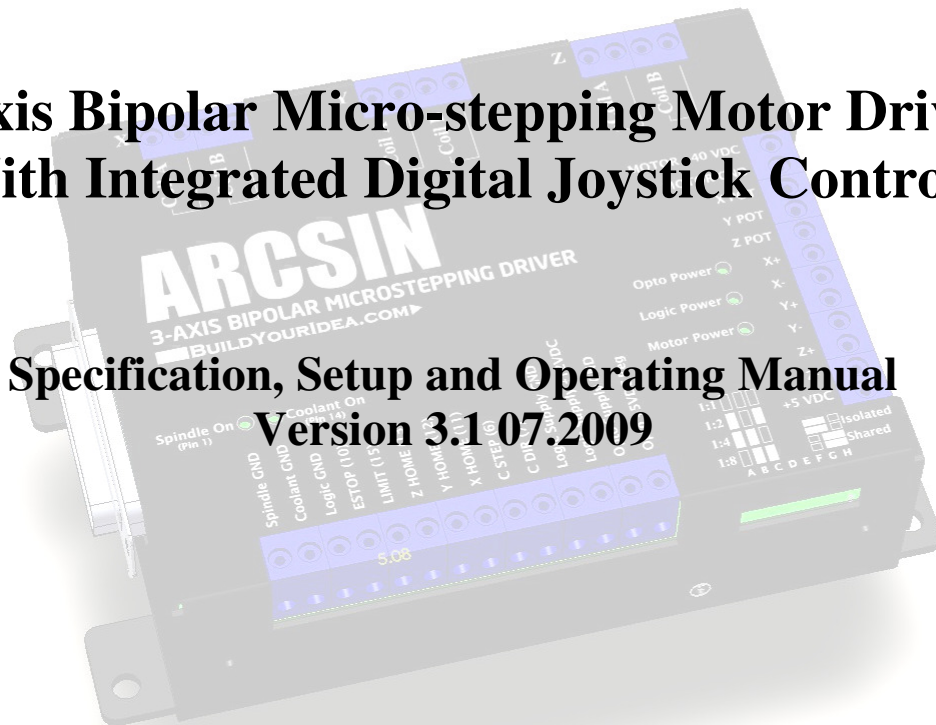


# ARCSIN

## 3-Axis Bipolar Micro-stepping Motor Driver With Integrated Digital Joystick Control

### Specification, Setup and Operating Manual Version 3.1 07.2009



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# ARCSIN

## 3-Axis Bipolar Micro-stepping Motor Driver with Integrated Digital Joystick Control

### General Description

The ARCSIN is a full-featured three axis bipolar stepper motor driver capable of delivering 3A per phase continuous and up to 6A peak at intermittent duty. With its powerful FET based power section, the ARCSIN is the perfect choice for driving small 3-axis CNC mills using 4-wire bipolar stepper motors. The ARCSIN has a variety of input and output signals to sense home, e-stop and limit switches and also control spindle motors and coolant pumps. Micro-stepping is configured via a set of easily accessible jumpers which allow the ARCSIN to be set up for either full, half, quarter or eight micro-steps. Separate power planes are used in the design along with full optical isolation on all of the inputs and outputs from the PC parallel port for noise suppression. Each of the three axes of the ARCSIN can be controlled with digital joystick inputs for accurately positioning the cutting head of the CNC machine or just for spinning the motors. The ARCSIN also features a black anodized aluminum chassis/heat-sink combo to provide heat dissipation to the power H-bridge section and protect all of the goodness inside.

This product is named after ARCSIN, the inverse function of the SIN, pronounced ARC-SINE.

### Features

- Full 3-Axis interpolation capable
- 20Khz PWM
- DMOS H-bridge power section delivering 3A/phase continuous, 6A peak momentary
- Jumper selectable full, half, quarter and eighth micro-stepping
- Each axis programmable to a different micro-step resolution
- Adjustable output current
- Fully integrated digital joystick control
- Idle current reduction after 5s of no step activity
- Power section thermal shutdown @ 155° C
- Separate power planes for logic and optical isolation supplies
- 30Khz max step rate
- Option C axis step/dir outputs
- Optically isolated 12v @ 1A spindle motor and coolant pump output transistors
- Home, limit and E-stop inputs all optically isolated
- Integrated heat-sink/chassis

### Applications

- 3-Axis CNC machines
- Robotics
- Linear motion/positioning

## Absolute Maximum Ratings

VccMotor = +48V  
 LogicSupply = +18V  
 OptoSupply = +5V Regulated

Spindle and Coolant Output = +24V, 2A  
 CStep/Dir = +5V TTL Opto Isolated

### Operating Conditions

Temperature Range (Tc)  
 -10°C to +48°C

## Electrical Characteristics

The following specifications apply for VccMotor = 40V, Tc = 25°C fan cooled

Symbol/Signal	Conditions	Typical	Limit
<b>POWER OUTPUT STAGE</b>			
Current limit per coil/phase	VccMotor = 40V, Tc = 25°C	I <sub>LOAD</sub> = 3A	I <sub>LOAD</sub> = 6A
<b>DC LOGIC SUPPLY</b>			
	n/a	+12V DC	+18V DC
<b>DC OPTICAL ISOLATION POWER SUPPLY</b>			
	n/a	+5V DC Regulated	+5V DC Regulated
<b>LOGIC INPUTS (ESTOP/LIMIT/HOME)</b>			
	n/a	+5V DC Regulated	+5V DC Regulated
<b>SPINDLE/COOLANT OUTPUT NPN Darlington</b>			
	Logic Supply +12VDC Tc = 25°C fan cooled	I <sub>LOAD</sub> = 1A	I <sub>LOAD</sub> = 2A
<b>CStep/Direction</b>			
	Optically isolated +5V TTL signals	+5V DC Regulated	+5V DC Regulated
<b>Step Rate</b>			
	n/a	30Khz	30Khz

## Disclaimers and Safety Concerns

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Buildyouridea.com has made every effort to provide you with a top-quality stepper motor driver that is simple to set up and safe to use. Close attention should be paid to warnings and safety advisories to avoid damage to the ARCSIN board and damage to you! To avoid electrical damage to the delicate FET components and other electrically sensitive parts, check and double-check your connections before applying power to the ARCSIN.

- Hazardous and/or lethal voltages and current levels exist on the ARCSIN. Disconnect all power to the ARCSIN before touching the board! Disconnect all power before configuring jumpers or resistor values!
- The voltages applied to ARCSIN power connections must not exceed ratings or ARCSIN may be damaged.
- Motor power must be turned off when connecting or disconnecting stepper motors or ARCSIN may be damaged. Pay attention to the Polarity Matters Icon! When you see this, double check to make sure that you are using the correct polarity on the connection! The polarity of power connections must be observed or ARCSIN will be damaged.
- Buildyouridea.com does not accept any responsibility regarding content, errors, omissions or the correctness of the information contained in this manual. Use the information contained herein at your own risk. Buildyouridea.com is not responsible for any loss or accident to you or to third-parties including loss of business, loss of sale, equipment or property damage, injury or death resulting from or to you or other third-parties while using this product or the information contained herein.
- CNC machines are dangerous and can cause injury or even death. Buildyouridea.com cannot be held responsible for any injuries or damage (to people or property) caused through the use or misuse of the ARCSIN controller.

## Additional Items needed to get the ARCSIN Running

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(Refer to the ARCSIN Interconnection Diagram on page 21 as you review this.)

