CNC Control with Raspberry Pi, UGS and Piggy-Back Pi

Introduction

I have had a Bob's CNC machine for about two years now. When I first got my E4 up and running, I used a Windows-based laptop running UGS to control my machine. When the Evolution 4 was introduced, I bought the upgrade kit and made the conversion. I had some issues with UGS stopping in the middle of a cut, so I started experimenting with some other G-code senders. I ended up deciding on OpenBuilds Control. It was simple and stable.

Last fall, when the Raspberry Pi foundation introduced the Raspberry Pi 400, which is basically a computer in a keyboard, I bought one and decided to use that for controlling my CNC. A major advantage is that it is passively cooled and doesn't have any fans sucking dust into the computer. OpenBuilds was also available for the Raspberry Pi, although it is not officially supported, and this is the setup that I used for several months. I even did a YouTube video about my setup. After the video had been posted for a while, someone asked me if I had any issues running large gcode files with OpenBuilds on the Raspberry Pi. I had not run any extremely large files with the setup yet, so I searched back through some of the 3D files that I had carved before switching to the Raspberry Pi and found that OpenBuilds was not robust when running a program that had more than about 250,000 lines of gcode. In fact, mostly it will not run files this large on the Raspberry Pi.

At that point it was back to the drawing board, so I revisited UGS and bCNC. I have gotten both to work reliably, and while I may migrate to bCNC at some point in the future (because it seems to have more features), I have settled on UGS for now, because I am familiar with it.

Purpose and Scope of this Document

There are two main points that I want to cover in this document:

1. Installing UGS on a Raspberry Pi is not the same as installing on a Windows machine, so I thought I would outline what I did to get UGS up and running. In some ways, it is a little trickier, but in other ways it is more straight forward than Windows. I will assume that you have a Raspberry Pi 4 or Raspberry Pi 400 already running Raspberry Pi OS – there are plenty of tutorials about how to do that. I have to warn everyone, that this method is only tested and found to work with a Pi 4 or 400 and with the latest install of Raspberry Pi OS. I simply don't know if it will work on earlier Pi models or an OS different than the latest Raspberry Pi OS. That being said, I have successfully installed using Twister OS, which is built on Raspberry Pi OS. While I prefer Twister OS for my desktop, I am using Raspberry Pi OS on my CNC. I am also not going to go into any details about actually using UGS once it is installed. There are plenty of resources about how to get it connected to the Arduino controller, and setting UGS up for your individual use.
2. The second point is kind of interesting to me, and I hope to you as well. As I have worked more with the Raspberry Pi, I developed a method where I have mounted a Raspberry Pi 4 directly on the CNC gantry and I control it wirelessly with an Android tablet. This would also work with an iPad. You could even do with your phone, but I don't think that would be very usable – unless you have very good eyes and very small fingers. I have dubbed this the Piggy-Back Pi, and I will go through what hardware you would need to have and how to set up for the wireless control. Note: You must have a wireless network available in your workshop for this to work.

CNC Control with Raspberry Pi, UGS and Piggy-Back Pi

Installing UGS and getting it to run on a Raspberry Pi

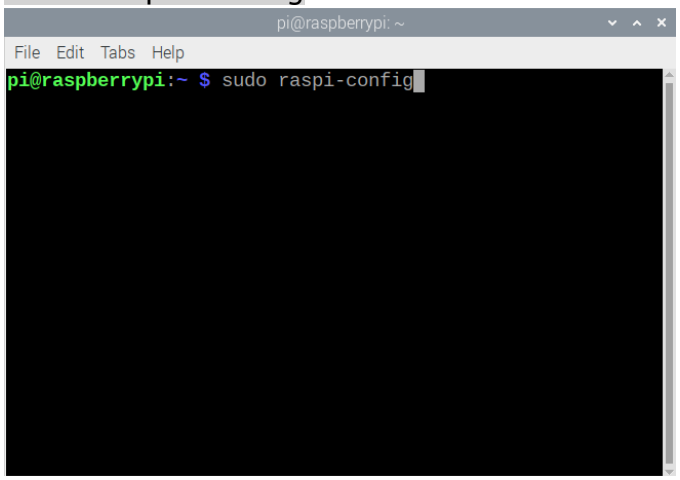
There are three major steps to installing UGS on the Raspberry Pi:

1. Adjust the OpenGL driver on the Raspberry Pi for the display.
2. Download and uncompress the UGS software.
3. Create a script file and set up a shortcut in the Menu system to start UGS.

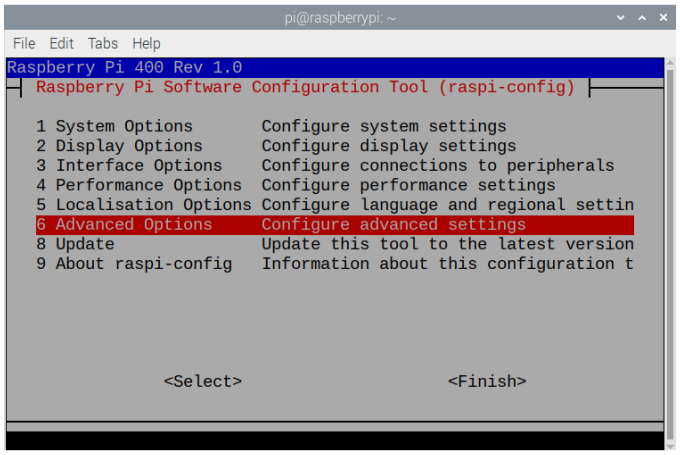
STEP 1: Adjust the OpenGL driver for the display:

