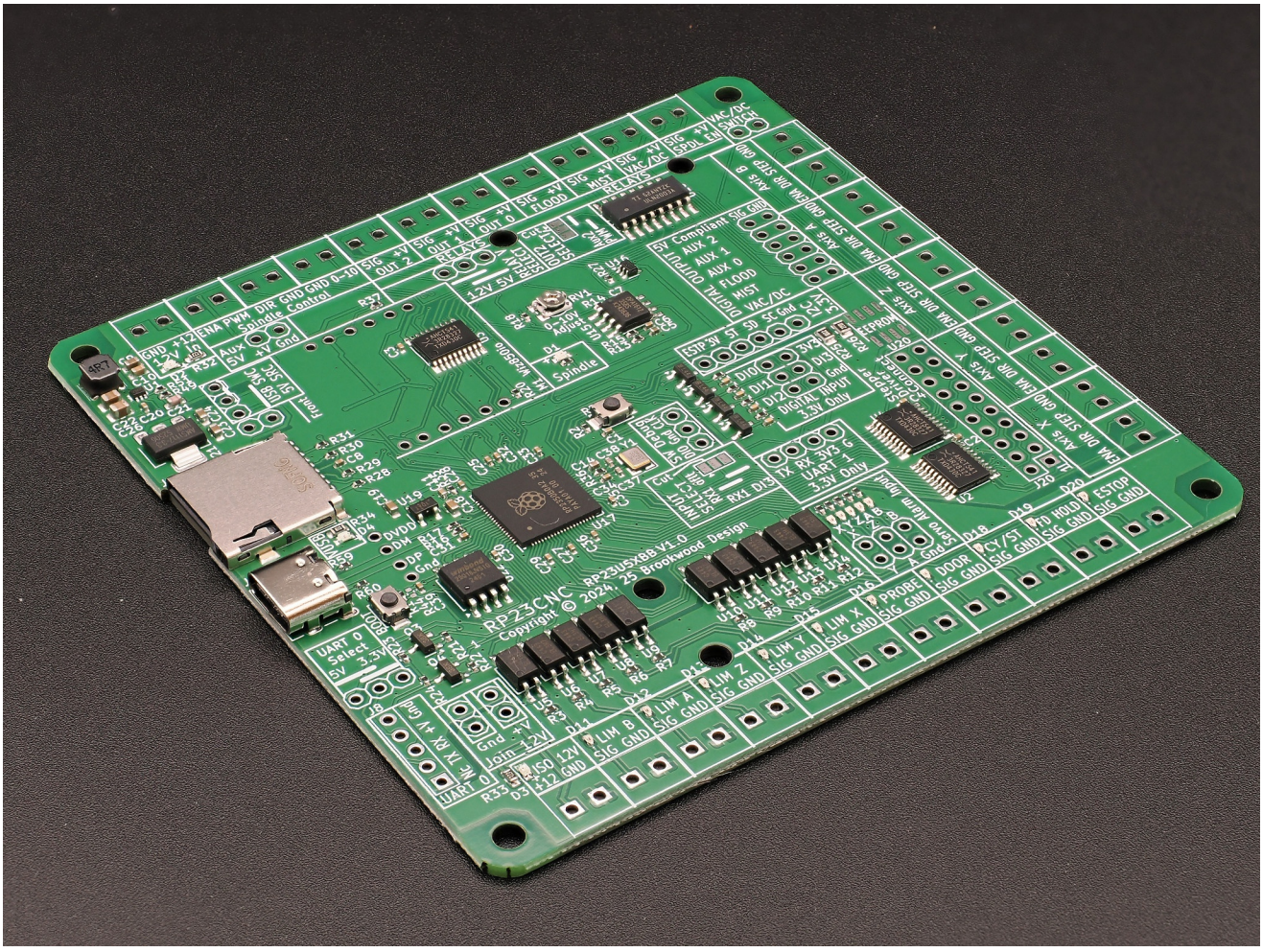
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RP23CNC User Manual

RP23U5XBB Version 1.0, 1.01

Brookwood Design



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Introduction

The RP23U5XBB is a 5 Axis motion controller board that supports grblHAL. It has the following features:

- 5 Axis control outputs
  - 5V compatible
  - Step, Direction and Enable
  - Screw Terminal and Pin Header
  - Independent Enables for all axes
- Spindle control
  - PWM (5V)
  - Enable and Direction outputs (5V)
  - 0-10V Speed control with 0-10V adjustment
  - 12V PWM supported (open collector output)
- Limit inputs for all axes
  - Opto-isolated
  - Supports switch and powered proximity sensors
  - 12V for better EMI immunity
  - Separate 12V power supply for full isolation
  - LED indicators for Limit input activity
- Servo Alarm Inputs for all Axes with LED indicators
- Standard Grbl control inputs
  - Opto-isolated
  - Cycle Start, Feed Hold, Safety Door, Reset
- Opto-isolated Probe input
- Relay Support
  - Directly drive up to 7 Relay coils
  - Relay Coil drive voltage selectable – 5V or 12V
  - Drive up to 7 SSR or Logic Level relay modules
  - Spindle Enable, Flood, Mist, Dust Collection, 3 auxiliary outputs
- Dust Extraction Support
  - Relay Coil, SSR or Logic Level module support
  - Activated by Spindle Enable
  - Manual Control of Dust Extractor via header using user supplied external switch
- Flood and Mist coolant control
  - Relay Coil, SSR or Logic Level module support
- 5V compatible Digital Outputs (Spindle Enable, Flood, Mist, Dust Collection, 3 auxiliary)
- 4 Digital Inputs (3.3V)
- Communications
  - 2 UARTs
  - USB
  - Ethernet (via optional Wiz850io adapter)
  - I2C
  - SPI
- MicroSD card adapter
- UART 0 3.3/5V translation
- SWDebug header
- Boot and RESET buttons for easy firmware loading and network configuration.

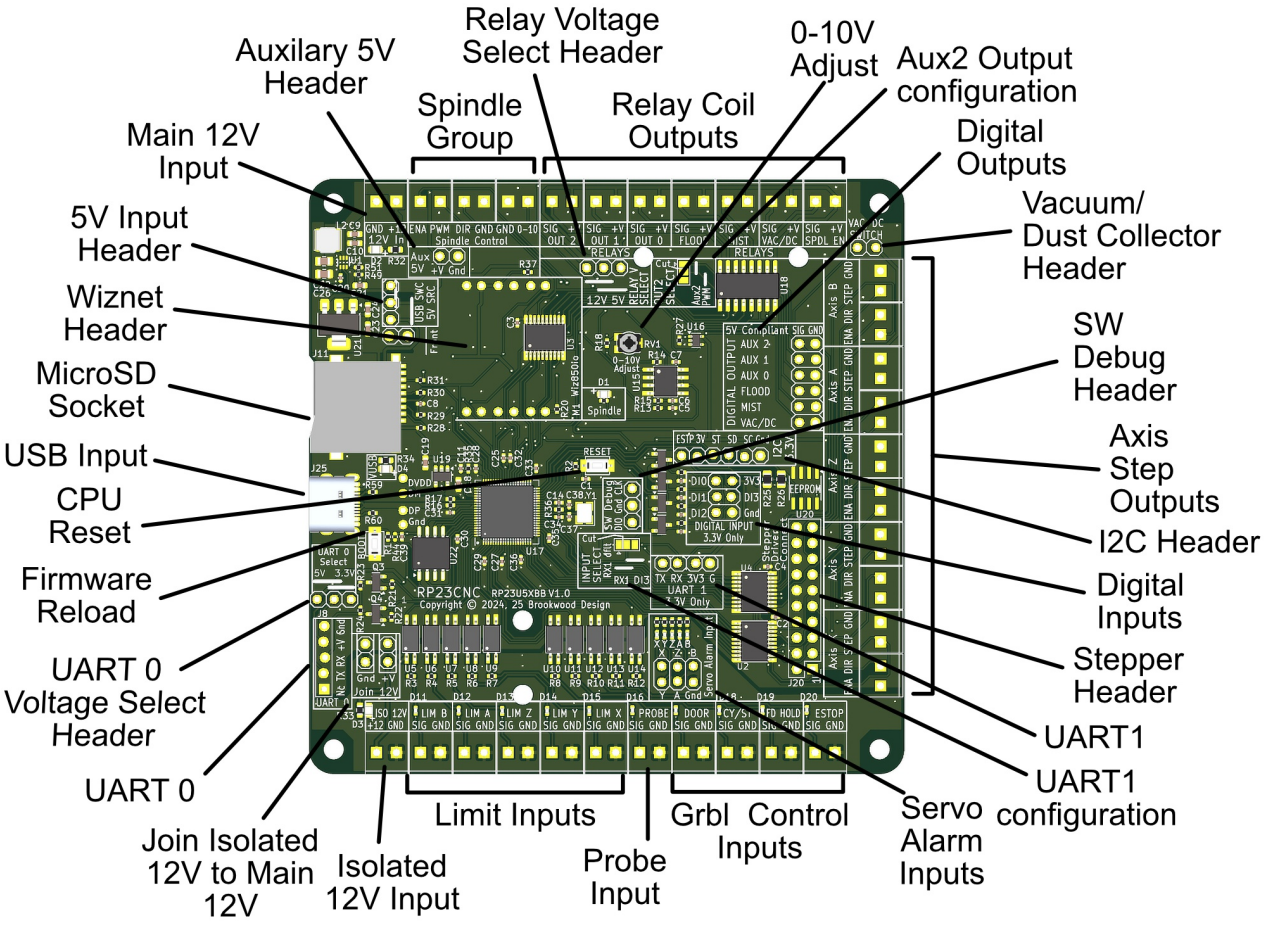
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- Flexible power supply setup.
  - 12V Main board input
  - 12V Isolated section input
  - Main and Isolated sections maybe joined and powered by a single PSU
  - Auxiliary 5V output header.
  - 5V section may alternately be powered by USB 5V
- Broad range of LED indicators to aid system install and problem diagnosis
  - Power section LEDs (12V Main, 12V Isolated, 5V USB)
  - Spindle on LED tied to PWM to show speed
  - Limit input LEDs to show limit state
  - Probe LED to show probe state
  - Control Input LEDs to show switch state
  - Servo Alarm input LED to show Servo state

Note: In the various board drawings and photographs in this manual, please be aware that some optional components are shown.

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Key Features



Stepper Driver outputs.

There are 5 sets of standard Grbl stepper driver outputs: X, Y, Z, A and B axes. Each has 4 pins: step, direction, enable and Gnd. Each are 5V compatible and capable of driving opto-isolated stepper driver inputs. Each axis has a set of screw terminals as well as pin headers (0.1”/2.54 mm spacing). These signals are also available on J20, a 2x10 header.

Limit Pins.

There are 5 limit inputs: X, Y, Z, A and B. All are opto-isolated and available via screw terminals. Powered by 12V. Fully compatible with mechanical switches or 12V powered NPN proximity switches. When powered via an isolated 12VDC supply, they are fully isolated from the main processor and associated logic.

Control Input Pins.

Standard Grbl control input pins are supported via screw terminals: Feed/Hold, Cycle/Start, Halt/Stop and Safety Door open. These are opto-isolated. When powered via an isolated 12VDC supply, they are fully isolated from the main processor and associated logic.

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Probe Input

Probe input is opto-isolated and available via screw terminals. When powered via a separate 12VDC supply, it is fully isolated from the main processor and associated logic.

Spindle Control.

Outputs for Spindle Enable, Spindle Direction and PWM signals available via screw terminal and pin header. These are 5V TTL logic compatible. There are relay outputs for the spindle (direct relay coil and 5V TTL). See the Using Relay and Digital Outputs section for more details. Standard 0-10V output for spindle control is provided via a screw terminal. One auxiliary output (Aux Output 2) can be set up to support 12V PWM output, open collector.

Relay outputs.

Standard Grbl Flood and Mist relay coil outputs are supported via screw terminals. Spindle relay output via a screw terminal is supported and controlled by Spindle Enable. In addition, a separate screw terminal relay output for Dust Collection is activated by either the Spindle Enable output or a separate pin header.

3 auxiliary relay coil outputs, Aux0 - Aux2 are supported via screw terminals and used via M62-M65 grblHAL pin control.

All relay coil outputs are configured as open collector drivers and capable of directly driving relay coils. Each relay driver is capable of up to 100 mA. All 7 are limited to 500 mA in total. Above 250 mA, forced air cooling is recommended. All relay coil drivers have open collector outputs.

Each relay signal also has a 5V TTL output that can be used to drive solid state relays, separate relay boards or other low voltage activated devices.

Relay coil voltage is selectable between 5V and 12V via the Relay Voltage header in the upper middle of the PCB.

One auxillary output (Aux 2) may be connected to the spindle PWM signal to drive 12V devices. It can be used as an open collector driver or with an optional pull up resistor. See Board Level Configuration section.

All relay coil outputs have an optional pull up resistor pad.

Ethernet I/O.

Standard 10/100 Mbit Ethernet is available via the SPI header interface via an optional WizNet Wiz850io module. See the Ethernet section below.

Digital Inputs.

Four digital input are provided. They are clamp diode protected and have a low pass filter with a cut off frequency of 15.915 kHz. 3.3V only. Digital Input 3 requires shares the input pin with UART 1 RX. See Board Level Configuration section.

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Digital Outputs

Name	Open Collector Screw Terminal	TTL/SSR Pin Header*	Notes
Spindle	✓	✓	TTL* signal also available via Screw Terminal
Dust Extraction/Vacuum	✓	✗	Triggered via Spindle or Pin Header
Mist	✓	✓	
Flood	✓	✓	
Aux 0	✓	✓	
Aux 1	✓	✓	
Aux 2	✓	✓	Assignable as a 5V or 12V spindle PWM output. RP2350 pin is shared with UART 1 TX.

* A note on TTL. Technically, this should be referred to as “Logic Level” but we use TTL as a convenient, if imprecise, shorthand.

I2C Header

An I2C header is provided. 3.3V only, there is no translation to/from 5V and the inputs are not 5V tolerant. A strobe line is provided on the header. In addition, a line for an E-Stop signal is routed directly to the Grbl Halt input. Currently, only a limited number of devices are supported. Check the grblHAL github site for more details.

SPI Header

An SPI header is provided in the Wiz850io module format. 3.3V only, there is no translation to/from 5V and the inputs are not 5V tolerant. The SPI signals are spread between 2 headers.

UART Headers

Two UART headers are provided. UART 0 supports 3.3V/5V translation, the interface voltage is selected via the UART 0 Voltage pin header. UART 1 is 3.3V only and the RX pin can be configured via the solder jumper adjacent to the UART header. Default setting is for the RX pin.

Servo Alarm Header

Up to 5 servo alarm outputs may be connected to the RP23U5XBB via the Servo Alarm Input header in the lower middle of the PCB. They are 12V Open-collector (sinking) inputs. Consult your servo manual for proper configuration of the servo alarm output.

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External Connections

12VDC, Input, main power.
Supply for relays, 0-10V output amplifier and 5V regulator.

12VDC, Input, isolated power.
Supply for opto-isolated input switches.

Stepper motor, Output
5 Axes
5V Logic Signals.

