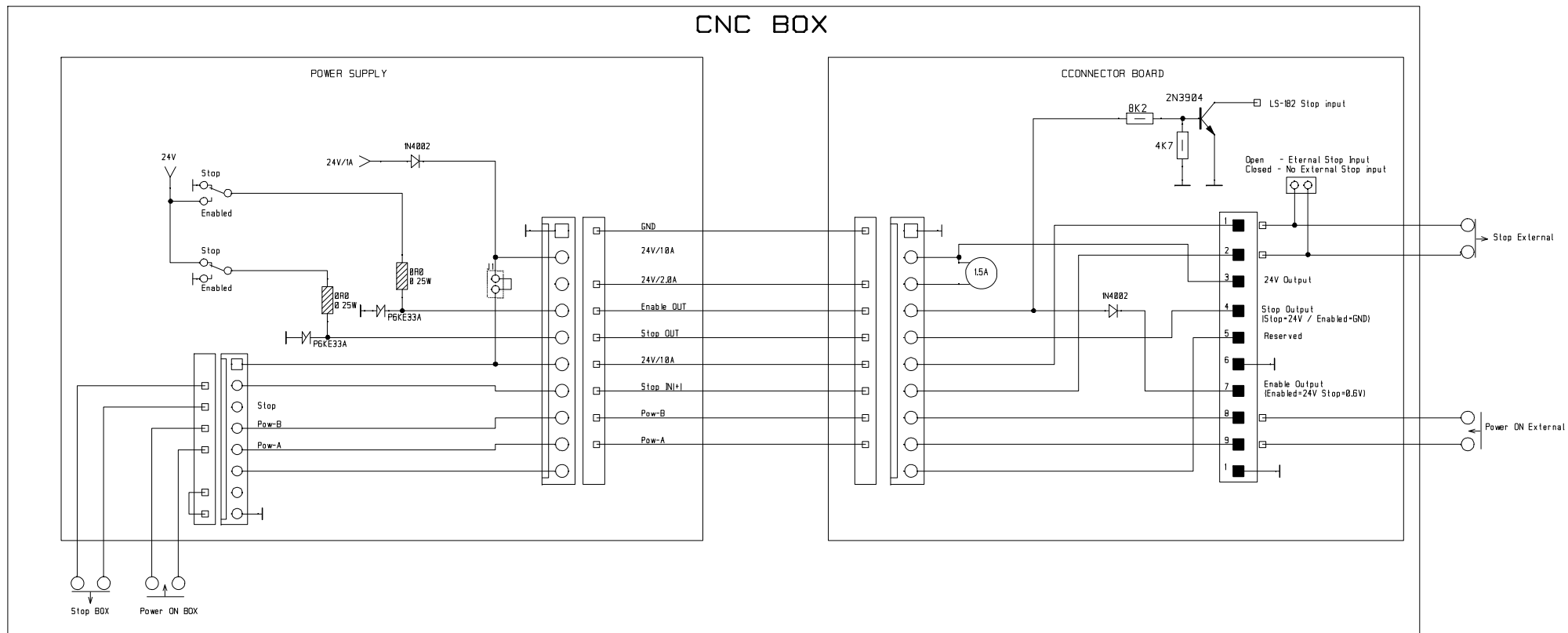


Internal Wiring From Motor Connector to Individual Servo Drive



Internal Wiring from FlashCut DB25 Interface Cable to Individual Servo Drives

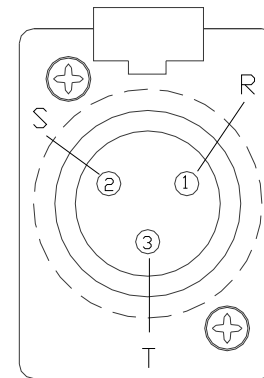
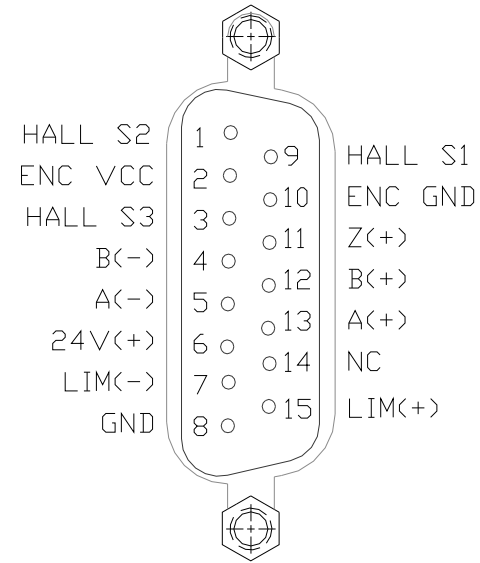