- **Logic Power Supply:** A 9 to 18 volt at 200 milliamp or more DC power supply. A plug-in supply (wallwort) will work fine here. For this power supply a 9 volt supply is preferable to a 20 volt one. NOTE: If you connect a 12 volt fan to the Fan Power connector on ARCSIN, the Logic Power Supply voltage should not exceed 15 volts.
- **Motor Power Supply:** A 12 to 40 volt DC power supply with adequate current capacity to power the motors you intend to use. For this power supply a 40 volt supply is preferable to a 12 volt one. See the Motor Power supply discussion on page 10 for further information.
- **Optoisolator Power Supply** (optional): A 5.0 volt at 50 milliamp power supply. This power supply must be isolated (have a separate ground) from the Logic and Motor power supplies. See the Optoisolator Power supply discussion on page 13 for further information.
- **Cooling Fan** (optional) A small 12 volt DC cooling fan. Virtually any P.C. type cooling fan will do the trick. NOTE: If you connect the fan to the Logic Power Supply terminals on the ARCSIN, the logic supply voltage should not exceed 15 volts.
- **P.C. Parallel Port Cable:** A DB25 Male to DB25 Female straight-through cable with a maximum length of 25 feet (shorter is better.)
- **Joystick** (optional): A joystick or switch arrangement that provides individual contact closures (switches) for X+,X-,Y+,Y-,Z+,Z- movement. See Joystick Setup and Control on page 9 for further information.
- **Joystick Speed Control Potentiometer(s)** (optional): 1 to 3 potentiometers (pots) with a resistance rating of anywhere from 1 K 10K (1000 to 10000) ohms. Any value in this range will work identically. See Joystick Setup and Control on page 9 for further information.
- **Stepper Motor(s):** Up to 3 each 4, 6, or 8 wire stepper motors (5 wire steppers will not work) suited to your application. See the Stepper Motor discussion on page 15 for further information.
- **Computer and Software:** A computer with a P.C. compatible parallel (printer) port and CNC software that is capable of using the parallel port to drive Step/Direction motor drives. See ARCSIN Configuration on page 8 for further information.

# ARCSIN Start-Up Guide

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(Refer to ARCSIN Interconnection diagram on page 21 as you proceed.)

1. Position the ARCSIN so that the screw terminals are easily accessible. For optimal heat dissipation, mount the ARCSIN to an aluminum plate or the chassis of your CNC machine.
2. Set the micro-step jumpers to the desired step rate as indicated on the top cover of the ARCSIN. If you don't know what settings to use, use the factory default of 1:1.
3. Connect your stepper motors to the motor terminal blocks. Be sure to connect one winding of a motor to the first two terminals on a block, and the other winding to the second two terminals. If you are not sure about the wiring of your motors, refer to the Stepper Motor discussion on page 15.
4. Connect your Logic Power Supply to its terminal block. Be sure to observe polarity. The ARCSIN has a polarity protection diode in series with this supply to protect the microcontrollers, but you should still double check your connection before powering up.
5. Connect your Motor Power Supply to its terminal block. Be sure to observe polarity. NOTE: If you are using a 12 volt supply for the motors (this can be done, but is not recommended other than for testing), you can use the same power source for your logic supply. Just wire the motor supply and logic supply terminals together.
6. Connect one end of a 6 inch piece of jumper wire to one of the GND terminals on the Joystick terminal block. Strip 1/8" of insulation off the other end of the jumper. This will be used to test operation from joystick inputs.
7. Recheck all the connections and settings made thus far.
8. Power on the Logic Power Supply *only* (unless you are using a single supply). The Logic Power LED should light and the Opto Power LED should light if you left Jumpers F,G,H in their factory configured positions for shared power.
9. Power on the Motor Power Supply. At this point the stepper motor rotors should lock.
10. Tap the joystick jumper wire on the X+,X-,Y+,Y-,Z+,Z- terminals of the joystick terminal block. The appropriate stepper motor should respond by jogging one direction for a tap on the (+) terminal for that axis, and the other direction for a tap on the (-) terminal
11. Power off the Motor and Logic Power Supplies.
12. Configure your CNC software to work with ARCSIN. See the ARCSIN Configuration page in this manual for the required settings.
13. Connect ARCSIN to the parallel (printer) port of your P.C. Use a DB25Male-DB25Female interconnecting cable.
14. Power on the Logic and Motor Power Supplies.
15. Start your CNC software on the computer and test stepper operation with the software. (The means of testing will depend on your software, but it is likely that there will be 'Jog' functionality that will allow you to rotate the steppers for each axis.)

# ARCSIN Configuration and Operation

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## Configuring your CNC software to run ARCSIN

ARCSIN connects to your computer's parallel (printer or LPT) port and accepts step and direction pulses from your computer. CNC software running on your computer sends these step and direction signals to the ARCSIN board. (Configuration of the items in this section will be done in your CNC software.)

ARCSIN will work with many popular CNC software packages using step and direction signals through the parallel port. ARCSIN has been thoroughly tested with TurboCNC and Mach3, two popular CNC software packages available online at a nominal cost. Configuration related discussion of these machine control tools is outside of the scope of this manual and will not be included. Please see TurboCNC and/or Mach3 documentation for details on how to set-up your parallel port to run the ARCSIN.

Your CNC software must be able to configure the parallel port pins as follows:

### Parallel Port Pin Assignments:

#### OUTPUTS:

- X Axis Step: Pin 2;                      X Direction: Pin 3
- Y Axis Step: Pin 4;                      Y Direction: Pin 5
- Z Axis Step: Pin 6;                      Z Direction: Pin 7
- C Axis Step: Pin 8;                      C Direction: Pin 9
- Spindle:                      Pin 1
- Coolant:                      Pin 14

#### INPUTS

- E-Stop:                      Pin 10
- Limit:                      Pin 15
- X-Home:                      Pin 11
- Y-Home:                      Pin 12
- Z-Home:                      Pin 13

### Parallel Port Logic Polarity and Timing:

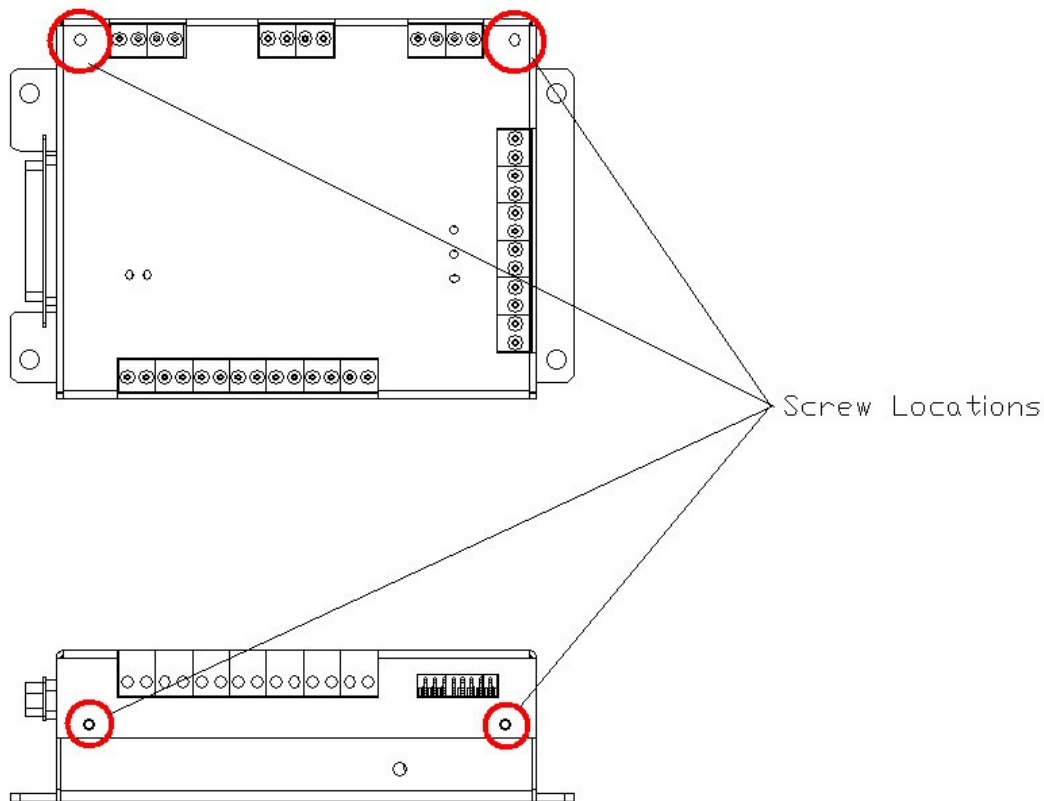
- Step and Direction Pulse **Logic(polarity): Negative (-)**
- Step and Direction **Pulse Width: 5uSec**(microseconds) nominal (2 to 20uSec are acceptable)