Pin	Signal
G	Ground
Stp	Step Pulse. Positive.
Dir	Direction
En	Enable

Limit Switches, Input
One input for each axis. Opto-isolated, 12V.

EStop, Door, Cycle/Start and Feed/Hold, Input
Opto-isolated, 12V.

Probe
Opto-isolated, 12V.

Spindle Group, Output.
PWM, Direction, Enable. 5V compatible.
0-10V.

Relay Coil Group, Output
These are open collector sinks. They run at the selected relay voltage.
Flood, Mist, Spindle, Vac/Dust Collector, Aux0, Aux1, Aux2

Relay TTL Group, Output.
These are 5V, TTL compatible outputs suitable for SSR, powered relay modules or any 5V compatible logic.
Spindle, Flood, Mist, Vac/Dust Collector, Aux0, Aux1, Aux2.
Note: Enable in the Spindle Group is capable of driving an SSR, powered relay modules or 5V compatible logic.

Vac/DC trigger.
External Switch to activate a vacuum or dust collector.

Auxiliary +5V Header.
+5V and Gnd are available via this header. Maximum current is 50mA.

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I2C Header, Input/Output.

Pin	Signal
G	Ground
SC	I2C SCL
SD	I2C SDA
St	Strobe, used for signaling outside of I2C
3V	3.3VDC, sourced by RP23U5XBB
Hlt	Halt Signal. Connected directly to the Halt input pin. 3.3V only.

SPI Header Input/Output

Pin	Signal
Gnd	Ground
RX	SPI Device output, MISO
CK	SPI Clock
TX	SPI Device input, MOSI
CS	Component (Device) Select
RST	Reset. Specific to the Wiz850io module
INT	Interrupt. Specific to the Wiz850io module
3V3	3.3VDC, sourced by RP23U5XBB

The Wiz850io Module takes over the SPI header.

UART 0 Header Input/Output

Pin	Signal
Gnd	Ground
V+	3.3V or 5V, selected via UART Voltage select header
RX	Receive, 3.3V or 5V
TX	Transmit, 3.3V or 5V
NC	No Connect

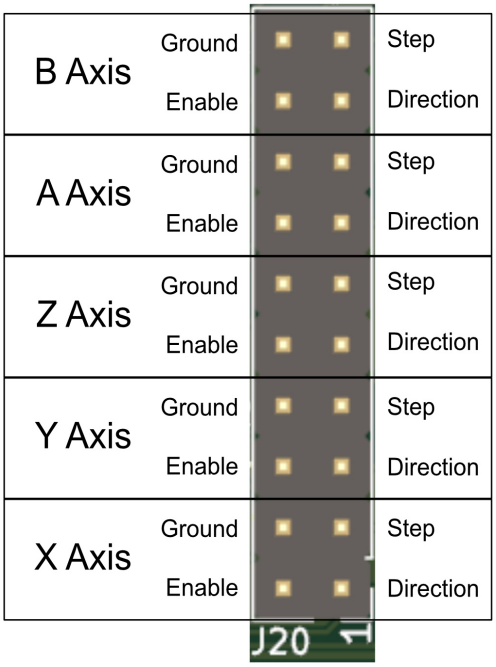
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UART 1 Header Input/Output

Pin	Signal
Gnd	Ground
V+	3.3V Only
RX	Receive, 3.3V
TX	Transmit, 3.3V

Stepper Driver Connect Pin Header

All signals are 5V Logic.



Servo Alarm Input

Five open collector servo alarm inputs are provided.

Serial Wire Debug Interface

A 3 pin header for the standard Serial Wire Debug Interface is provided.

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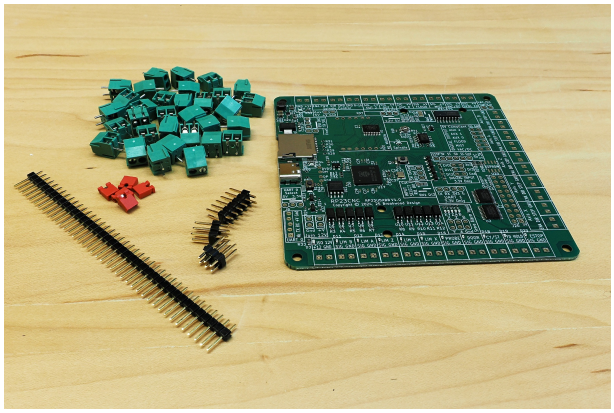
Assembling the RP23U5XBB

Assembling the Basic Components

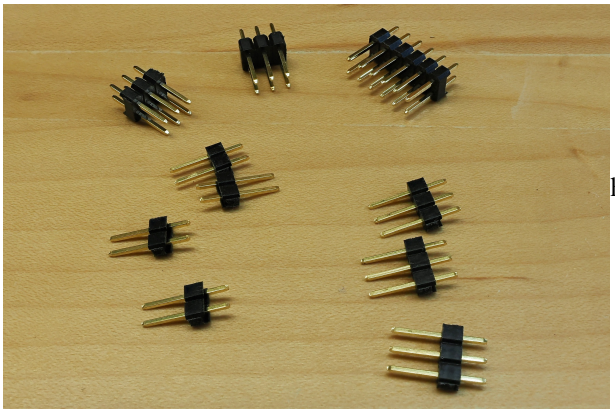
These instructions assume you have the optional assembly kit.

Step 1. Take inventory. You should have

- 1 RP23U5XBB PCB
- 32 3.5mm Screw Terminals
- 1 1x40 2.54mm pin header
- 1 2x6 2,54mm pin header
- 2 2x3 2.54mm pin headers
- 5 2.54mm shorting plugs



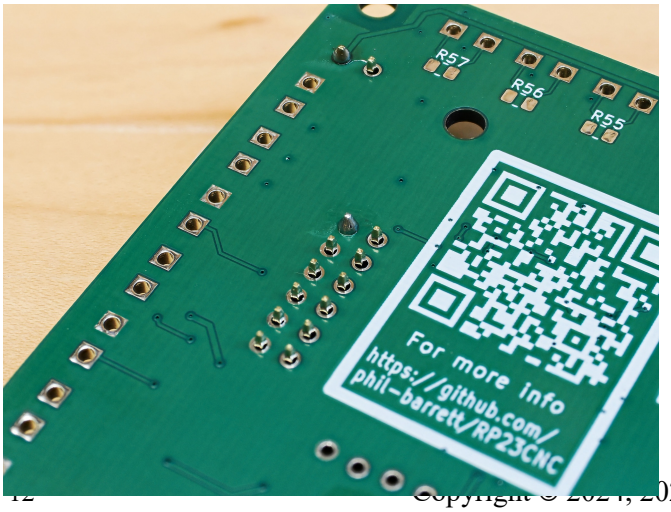
Step 2. Prepare headers. Break off smaller headers from the 1x40 strip. You will need four 1x2 headers and three 1x3 headers. Locate the 2x3 and 2x6 headers.

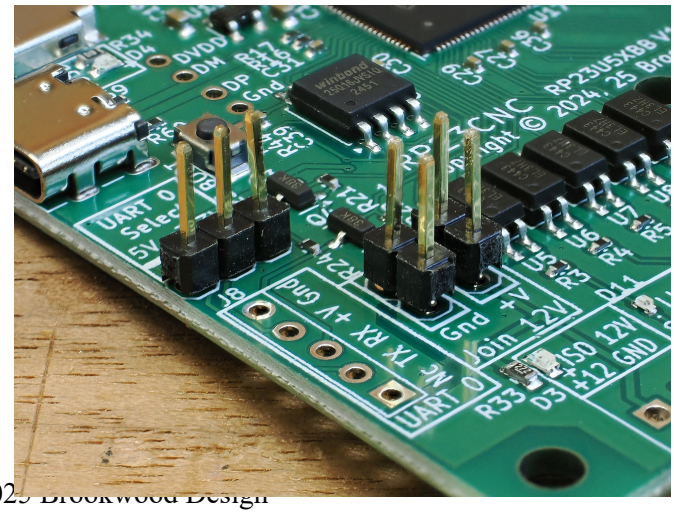


Note that the Optional headers should only be installed if you have a specific application that will use them. The 1x40 header provided in the kit is enough to populate all headers on the board. However, you may want to use sockets instead of pin headers based on what you will be connecting to them.

Step 3. Insert the headers in the Basic locations indicated in the illustration. The headers should snap into place but if they don't, use a bit of painter's tape to hold them in place. Flip the board over and solder one pin of each header. Check for proper seating.

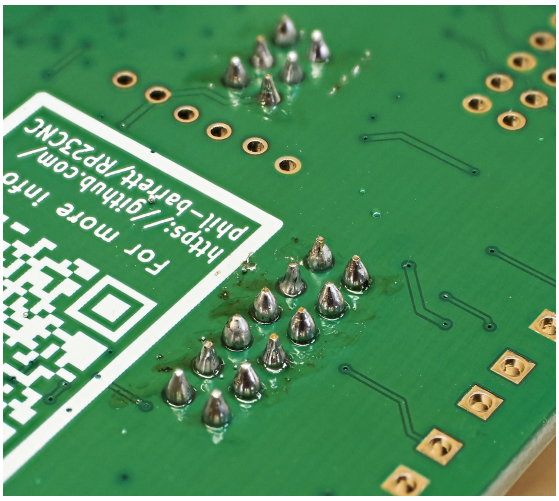
If any header is not properly seated, use a finger to press the header in position while touching the soldering iron to the previously soldered pin. Be careful not to push on the pin that has the solder (it will get hot very fast).





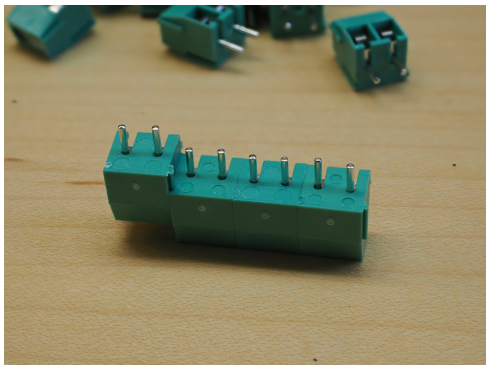
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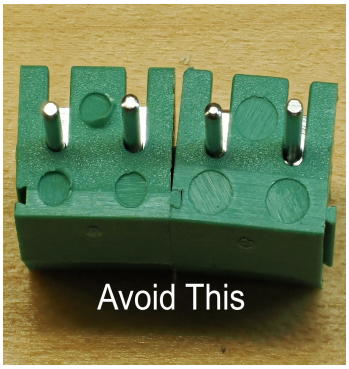
Once the headers are properly seated, flip the board bottom side up and solder the remaining pins.

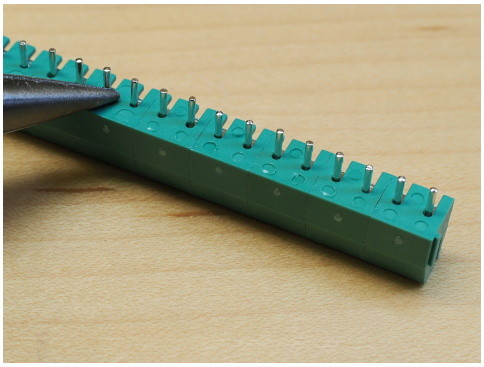


Step 4. Install the screw terminals.

Join the screw terminals together. They slide together via interlocking “dove tails”. You will need to create 3 strips. Two of 11 pieces and one of 10 pieces. Take care to make all the terminals in a strip perfectly flush. Place the strip upside down on a hard surface and use a screwdriver, needle nosed pliers or similar to force each terminal flush.

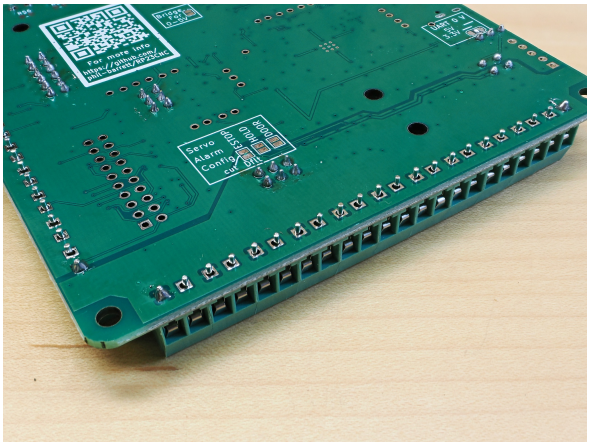


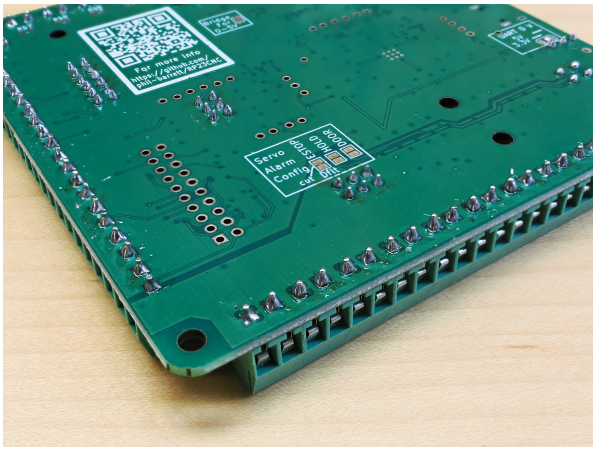




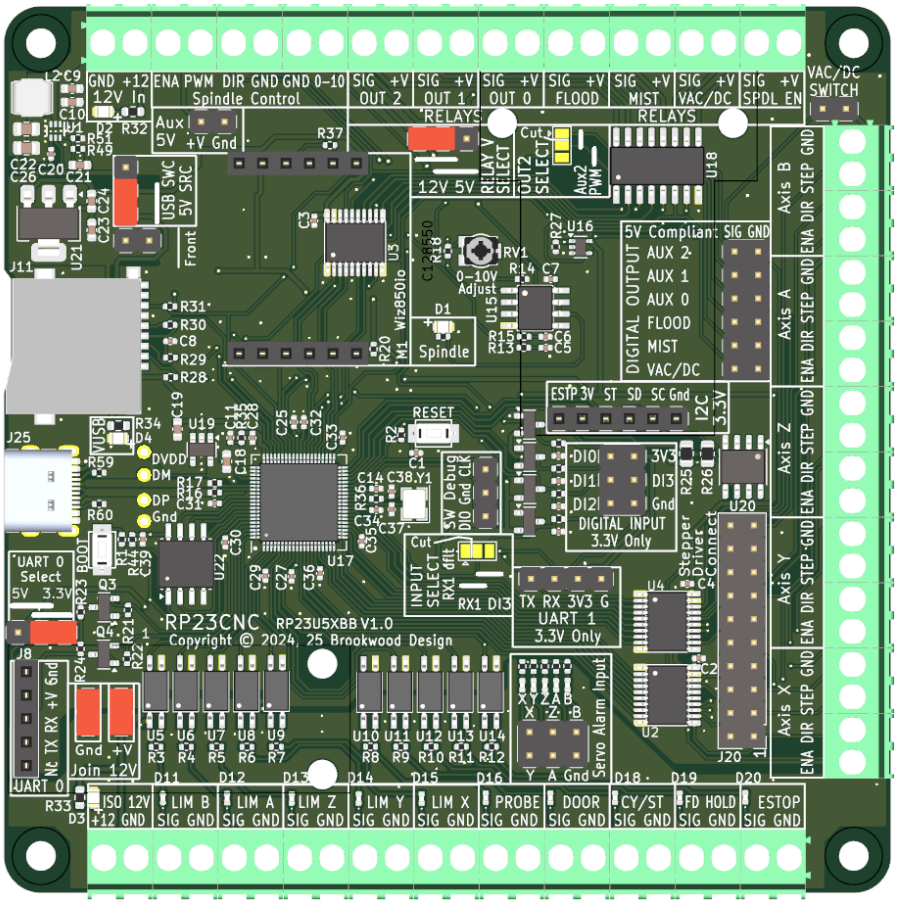
Insert the terminal strips into the holes on the board. Flip the board bottom side up and solder one pin at each end of the terminal strips. Verify alignment and seating. Similarly to how we seated the pin headers, use your thump to push each end terminal into place while holding a soldering iron to the one previously soldered pin. Verify alignment and then solder the rest of the pins. If the strip is very bowed, you can solder a middle pin first while pushing on the strip to straighten it out. Note: make sure you install the screw terminals with the wire openings outward – don't ask how I know this.