Wiring for MCG Automation Duty Connectors

Sensor Feedback Connector 24-26 gauge shielded cable	DB-15 Connector	Signal Name
A	NC	Thermostat
B	NC	Thermostat
C	1	S2 / Hall B
D	11	Enc Z / Index
E	NC	Enc Z~ / Index~
F	13	Enc A
G	5	Enc A~
H	10	Encoder GND
J	10	Sensor GND
K	2	Encoder VCC
L	2	Sensor VCC
M	9	S1 / Hall A
N	12	Enc B
P	4	Enc B~
R	3	S3 / Hall C
S, T, U, V	NC	
Cable Shield	Drain	Cable Shield
	6	No Connection
	7	NC or Lim(-)*
	8	NC or Lim GND*
	14	No Connection
	15	NC or Lim(+)*

Motor Connector 18 gauge shielded cable	3 Pin Motor Connector	Signal Name
1	1	AC1 / Phase R
2	2	AC2 / Phase S
3	3	AC3 / Phase T
4	Shield	Cable Shield



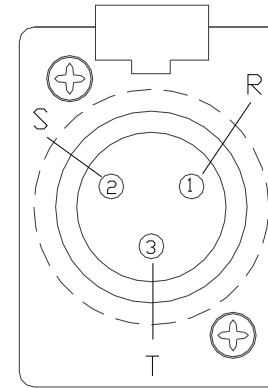
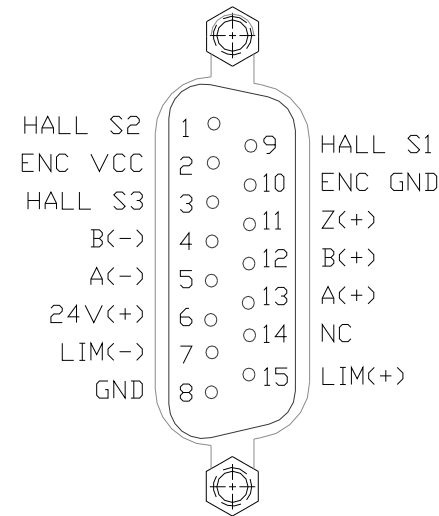
Connectors on Cables are DB15 Male and a Male Audio Connector (Neutrik NC3MX or equivalent).

* You can build an optional Limit Switch Cable connected to your DB15 Cable using pins 7, 8 and 15.

Wiring for MCG Instrument Duty Motors

Encoder Lead Wire Connection 24-26 gauge shielded cable	DB-15 Connector	Signal Name
1 – Red	2	Encoder VCC
2 – Black	10	Encoder Ground
3 – White	13	Enc A
4 – Yellow	5	Enc A~
5 – Green	12	Enc B
6 – Blue	4	Enc B~
7 – Orange	11	Enc Z / Index
8 – Brown	NC	Enc Z~ / Index~
Cable Shield	Drain	Cable Shield
Sensor Lead Wire Connection		
White	9	S1 / Hall A
Orange	1	S2 / Hall B
Green	3	S3 / Hall C
Red	2	Sensor VCC
Black	10	Sensor GND
	6	No Connection
	7	NC or Lim(-)*
	8	NC or Lim GND*
	14	No Connection
	15	NC or Lim(+)*

Motor Lead Wire Connection 18 gauge	3 Pin Motor Connector	Signal Name
Red	1	AC1 / Phase R
White	2	AC2 / Phase S
Black	3	AC3 / Phase T
Cable Shield	Shield	Cable Shield