### Programming Different Step Rates on Each Axis

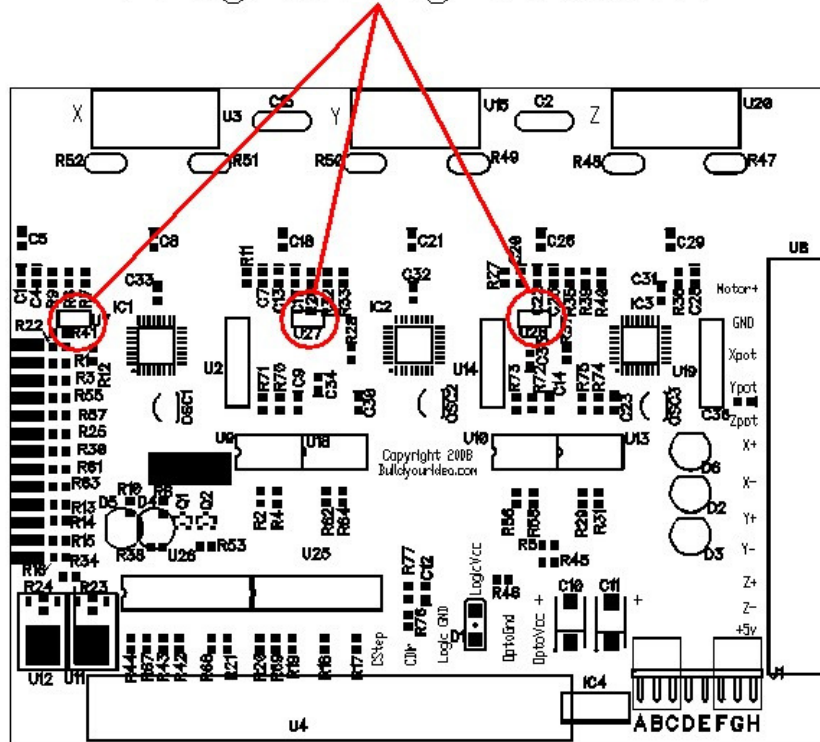
A provision has been made to allow ARCSIN users to run a different step rate on each axis. This is sometimes useful if different stepper motors or different lead screws are used in the positioning system. To accomplish this, the ARCSIN can be programmed to store different step rates for each axis in EEPROM (Electrically Erasable Programmable Read Only Memory). This is a fancy way of saying that once you program your ARCSIN X, Y or Z axis to a certain step rate, it will stay that way even after you power cycle the ARCSIN. These changes will stay in effect until you either clear the settings or program them to another step rate.

To program the ARCSIN axes to different step rates, you must open the hood of the ARCSIN to access the programming jumpers. Before you begin, remove all power connections to the ARCSIN, remove all wires going into the screw terminals, and remove the micro-step configuration jumpers. The red power jumpers can stay in place as they do not prevent the hood removal. As shown in the figure below, begin by removing the two screws on the front of the ARCSIN. Next, remove the two screws at the upper left and right corners of the ARCSIN housing as seen in figure y. The hood should now come straight up and away from the bottom heat-sink.



Once the hood is up, locate the programming headers as shown in the diagram below.

## Step Rate Programming Headers



The example below will be for programming the X axis, but the same technique is used to program the Y and Z axes as well.

1. To program the X axis to 1:4 step rate, place the micro-step configuration jumpers into positions A and B for 1:4 step rate.
2. Place one of the shorting blocks included with the ARCSIN onto the programming header of the X axis.
3. With the power off, reconnect the logic power supply to the correct screw terminals and double check that you have the polarity and position correct.
4. When you are ready, turn on the logic supply.
5. Within 5 seconds of turning on the logic supply, pull the shorting block off the programming header.
6. Turn off the logic power supply, put the shorting block back on the X axis programming header.
7. The X axis should now be programmed to run at 1:4 step rate.
8. To revert back to having the step rate jumpers control the step rate for all three axes, remove the shorting block on the programming header for each axis.

### Setting the Output Current of each Axis

The ARCSIN power output can be configured for different current requirements depending on your motors and application specific torque requirements. The ARCSIN is factory configured for a maximum of 3 amps per phase of output current but this can be easily changed by plugging in the appropriate resistor values into the **output current resistor sockets**.

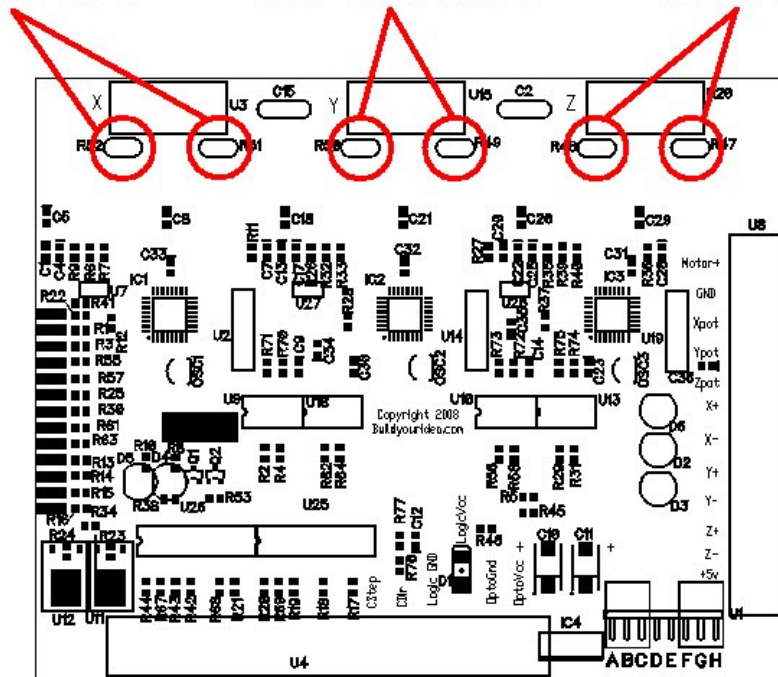
To access these resistors, you must open the hood of the ARCSIN. Before you begin, remove all power connections to the ARCSIN, remove all wires going into the screw terminals, and remove the micro-step configuration jumpers. The red power jumpers can stay in place as they do not prevent the hood removal. As shown in the figure on the previous page, begin by removing the two screws on the front of the ARCSIN. Next, remove the two screws at the upper left and right corners of the ARCSIN housing as seen in figure y. The hood should now come straight up and away from the bottom heat-sink.

