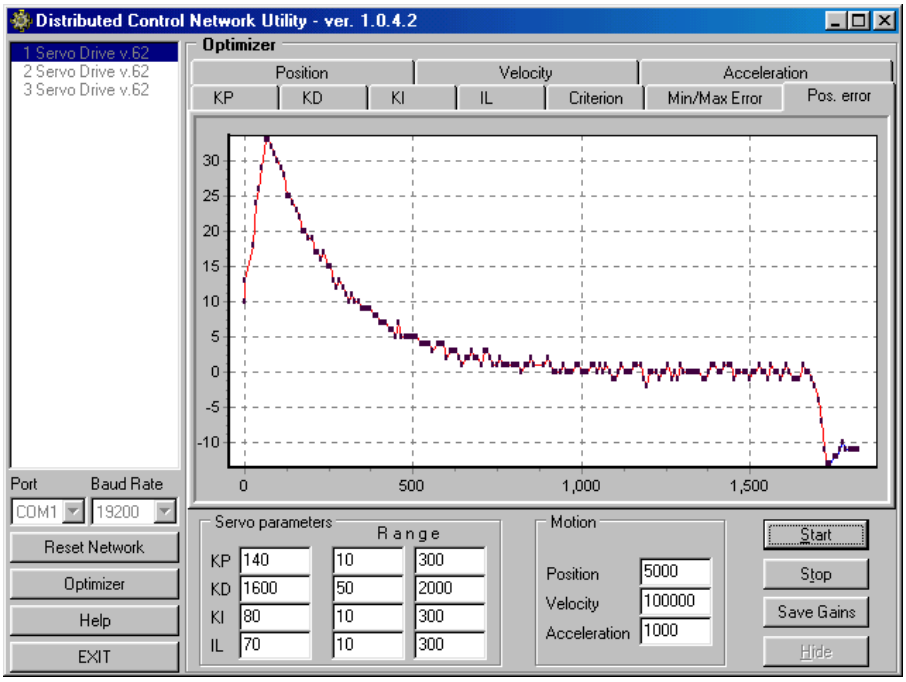
FLASHCUT CNC

Control Made Simple

Servo System Setup



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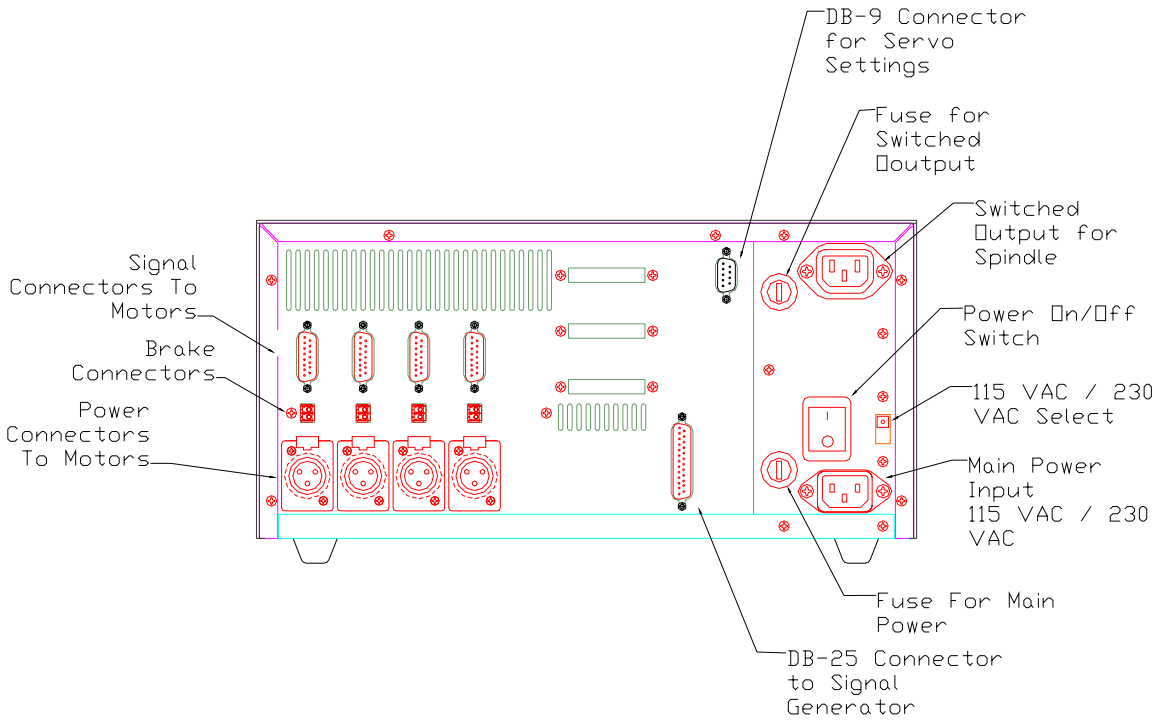
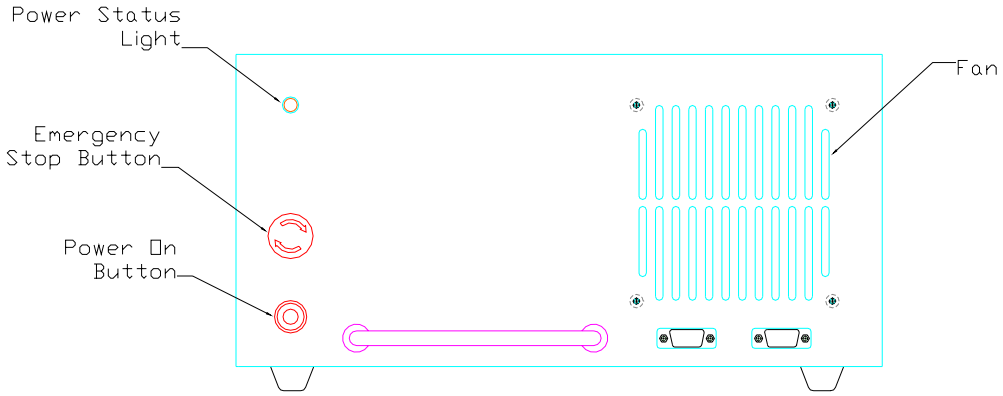
1. Cable Connections





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

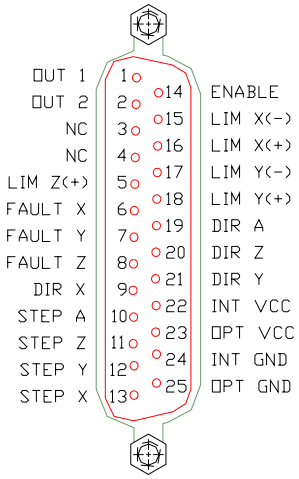
115 VAC / 230 VAC Select – This switch allows you to choose the type of power going into the Main Power Input.

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.

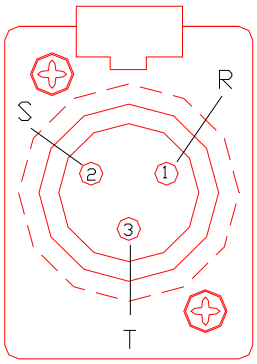
Main Power Input – This uses a standard power cord connected to 115VAC or 230VAC. Make sure the 115VAC / 230VAC Selector switch is set properly for your power.

Fuse for Main Power – In here is a 6 A fuse. 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 plus the device that is connected to this switched output line (see Fuse for Switched Output below). For example, if you have a 4 axis system with 200 W servo motors on each axis, you will need 4 x 200W / 115V = 7A plus the current draw from the switched output (lets say it was 8A) making a total of 15A. This would need at least a 15-amp fuse.

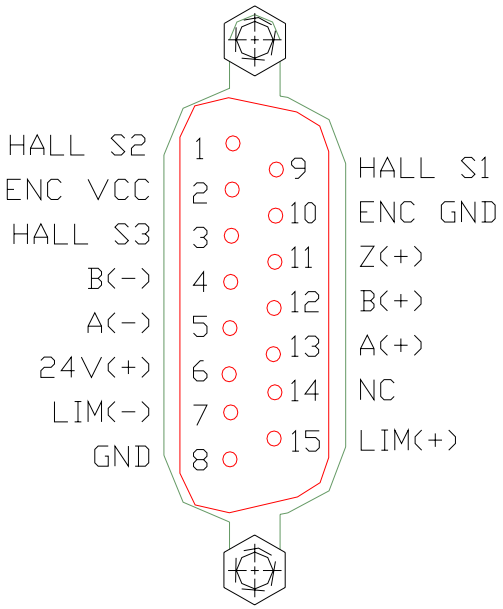
DB-25 Connector to Signal Generator – This uses a DB-25 Cable to receive signals from the FlashCut CNC Signal Generator.