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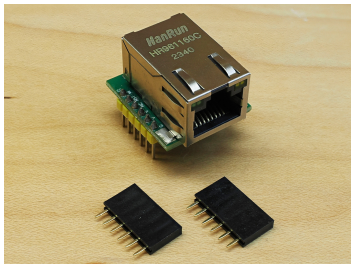
The board is now assembled. Install the shorting plugs in the indicated locations. This will allow you to bench test your board with USB power. Before installing the board into your machine cabinet, move the shorting plug on the 5V Source header to SWC (board generated 5V).



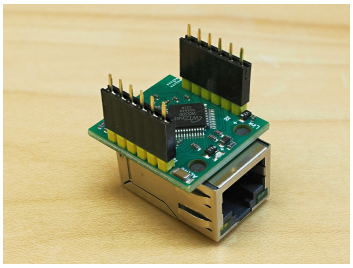
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Installing the optional Ethernet Kit

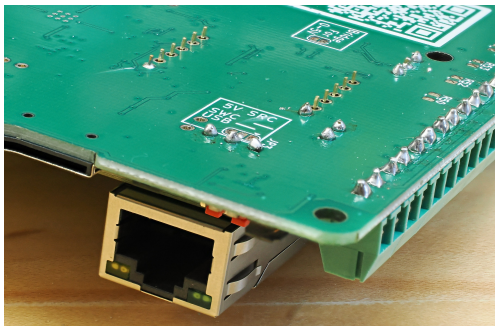
Take inventory. You should have two 1x6 2.54mm sockets and the Wiz850io module with pin headers installed.



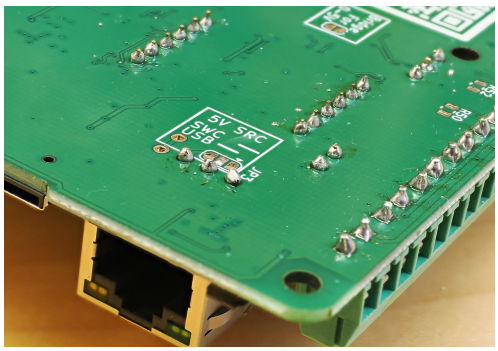
Insert the sockets onto the pin headers on the Wiz850io.



Insert this assembly into the holes for the Wiz850io on the RP23U5XBB. Solder one pin on each socket. Verify the sockets are properly seated and correct if necessary.



Solder the remaining pins.



See the section Setting up Ethernet for instructions on how to get Ethernet running.

Note, it is acceptable to mount and solder the Wiz850io module directly in the header holes without the sockets. This is good for high vibration environments. You will need to remove the 5V Source Select header as it blocks access to the RJ45 jack. Use the solder jumper on the bottom of the board to select 5V source. See the Board Level Configuration section for information on that.

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Wiz850io Ethernet Module

The Ethernet Kit that contains the Wiz850io module and 6x1 sockets is available for purchase. However, the Wix850io is also widely available if you wish to purchase it separately. There is a fair amount of confusion around the name of the module. Some vendors call it Wiz820io compatible. In the Web Builder, you will select WIZ550io (W5500). The WIZ550io uses the same chip but has a different pin out and is not compatible with the RP23U5XBB. The WIZ820io uses a different chip set and is not compatible with the RP23U5XBB. The key to getting the right one is that it must have the W5500 chip on it and have two sets of 6 pins headers. Most vendors do list the chip so if you can not see W5500 in the description, buy it elsewhere.

Relay Voltage

Relay Coil Voltage source is selectable between 5V and 12V. Use a “suitcase jumper” as indicated on the PCB to select the desired voltage.

The user is responsible for ensuring that all relays are rated for the voltage they select.

Note: it is recommended to not use the stepper motor supply for the relay supply. It could be a source of EMI and cause erratic operation of the system.

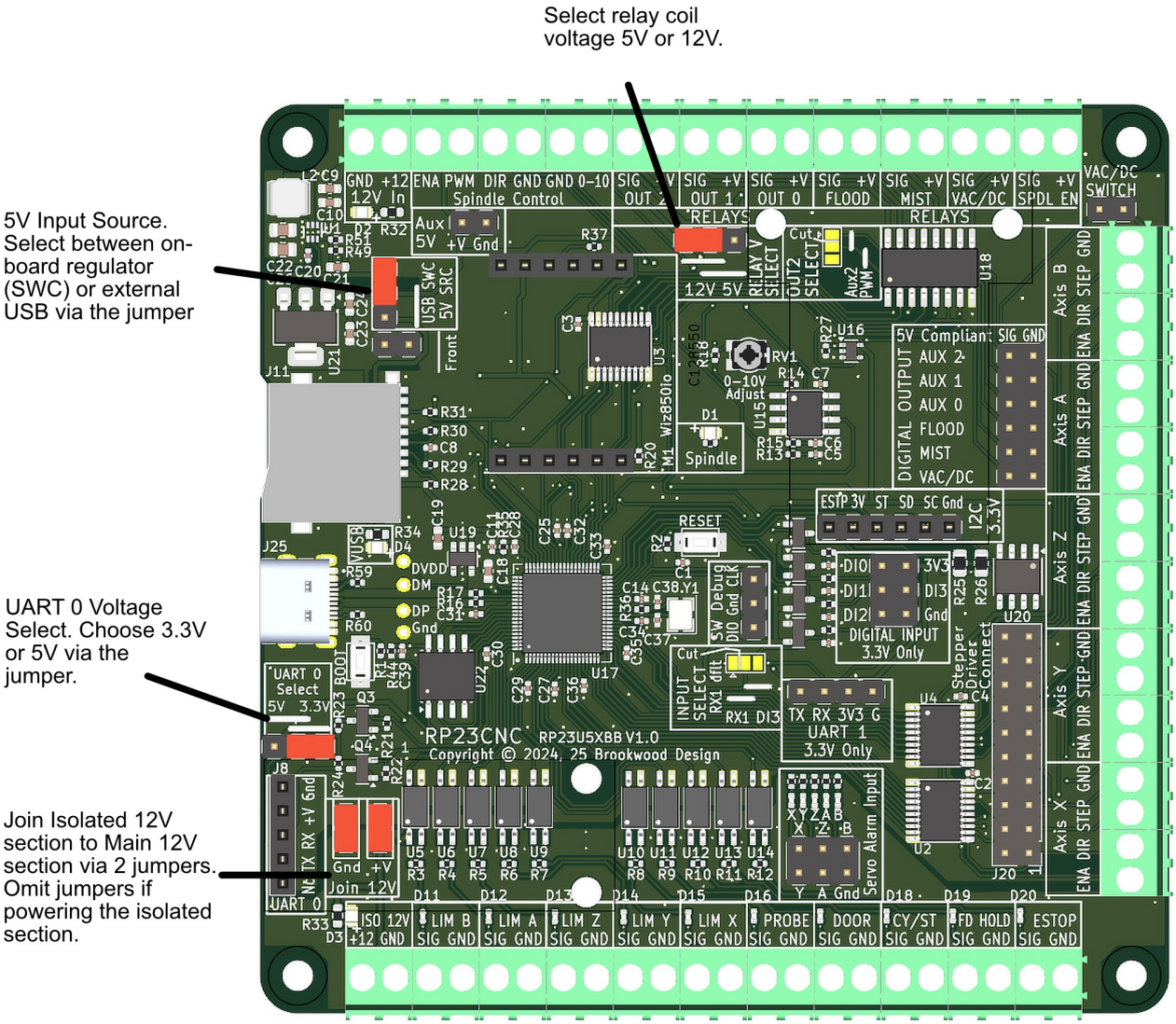
Dust Collector/Vacuum Control

An additional driver is provided for a dust collector relay. It is activated whenever the spindle is turned on (M3). In addition, this relay output can be independently activated by an on/off (SPST) switch that connects to the pin header labeled Vac/DC Trigger. This makes it easy to do clean up with the same Vacuum or Dust Collector used for dust extraction while running your CNC machine.

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Initial Board setup

The RP23U5XBB has a number of jumpers that you need to set up to make your board ready for the next steps. Note the position of the shorting plugs (red, your kit color may vary). This is for a single 12V supply configuration. For other power configurations, see the Power Inputs and Settings section.



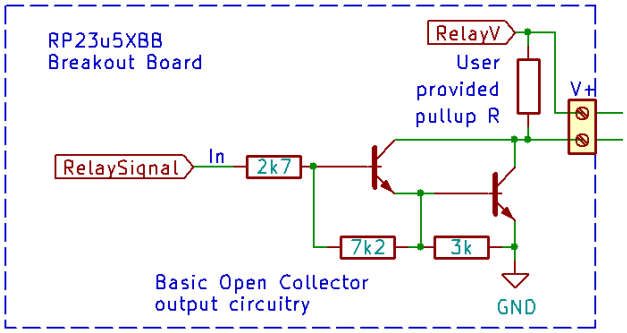
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Board Level Configuration Options

There are several options to modify the behavior of the RP23U5XBB board.

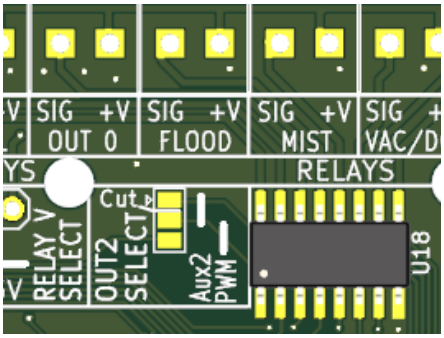
Open Collector Output Pull Up Resistor.

The relay outputs use an open collector to drive relay coils. Pads for pull up resistors are available if needed. They are located on the bottom of the PCB and are labeled for their associated output. Use an 805 SMD resistor. You may also use a leaded resistor instead of the SDM one. 10K ohms is a common pull-up value and should work for most situations but it is up to the user to determine the appropriate resistor value. Refer to the diagram to understand how the output works. Note that the attached device needs to share a common ground with the RP23U5XBB board. See the General Purpose Open Collector Driver section for more detail.



Aux2 Spindle PWM Output

While the Aux2 Output is normally directed to the Aux 2 pins, spindle PWM can be directed to them instead. This is controlled by the solder jumper. Aux 2 output is the default configuration but can be changed by cutting the trace indicated by the “cut” line on the board. After cutting the trace, use solder to bridge the pins indicated by PWM on the board. Verify that the trace is actually cut by using a DMM to measure the resistance between the Aux2 pads.

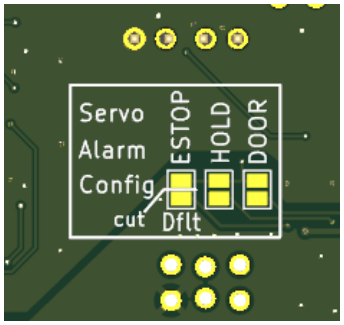


The voltage used for PWM is selected by the relay jumper – 5V or 12V depending on your selection. Note that a maximum PWM frequency of 50K is supported. Maximum current draw is 250 mA. Aux2 can not be used for M62-M65 control when configured for PWM.

This allows a higher voltage and higher current PWM output. It is also an open collector output.

Servo Alarm signal pin

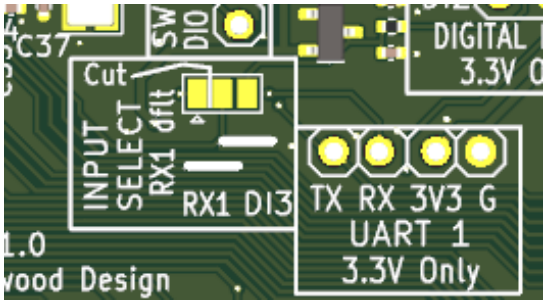
The Servo Alarm input header allows multiple open collector alarm signals to be communicated to a grblHAL input. The default input is Estop. This can be changed to Door or Feed Hold. Cut the default trace as indicated on the PCB and use a solder bridge on the indicated set of pads. Verify that the trace is actually cut by using a DMM to measure the resistance between the ESTOP pads.



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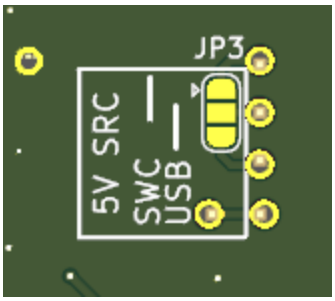
UART 1/Digital Input 3

Digital Input 3 (DI3) and UART 1 RX share a single unput pin on the RP2350 microcontroller. The default is to use the pin for the UART 1 RX input. If you need to use Digital Input 3 you will need to cut the trace as indicated on the PCB and use a solder bridge on the indicated set of pads.



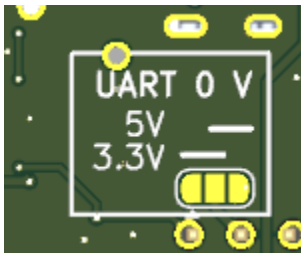
5V Source Configuration.

The board may be configured to use the on-board voltage regulator or USB supplied 5V. Using a shorting plug on the 5V SRC jumper header is the primary way to configure the 5V source on the RP23U5XBB. For high vibration environments, you can alternatively use a solder jumper on the bottom the board. Also, if you solder the Win850io directly on the RP23U5XBB, you will need to remove the pin header. It is important to only use one method. If you opt to use the solder jumper, we recommend you remove the 3 pin header to prevent joining the USB power bus and on board Switch Mode Controller 5V output. Use a soldering iron to bridge the desired pads as indicated on the bottom of the PCB.



UART 0 Voltage Configuration

UART 0 can be configured to work with either 3.3V or 5V. A sorting plug on the UART 0 Select header is the primary way to configure the UART voltage. However, in a high vibration environment you can use a solder jumper on the bottom of the PCB to configure the UART voltage. If you opt to use the solder jumper, we recommend you remove the 3 pin header to prevent accidentally joining the 3.3V and 5V power supplies. Use a soldering iron to bridge the desired pads as indicated on the bottom of the PCB.