For the axis you are configuring, locate the two output current resistor sockets from the diagram below:

X Axis Current  
Set Resistors

Y Axis Current  
Set Resistors

Z Axis Current  
Set Resistors



Use the following procedure to install the current set resistors:

1. Remove the two factory installed resistors.
2. Trim the legs of the two new resistors to the same length of the factory installed resistors
3. Install the two new resistors that are appropriate for your particular application and motors. You must use the same resistor values at both sockets for that axis or the ARCSIN may be damaged.
4. Bend the new resistors down so that they do not short out on the top cover above or the PCB below.

Resistor values for any motor drive current from .5 amp to 3 amps can be calculated using the formula (Resistor value in ohms) =  $20000 / (\text{Current setting in amps})$ . The ARCSIN comes with the correct resistor values to set the output current to 1, 2, or 3 amps (factory default). Do not use a resistance value of less than 6200 Ohms (6.2Kohms) or the ARCSIN power transistors may be damaged. *Example:* For a current setting of 1.5 amps the resistor values would be  $20000 / 1.5$  or 13,333 ohms. Use the nearest standard resistor value, which is 13,000 ohms.

### **Joystick Setup and Control**

Begin by selecting appropriate pots to control the jog-speed of the motors. You may use any resistance value from 1K to 10K ohms. The pots do not need to have a high power rating since only a few milliamps of current flows through them. You should, however, use pots that are fairly sturdy and knobs that are easy to grip i.e. 'trim-pots' are not desirable. I use surplus 5k pots with nice heavy-duty leads so I can easily solder wires to them.

Now you must determine whether you want a single pot to control the speed of each axis, individual pots controlling each axis, or if you want some combination of the two. I find that using one pot to control the X and Y axes and a separate pot for the Z axis works great. If you decide to follow this recommendation, you can gang the analog inputs of one or more axes together by connecting the output or center leg of one pot to two or more pot inputs on the ARCSIN.

The jog-speed of each axis can be changed while the stepper motor is moving i.e. jog speed dynamically follows the setting of the associated speed control pot.

### **Joystick Switches**

Almost any type of normally open, momentary switch will work. The current through the switch contacts is only a few milliamps so there is no need for switches with a high current rating. For the X and Y axes, a standard arcade-type micro-switch joystick works well. Digital joysticks can be purchased separately from [Buildyouridea.com](http://Buildyouridea.com) if you do not have one. If you do opt to use a joystick, remember that the micro-switches on some joysticks have both normally open and normally closed contacts. Be sure to use the normally open contacts.

For the Z axis, a pair of momentary pushbutton switches works well. I've found that two pushbutton switches enable me to accurately set the Z height of the cutter or bit before I start the cut. Momentary single-pole-double-throw-center-off (SPDT spring-return center-off) toggle switches will also work well. If you don't have (or don't want to use) a joystick, 6 pushbutton switches or 3 toggle switches (or even a mix of the two) will do the job.

### **Joystick Operation/Functionality**

The joystick inputs of ARCSIN are used to jog (move) the X, Y, and Z axes under the control of external switches such as a joystick. This movement is independent of any computer commands. The joystick can be used without a computer being connected to the ARCSIN. If a computer *is* connected, the joystick commands override any commands being sent by the computer. This is especially handy if you have to adjust the Z depth of a cut while the CNC machine is in motion.

## Motor Power Supply Discussion

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**The bottom line:** The higher the voltage output of the motor power supply, (up to the absolute maximum rating of 40 volts for the ARCSIN) the better. The simplest and most reliable power supply is a linear, unregulated supply i.e. a transformer, rectifier, and filter capacitor.

Calculating Motor Power Supply Current Requirements:

- The wattage requirement for the motor power supply will be approximately the total motor wattage divided by 70% (system efficiency).
- The current rating requirement for the motor power supply will be the (Wattage Requirement)/(Power Supply Voltage *Under Load*).
- Here are calculations for a hypothetical system using the following motors:
- X axis stepper rating per winding: 5 volts at 3 amps.
- Y axis stepper rating per winding: 5 volts at 3 amps.
- Z axis stepper rating per winding: 2 volts at 2 amps.
- Motor wattages:
  - X = 5 volts x 3 amps x 2 windings = 30 watts
  - Y = 5 volts x 3 amps x 2 windings = 30 watts
  - Z = 2 volts x 2 amps x 2 windings = 8 watts
- Total motor wattage = 68 watts
- System wattage requirement:
  - Motor Wattage / System Efficiency = 68 watts / 70% = 97 watts
- Motor Power Supply Current Requirement:
  - For a 40 volt (under load) power supply: 97 watts / 40 volts = 2.4 amps.
  - For a 12 volt (under load) power supply: 97 watts / 12 volts = 8.1 amps.

### The Whys and Wherefores:

You might be thinking “My motor says 4 volts at 3 amps on its nameplate. If I hook 48 volts or even 12 volts to my system won’t it burn up my motor? And besides, since my motor only requires 4 volts, why should I even bother with a higher voltage power supply? Won’t that just make the system bigger and less efficient? I also saw in the calculations that if you use a higher voltage you need less current and that doesn’t make sense to me” and you *should* be wondering about this stuff!

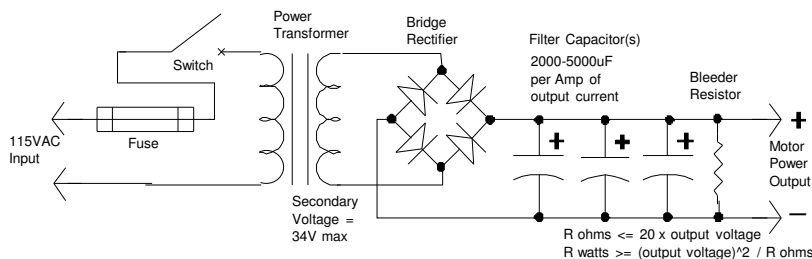
First it is necessary to know a little about how a **PWM (Pulse-Width Modulation)** drive like ARCSIN works. In a PWM drive the current out of the drive to a motor winding is *not* simply turned on and left on until the next step (or micro-step) occurs. The current output is instead continuously monitored and turned on only long enough for the current to reach the correct level and then turned off until the current drops a bit below that level. This monitoring/switching sequence occurs at a high rate of speed – generally around 20000 times a second – so the average current in the winding is correct for the current step or micro-step, even though the winding is connected to the power supply only a portion of the time.

Two things work together to determine the percentage of the time the winding is connected to power at any point in time: the average current requested by the stepper drive for the current micro-step, and the output voltage of the power supply. The lower the current, the lower the duty cycle. The higher the lower supply voltage, the lower the duty cycle.

If you think about the previous paragraph, several of the questions answer themselves. Your motor doesn't burn up because ARCSIN is continuously monitoring the current in each winding and maintaining the proper *average* current at any time regardless of power supply voltage. It also makes sense that power supply current drain goes down as power supply voltage goes up. If the voltage going to the winding is higher it's going to take less time for the current to reach the requested level.

That means that the percentage of the time the power supply will actually be connected to the motor will go down as the power supply voltage goes up. If the duty cycle goes down, then the *average* current drain on the power supply goes down as well.

So what kind of power supply is best? There's no simple answer. It has to put out at least 12 volts. It can't put out more than 48 volts, even when unloaded. It has to have enough current capacity to power your motors as calculated above. If you're step rate is going to be low (up to a rotor speed of 60rpm or so) the 12 volt output of an old P.C. power supply will probably get you by if it has sufficient current capacity. If you have a regulated power supply with the output voltage you want and adequate current capacity you need, that should work fine. If your regulated power supply is a switching supply (as opposed to a linear supply), you should consider adding additional filter capacitance across the supply output (1000 or 2000 uF per amp of expected current drain should probably be OK). Or you can throw together a very simple unregulated supply similar to the one to the right.