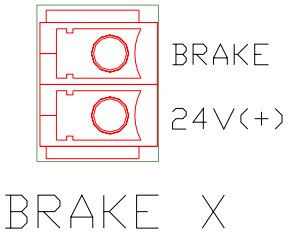
Power Connector to Motors –The power lines for motors 1-4 plug into these female audio connectors. The motor lines 1-4 are correlated to X, Y, Z and A axis in the motor signal settings in FlashCut. All four motor connectors are available only if you ordered the 4-Axis version. If you did not order a 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 30Amps, however, the fuse for it is only 6 Amps. A mating connector is provided with the unit.

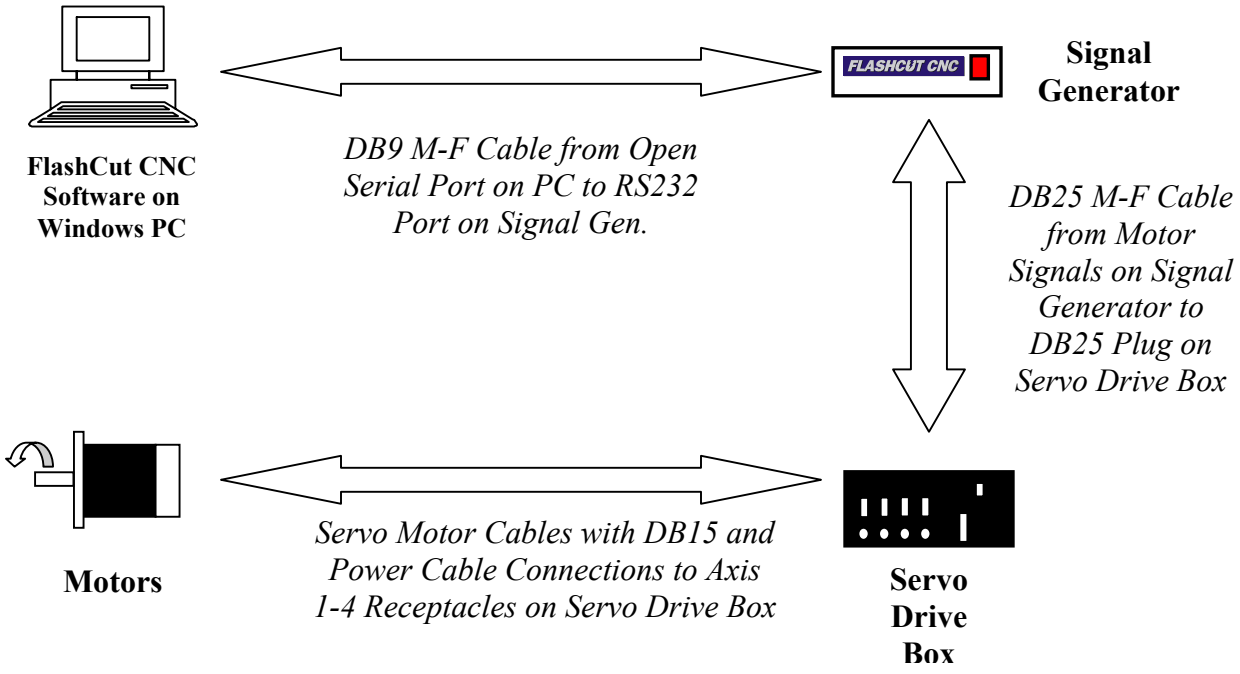
Fuse for Switched Output– In here is a 6 A fuse. You can use a coin to open it. If you have chronic fuse problems, please call FlashCut for assistance. Note that this fuse should be sized for your device that is connected to this switched output line. For example, if you have a 900W spindle and connected to 115VAC, then the current draw would be 900/115= 7.8 amps. This would need at least a 8 or 9 amp fuse.

Power Status Light–This light 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

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–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.

2. System Hook Up Diagram



3. FlashCut Software Settings

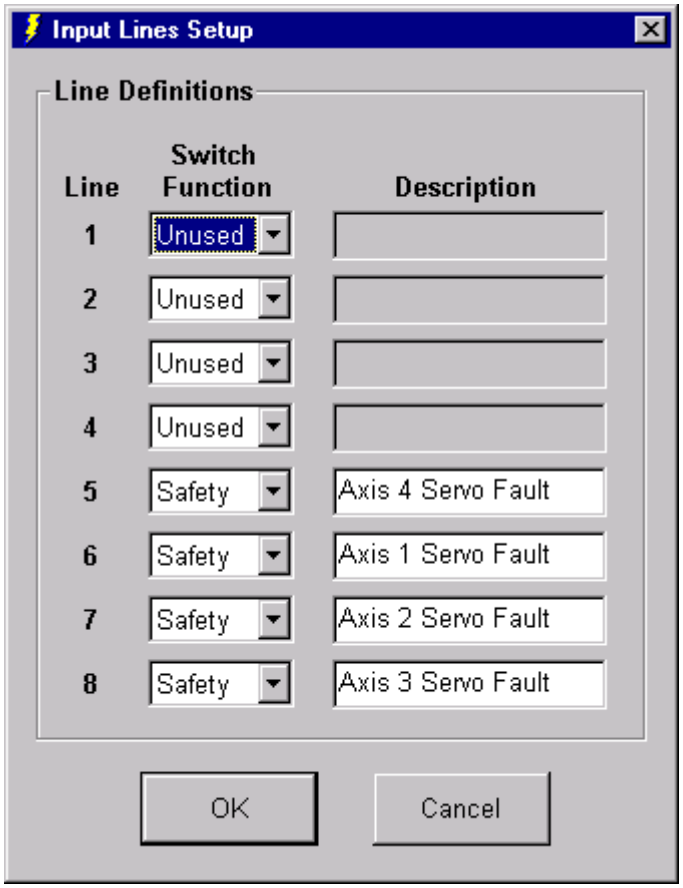
Motor Signal Setup:

Motor Line – Correlate motor lines with machine axes
Step Pulse- High
Step Pulse Width – 15
Enable Signal – Low
Dynamic Enable Line - unchecked

Input Lines Setup:

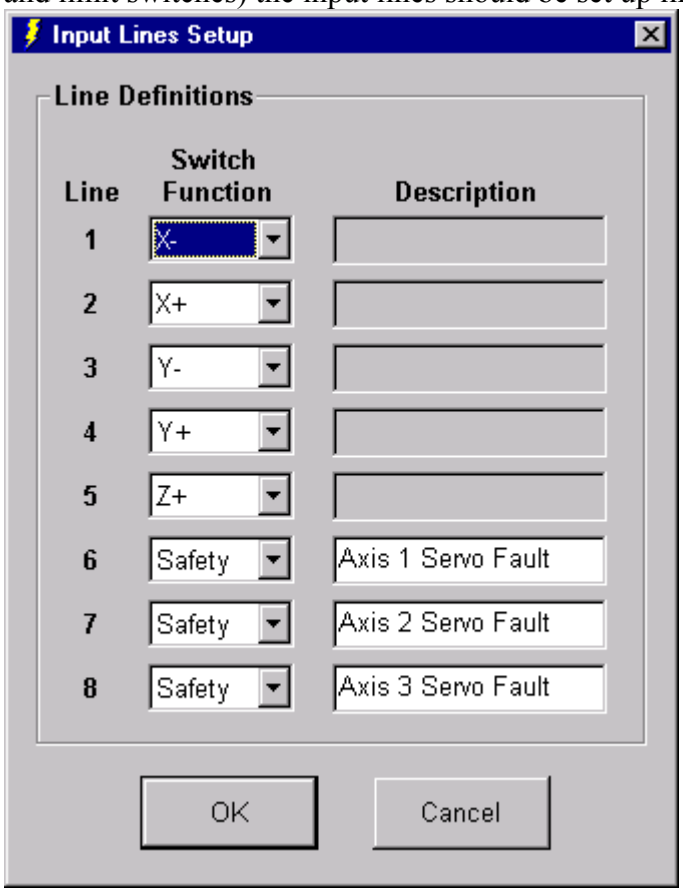
If you overdrive the servomotors, they will get out of position beyond their programmed tolerance. If this occurs a fault signal will be sent from the servo box to the signal generator through one of the above input lines.