0-5V Spindle configuration

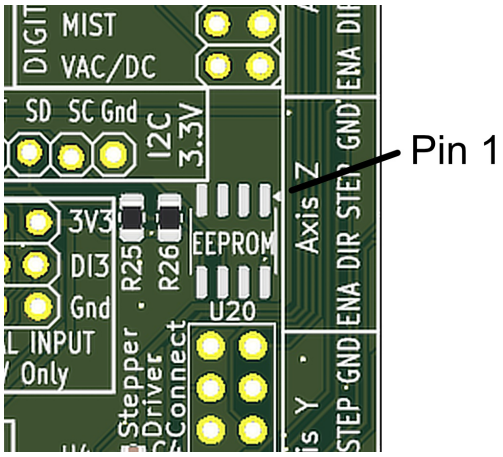
Some spindle controllers require a 0-5V control voltage (as opposed to the more standard 0-10V). You can convert the 0-10V circuit to 0-5V by shorting the pads on the bottom of the PCB. Use a soldering iron to short the indicated pads.



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EEPROM

The RP23CNC allows use of an Electrically Erasable PROM memory chip to store settings. Generally, this is not necessary since the grblHAL can use the RP2350 microcontroller's flash memory for settings. But, it can be useful for situations where you will update grblHAL settings frequently – flash memory has a limited number of program cycles. Note: this is not an issue for general usage but is a concern when using the Odometer plugin as it logs a significant amount of data. In this case FRAM is required. It has a specified lifespan of billions <verify actual number> of cycles.



To use an EEPROM, you must solder the chip on the provided footprint on the RP23U5XBB. Pay close attention the pin 1 indicator. Use a fine tip soldering iron and flux the pads before soldering. The recommended chip is the <insert specific part number>. <insert photo of chip with pin 1 marking noted>

You will need to build a version of grblHAL that uses FRAM. <show screenshot of specific entries in web builder>.

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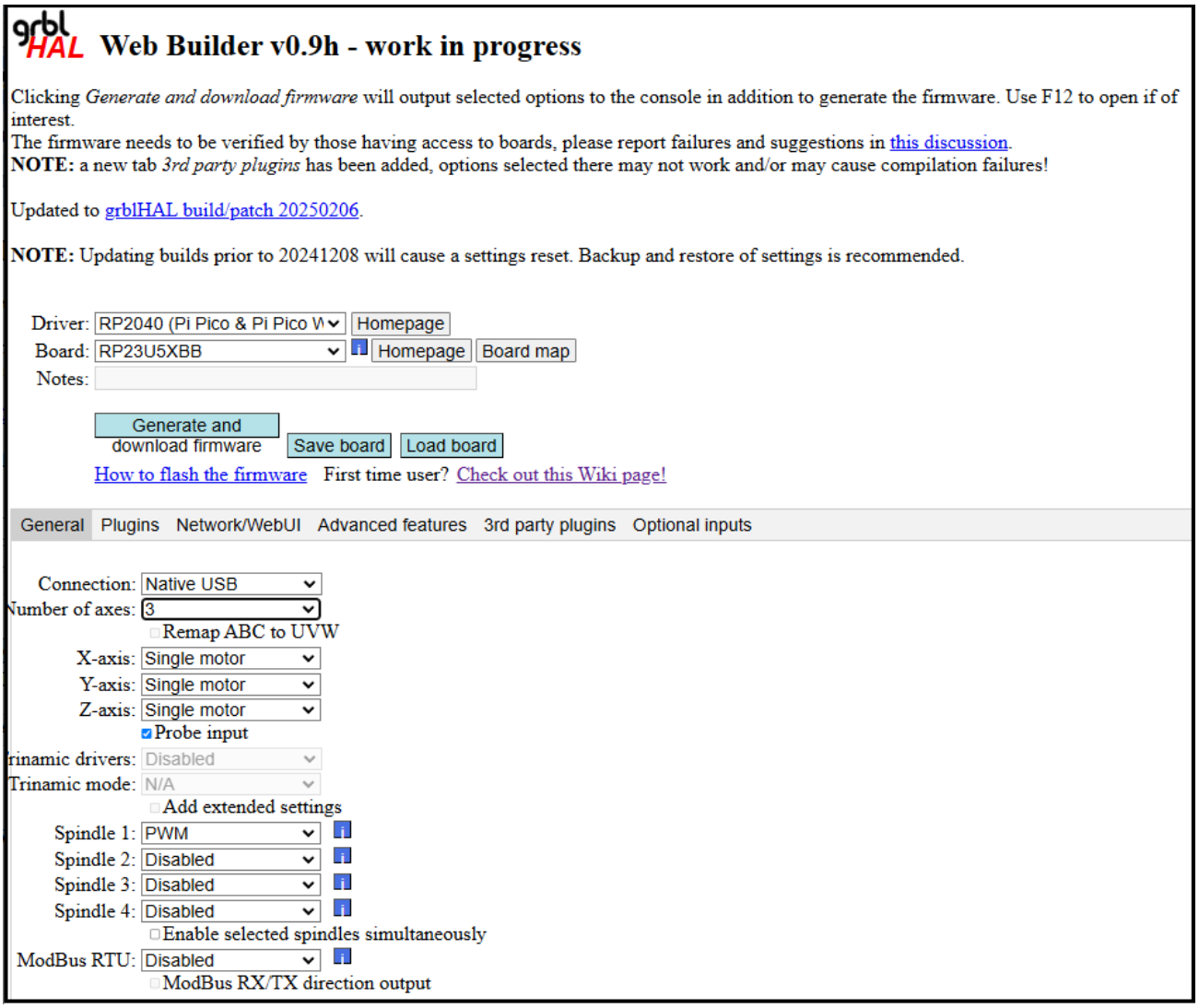
Building grblHAL

The grblHAL Web Builder site is used to create the proper firmware for your RP23U5XBB board.

Select RP2040 (Pi Pico and Pi Pico W) in the Driver box and RP23U5XBB in the Board box.
In the General panel, select the Number of axes and the appropriate axis configurations for your CNC machine. A moving gantry machine will typically use Ganged Motors for Y.

In the Plugins panel, select Enable or Ymodem in the SD card option. Ymodem will speed up transmission of large files.

If you have a Wiz850io Ethernet module, see Setting up Ethernet below.



Then press the Generate and Download button. Save the firmware file for use in the next section. Also, press the Save board button so that you will have the configuration if you need to make changes later.

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Installing grblHAL

Installing the firmware is very easy! Once you have a firmware file (.uf2 extension), connect a USB cable from your computer to the RP23U5XBB. Then:

1. Press and hold the RESET* button on the board.
2. Press and hold the BOOT button on the board.
3. Release the RESET* button on the board.
4. Release the BOOT button on the board. This will place the RP2350 into BOOTSEL mode to allow firmware loading.

[*] Some older versions have the RESET button labeled RUN.

On Windows

The first time you do this, a USB configuration notification may come up. This may also happen when you initially plug in the USB cable. For options, select "Open File Explorer Window". After that, all subsequent RESET/BOOT operations will cause a file explorer window to open. Drag and drop your firmware file onto the window. You will see a progress indicator as the firmware file is uploaded to the RP2350. When done, you can start your GCode sender application and connect to the com port associated with the RP2350. Use the Device Manager to determine which one it is if you are having difficulty finding it.

Note, on some Windows machines, the file explorer window may not open when the RP2350 is put into BOOTSEL mode. However, you should see the drive in the left-hand panel of any file explorer window. You can drop the .uf2 file on the drive itself and it will load the firmware.

On Mac OS <untested>

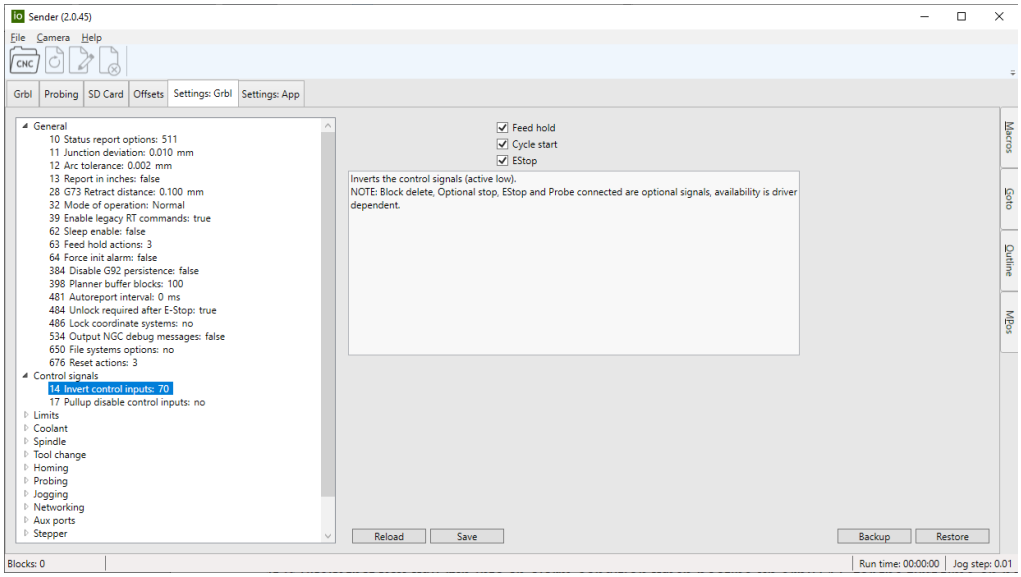
A drive called RPI-RP2 will appear on your desktop. Double click on RPI-RP2 and a finder window will open. Drag and drop the firmware document onto the window. When done, you can start your GCode sender and connect to the RP2350.

If you are interested in building grblHAL from source, you can download the source code at https://github.com/grblHAL Note that there are multiple projects and libraries that you will need to download. A complete discussion of installing and building the source code is beyond the scope of this document. Start with the core wiki to understand how to build grblHAL – https://github.com/grblHAL/core/wiki/Compiling-grblHAL.

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First run issues

It is likely that you will run into an alarm condition when booting up grblHAL for the first time on new hardware. You will need to invert 3 inputs: Estop, Feed hold and Cycle start. In ioSender you can do this on the Setting: Grbl tab under the Control signals section. Make sure to save the setting and then reboot grblHAL.



In other GCode senders, you can simply send $14=70 to grblHAL via the console.

For more information see below in the section **Some Initial Grbl Settings.**

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Setting Up Ethernet

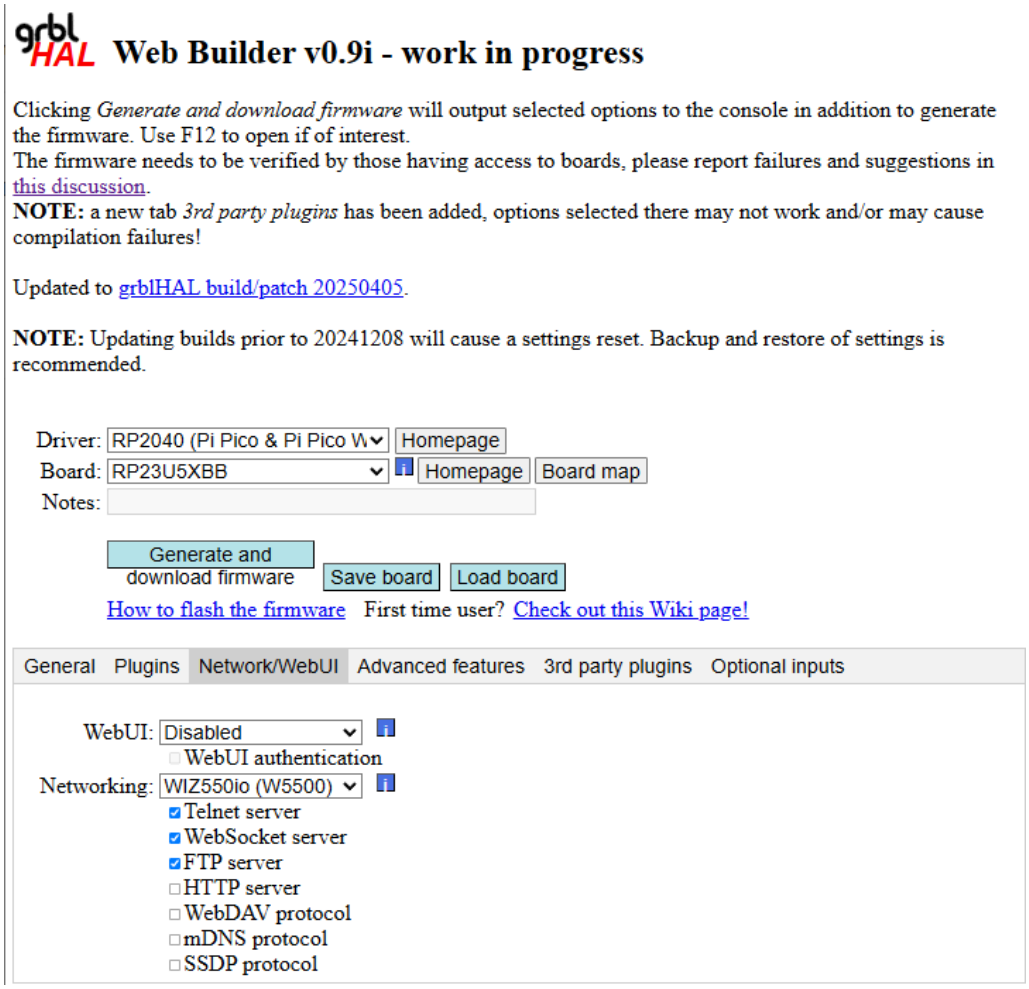
To use the RP23U5XBB with Ethernet you need to have a Wiz850io module installed. You will also need a working Ethernet setup with an active DHCP host (most do) and an Ethernet Cable connecting the RP23U5XBB to your network. This section will focus on setting up for a DHCP system via an Ethernet router.

The necessary steps:

1. Build grblHAL firmware with networking enabled and install it on the RP23U5XBB.
2. Start up your GCode sender, connect to the board via USB and determine the assigned Ethernet IP address.
3. Start the GCode Sender and connect via Telnet to the IP address obtained in step 2.
4. Verify the Ethernet connection.