1. Open terminal (It's the icon with the little black screen)

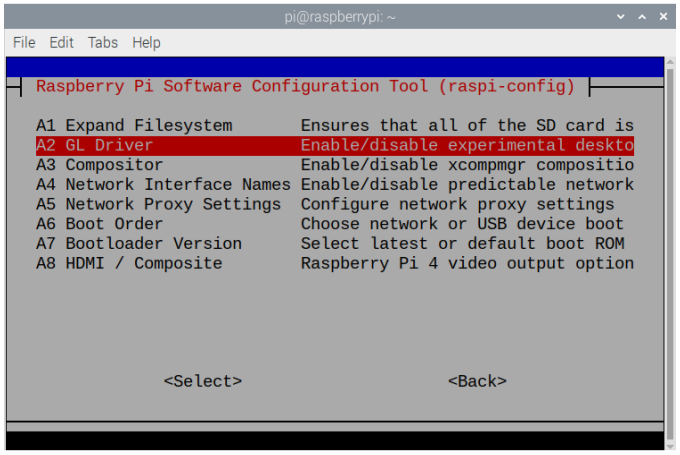
2. Run raspi-config by typing
   `sudo raspi-config`



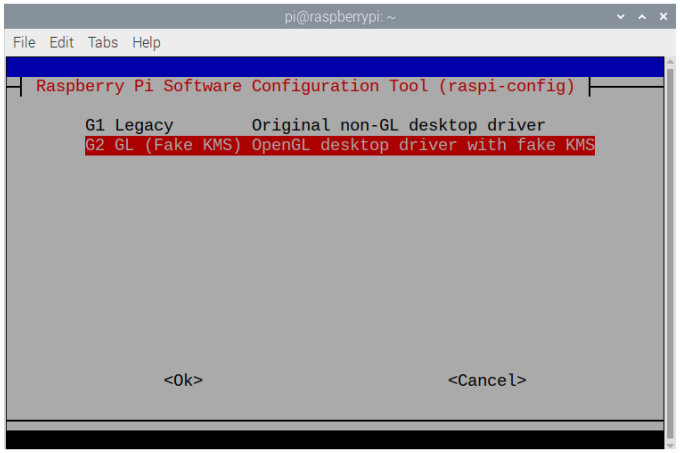
3. With the arrow keys and the Enter key, select Advanced Options



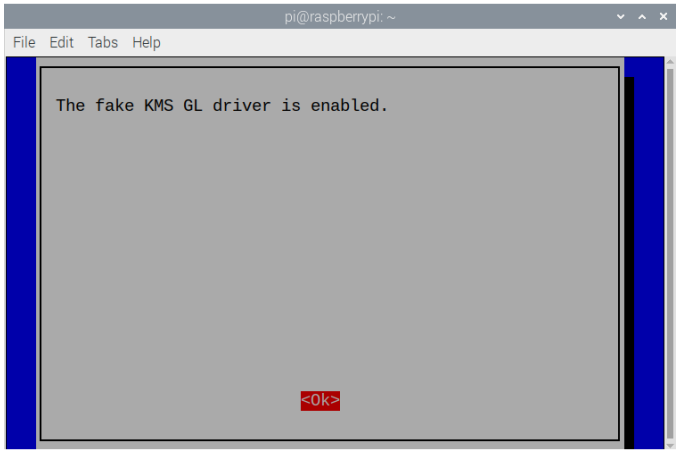
4. Select GL Driver



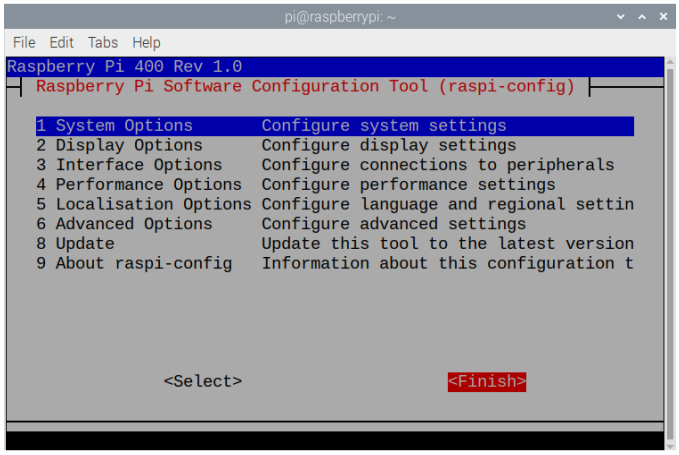
5. Select GL (Fake KMS) OpenGL desktop driver with fake KMS



6. Hit the enter key to accept that the fake driver is enabled



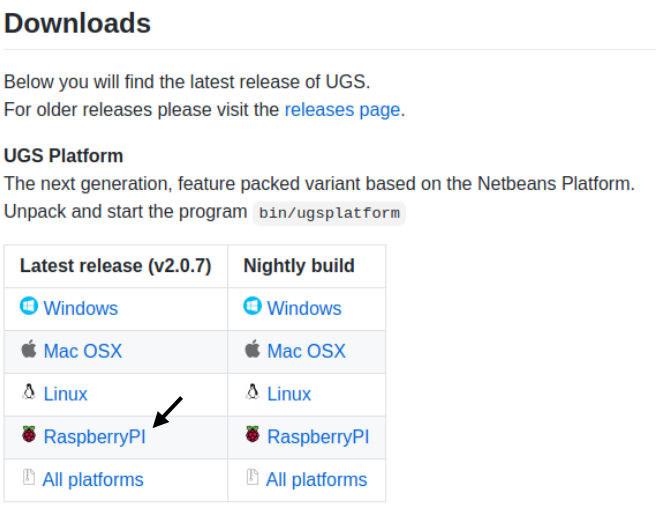
7. Hit the right arrow key a couple of times until Finish is highlighted and then hit the Enter key



Step 1 is complete.