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.



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:



System Options Setup:

Signal Generator – 401A (Inputs N.C.)

4. Signal Generator Settings

For 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:

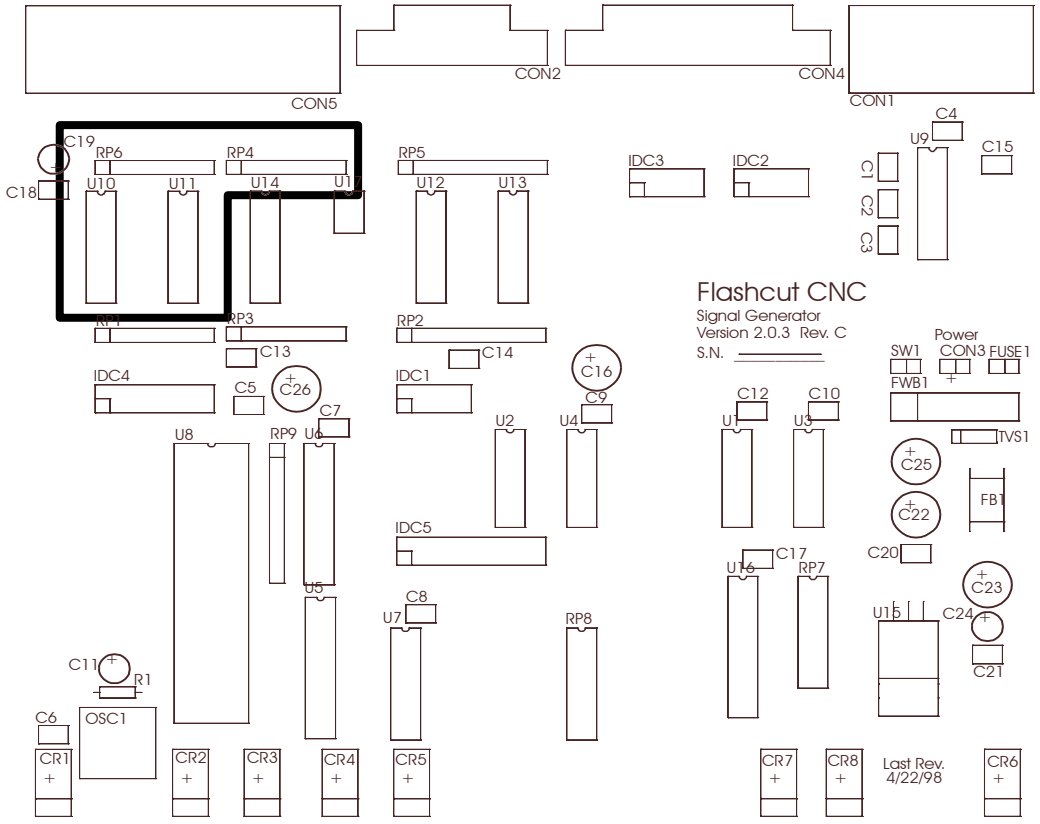
Remove the two Phillips screws on the bottom of the signal generator.
Remove the cover and locate the two 9 pin resistor packs RP4 and RP6.
Carefully remove these resistors from their sockets.
Replace the resistors with the proper value if necessary. Please note that these resistors are not symmetrical. 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.

For Signal Generators with serial numbers above 102000:

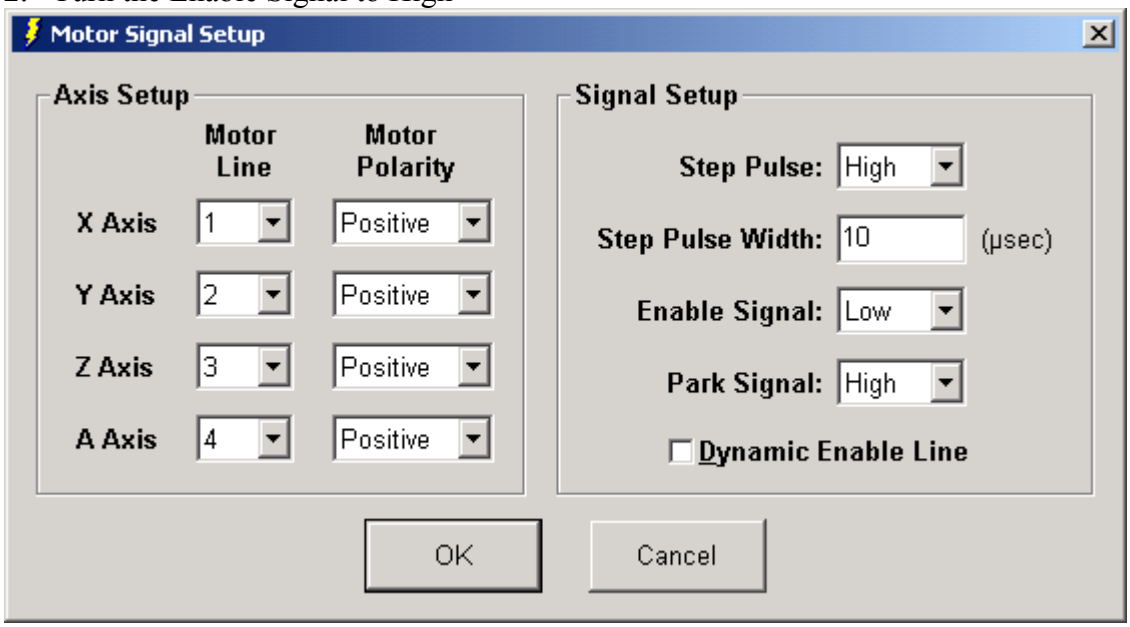
There is no need to configure the signal strength of the motor signals or output signals.



4. Resetting Your Servo Drive

If a Servo Fault occurs you must reset the Servo Module. To reset the module, you can turn the Servo Drive Unit off (wait for 30 seconds) and back on again, or you can toggle the Enable Signal to the servo drive from Low to High and Back to Low in the FlashCut CNC Software. To do this:

1. Go to Setup…Motor Signals
2. Turn the Enable Signal to High



3. Choose OK
4. In the FlashCut CNC Software go to Setup…Motor Signals
5. Turn the Enable Signal back to Low
6. Choose OK
7. Check your feedrate/ramping settings to make sure they are not too aggressive.
8. 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. 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. Place the DCN diskette into your floppy drive.
2. From the Start menu choose Run.. and type "A:dcn_v1053.EXE" (If you have a later version of DCN, please use the file name on the diskette label.)
3. This is a self-extracting program. It will then ask you for the directory that you want to install the servo software to. For example, "C:\FlashCut Servo Software".
4. There are also may be set up files on the same diskette that have an .led extension. Copy those files into the same directory that you installed DCN.