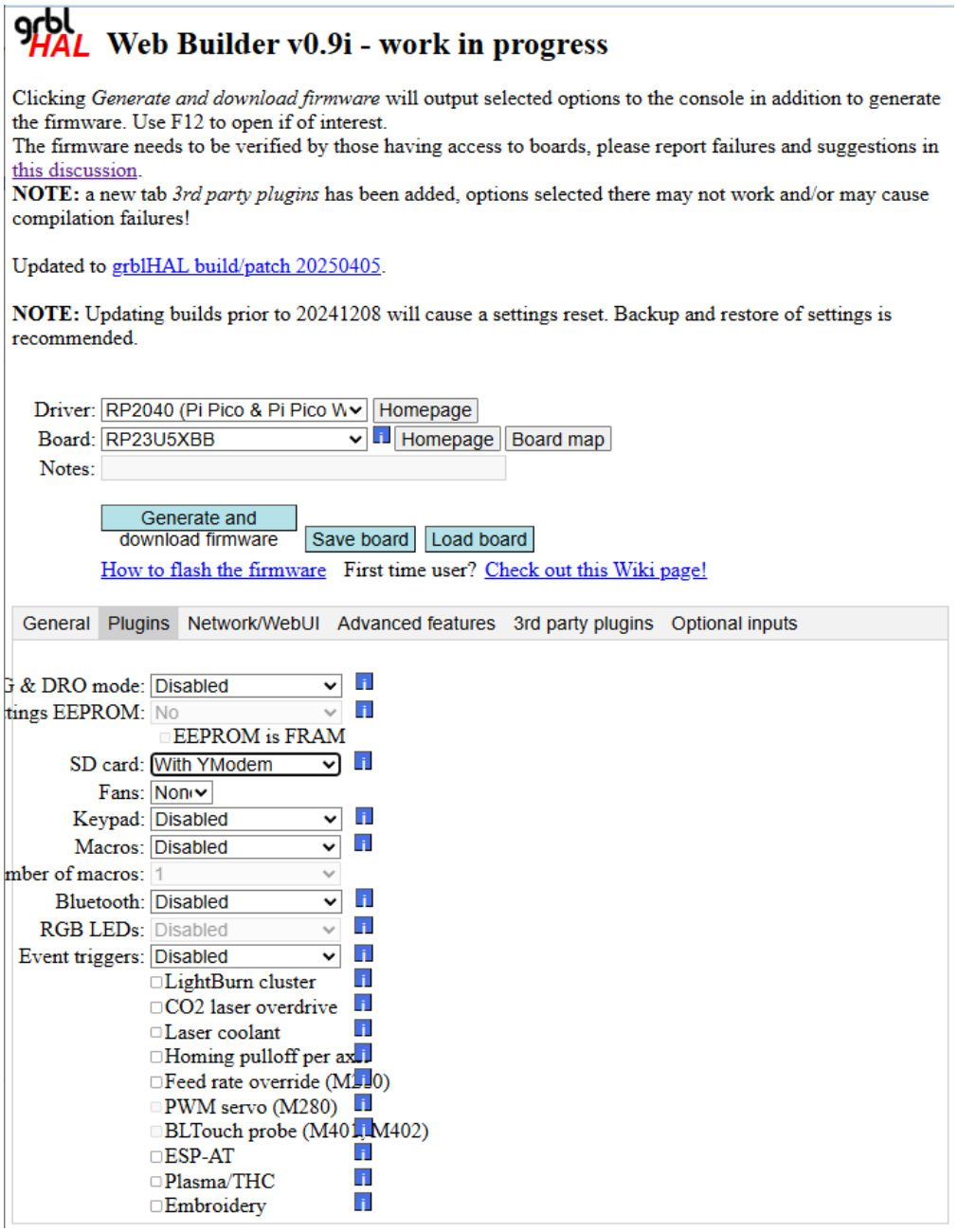
Build the firmware

Use the grblHAL Web Builder as before and load your previously saved configuration. Go to the Network/WebUI tab. In the Networking section, select Wiz550io (W5500) and check Telnet server, WebSocket server and FTP server as shown below.



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Also, in the Plugins tab, SD card box, select With Ymodem.

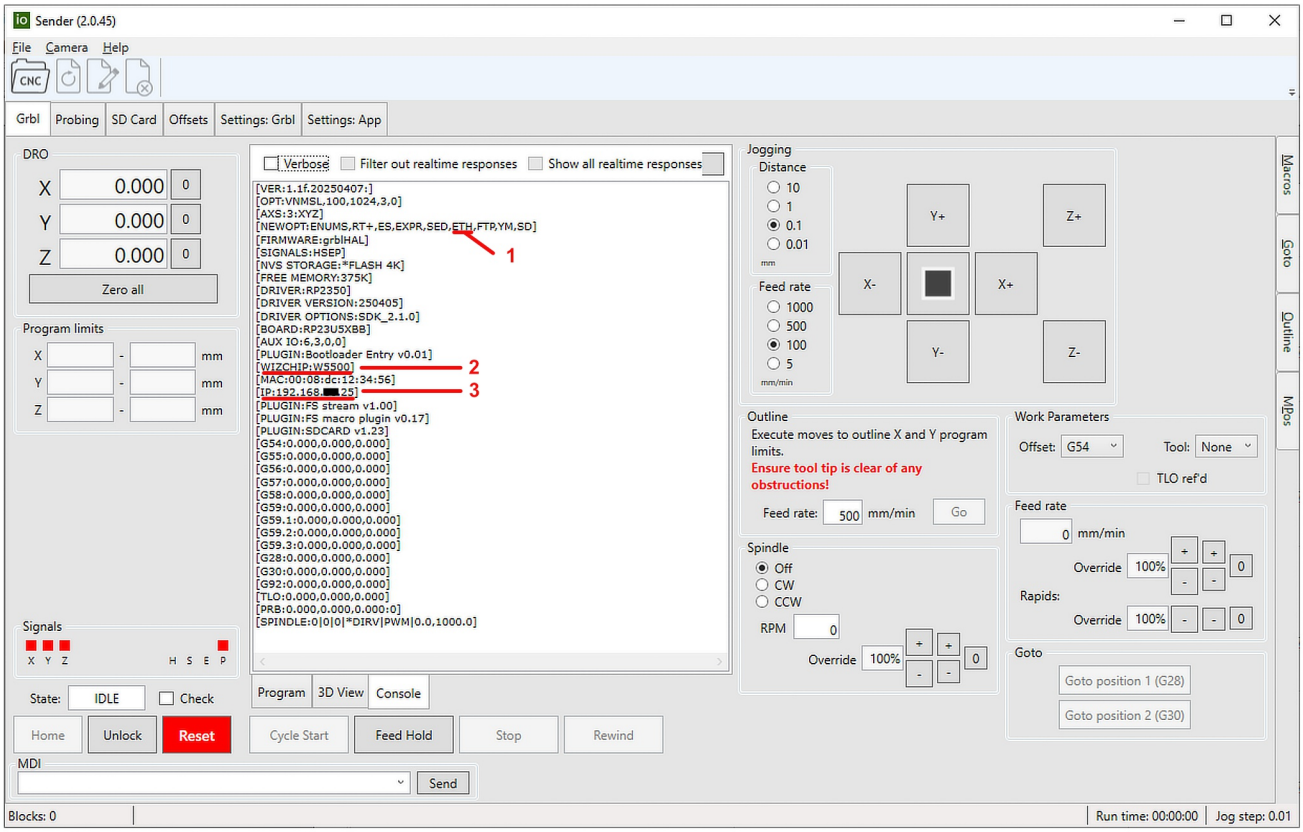


Follow the instructions on installing the firmware as before.

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Start the GCode Sender and connect.

Make sure you have an Ethernet cable connected. The LED on the Wiz850io should be flickering. If not, double check your networking set up. Next, connect the USB cable. Start your GCode Sender and connect. Once you are up and running on the new firmware open the Console tab and look at the boot output. In ioSender it should look like this:



Note the following items:

1. The build has Ethernet (ETH) enabled.
2. The WIZCHIP: W5500 is showing
3. There is an IP address showing. If there is no IP Address you probably aren't connected to a network.

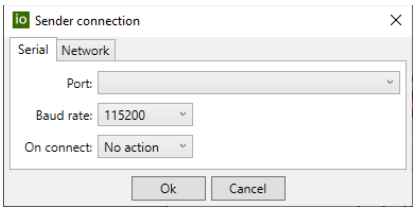
Write down the IP Address, you will need it in the next step.

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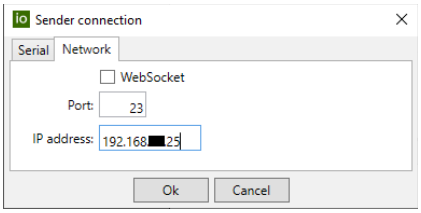
Connect via Ethernet

Close your GCode Sender. We will then restart it to connect via the IP Address we just obtained. Each GCode Sender is different and will require different steps. Refer to the documentation for details. With ioSender and the RP23U5XBB do the following:

1. Make sure ioSender is closed.
2. Hold down the RESET button on the RP23U5XBB.
3. Start ioSender.
4. When ioSender displays the sender connection message, release the RESET button.



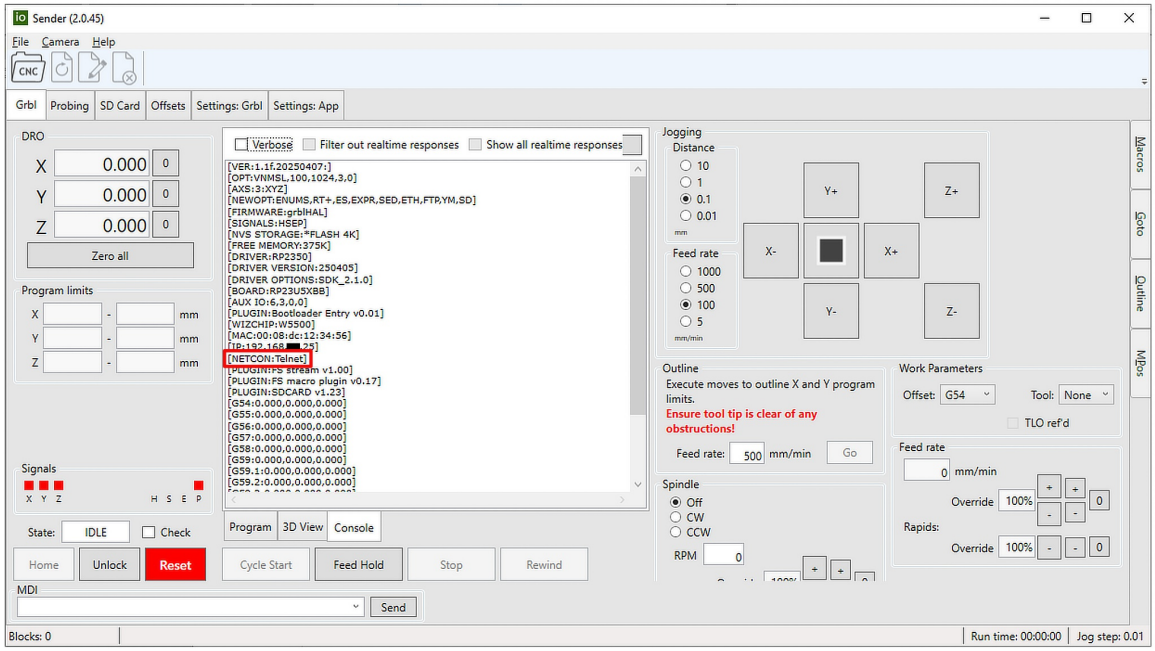
5. Click on the Network tab and fill in the IP Address we got in the previous step. Click OK.



6. When ioSender comes back up, click on the Console tab.

Verify the Ethernet Connection

You should see [NETCON: Telnet], indicating that you are now connected via Ethernet. You can now disconnect the USB cable (make sure Your 5V Select header is set to SWC). ioSender will remember your IP Address so you will want to go into your router and lock the address so it won't get reassigned.



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Connecting directly to a PC Via Ethernet

Connecting the RP23U5XBB directly to a PC (or Mac or Linux) via Ethernet is relatively straight forward. This blog post gives a full description of the process. You can skip past the build and install instructions.

Note that a direct connection is not strictly necessary. It is very secure in that the RP23U5XBB is not reachable other than through the connected PC. However, connecting via an Ethernet switch has flexibility and you can even use PCs that are connected via WiFi which is often the case with laptops.

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Running grblHAL on your machine

Once you have finished board assembly and installed the firmware, your grblHAL RP23U5XBB based Motion Controller is ready to test in your CNC machine. Attach it to a PC via a USB cable or an Ethernet cable if configured for networking and run a compatible GCode sender application on the PC. We recommend ioSender and use it for our examples but any GCode Sender should work. Check for the most recent release. Next, you will need to set up Grbl to reflect your hardware. Actual Grbl setting values are also shown. Follow these steps:

1. If you have them, hook up your control buttons: Feed Hold, Cycle Start and EStop.
2. Apply 12V to the 12V In screw terminal in the upper left hand part of the board. You should see an LED turn on when powered. If you do not have a 12V supply available, you can use the USB setting of the 5V SRC header. Note that 12V is required for external switches (Limits, ESTOP, Feed and Hold) to work. See the Power Inputs and Settings section for more details.
3. Connect a USB or Network cable from your PC to the RP23U5XBB and run ioSender. If it is the first time you have run ioSender, you may need to have it create the configuration file and select the COM Port.
4. Open the **Settings: Grbl** panel. You will see a list of parameters that control grblHAL.
5. If the board comes up in Alarm you need to set $14 to invert Feed Hold, Cycle Start and Estop.
6. In the Stepper section, $4, Invert stepper enable pins (s), Check all boxes. $4=7 for a 3 Axis machine. $4=15 for a 4 Axis machine. $4=31 for a 5 Axis machine.
7. Press the save button and return to the main tab (**Grbl** panel, you should see the DRO section).
8. Press the Red Reset button if an ALARM state is showing, then press Unlock.
9. Open the **Jog** panel and click on any of the jog direction buttons. The DRO should show movement. If you have drivers and motors hooked up, they should show movement.
10. If you have any control buttons attached, test them. It should show activity. Note the associated “LED” in ioSender when you press a button. Also, note that the LED on the board associated with the button will change state. If nothing happens, verify your connections.
11. If everything works to your satisfaction, you should now proceed to full testing of your machine.

    Note, you must have 12V connected to the Iso 12V terminal (or installed jumpers on the headers next to the terminal) for the input signals (limit switches, probe and control inputs) to work. You will see a lit LED near the Iso 12V screw terminal if the isolated section has power.

There is a lot more information in the grblHAL wiki at https://github.com/grblHAL/core/wiki. In particular, we recommend you study the First Run Grbl Settings section.

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Some Initial Grbl Settings

Grbl settings are dependent on your hardware so you might have to experiment a bit. Here are some key settings that will help you get going quickly. You should spend some time studying all the Grbl settings. We suggest you start conservatively and tune your machine to higher performance one parameter at a time.