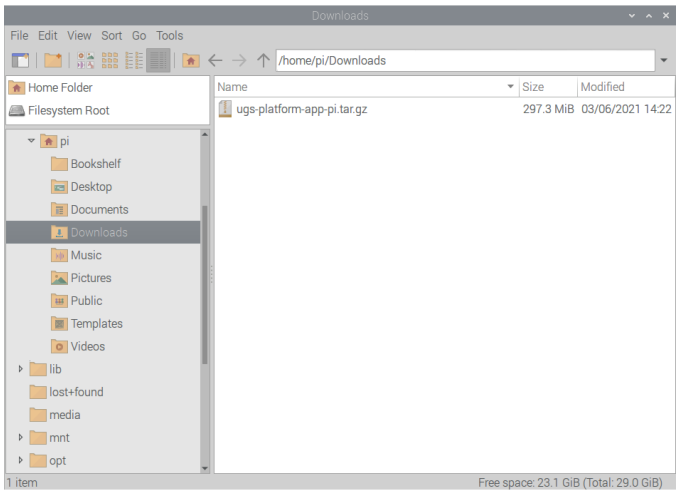
STEP 2: Download and uncompress the UGS software.

1. Using the browser on the Raspberry Pi, go to this website: https://github.com/winder/Universal-G-Code-Sender#downloads
2. Select the Raspberry Pi in the first column – it is the latest stable release.

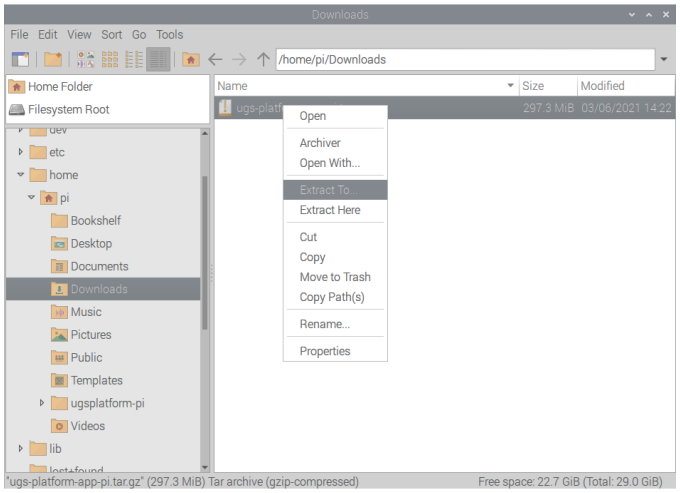


3. After it has downloaded, you can close the web browser and open the File Manager (it's the icon with the two file folders)

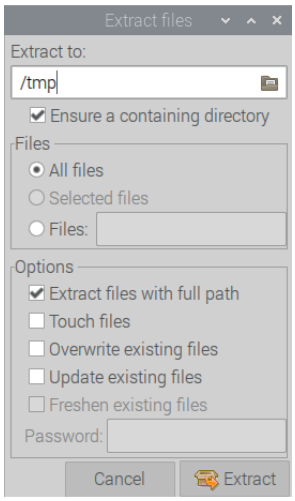
4. When the File Manager opens, go to the Downloads directory and you should see this:



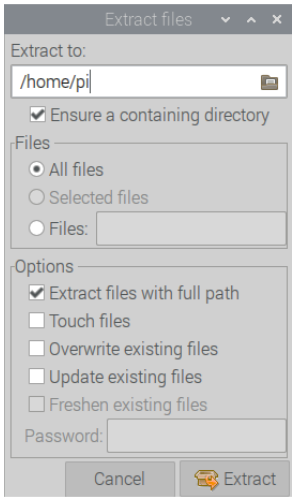
5. Right-click on the ugs-platform-app-pi.tar.gz and select Extract to…



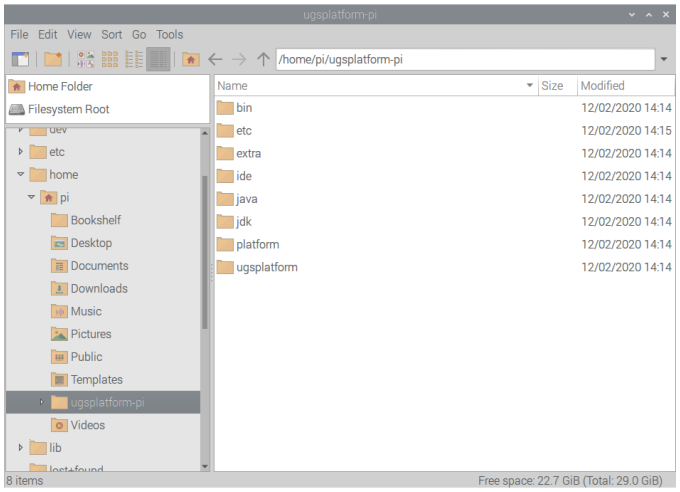
6. After a couple of seconds, you will see this dialog:



7. Change `/tmp` to `/home/pi` and click extract



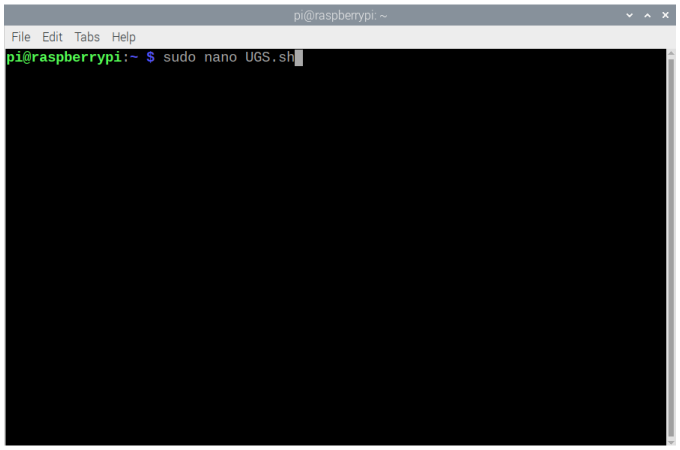
8. After it is done extracting, you should have a ugsplatform-pi directory within your pi directory as shown.



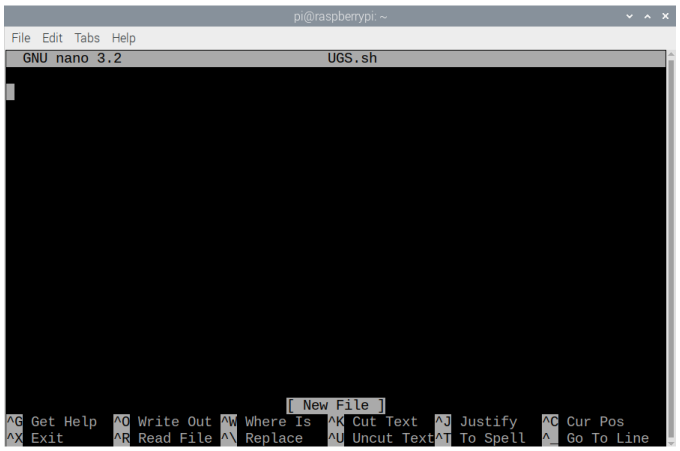
STEP 3: Create a script file and set up a shortcut in the Menu system to start UGS.

1. Close the File Manager and click on the terminal button (it's the one to the right with the >_

2. Terminal will open and type sudo nano UGS.sh (please note that Linux is case-sensitive when dealing with folder and file names), then press Enter



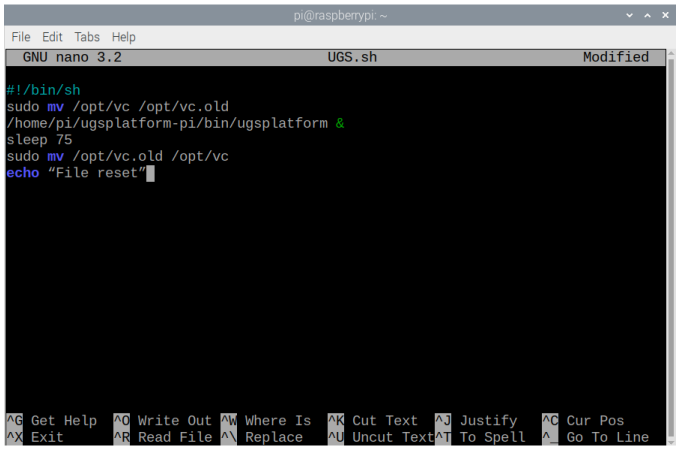
3. You will see a blank text editor window (nano)



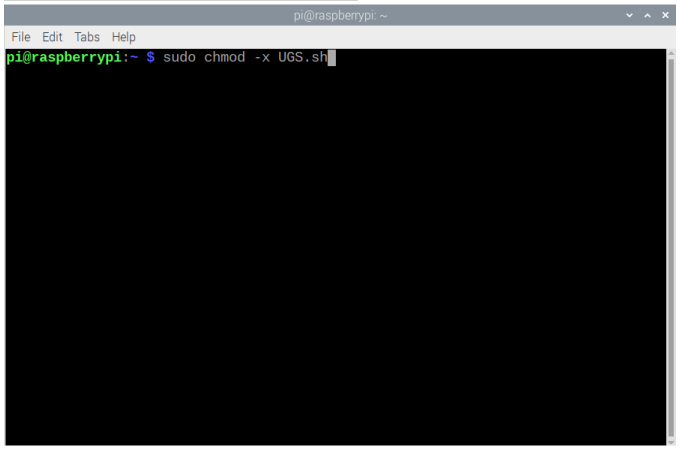
4. In the text editor type (or cut & paste) the following text

```
#!/bin/sh
sudo mv /opt/vc /opt/vc.old
/home/pi/ugsplatform-pi/bin/ugsplatform &
sleep 75
sudo mv /opt/vc.old /opt/vc
echo “File reset”
```