**Figure 9**

We're still left wondering why to bother with a higher voltage power supply when it appears a 12 volt supply will do just fine if it has the current capacity. Another good question. The short answer is that your steppers will give you useful output torque at higher speeds if you use a higher power supply voltage. A system that might start weakening at 120rpm with a 12 volt supply might be just as strong at 600rpm with a 40 volt supply.

Here's why: Besides resistance, a stepper motor winding has another characteristic called inductance. *Resistance* determines *how much* steady-state current will flow in the winding for a given applied voltage. *Inductance*, on the other hand, determines *how long* it will take the current to reach a steady-state value after voltage is applied. A stepper motor creates torque proportional to the *current* flowing in its windings which produce magnetic flux in the motor's stator. When the stepper is at rest, or is being stepped at a low rate of speed, there is plenty of time for the current in the windings to reach its proper level and thereby provide torque. As the step rate is increased, however, the rate of change of the voltages across the windings increases and the current lags further and further behind because of the winding inductance. This means that the current no longer has time to reach the full value requested and therefore motor output torque decreases. Not a good thing. The way we get around this is by increasing the power supply voltage. If you double the voltage impressed across an inductor, you halve the time it takes for the current in that inductor to reach a given value (i.e. you halve the *current rise time*). It follows that if you increased the voltage by a factor of ten, the current rise time to a given value would be decreased by a factor of 10. That's the phenomenon we're taking advantage of by increasing the power supply voltage. We're making the system force current into the windings more quickly so that we can step the motors more rapidly before the current falls behind to the point that output torque suffers.

There's another technical reason that higher supply voltages are desirable: The switching transistors in ARCSIN (as in any PWM drive) are not perfect switches. This causes them to produce heat during the time they are turned on. The higher the supply voltage, the lower the duty cycle of the transistor switches will be, thus reducing heating in the driver and increasing system efficiency to a degree.



## Optical Isolation and Supply Discussion

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The bottom line: For the most stable operation of your system, set the opto-isolator power jumpers on ARCSIN for **isolated** power (shorting jumpers oriented horizontally between G and H) and connect a *separate, isolated, regulated* 5.0 volt power supply rated at 50 milliamps or more to the opto-isolator Power Supply Input terminal block. Refer to ARCSIN Configuration Jumpers drawing on page 24 for locations and jumper settings.

*Or...* Set the opto-isolator power jumpers to **shared** and omit the opto power supply for now. Set up and test the system. If it is stable, you may not need separate opto power. If you have noise (glitch) problems, you can add the opto supply later.

*Or...* Look at the notes below, and consider picking up opto power from your computer by one of the ‘unapproved’ methods. Any of these connection methods should result in the same stability as what would be obtained by using a separate opto supply.

So what is *Optical Isolation* anyway? If you answer: “Well, it’s *optical* so it must have something to do with lenses or light; and it’s *isolation*, so it must separate something from something else.” You are *absolutely* correct! In the case of ARCSIN, the opto part is the infrared LED and the photodiode inside a chip called an opto-isolator. The computer and the ARCSIN electronics are isolated from each other electrically. (By extension, all the stuff that connects to ARCSIN (power supplies, motors, and joystick) are also electrically isolated from the computer). You say, “But you show a cable from the computer to ARCSIN. Isn’t that an electrical connection? And you are correct. The actual isolation takes place right at the input section of ARCSIN, so actually the input section of ARCSIN *is* electrically connected **to** the computer. But all the rest of the circuitry is electrically isolated **from** the computer.

So why have it? The answer you impress your friends with is “To improve system noise immunity, of course.” The real answer is that when you have motors that are turning on and off, and switches that might spark a little, and maybe a router or other type of motor that might have some arcing in the brushes, you have all kinds electrical glitches and spikes and bumps floating around your system. And, believe it or not, many if not most of these glitches and bumps find their way around on the ground or neutral wiring in the system (strange, huh?). Well, the motors and the big power supplies and the switches and ARCSIN, for that matter, are designed to handle these glitches pretty well as long as they are wired up correctly. But the computer tends to get confused between glitches and data, and this causes problems. So if we can break the ‘glitch path’ from the system to the computer, it’s a really good thing. Since we know that the glitches travel along the ground wire as well as the other wires, we know we ought to isolate *all* the wires coming out of the computer from the rest of the system. The easiest and cheapest way to do this is with opto-isolation. This is a vastly simplified explanation and there things like ‘ground loops’ and ‘single-point grounds’ and whoknowswhatelse that come into play here. But they all come under the topic of improving noise immunity, so the answer you gave your friends is still accurate.

There is one (small) fly in the ointment, however: The opto-isolator input circuitry on ARCSIN (or any other optically isolated drive that I know of, for that matter) requires a tiny bit of power for the circuitry that connects to the computer. And since we know that we need to keep the grounds separate between the computer and ARCSIN, we also know that we can't use the same power supply for this power as the one we use for the rest of the power for ARCSIN. It's just a little bit of juice we need: 5 volts at a twentieth of an amp or so. But it's still a hassle. If there was a way to get power from the computer's power supply, that would be ideal. We actually can, but they haven't made it easy: You can open the computer and connect to one of the 5 volt power leads and bring the wire out the back of the case. Or you can pick it up from the game port on the computer if you know how. Or you can get it from a USB port if you know how. None of these methods is 'approved' by the P.C. folks, so you're on your own if you use any of them. The other way is to get a small 5 volt power supply (a 5 volt *regulated* wallwort would work just fine) and use it. This small extra power supply is the **opto-isolator power supply**.

# Stepper Motor Discussion

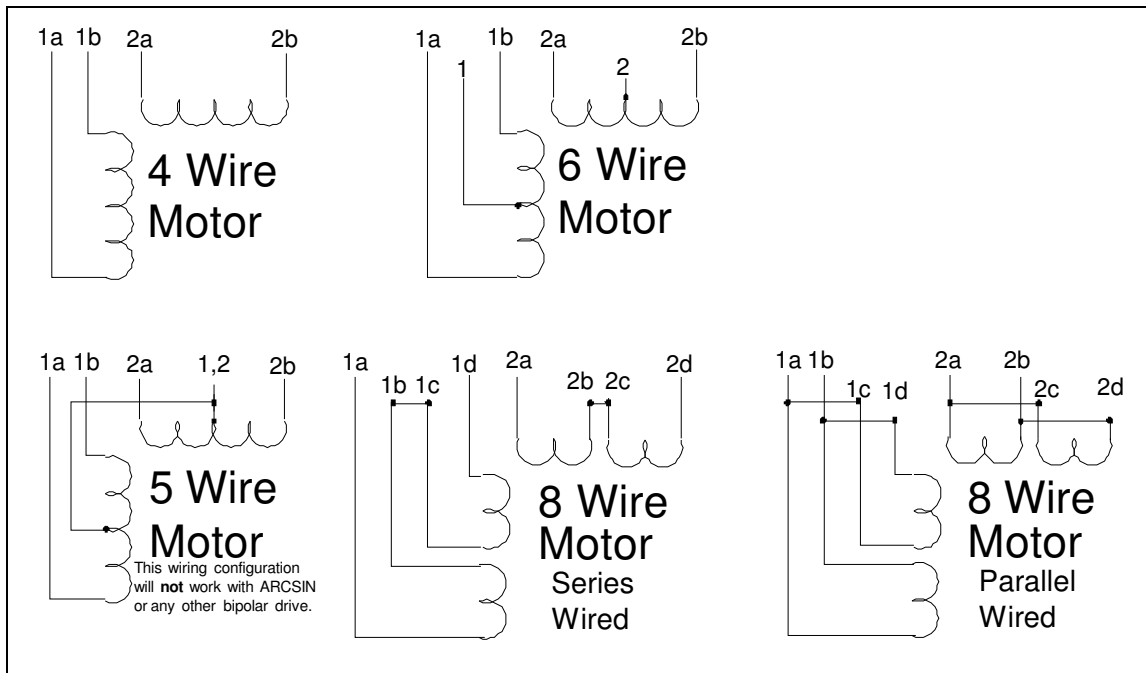
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The bottom line: Unfortunately, there *is no* simple bottom line on the subject of stepper motors unless it might be that new is better than used, bigger is better than smaller (but not always), and try to get the best price on them that you can. Not much help. Let's just start with a bunch of things we know, and work from there.