$ID	Name/meaning	Suggested Value	Comments
0	Step Pulse time in uS	3	Default is 10 but 3 will work well. Using the default will cause problems for step rates above 80 kHz. Minimum is 2 uS.
4	Step Enable invert bit mask, one per axis	7 (3 axis), 15 (4 axis) 31 (5 axis)	Bitmap field. A 1 bit means invert. A 3 axis machine would have 7 as the value, a 4 axis machine would have 15 and a 5 axis would have 31. Bit 0 is X, 1 is Y, 2 is Z, A is 3 and B is 4.
5	Invert Limit Input bit mask, one per axis	7 (3 axis) 15 (4 axis) 31 (5 axis)	Bitmap field. Set each bit to 1 to use N.O. Switches/sensors as limit inputs. For N.C. Switches/sensors, set each bit to 0.
14	Control pin inversion bit mask, one per pin.	70 - invert Feed Hold, Cycle Start and Estop	A 1 bit means invert. Reset is bit 0, Feed Hold – 1, Cycle Start – 2, Safety Door – 3, Estop is 6. This assumes you are using N.O. switches for input.
30	Max spindle speed in RPM	1000 or VFD max.	Default is 1000. If you have a VFD, you will need to set this to the spindle max. In G-Code, the Sxxx parameter controls speed and to get full speed, you will need to have xxx match this parameter (S1000, in the case of the default).
100, 101, 102, 103, 104	Steps/mm. One for each Axis. 100 – X, 101 – Y, and so on.	varies	Set these based on your hardware – lead screw/belt ratios, microstepping. The Grbl defaults are likely wrong for your machine but you will still get movement. On a per axis basis, determine the number of steps (including microsteps) it will take to make one full rotation of the lead screw. Determine how many mm that axis will move with one full rotation of the lead screw, pinion gear or belt driver pulley. Divide the first number by the second to get the value you will use.
110, 111, 112, 113, 114	Max Rate	2500 mm/Min	This is a reasonable starting point for a hobby machine. Higher performance machines can easily support 5000 or higher.
120, 121, 122, 123, 124	Acceleration in mm/Sec^2	500 mm/Sec^2	This is a reasonable starting point for a hobby machine. High performance stepper motors and servos can support significantly higher acceleration

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Compatible G-Code Senders

Most senders are compatible with grblHAL. If your preferred sender is having problems, you may need to use a version of grblHAL built with compatibility settings. Use the grblHAL Web Builder interface described in the Firmware section above. Compatibility Level is set in the Advanced features panel. [**note:** this is increasingly becoming unnecessary.]

0-10V Spindle output setup

The 0-10V circuit works by using an opamp to filter a 5V PWM signal and amplify it to 10V. As such it needs 12V or higher input which the user must provide via the 12V screw terminals. A second order filter with an aggressive low pass cut off frequency is used to provide a stable signal for the spindle controller.

Because source voltage level can vary, the amplifier must be adjusted. You can do this by turning on your spindle in GCode (via M3Sxxxx) to full speed and adjusting RV1 (the blue box with the screw) until the voltage on the 0-10V terminal reads 10V. Here is a step-by-step method you can use:

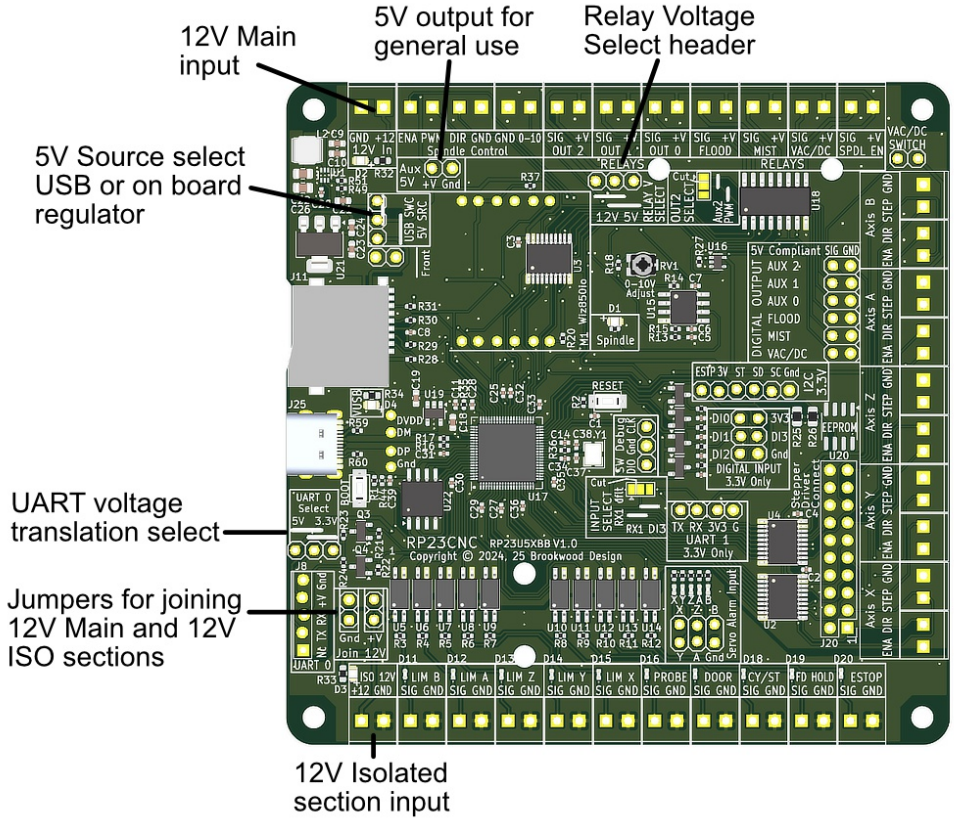
1 Disconnect your spindle or VFD.
2 In the **Settings: Grbl** tab, set $30, **Maximum Spindle Speed**, to 1000.
3 Send the following command to grblHAL: **M3 S1000.** This turns on the spindle and causes the speed to be set to 100%.
4 With a digital multimeter, measure the voltage between the 0-10V output and G terminals.
5 With a screwdriver, adjust RV1, labeled “0-10V Adjust”, until the voltage is as close to 10V as you can get. Anything in the range 9.990V to 10.010V is acceptable.
6 Send the following command to grblHAL: M5. This turns off the spindle and you should read 0V.
7 Reconnect your spindle or VFD and test.
8 Change the max spindle speed setting, $30, to something more appropriate for your spindle.

You may want to repeat the above process with the spindle connected and running to fine tune the maximum speed. Most VFDs will show you the actual spindle speed.

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Power Inputs and Settings

This diagram shows the various power related headers and inputs.



Isolated vs Main 12V

The RP23U5XBB has an isolated 12V section for limit switches and input controls. This is not connected electrically to the rest of the board which uses the 12V main supply. Using a separate 12V PSU for the ISO section is the recommend configuration for best EMI immunity. The Join 12V jumpers allow using a single 12 PSU if the user wishes to economize. In many cases the opto-isolators provide sufficient isolation without a separate 12V PSU.

The RP23U5XBB requires 12V input. It will draw up to approximately 500 mA though any directly driven relay coils or other devices will add to that.

Warning

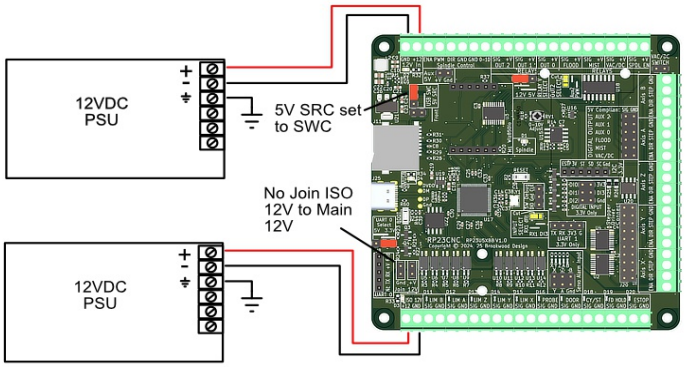
- Do not use a PSU that may go above 12V. Unregulated wall adapters (aka “wall warts”) can go quite high. These can damage the RP23U5XBB. Use a regulated PSU that outputs 12V even with no load.
- Do not reverse polarity. Connect plus (+) on the PSU to (+) on the RP23U5XBB board. Connect minus (-) (or Gnd) on the PSU to Gnd on the RP23U5XBB board.
- Do not “hot plug” the 12V source. This entails plugging an already powered PSU into the RP23U5XBB. It may cause a voltage surge which can lead to circuit damage. Best practice is to connect the PSU before powering it on.

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3 ways to power the RP23U5XBB board.

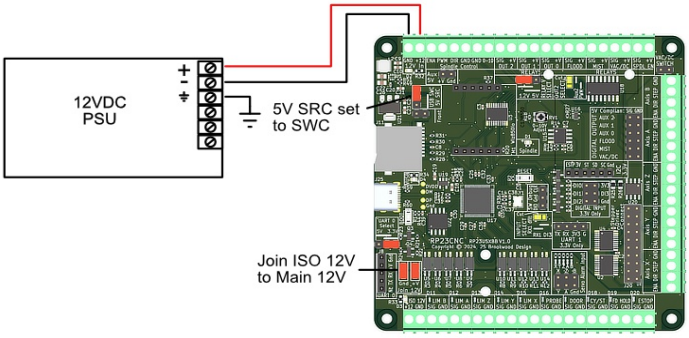
1) Dual PSUs, Fully Isolated. recommended.

This provides separate power for the relay and spindle sections as well as isolated power for the limit sensors/switches. The digital section – the RP2350 itself and all the digital logic on the RP23U5XBB – are powered by on-board 3.3V and 5V regulators fed from the 12V relay input. 1 Amp PSUs are acceptable for either PSU. If you have other 12V items to power, use the main section PSU and size accordingly to the additional load. Select SWC as the 5V SRC. Note the position of the shorting plugs in the image to the right.



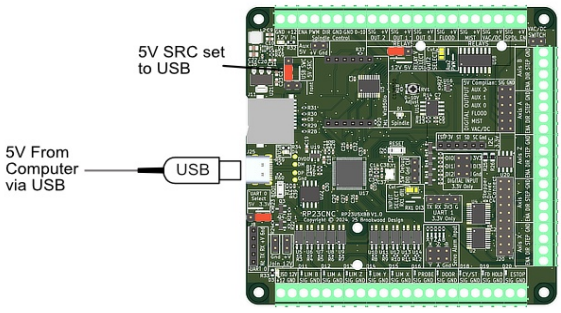
2) Single PSU.

For budget conscious builders, there is the option to use a single PSU. The 2 2 pin headers near the 12V Iso input can be jumpered to join the two 12V sections together and thus have one 12V PSU power the entire board. This does not provide true isolation for the limit, probe and control input section but may be acceptable, especially if good EMI practices are followed. The opto-isolators provide some EMI protection even without a fully isolated PSU. See "EMI Considerations" below. Select SWC as the 5V SRC. Note the position of the shorting plugs in the image to the right.



3) Logic Powered from USB

For initial testing outside the electronics case, the core digital section of the RP23U5XBB can be powered via USB power. This is acceptable if you do not power any relays or other devices. However, the Limit, Probe and Input sections require 12V power to function. If you do not supply 12V to the RP23U5XBB, grblHAL may boot up in an error state. See the First Run Settings in the wiki for how to deal with that. Select USB as the 5V SRC. Note the position of the shorting plugs in the image to the right.



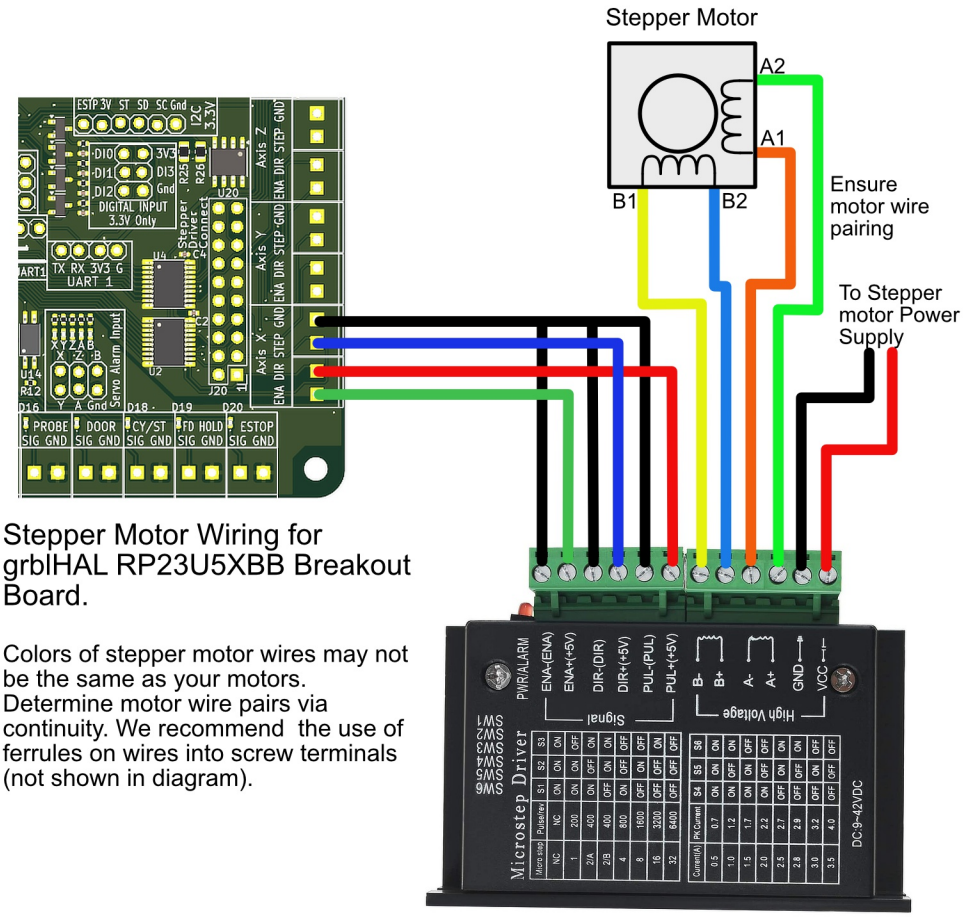
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External Device Connections

Connecting Stepper Drivers to the RP23U5XBB

Using stepper motors with the RP23U5XBB is fairly simple. Typically, a Stepper Motor Driver is used to turn the RP23U5XBB's Step and Direction signals into voltage and current that cause the desired step motions of the stepper motor. Servo drivers do a similar operation so, for simplicity, we will just talk about steppers here but the following applies to servos as well.

Most stepper drivers use opto-isolators for input so you will see a plus (+) and minus (-) terminal for each signal. In our case, we will connect the minus (-) inputs to ground on the RP23U5XBB board and the plus inputs (+) to the named signals (Step, Direction and Enable) on the RP23U5XBB board. Typically the Step terminals on drivers are labeled PUL (pulse), the Direction terminals are labeled DIR (direction) and the Enable terminals are labeled ENA (enable). Other stepper drivers may have variations on these names.



Stepper Motor Wiring for grblHAL RP23U5XBB Breakout Board.

Colors of stepper motor wires may not be the same as your motors. Determine motor wire pairs via continuity. We recommend the use of ferrules on wires into screw terminals (not shown in diagram).

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Using servos with the RP23U5XBB board.

The connection are similar to the above diagram. In addition, servos also have an alarm output, often labeled ER, ALM or similar. This signal indicates when the servo has failed to operate as directed, often due to lost steps. The RP23U5XBB has a header for servo alarm signals. This requires open-collector outputs (common on most servo drivers). Each axis has its own alarm input along with an LED that will illuminate when the alarm signal is asserted.

The default grblHAL input pin for the servo alarm signal is the Estop/Halt signal. When an alarm is asserted, the controller will enter the halt state. This will cause your GCode program to stop. The grblHAL input pin is configurable at the board level. The default is Estop/Halt but you can also select Door (Safety Door) or Feed Hold via the solder jumper pads on the bottom of the RP23U5XBB. You will need to cut the default connection trace and use solder to bridge the pads for the desired input. The Estop/HALT input pin must be inverted and the physical Estop switch be Normally Open (NO). See the Board Level Configuration section on how to change to a different input pin.