5. It should look like this:

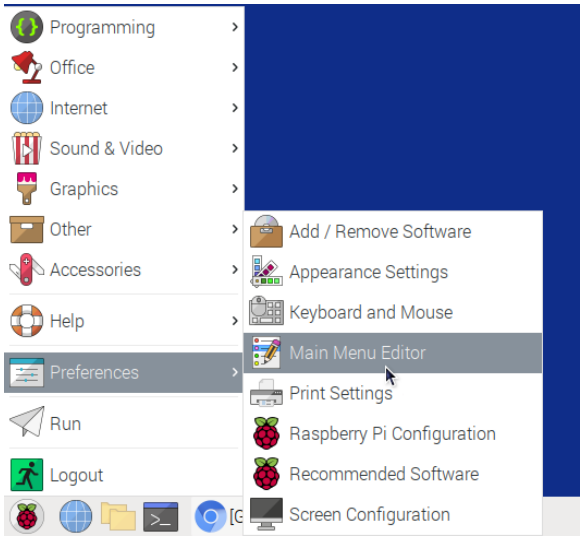


6. Press Ctrl-X to exit, it will ask if you want to save the file – type Y, then press Enter to save as UGS.sh.
7. Now we have to make the file executable. Still in Terminal, type `Sudo chmod -x UGS.sh` then press Enter.

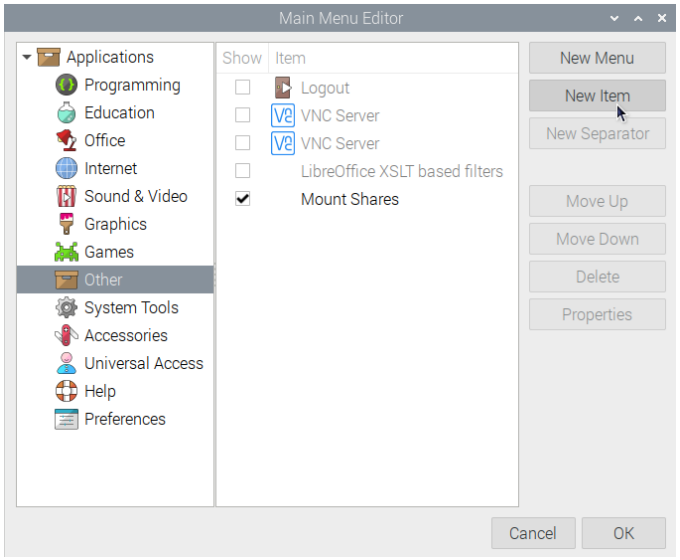


8. You can now exit terminal
9. Special thanks to cebess at https://cebess.wordpress.com/ for the solution of using the script file for ensuring that the visualizer will work properly.
10. Click on the start button (it's the Raspberry icon)

11. Select Preferences – Main Menu Editor
    (Note only for those who might be using Twister OS, you would Select Settings – Menu Editor. The editor works a little differently, but the main concept is the same – select the Other folder, click on the Green plus icon at the top and choose Add Launcher. To Enter the name for the launcher UGS, click on New Launcher field)

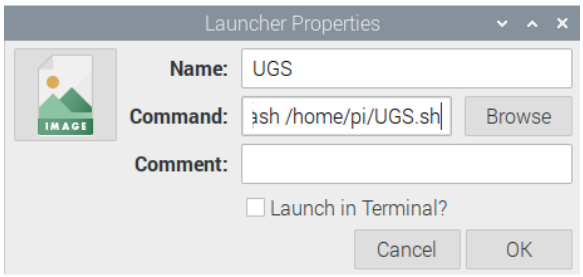


12. In the menu editor, click on Other and then New Item



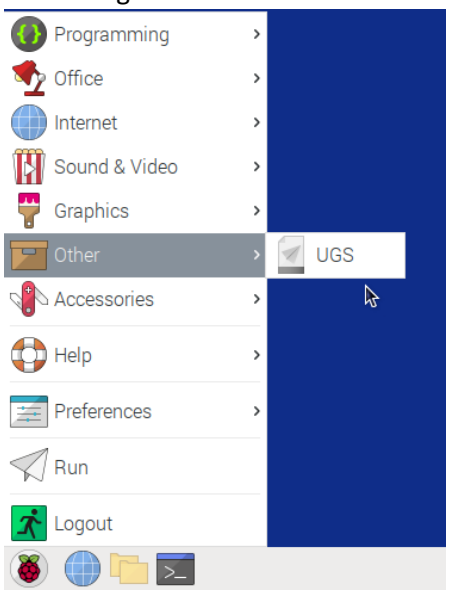
By the way, you probably won't have as many items listed in the Other folder – I have done some other stuff unrelated to this.

13. In the Dialog that Pops up, Enter `UGS` for the name and for the command type `/bin/bash /home/pi/UGS.sh`
    Then click OK

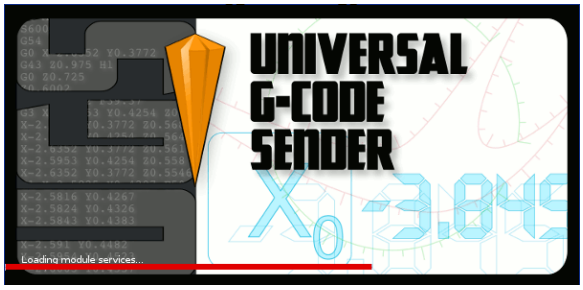


    There will be a rather boring standard icon assigned – if you feel creative you can find a more exciting icon on line somewhere – download it, and attach it by clicking on the image button and browsing for the file. You can also do this later by coming back in and editing this entry.