## Stepper Motor Facts

(ARCSIN is a *Bipolar PWM* stepper drive system. The facts below apply to a system incorporating ARCSIN or essentially any system utilizing modern Bipolar PWM drives.)

- ARCSIN works with 4, 6, or 8 wire stepper motors (see the figure below).
- ARCSIN works with 2 phase (and not with 5 phase) stepper motors.
- Stepper motors with low voltage ratings (i.e. low winding resistances) will generally perform better at higher speeds than motors with higher voltage ratings, assuming equal torque ratings for the motors.
- You can use a stepper motor with practically any voltage rating. The motor voltage rating does *not* dictate the motor power supply voltage. You can use a 2 volt stepper and a 24 volt power supply (and the motor will actually perform very well). You can use a 24 volt stepper and a 12 volt power supply and nothing will be damaged (the torque/speed performance of the motor will be awful, however).
- It is fine to use a stepper motor with a higher current rating than the drive (3 amps for ARCSIN). You just won't get the full rated torque from the motor. You may, however, get a considerably higher percentage of full torque than the current percentage would indicate, depending on the motor. For example, running a 5 amp motor at 3 amps (60% of rating) might deliver 80% of rated torque in some cases.
- It is usually fine to use a slightly higher drive current (say 20 or 30 percent) than the rating of the stepper motor in order to try to get a bit of extra torque from the motor. This may or may not help. If you do this you *must* set the idle current well below the motor's current rating to reduce heating.
- Two phase stepper motors come in many different sizes and shapes and in many different step increments (degrees per step, or steps per revolution). For CNC applications where ARCSIN (or other similar drive systems for that matter) is used it is generally recommended to use 1.8 degree per step (200 steps per revolution) motors in either NEMA 23 or NEMA 34 frame sizes. For a given general motor design, voltage and torque rating, a NEMA 23 size motor will generally perform better at high step rates than a NEMA 34 motor.



All Two-Phase Steppers have two field (or phase) windings. These windings may have an additional connection in the center (5,6 wire), may be connected together inside the motor (5 wire), or each may be split into two halves (8 wire). The number of wires a motor has does not affect the motor's basic electromechanical characteristics. There just have to be enough wires to provide external access to all the winding terminals. Note that there are two different connection methods for an 8 wire motor. How would you know which one is best? The short answer is that for 8 wire motors with relatively low voltage ratings and high current ratings, the series wiring scheme is generally best; for high voltage ratings and low current ratings, the parallel scheme is best. (It's important to realize that with the parallel scheme only half of the drive current flows in each half of the phase winding, while in the series scheme, each half of the winding receives full current.) Here are some hypothetical examples:

- Winding current rating: 1 amp; voltage rating: 12 volts total or 6 volts per winding half: For best speed/torque performance wire the motor parallel and set the drive current for 2 amps.
- Winding current rating: 3 amps; voltage rating: 5 volts total or 2.5 volts per winding half: For best speed/torque performance within ARCSIN's ratings wire the motor series and set the drive current for 3 amps.
- Winding current rating: 2 amps; voltage rating: 12 volts total or 6 volts per winding half: For best speed/torque performance within ARCSIN's ratings you will have to experiment: Wire the motor series and set the drive current for 2 amps. Wire the motor parallel and set drive current for 3 amps. Select the scheme that gives the best speed/torque performance in your application. Notice that with the parallel scheme you are driving the motor with only 1.5 amps per winding.

Your low speed and holding torque will be less here than with the series scheme. BUT your high speed torque may be better with this scheme because you are driving the windings with twice the voltage per winding, thereby halving the current rise time (discussed in the motor power supply section of the manual) thereby improving high-speed performance.

Deciphering ratings from stepper nameplates can be confusing. Sometimes a voltage and a current rating are given, sometimes a resistance and a current rating, sometimes a resistance and a voltage rating, and sometimes all three. If you are given two of the three ratings you can derive the third using Ohm's law. Ohms Law states that  $E = IR$  where  $E = \text{Volts}$ ,  $I = \text{Amps}$ ,  $R = \text{Ohms}$ . Here are the formulae:

$\text{Volts} = \text{Amps} * \text{Ohms}$   $\text{Amps} = \text{Volts} / \text{Ohms}$   $\text{Ohms} = \text{Volts} / \text{Amps}$ .

Another confusion factor arises from the question as to whether the nameplate ratings are stated for unipolar or bipolar drives. So what does it matter, you say? If you have a motor that is spec'ed (i.e. a given torque for a given current) for unipolar operation, you only need about 2/3 that much drive current from a bipolar drive like ARCSIN. For example, if you use a bipolar motor with a current rating of 3 amps, this would only require 2 amps of drive current if you are driving the motor with a bipolar drive. The problem is that oftentimes there is no indication on the motor nameplate whether the current rating is for unipolar or bipolar operation. You can make an educated guess, however: If it's a 4 wire motor, you can bet that the current rating is for bipolar operation. If it's a 5 or 6 wire motor, the rating is probably for unipolar operation. If it's an 8 wire motor, it's anybody's guess but there's a somewhat better chance that the rating is for bipolar operation.