To Use DCN:

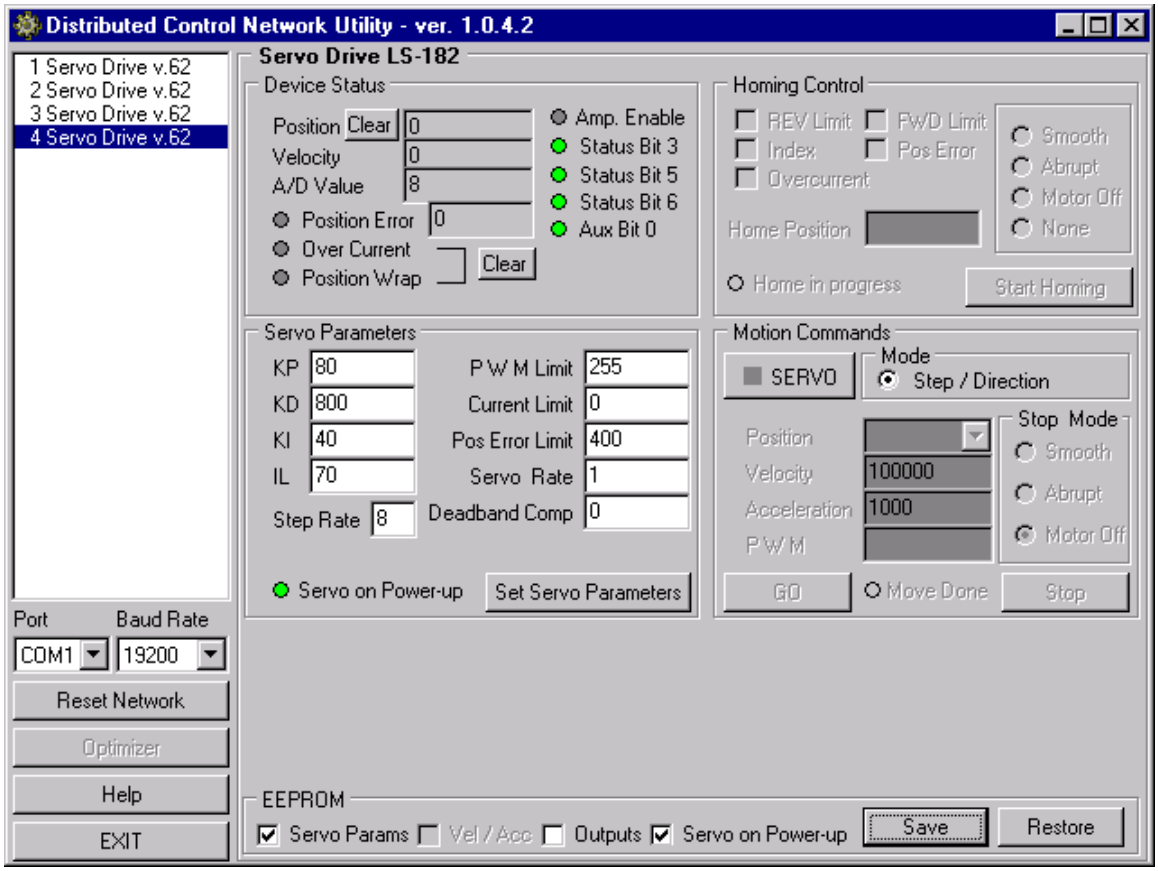
1. <u>If you have 2 available serial ports, or 2 computers:</u>

   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.

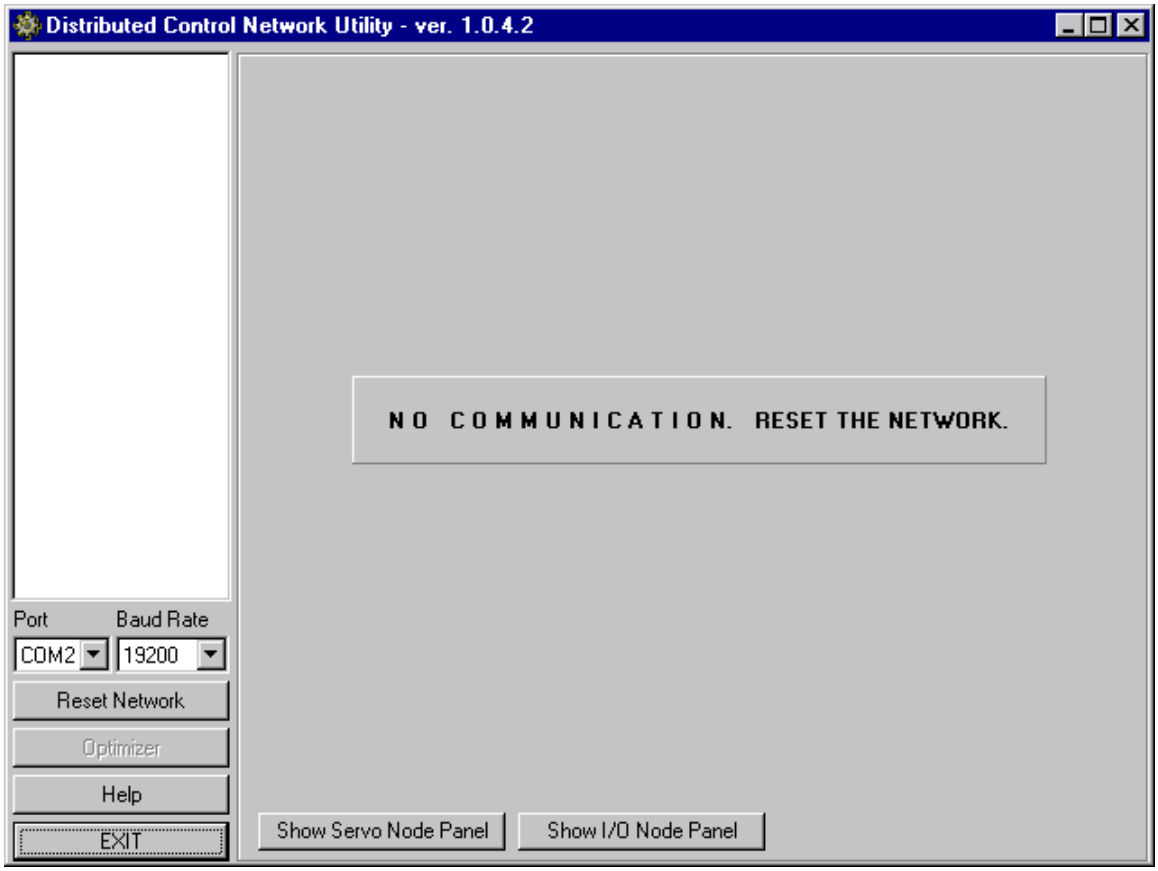
If you have only one serial port available:

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.

2. 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:

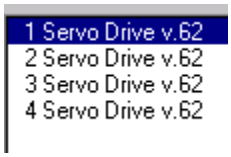


If instead you get a screen that looks like this:



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

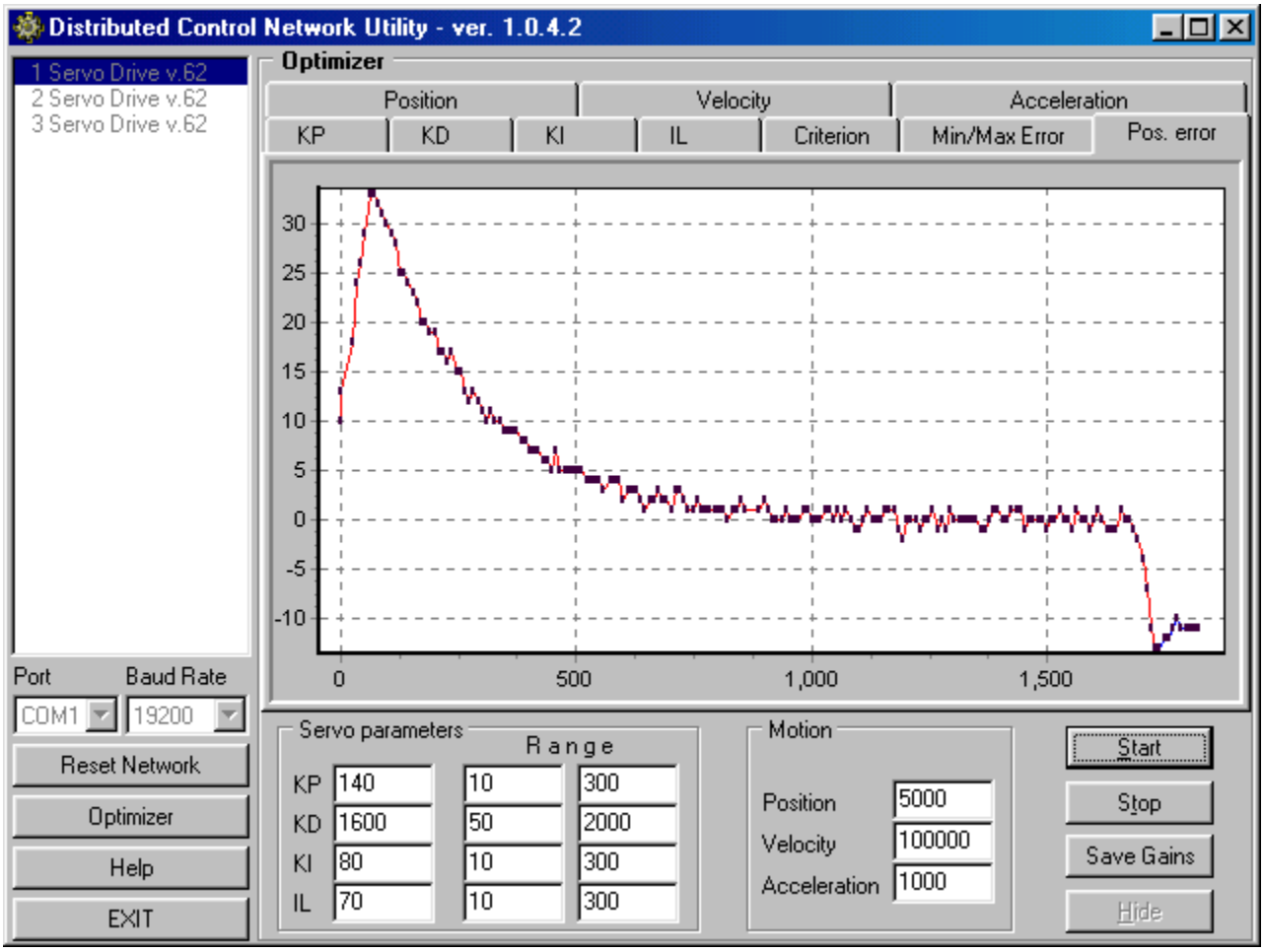
1. Choose that drive from the module list.
2. Change the servo parameters you need to change for the drive. (See Servo Parameters in Appendix I.)
3. Turn the servo off by choosing the Servo button in the Motion Commands area of the window. When the servo is on it will have a little green square in the 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. 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.