14. Exit the Main Menu Editor, and if you click on the start icon, and then on the other folder, it should look something like this:

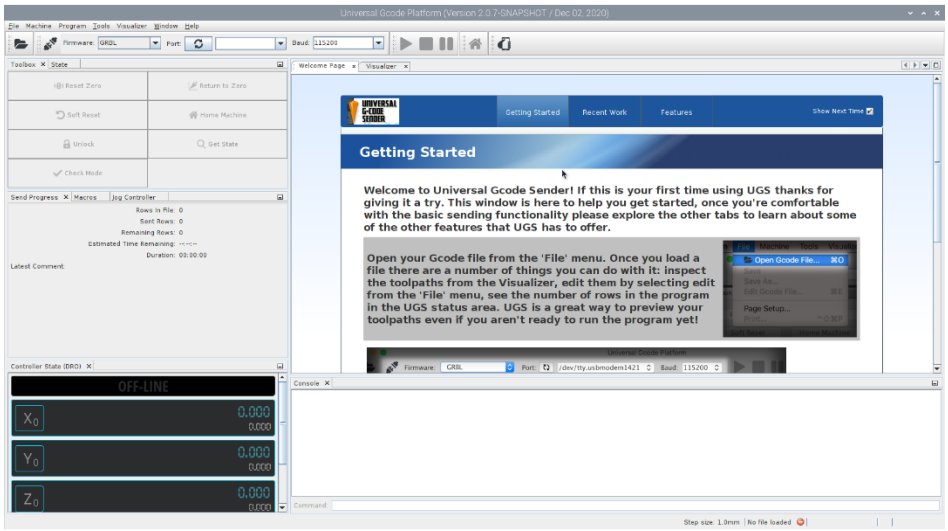


15. Select UGS, and after a few seconds, you should see the UGS splash screen



    And then…….(wait for it – no, seriously, wait for it – it takes a little while especially the first time)

Ta-da!!!



16. OK, I know I said I wasn't going to get into the actual connection and operation of UGS, but there is one thing I want to touch on. When you go to select the port when using a Raspberry Pi, you won't get the conventional Comm3 type notation. Raspberry Pi names the ports differently (which I don't fully understand, but managed to work around). When I selected the drop-down list, there were two ports listed - /dev/ttyACM0 and /dev/ttyAMA0. There may be others too when you first try to connect, but these are the important ones. Through trial and error, I determined that on mine, the correct port was /dev/ttyACM0. It is interesting that using either one connects to something, but you can tell you have the right one when the Alarm comes on and the Home button is enabled. OK – that's all about connecting and running UGS.

BONUS STEP 4: Installing bCNC, in case that is your preference or you would like to play around with it.

bCNC is actually easier to install and then you have to go through the same process used for UGS to set up a shortcut to run it in the menu.

1. Open the Terminal (just like Step 1 – Number 1 above.
2. As with installing all software from the terminal, unless you have recently updated your Pi, you should always type these two commands:
   `sudo apt update`
   and then
   `sudo apt upgrade`
   you will have to confirm the upgrade, if there are upgrades needed. This makes sure that all of the programs and supporting files are up to date.
3. After that is complete type the following command in the terminal
   `pip install –upgrade bCNC`
   after it is complete, you can exit the terminal.
4. Adding a menu shortcut is the same process outlined in Step 3 – numbers 1-4 above. Just add another new item and for this enter the following.
   Name: `bCNC`
   Command: `python – m bCNC`
   Exit the Main Menu Editor
5. That's it, bCNC should now run from the menu.

Building, Configuring and Operating the Piggy-Back Pi

So, I like tinker and am always trying to improve things – even if I'm the only one that sees it as an improvement. Anyway, I had played with Raspberry Pi quite a few years ago, but when they came out with the Raspberry Pi 400, I just had to have one. As I mentioned, I had switched over to the Raspberry Pi 400 from my Microsoft Surface that I was running the CNC with. I was concerned about all the dust that was being sucked into a laptop that is not that cheap. While the Raspberry Pi 400 fit in very well as a direct replacement for the Windows machine, I kept thinking that there had to be a better way. I still had that long USB cord running rom the computer to the Arduino, and I was still stuck at the keyboard for jogging. I used the jog controller from my phone occasionally, but it just wasn't that convenient.

So, to make a long story short, what I came up with was the Piggy-Back Pi.