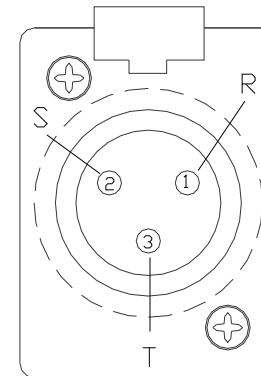
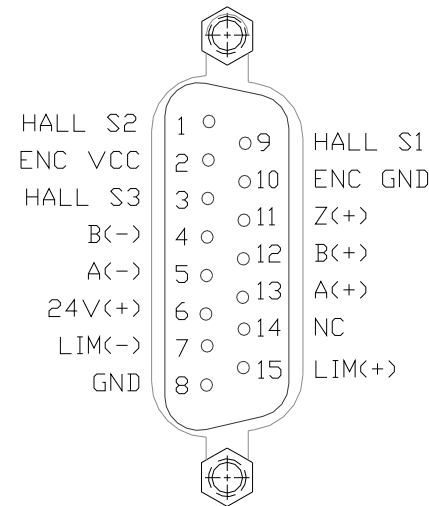
Connectors on Cables are DB15 Male and a Male Audio Connector (Neutrik NC3MX or equivalent).

* You can build an optional Limit Switch Cable connected to your DB15 Cable using pins 7, 8 and 15.

Wiring for Brushless Servo Motors with Single Ended or Differential Encoder

DB-15 Connector	Signal Name
2	Encoder VCC
10	Encoder Ground
13	Enc A
5	Enc A~ NC for Single Ended
12	Enc B
4	Enc B~ NC for Single Ended
11	Enc Z / Index NC if Not Available
NC	Enc Z~ / Index~
Drain	Cable Shield
9	S1 / Hall A
1	S2 / Hall B
3	S3 / Hall C
2	Sensor VCC
10	Sensor GND
6	No Connection
7	NC or Lim(-)*
8	NC or Lim GND*
14	No Connection
15	NC or Lim(+)*

3 Pin Motor Connector	Signal Name
1	AC1 / Phase R
2	AC2 / Phase S
3	AC3 / Phase T
Shield	Cable Shield



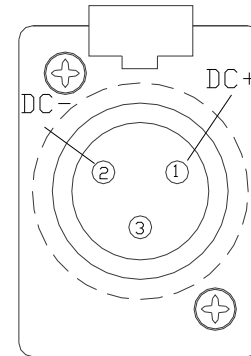
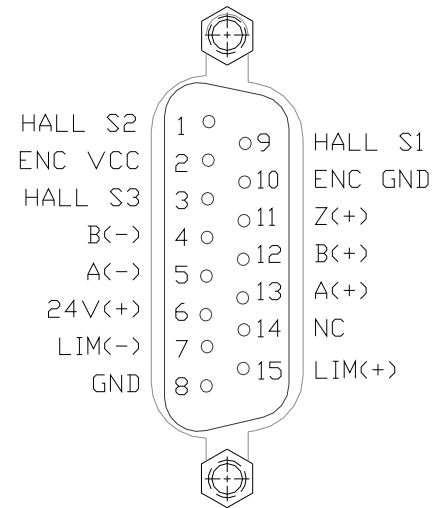
Connectors on Cables are DB15 Male and a Male Audio Connector (Neutrik NC3MX or equivalent).

* You can build an optional Limit Switch Cable connected to your DB15 Cable using pins 7, 8 and 15.

Wiring for Brush-Type Servo Motors with Single Ended or Differential Encoder

DB-15 Connector	Signal Name
2	Encoder VCC
10	Encoder Ground
13	Enc A
5	Enc A~ NC for Single Ended
12	Enc B
4	Enc B~ NC for Single Ended
11	Enc Z / Index NC if Not Available
NC	Enc Z~ / Index~
Drain	Cable Shield
9	NC
1	NC
3	NC
6	No Connection
7	NC or Lim(-)*
8	NC or Lim GND*
14	No Connection
15	NC or Lim(+)*

3 Pin Motor Connector	Signal Name
1	DC+
2	DC-
3	NC
Shield	Cable Shield



Connectors on Cables are DB15 Male and a Male Audio Connector (Neutrik NC3MX or equivalent).

* You can build an optional Limit Switch Cable connected to your DB15 Cable using pins 7, 8 and 15.