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. 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 he 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. Quadrature encoder counts = Encoder counts x 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. The optimizer will increment each of the parameters within the given range and find a local optimum value.
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).
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) and exit the Optimizer. (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.

6. 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.

7. Support:

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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:

output = Kp(pos_error) - Kd(pos_error - prev_pos_error) + Ki(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:

PWM = min(abs(output/256), output_limit)) - current_limit_adjustment
Dir = 0 if output>0, Dir = 1 if 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_adustment = 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(abs(*output/256), 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 incrementaladjustment 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 *abs(*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, Kp, and the integral gain, Ki, to 0. Keep increasing the derivative gain, Kd, until the motor starts to hum, and then back off a little bit. The motor shaft should feel more sluggish as the value for Kd is increased.

2. With Kd set at this maximal value, start increasing Kp 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 Kp and Kd set as above. If this is the case, first set a value for IL of 16000 and then start increasing the value of Ki until the steady state error is reduced to an acceptable level within an acceptable time. Increasing Ki will typically introduce some overshoot in the position. The best value for Kp 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 Kd 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 Kd/10. The minimum possible servo rate is 7.6 Hz.

In summary, we have a total of eight control filter parameters: Position Gain (Kp), Derivative Gain (Kd), Integral Gain (Ki), 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.

Step Rate

The Step rate multiplies each step coming from the signal generator into quadrature encoder ticks. For example if you want the equivalent of a ½ stepping motor (400 half steps per revolution) and you had a 1000 line encoder which has 4000 quadrature counts per revolution, then you would need a step multiplier of 10. If you want the equivalent of quarter stepping for the same motor than you would use a step multiplier of 5.

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

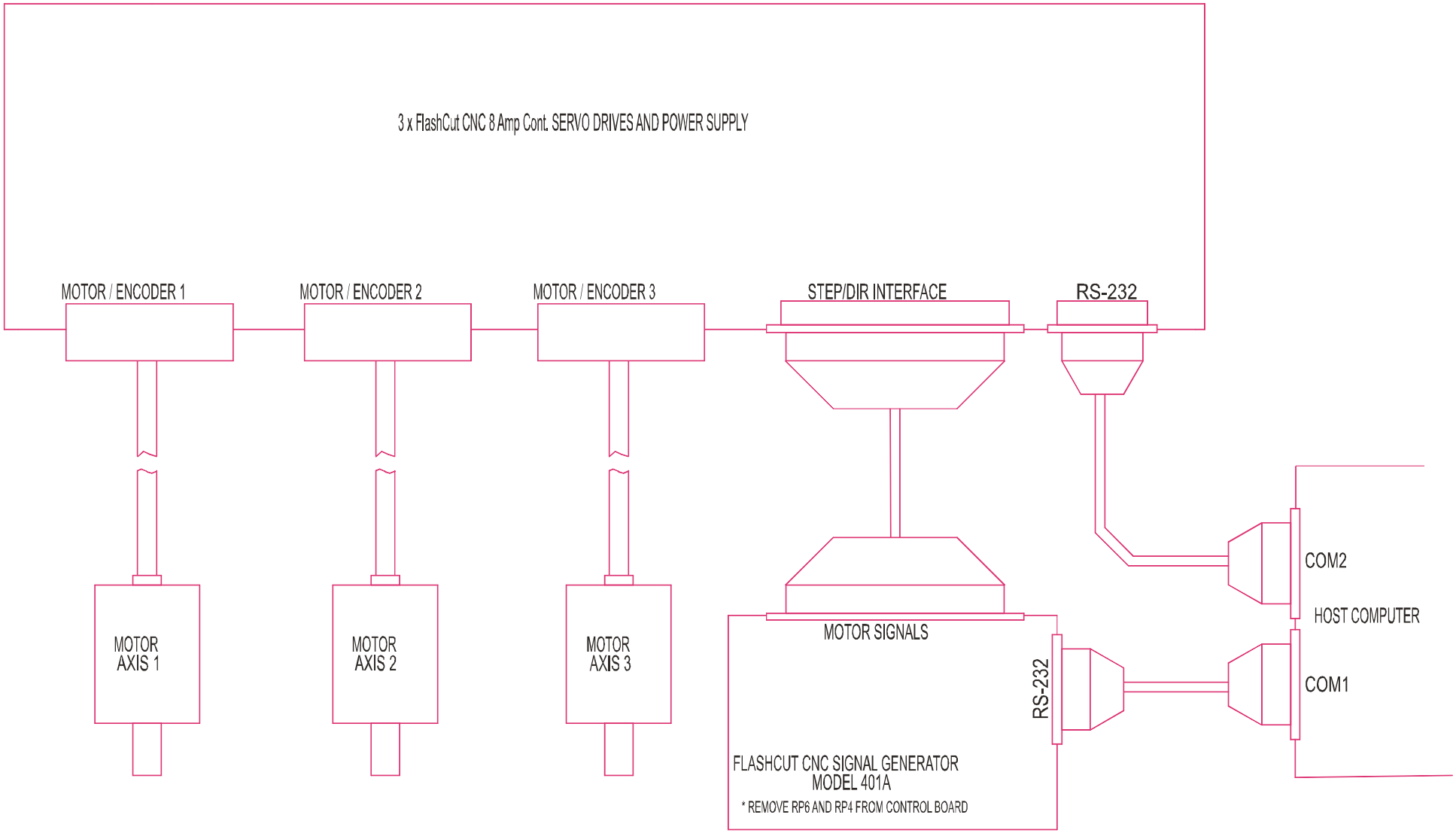
The servo rate is a clock divisor, which determines the length of a servo tick. The servo tick time is equal to 0.512 milliseconds multiplied by the servo rate divisor value. This value must be between 1 and 255. In general, this value may be left at the default value of 1, but for systems with a large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