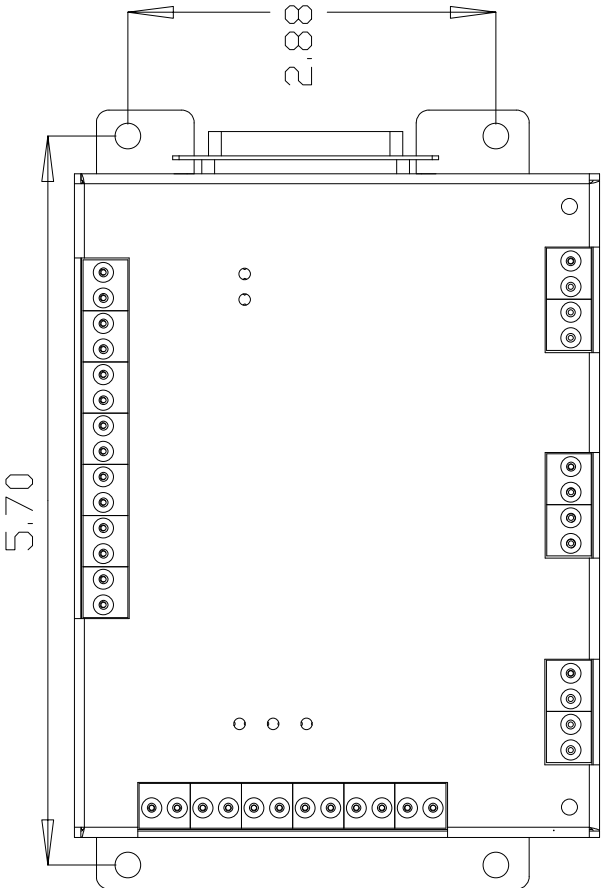
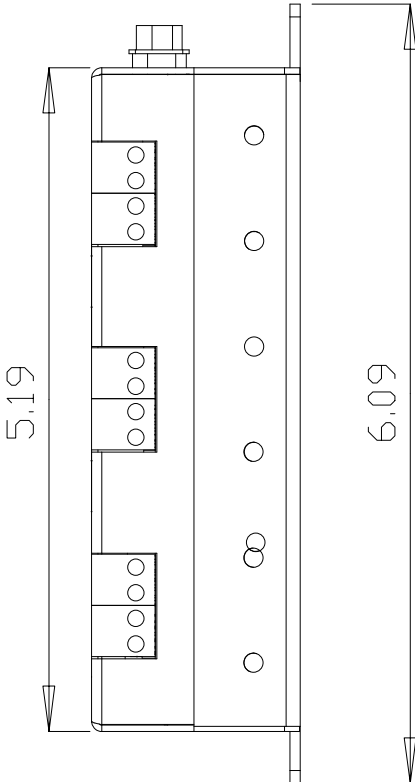
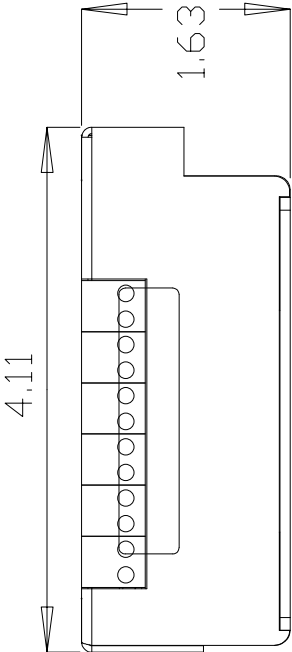
As stated previously, the user has some latitude with drive currents – it's always OK to under-drive a motor; all that suffers is torque performance. It's generally OK to over-drive a motor as much as 20 or 30 percent, understanding that more motor heating will occur. As long as the motor is not allowed to overheat, things should be OK. Stepper motors are commonly rated to work up to 85 degrees centigrade or more, so a motor may become very hot to the touch and still not be overheated. (As stated previously, be certain to take advantage of the idle-current reduction feature of the drive to reduce heating.) And, of course, good operating practice dictates that you either stay within the ratings of your motors, or else use the minimum amount of drive current that will move your system reliably.

Stepping motors and drive systems can exhibit any number of weird behaviors that are difficult to neatly categorize. We have discussed some of the more easily identifiable behavior and performance issues, but many more questions may come up.

- If a stepping motor is wired or connected to the drive incorrectly, it may fail to do anything; the rotor of the motor may just turn freely by hand. The rotor may only stutter in one place when steps are applied. It may seem to want to turn one direction for awhile and then the other, even when the direction signal to the drive remains constant. It may turn in only one direction regardless of the direction signal sent to the drive. It may rotate only when stepped at a certain rate and not at higher or lower rates. It may rotate correctly, but have very poor torque performance.
- All stepping motors have electromechanical resonances. These resonances may cause the motor to vibrate excessively at certain step rates. Motor output torque may drop to zero at resonance, causing motor lockup to occur. Increasing micro-step resolution (e.g. going from half-step to quarter or eighth step) will reduce (but not eliminate) resonance effects. System step rates for cutting and rapid traverse must not be near resonances. System step rate ramping must be rapid enough to avoid resonance rates for any sustained period of time. Resonance rates are different for an unloaded motor (i.e. on the bench) than for one integrated into a mechanical system.
- A stepping motor in a system may randomly step, seemingly of its own accord. This probably has nothing at all to do with the motor itself, but rather is caused by electrical noise getting into the control system (generally between the computer and the drive) and being interpreted as step pulses. (To check for this, be sure to turn on all your noise-producing machinery such as spindle motor/router, air compressor, etc.) This has been discussed to some degree previously in the Optical Isolation discussion.

Repeatability of the system motor is poor (i.e. when a series of moves is sent to the system, the resultant move is a slightly different distance from one time to the next.) Mechanical issues can come into play here: There may be 'give' or 'play' in the mechanics of the system. If accuracy is good when the system is run at slow speeds, but moves seem to shorten or become less repeatable as speed increases, then you may be expecting too much speed/torque performance from your motor, or you may have mechanical binding in the system that is not evident at lower speeds (check lead screws especially). (Make certain that you have drive current set properly for the motor in use.) If the system locks up immediately when a relatively high rate of speed is attempted, check the step-rate ramping rate in your software: it may be ramping too rapidly. If repeatability is poor at low step rates and moves tend to be longer than they should be, check the system for electrical noise (see above). If repeatability is poor and moves tend to be short, check for mechanical binding and check computer configuration for proper pulse polarity and timing.

ARCSIN Dimensions



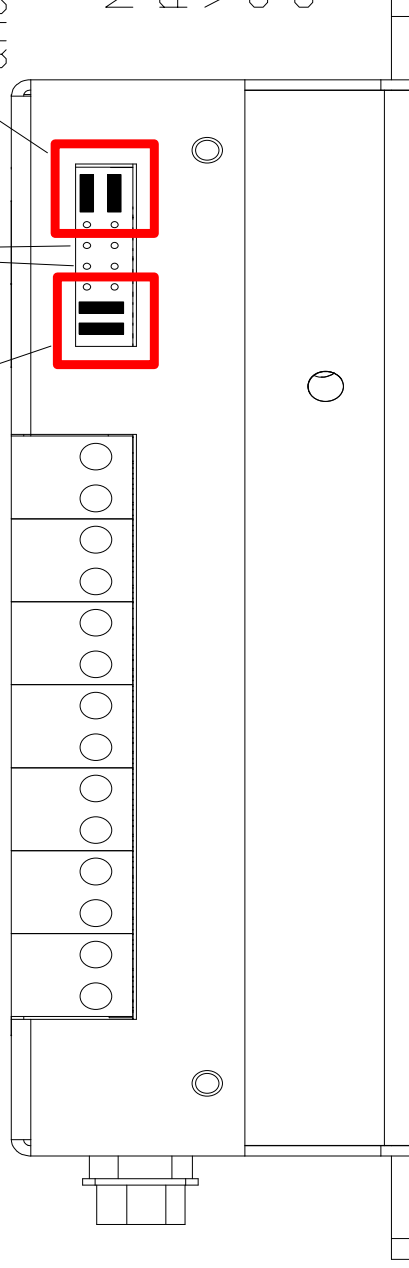
# Arcsin Microstep Config Jumpers and Opto-isolator Power Jumpers

Unused --do not jumper!