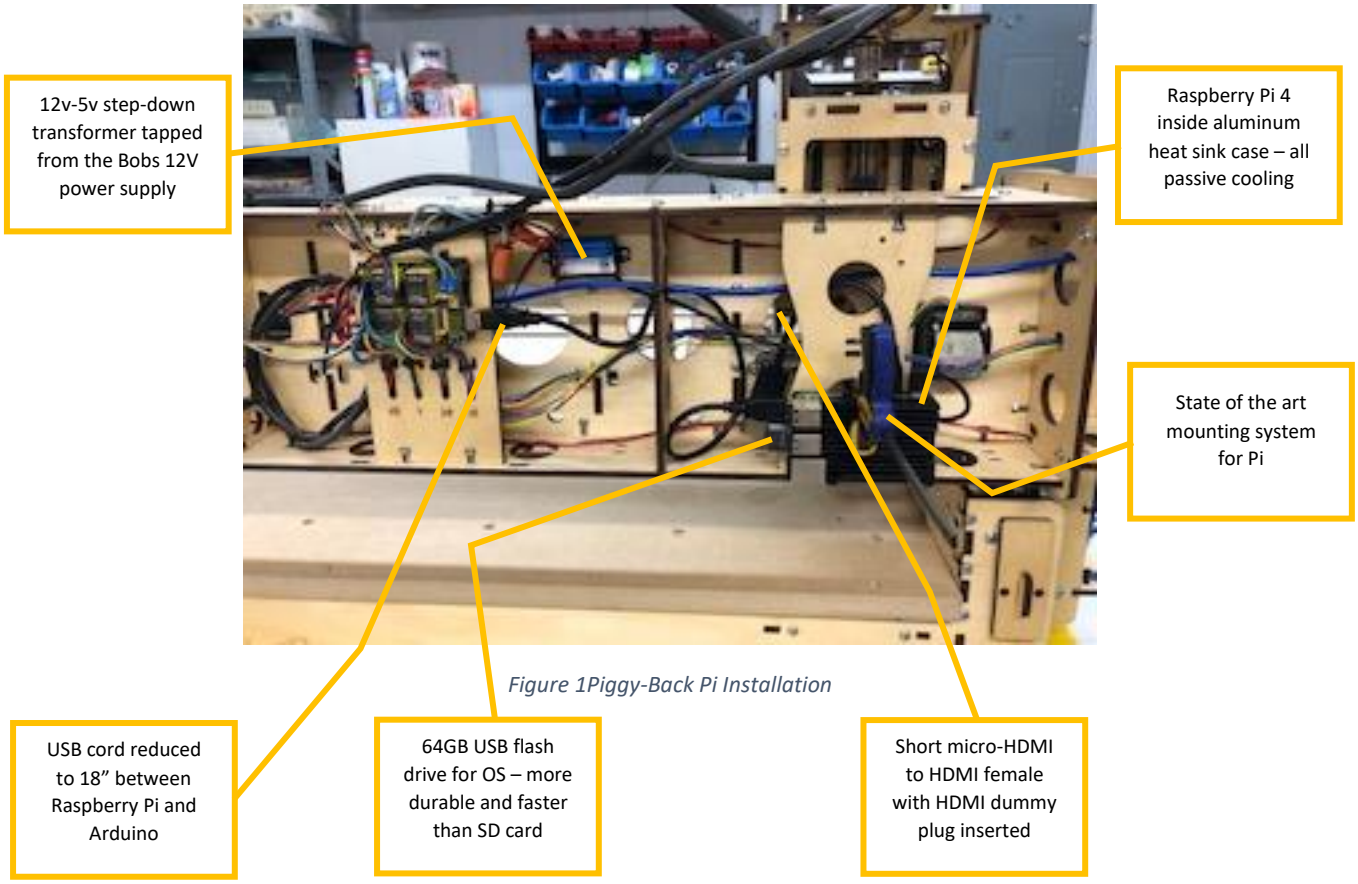


Figure 1Piggy-Back Pi Installation

So how do you control it? There's no keyboard, no mouse and no monitor.

Raspberry Pi OS comes with VNC Server from RealVNC already installed – it just has to be enabled. VNC is a way of remotely controlling computers. In this case, I downloaded the VNC Viewer for my Fire Tablet and I now have the means to view and control UGS running on the Raspberry Pi from my tablet. Because they are communicating wirelessly over my Wi-Fi network, I can carry the tablet around and have full control of UGS. I can even connect a second device simultaneously, so I can monitor the UGS screen from the Raspberry Pi 400 that I have in my office which also has VNC viewer installed.