Deadband Compensation

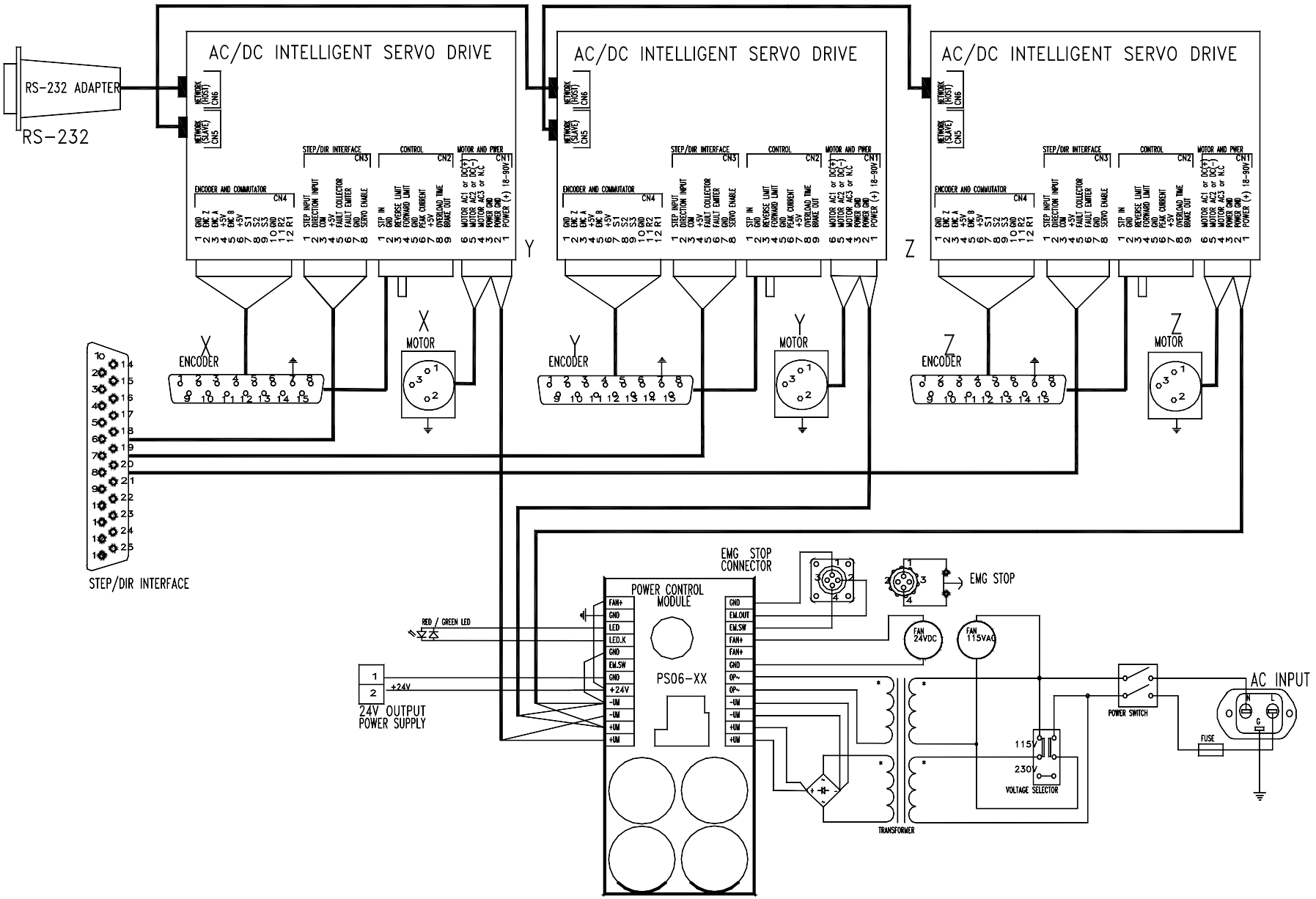
Some amplifier/motor combinations will exhibit a deadband around a zero PWM output. That is, small PWM values will have no visible effect on driving the motor. While servoing, the deadband compensation value will be added to the magnitude of the PWM output, thus boosting the control signal into the active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

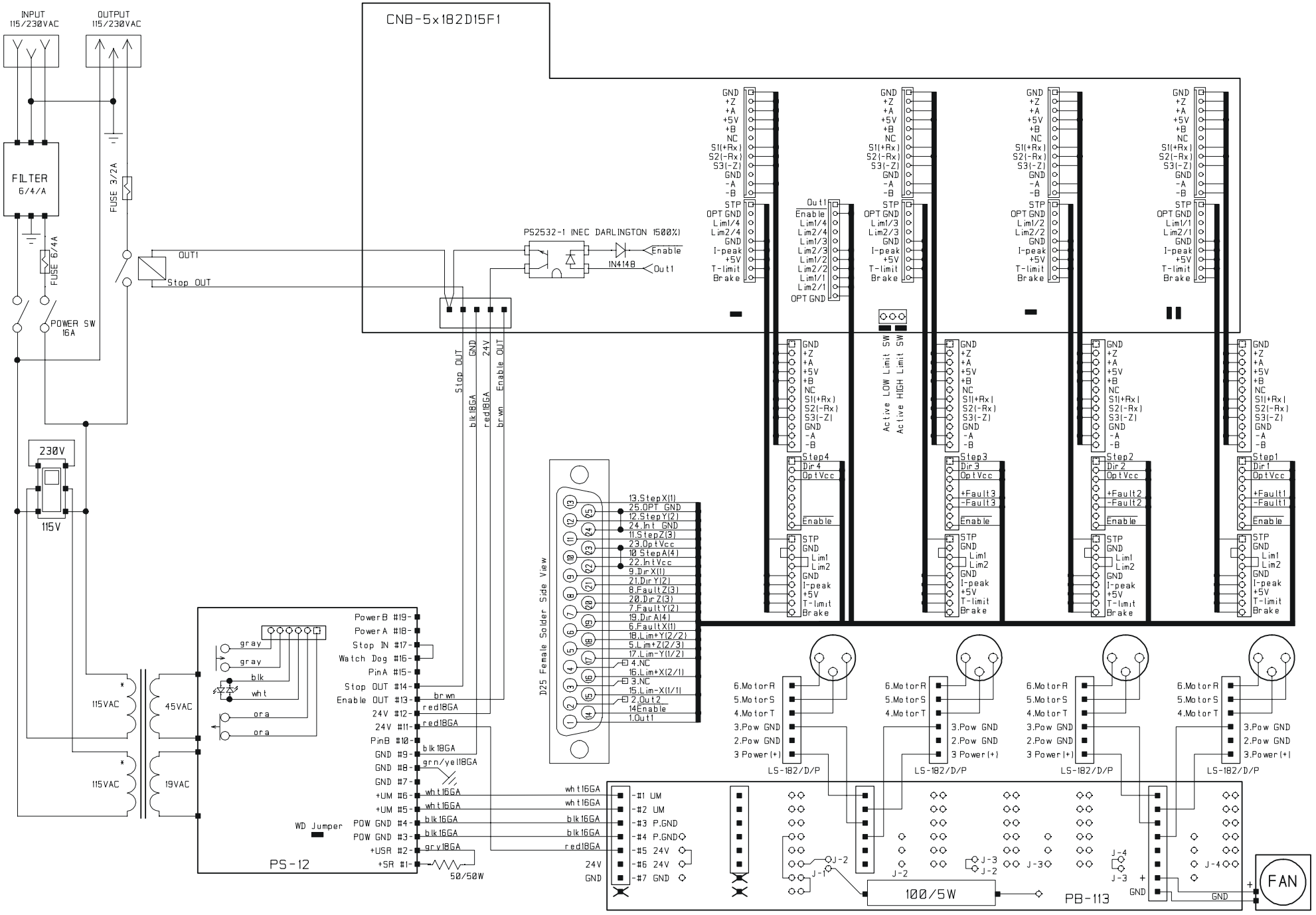
Appendix II. Schematics:

FlashCut CNC - THREE AXES CNC SERVO CONTROL SYSTEM

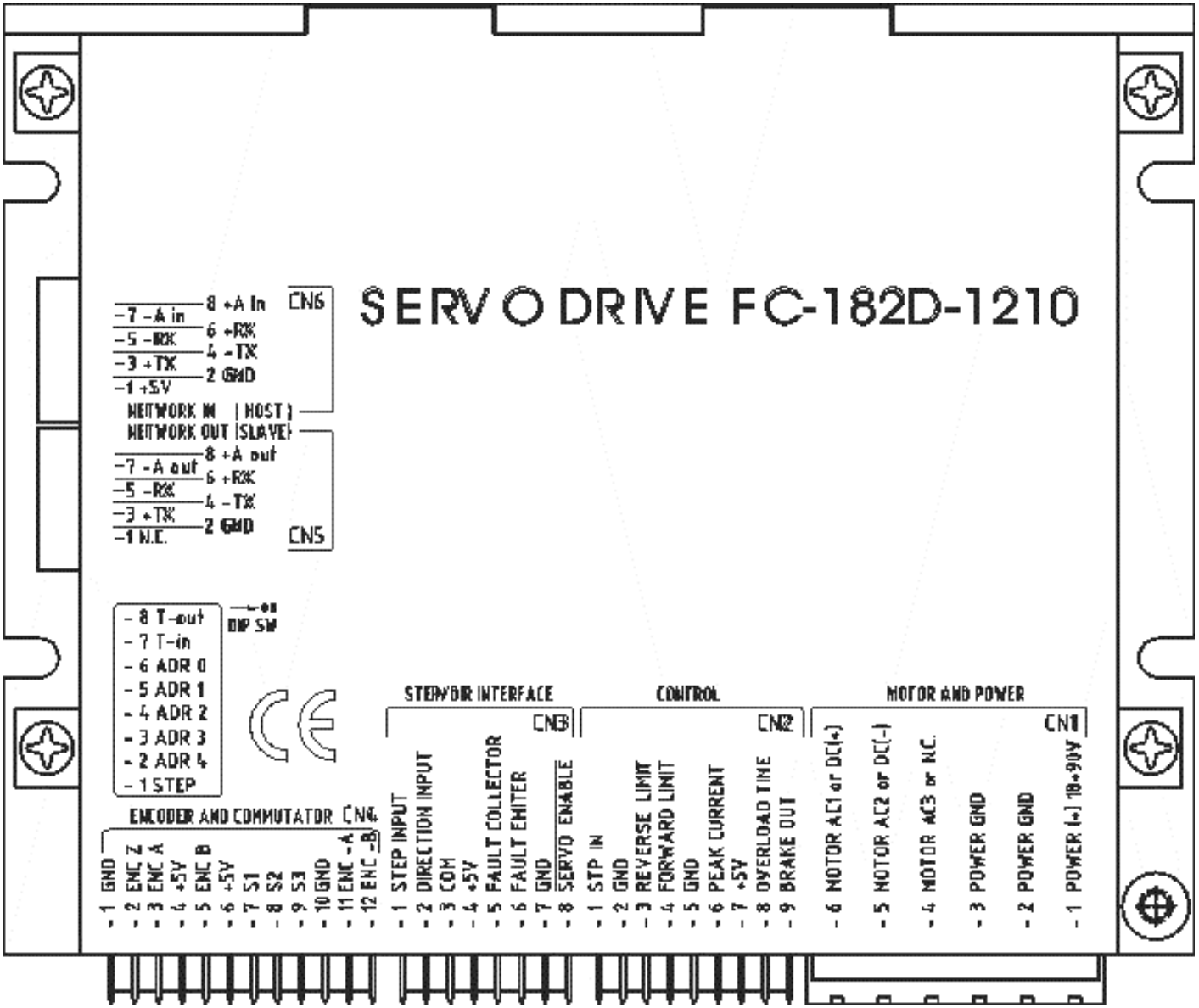


FlashCut CNC– THREE AXES CNC SERVO CONTROL SYSTEM

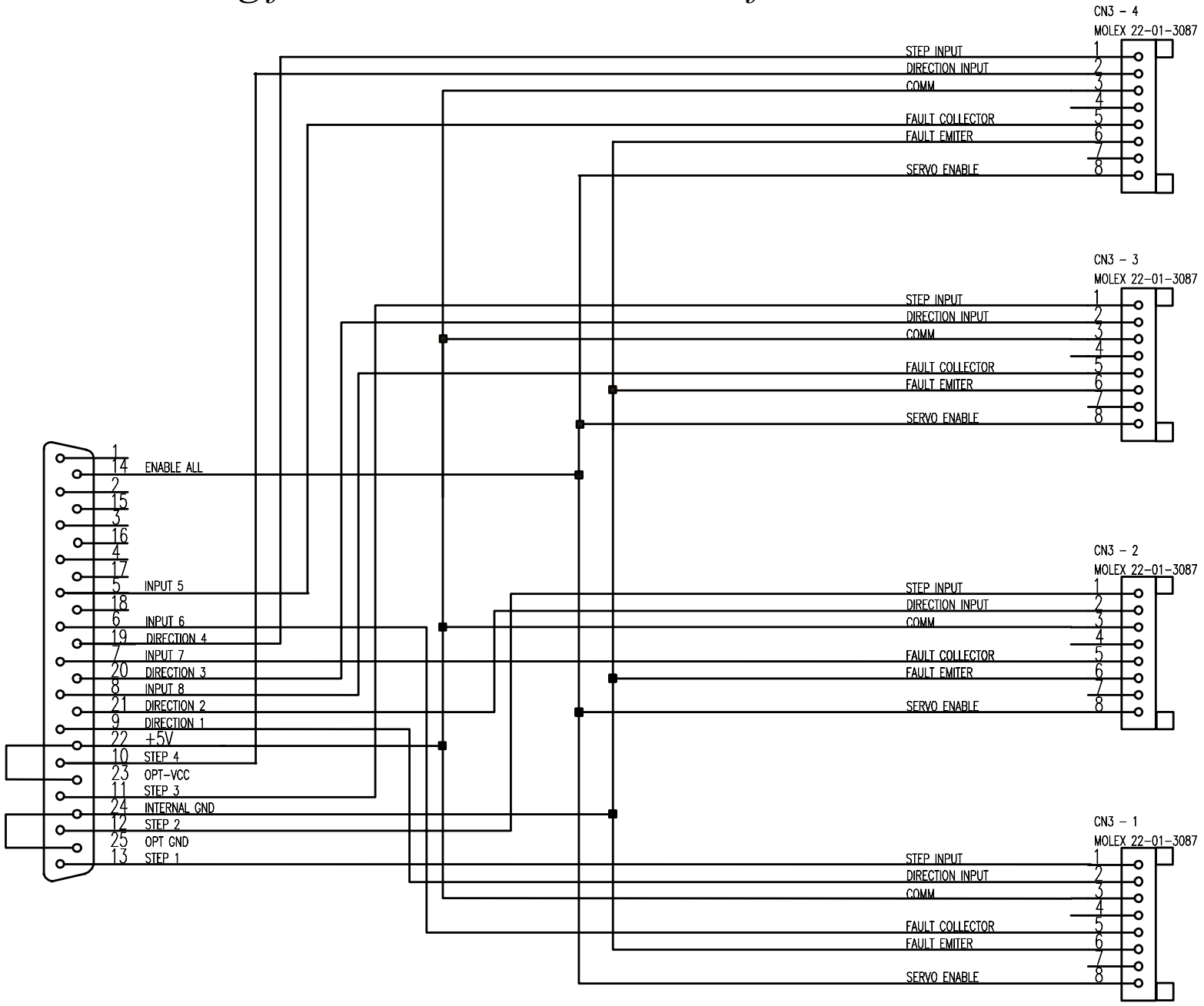



INPUT
115/230VAC
OUTPUT
115/230VAC
CNB-5x182D15F1
FILTER
6/4/A
FUSE 3/2A
FUSE 6/4A
POWER SW
16A
230V
115V
OUT1
Stop OUT
PS2532-1 (NEC DARLINGTON 1500%)
Enable
1N4148
Out1
Stop OUT
GND
24V
Enable OUT
blk18GA
red18GA
brwn
Active LOW Limit SW
Active HIGH Limit SW
D25 Female Solder Side View
13.StepX(1)
25.OPT GND
12.StepY(2)
24.Int GND
11.StepZ(3)
23.OptVcc
10.StepA(4)
22.IntVcc
9.DirX(1)
21.DirY(2)
8.FaultZ(3)
20.DirZ(3)
7.FaultY(2)
19.DirA(4)
6.FaultX(1)
18.Lim+Y(2/2)
5.Lim+Z(2/3)
17.Lim-Y(1/2)
4.NC
16.Lim+X(2/1)
3.NC
15.Lim-X(1/1)
2.Out2
14.Enable
1.Out1
gray
gray
blk
wht
ora
ora
115VAC
45VAC
115VAC
19VAC
WD Jumper
PS-12
PowerB #19
PowerA #18
Stop IN #17
Watch Dog #16
PinA #15
Stop OUT #14
Enable OUT #13
24V #12
24V #11
PinB #10
GND #9
GND #8
GND #7
+UM #6
+UM #5
POW GND #4
POW GND #3
+USR #2
+5R #1
grn/yel18GA
wht16GA
blk16GA
red18GA
50/50W
#1 UM
#2 UM
#3 P.GND
#4 P.GND
#5 24V
#6 24V
#7 GND
6.MotorR
5.MotorS
4.MotorT
3.Pow GND
2.Pow GND
3 Power(+)
LS-182/D/P
J-1
J-2
J-3
J-4
100/5W
PB-113
FAN
GND
STP
OPT GND
Lim1/4
Lim2/4
Lim1/3
Lim2/3
Lim1/2
Lim2/2
Lim1/1
Lim2/1
I-peak
+5V
T-limit
Brake
Step4
Step3
Step2
Step1
Dir4
Dir3
Dir2
Dir1
OptVcc
Enable
+Fault3
-Fault3
+Fault2
-Fault2
+Fault1
-Fault1
Lim1
Lim2