Microstep Config Jumpers  
configure for quarter step

Opto-isolator Power  
Jumpers  
configured to share logic  
and opto power

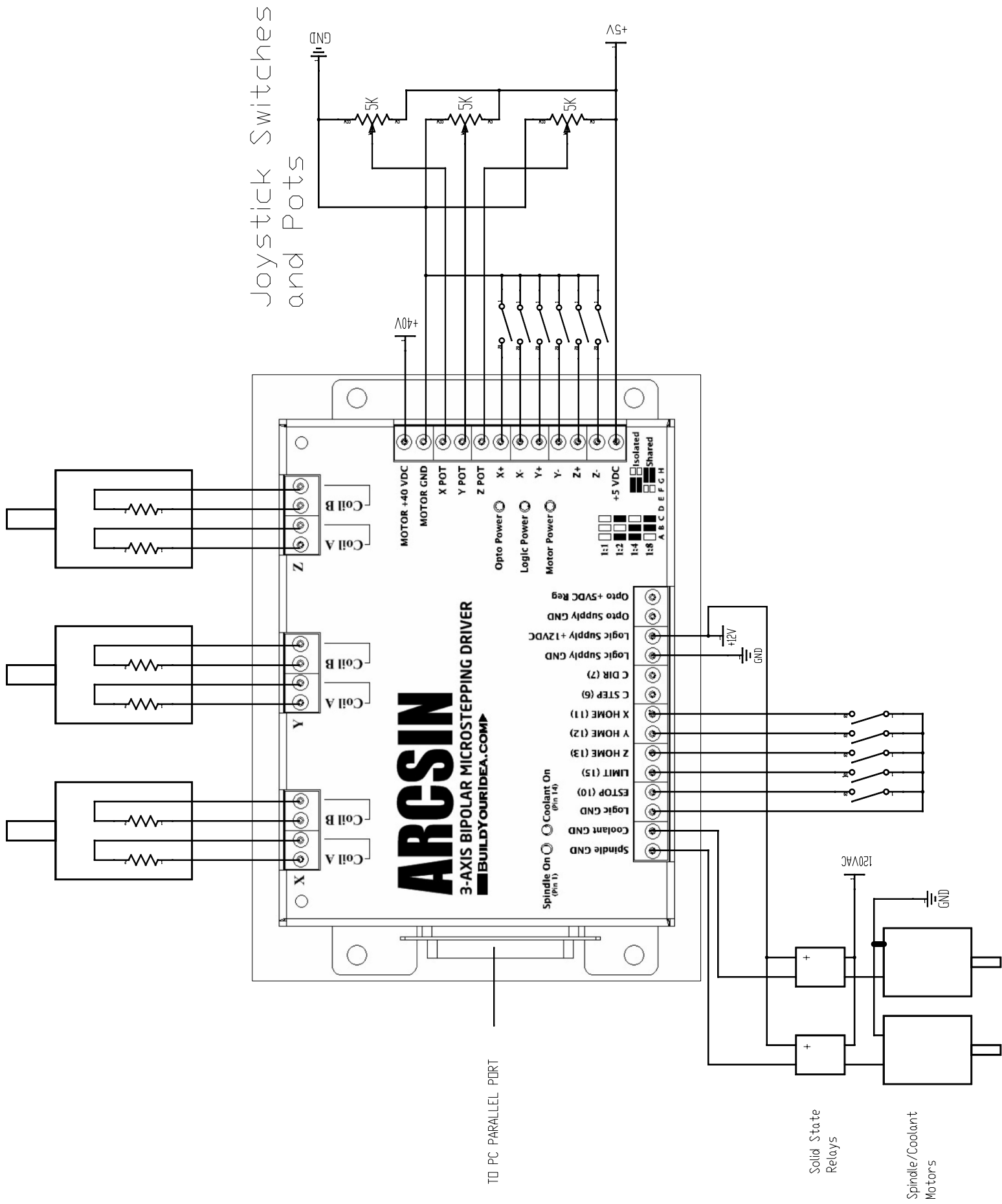
Note: Do not orient  
power jumpers  
vertically  
or you will blow fuses  
and/or damage ARCSIN



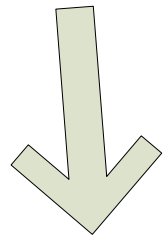


# ARCSIN Recommended Interconnection Diagram

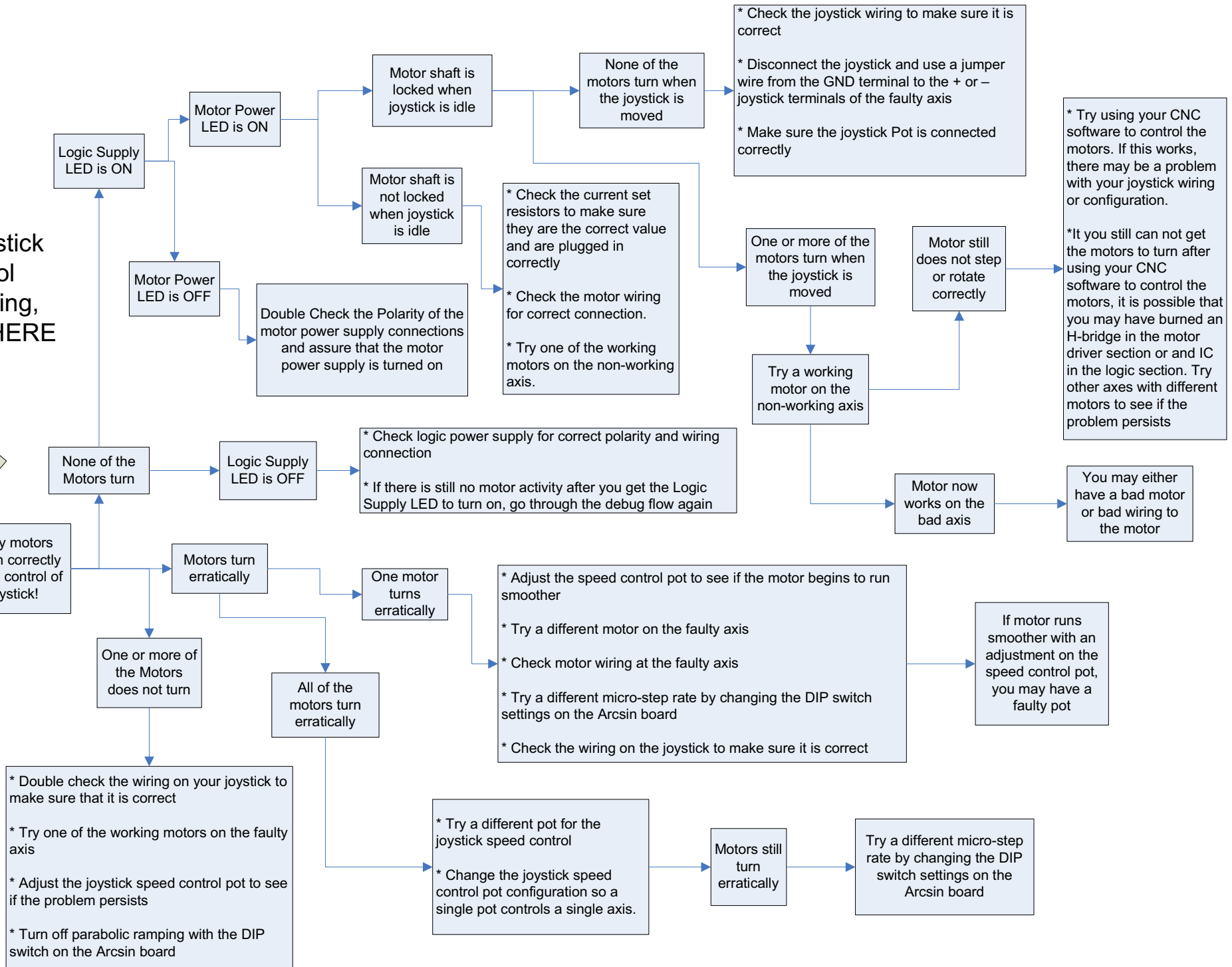
BIPOLAR STEPPER MOTORS



# For Joystick control debugging, START HERE



Help! My motors won't turn correctly under the control of the joystick!



For debugging the Arcsin while under control of parallel port step/dir signals, **START HERE**