It is also possible to connect servo alarm output for a given Axis to the associated limit input. It can be connected in parallel with an N.O. NPN sensor on the associated axis limit input. PNP and N.C. sensors are not supported. You will need to configure your Grbl Settings to use hard limits and have correct inversion on the limit input.

Many servo controllers allow configuration of the alarm output. Select “sinking” or open collector output when using the alarm inputs of the RP23U5XBB.

Note: If you switch the Alarm input to Door, you will need to rebuild the firmware with Safety door enabled. It is not enabled by default. In the grblHAL Web Builder, you can find the Safety door check box on the Optional inputs page.

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Connecting to a spindle

There are several different ways you can connect the RP23U5XBB board to control a spindle:

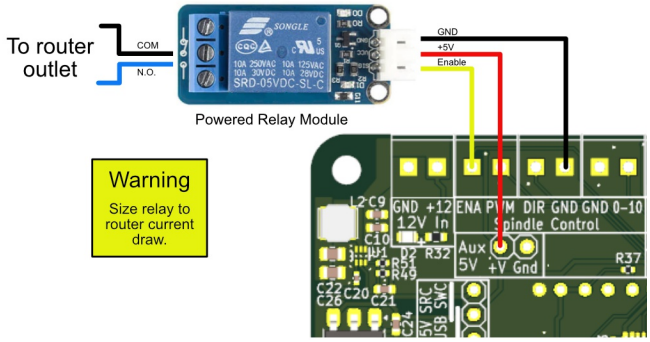
- On/Off control via spindle enable (En) or Relay.
- PWM control of a speed controller or VFD.
- 0-10V control of a VFD.
- Modbus/RS485.

On/Off control

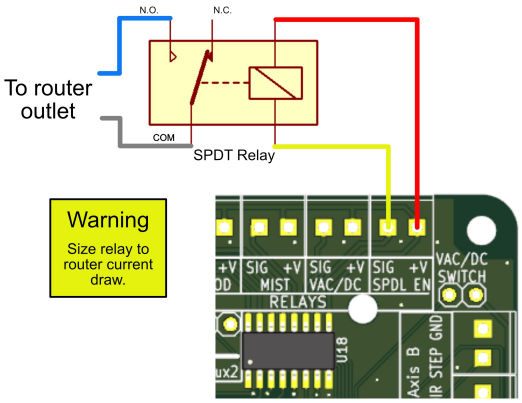
There are 2 places to control spindle On/Off: the En screw terminal in the spindle group (a 5V logic level output) or the SPDL EN screw terminal (an Open Collector output for a relay coil). Any of these can be used to control a relay to turn a spindle on or off. This is how you would use a router as the spindle.

Cautionary Notes:

- If you are unfamiliar with AC voltage, consult a professional electrician before proceeding.
- Be conservative in selecting a relay for it the right AC current. Most routers have a surge current that can be significant. Note also that inexpensive relays often have wishful ratings. Again, if unfamiliar with AC relays, consult a professional electrician.
- Only use connectors, plugs and outlets that are approved for line voltage and high current in your jurisdiction. Consult a professional electrician if you are not familiar with line voltage.
- Read the Using Relays section for information about relays with the RP23U5XBB.



On/Off control via a powered relay module.

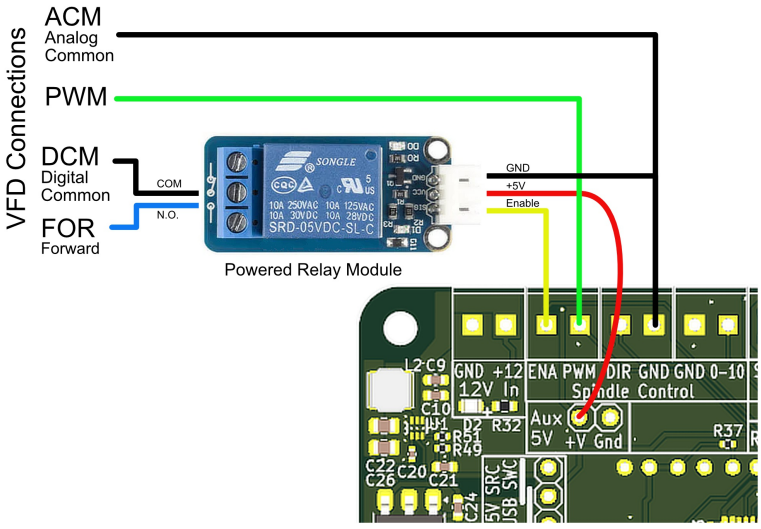


On/Off control via driving a relay coil

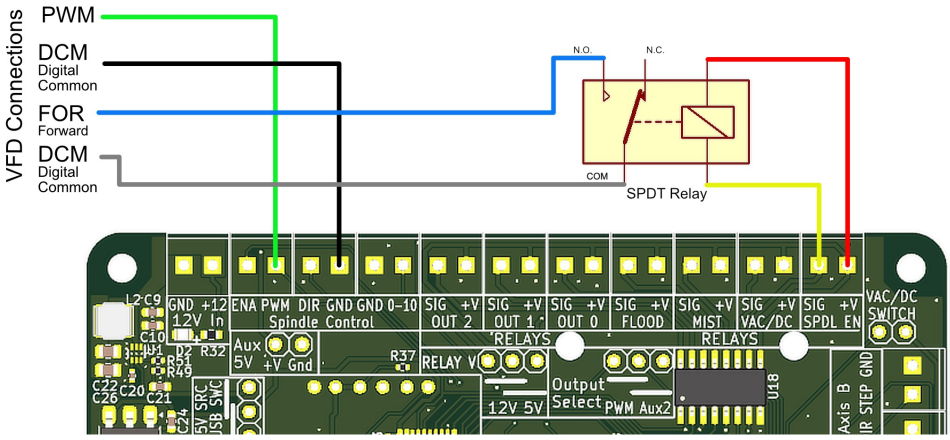
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VFD control via PWM

Some spindle controllers take 5V PWM control. This is common in DC motor controllers. You can use the PWM screw terminal output for this. If your DC motor controller requires a different output voltage, Aux2 can be configured to drive 12V PWM. See the 12V Spindle PWM section. If other than 5V or 12V are needed, an external voltage can be used in conjunction with Aux2 – see the General Purpose Open Collector section.



PWM Control via a powered relay module

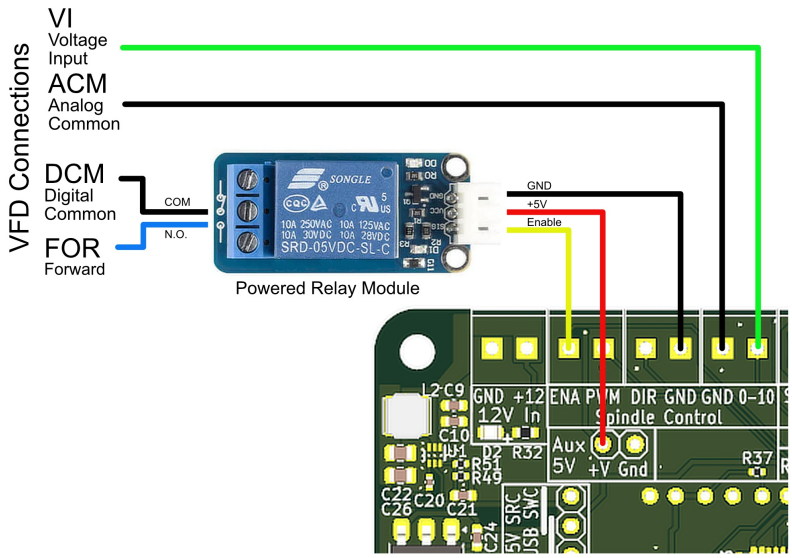


PWM Control via driving a relay coil
Make sure you select the correct relay voltage.

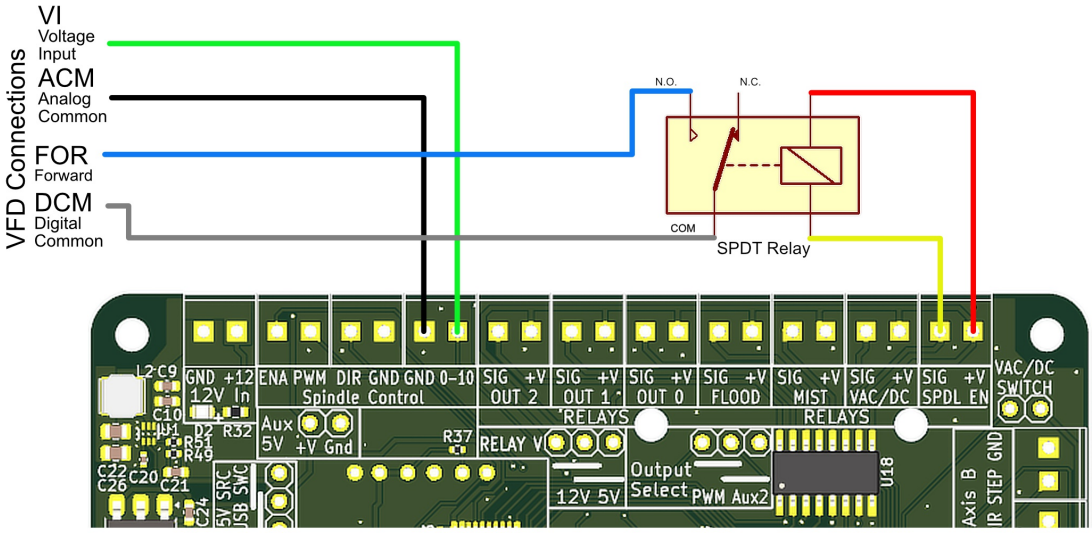
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VFD Control via 0-10V output

VFDs may be controlled via 0-10V output. A typical connection is shown below. The VFD must be configured to take an external voltage for control and set to 0-10V. Some VFDs will also take PWM control. The actual configuration steps for a VFD are beyond the scope of this manual. Consult with your VFD's user manual.



0-10V Control via a powered relay module



0-10V Control via driving a relay coil
Make sure you select the correct relay voltage.

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Modbus/RS485

This is not directly supported on the RP23U5XBB board but you may use a serial to Modbus adapter with either UART header.

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Board LED indicators

The RP23U5XBB has a number of LED indicators to help the user during installation and problem solving.

The Spindle On indicator brightness is taken from the PWM signal and thus is proportional to the spindle speed. It is useful when checking to see if the board is generating the speed signal. Note that below 20% the LED will appear to be off

USB 5V present indicator only lights when there is 5V present on the inserted USB cable.

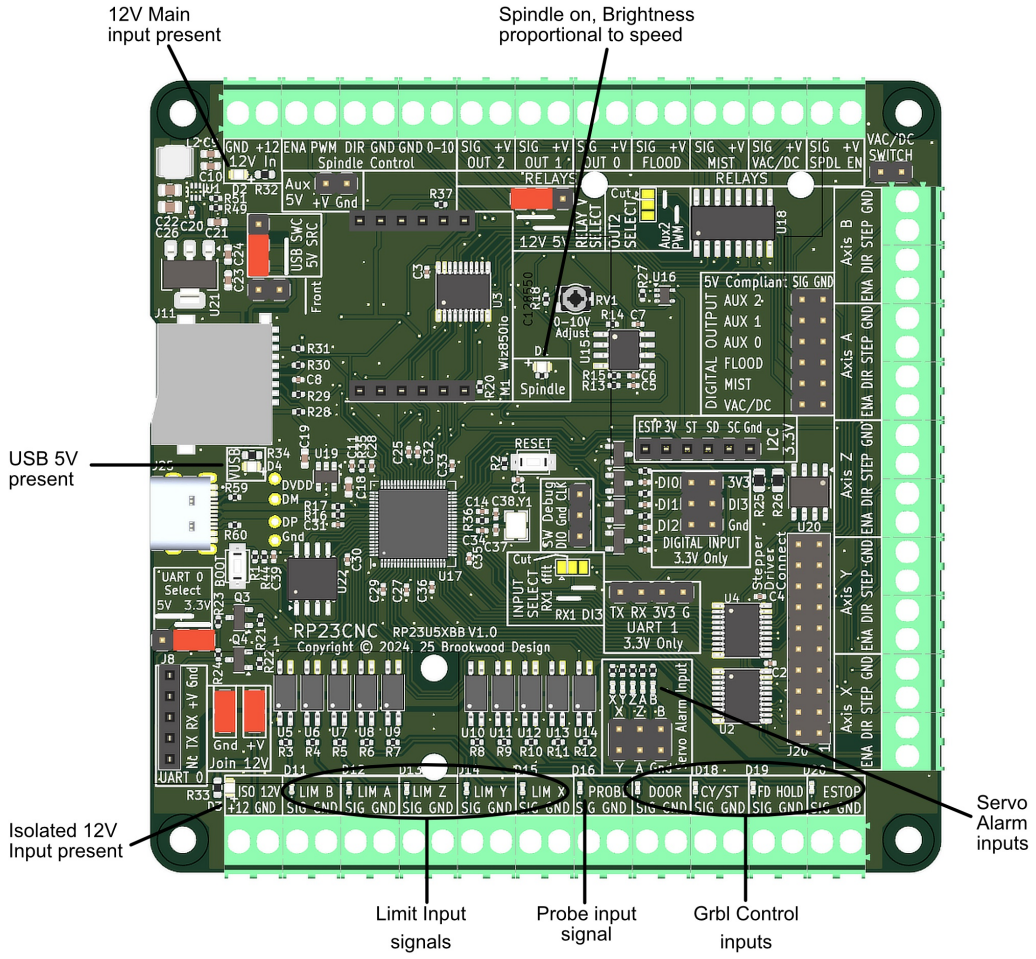
Isolated 12V indicator will light if there is isolated 12V input or when the isolated section is joined to the main power section.

Limit input indicators light when there is voltage on the input pin. This means that for N.O. sensors, the light will be on when the sensor is triggered and for N.C. sensors, it will be off when triggered.

Probe input indicator will be on when a N.O. probe makes contact and off when an N.C. probe makes contact.

Grbl control indicators will be lit when when an N.O. switch is closed and off when an N.C. switch is closed.

Servo Alarm Inputs expect open collector outputs from the servo driver. They will remain lit until the servo alarm condition is cleared. These will only work with NPN Open Collector outputs.