Internal Wiring From Motor Connector to Individual Servo Drive

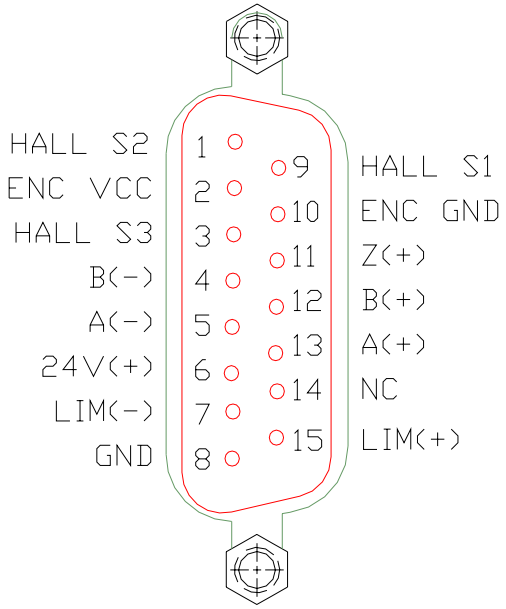


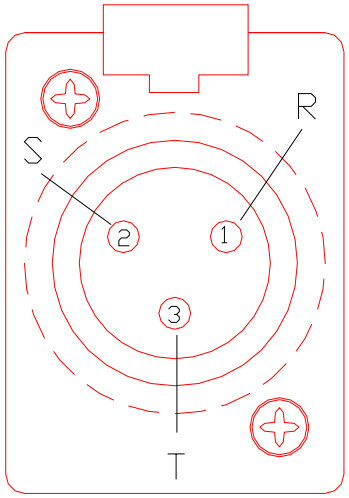
Internal Wiring from FlashCut DB25 Interface Cable to Individual Servo Drives



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(+)*



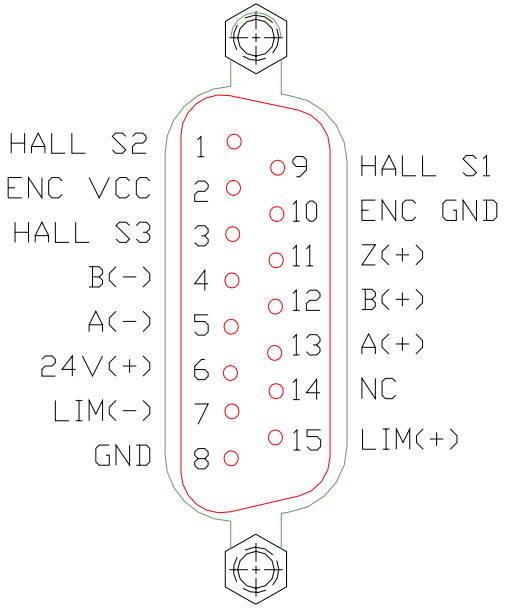


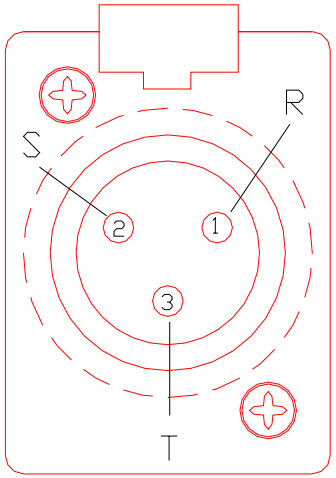
Motor Connector 18 gauge shielded cable	3 Pin Motor Connector	Signal Name
1	1	AC1 / Phase R
2	2	AC2 / Phase S
3	3	AC3 / Phase T
4	Shield	Cable Shield

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(+)*



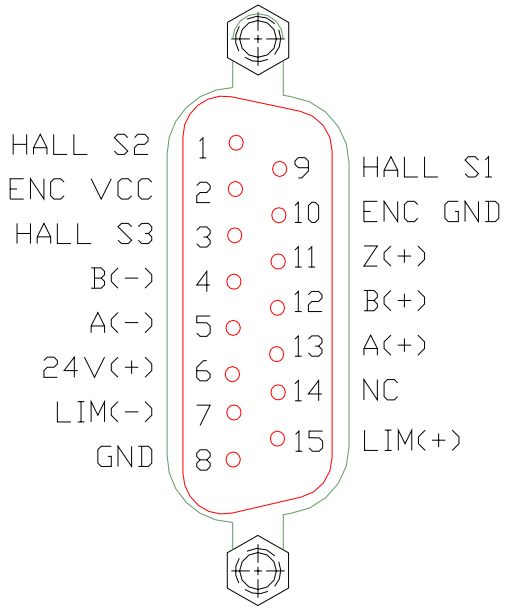


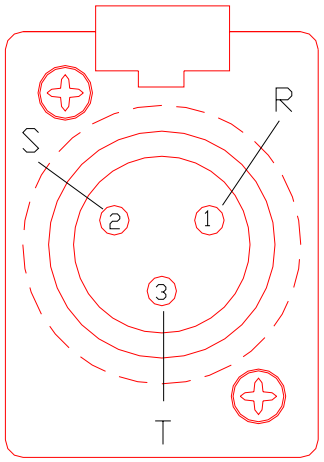
Motor Lead Wire Connection 18 gauge	3 Pin Motor Connector	Signal Name
Red	1	AC1 / Phase R
White	2	AC2 / Phase S
Black	3	AC3 / Phase T
Cable Shield	Shield	Cable Shield

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(+)*



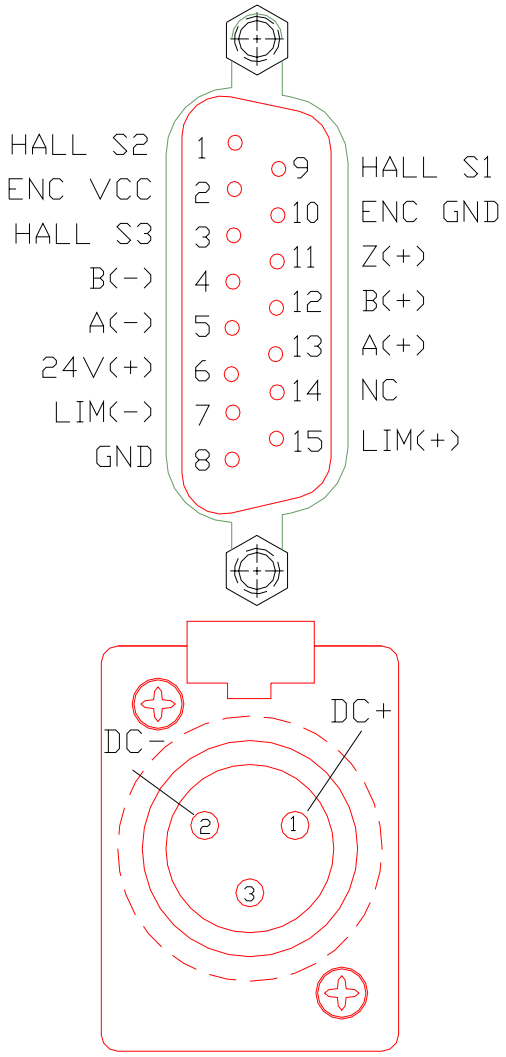


3 Pin Motor Connector	Signal Name
1	AC1 / Phase R
2	AC2 / Phase S
3	AC3 / Phase T
Shield	Cable Shield

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.