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Using Relay and Digital outputs with the RP23U5XBB board

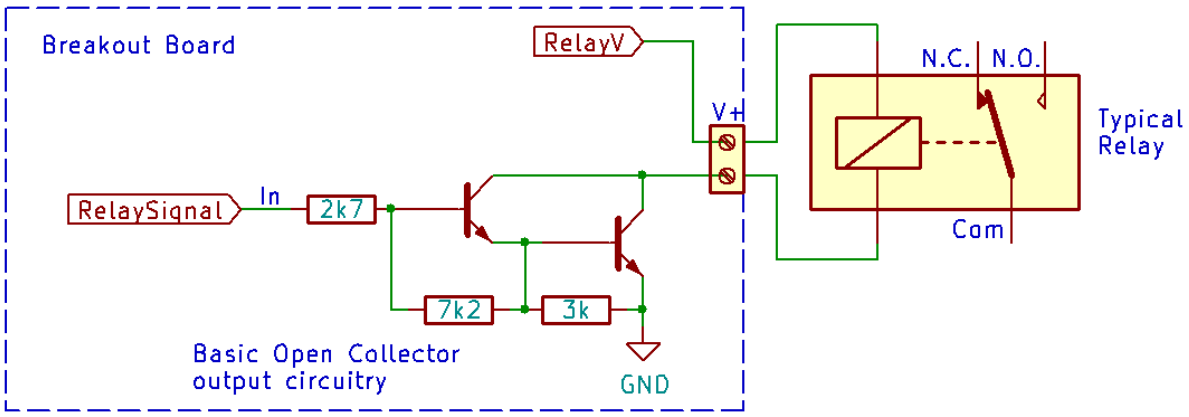
There are several ways to use the outputs of the RP23U5XBB board:

- To directly drive external 5V or 12V relay coils.
- Drive solid state relays (SSR).
- Drive powered relay boards (PRB) with 5V control inputs.
- Drive 5V logic (TTL) devices.
- As a general purpose open collector (OC) driver.

A note on using relays and other devices to switch 110/220 VAC: Please be aware of the risks associated with using relays to control high voltage devices like motors. If you are not familiar with high voltage, we recommend you consult a professional electrician for help in selecting the right devices and proper wiring techniques.

Directly driving external relay coils.

The relay screw terminal outputs of the RP23U5XBB board are used to drive relay coils. Automotive and DIN Rail mountable relays are commonly available. The relay coil is wired across the two terminals as shown below. Relay coil current up to 100 mA is supported. If only one relay is connected, up to 300 mA coil current is acceptable. The 12V relay section PSU supplies the current for relay coils. Add up total relay current draw plus 200 mA. Make sure that your PSU is capable of delivering that amount of current.



Driving solid state relays.

SSRs are driven from the Digital Output section pin headers. The output voltage level is +5V which is compatible with most SSRs but verify that yours is as well before proceeding. DIN rail mountable SSRs are readily available.

Driving powered relay boards.

Powered Relay Boards are driven from the Digital Output section pin headers. The output voltage level is +5V. Make sure that your PRB is compatible. PRB modules are readily available. Be aware that some cheaper modules use optimistically specified relays. We recommend derating relays contact ratings by at least 20% for safety.

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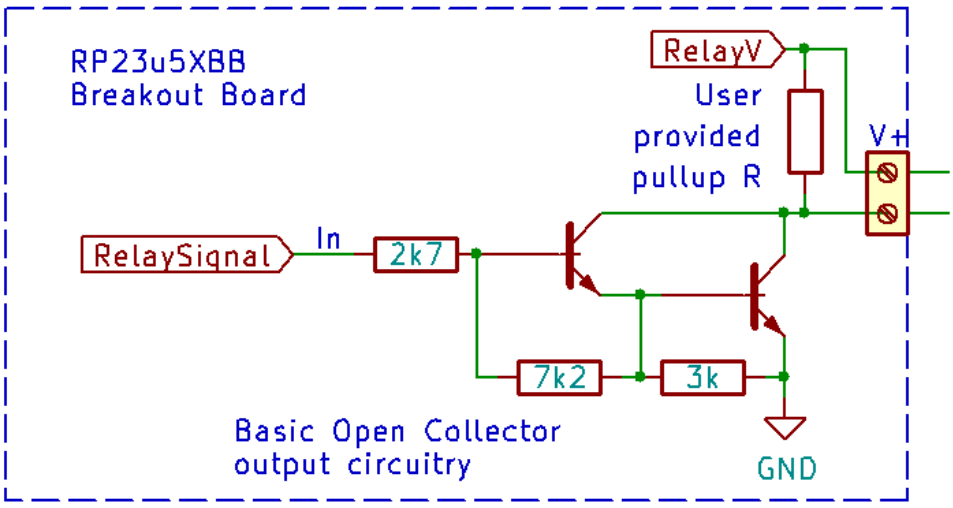
Driving 5V logic devices.

The Digital Output section pin headers are usable for general 5V logic signaling. For AuxOut 0-2, use the M62-M65 commands to turn then on or off. They can be issued from GCode, a macro in a GCode Sender or from direct GCode input via a GCode sender.

General Purpose Open Collector driver.

The open collector outputs of the relay screw terminals are available for general use. The current is limited to a sum total of 300 mA through all terminals at a 100% duty cycle. The v+ terminals supply either +5V or +12V, determined by the jumper on the Relay Voltage header. A common ground may be needed. Any unused ground terminal on the relay or stepper output section the RP23U5XBB can be used. Do not use a ground pin from the Limit or Control input sections.

If you need a pull up resistor for your application, there are pads on the bottom of the PCB for 0805 surface mount pull up resistors. Alternately, an external through hole resistor may be used.



Open collector circuit on the RP23U5XBB

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Environmental Considerations

Electro-Magnetic Interference

Electro-Magnetic Interference can cause significant disruptions to your CNC machine. It is best to build your system using good practices. Often your wiring can act as antennas for EMI and conduct it back into your electronics box. In designing the RP23U5XBB board, we used good practices to avoid EMI but further precautions are recommended. High voltage electrical devices are often a source of EMI and you should take additional steps to ensure that these sources are managed. Finding the source of EMI later can be difficult – we recommend that you design your system with EMI avoidance it in mind.

These are general recommendations, you don't need to follow all of them but the more you do the better chance you stand of having EMI free operations.

- Do not power 5V relay coils from the USB voltage supplied to the RP23U5XBB. Relays can produce EMI and power fluctuations. Use external power (see above).
- Do not power relay coils directly from the Stepper Motor power supply. It can be a significant source of EMI.
- Use shielded wires for signals. Make sure the shields are grounded in a star configuration at the controller box or other common ground.
- Use ferrite filters on all wires entering or exiting the RP23U5XBB.
- Avoid routing wires near EMI sources such as a VFD, Stepper motors, electrical motors or power supplies. Avoid co-routing unshielded wires with wires that are connected to those devices as well.
- If you are connecting to the RP23U5XBB via a USB cable, use one with a ferrite filter on it or add a clamp-on one close to the electronics box end of the cable.
- Use Ethernet to communicate to the RP23U5XBB. It is superior to USB in EMI resistance.

Ferrules

We recommend that all stranded wires have ferrules crimped on the end that goes into a screw terminal. This is a good practice. It ensures the best possible contact and helps to avoid stray “cat whiskers” - strands of wire that could cause errors. Kits with ferrules and a crimper are readily available for $20 to $30 USD. It is a worthwhile investment. Use 22 Ga ferrules for the assembly kit screw terminals on the RP23U5XBB. Larger ones may not fit. You may need to slightly flatten the tip of the ferrule to get it to initially go into the screw terminal.



High Vibration Environments

While the RP23U5XBB was designed to be relatively immune to vibration, you may want to take extra measure if installing it in a high vibration environment. There are several solder jumpers that you should use rather than pin header jumpers. In addition, hot melt glue is useful for affixing any plug in components like the Ethernet module and any pin header plugs.

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Errata/Change Log

V0.92 and V0.95

UART 1 RX line is not connected to RP2350 RX pin. Fixed in subsequent versions.

V1.0

Silk screen error on the 5V SRC header. Misplaced line indicating shorting position of the SWC plug. Fixed in subsequent versions.

V1.01

Minor relocation of 5V SRC header and Digital Input header.

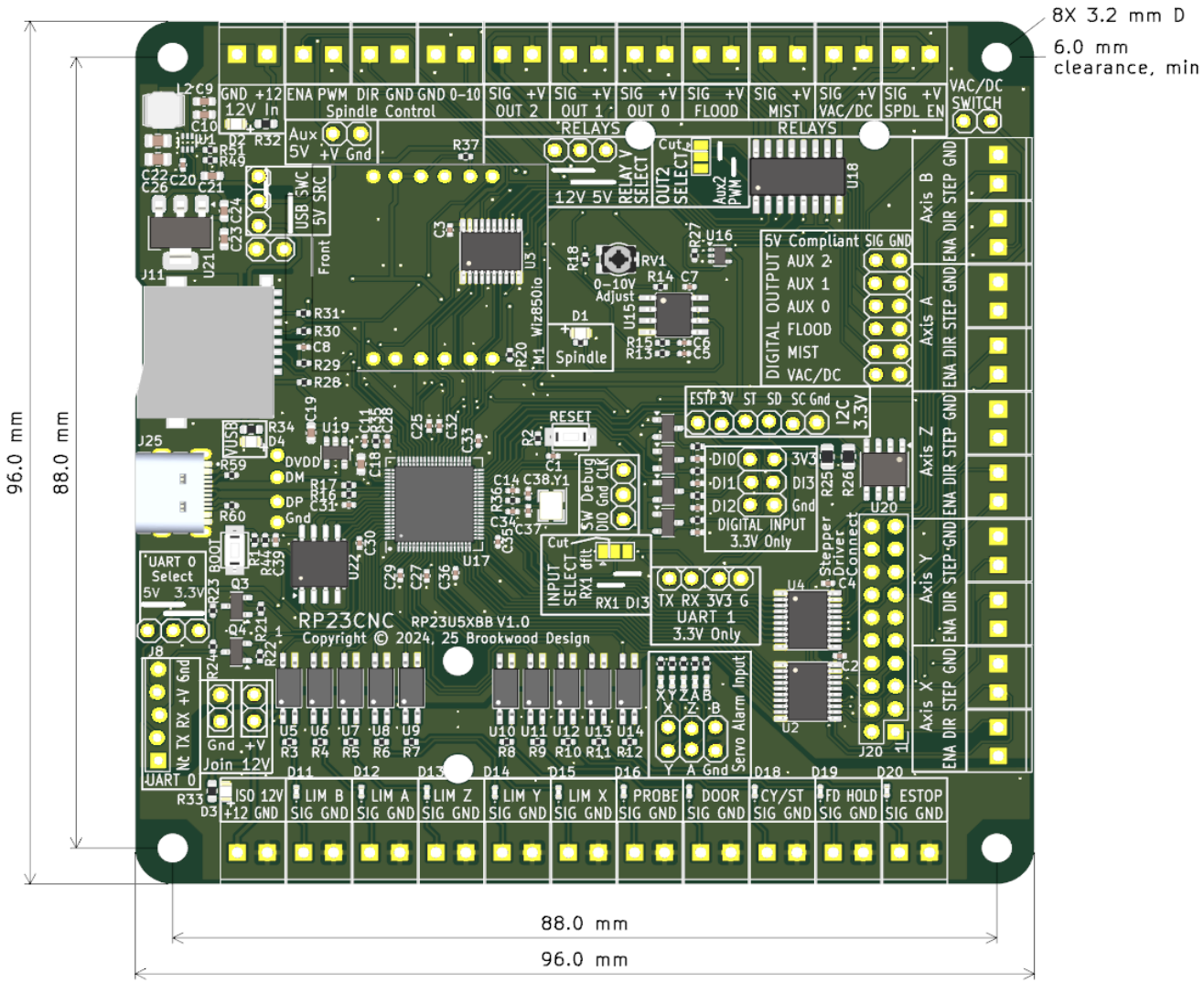
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Schematic

See https://github.com/phil-barrett/RP23CNC/tree/main/Schematic for the latest version.

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Board Measurements



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Bill of Materials

Designator	Footprint	Q.	Value	Mouser #
C1, C2, C20, C25, C27, C28, C29, C3, C30, C31, C32, C33, C34, C35, C36, C39, C4, C6, C7, C8	402	20	100nF	187-CL05A104KA5NNND
C10	603	1	100nF	187-CL10B104KA8NFNC
C11, C14	402	2	4.7uF	581-04023C333KAT2A
C12, C15, C16, C17	402	4	10nF	581-04023C103K4T2A
C18, C19	603	2	4.7uF	81-GRT188C81E475KE3D
C21	603	1	22pF	581-06033A220J
C22, C26	805	2	22uF	187-CL21A226MAYNNNE
C23, C24	603	2	10uF	187-CL10A106MA8NRNC
C37, C38	402	2	15pF	710-885012005041
C5	402	1	1uF	581-04023D105KAT2A
C9	603	1	10uF	187-CL10A106MA8NRNC
D1, D2, D3, D4	603	4		755-SML-D12M8WT86
D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, D20, D21, D22, D8, D9	402	15		442-BLHGE37AAVTB
D23, D5, D6, D7	SOT-23	4	BAT54S	821-BAT54SHRFG
J11	sdcard	1	MicroSD	798-DM3DSF41
J25	KH-TYPE-C-16P	1	USB-TYPE-C	523-GSB1C41110SSHR
L2	FNR4030S4	1	4.7uH	70-IHLP1616BZR4R7M51
Q3, Q4	SOT-23	2	BSS138	621-BSS138K-13
R1, R36, R38, R39, R40, R58	402	6	1K	603-RC0402FR-101KL
R10, R11, R12, R3, R4, R5, R6, R7, R8, R9	402	10	2K	603-RC0402FR-7D2KL
R13, R14, R15, R18, R2, R21, R22, R23, R24, R28, R29, R30, R31	402	13	10K	660-RK73H1ETTPD1002F
R16, R17	402	2	27	71-CRCW040227R0FKED
R19	402	1	470	791-RMC1/16SK4700FTH
R20, R37	402	2	4K7	791-RMC1/16SK472FTH
R25, R26	805	2	2.2K	603-AC0805FR-102K2L
R27	402	1	100K	603-AC0402FR-7D100K
R32, R33	603	2	2K7	603-AC0603FR-102K7L
R34	603	1	1K	603-AF0603FR-071KL
R35	402	1	33	71-CRCW040233R0FKEDC
R43, R45, R46, R47, R48	402	5	1K5	667-ERJ-2RKF1501X
R49	402	1	51K	603-RC0402FR-0751KL

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Designator	Footprint	Q.	Value	Mouser #
R51	402	1	9K76	603-RC0402FR-079K76L
R59, R60	402	2	5K1	603-AC0402FR-075K1L
RV1	SMD_trimmer	1	10K	652-TC33X-2-103E
SW1, SW2	2026	2	SW_SPST	113-MPTFP2-V-T/R
U1	DRL0006A	1	TPS562202D	595-TPS562202DRLR
U10, U11, U12, U13, U14, U5, U6, U7, U8, U9	EL3H7-G	10	EL3H7	638-EL3H7DTAVG
U15	SO08	1	LM358D	595-LM358DR
U16	SOT-353	1	74LVC1G32	621-74LVC1G32SE-7
U17	RP2350-QFN-80	1	RP2350B	
U18	SO16	1	ULN2003AD	595-ULN2003ADR
U19	SOT-23-5	1	TLV74311	595-TLV74311PDBVR
U2, U3, U4	TSSOP20-NXP	3	74AHCT541A	771-74AHCT541APWJ
U21	SOT-223-3	1	AMS1117-3.3	926-LM1117MPX3.3NOPB
U22	SOIC-8	1	W25Q16JVSSIQ	454-W25Q16JVSSIQ
Y1	3225-4Pin	1	X322512MMB4SI	815-ABM3B12000MHZBT

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