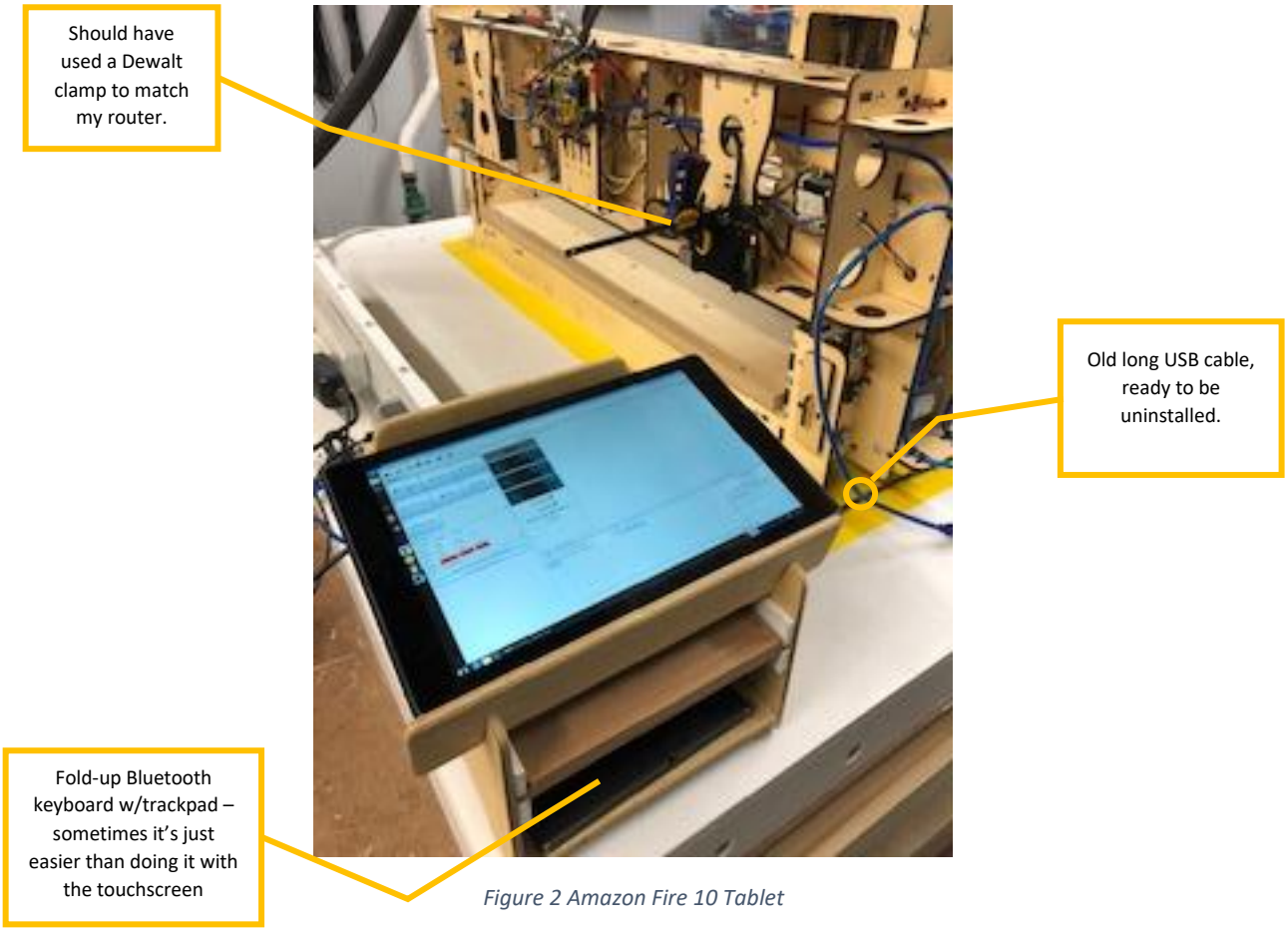


Figure 2 Amazon Fire 10 Tablet

So, let's go through the steps necessary to get this up and running.

1. Buy the hardware.
2. Configuring and installing software.
3. Build up the hardware and mount it on the gantry.
4. Running it.

STEP 1: Buy the Hardware – below is a table with links to Amazon and current prices as of today for everything I used on this project (with the exception of the mounting clamp – I already had that).

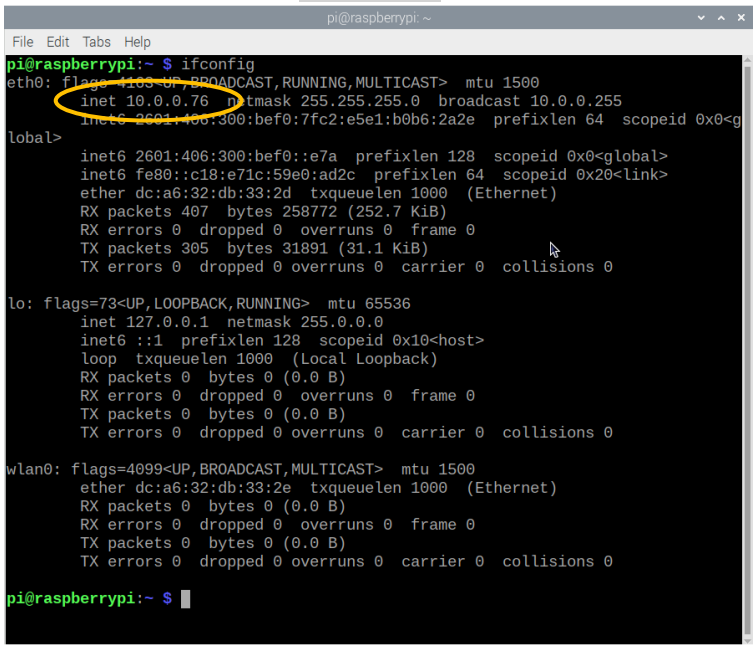
Item	Notes	Price
REQUIRED:		
Raspberry Pi 4 - 4GB		$61.30
Oliver Electronics Aluminum Heatsink Case		$14.79
Arctic MX-4 Thermal Compound Paste	For better heat dissipation	$8.99
18" USB A-B Cable		$4.99
Micro HDMI to HDMI Adapter Cable	2-Pack, only need one	$8.49
HDMI Dummy Plug		$7.99
12V to 5V USB Type-C Step-Down Power Converter		$11.99
64GB - USB 3.1 Flash Drive		$12.49
Android tablet (recommend 10”) or iPad	I already had a Fire tablet	Minimum $100.00
OPTIONAL BUT RECOMMENDED:		
Foldable Bluetooth Keyboard with touchpad		$34.99
Set of Computer Port Dust Plugs	Help for dust control	$8.99
Tablet Hand Strap	Help during mobility	$15.99
Total without Options		$231.03
Total with Options		$291.00

That total is quite large, but if you already have a Raspberry Pi 4 and a tablet to use, and forget the options, you’re only looking at about $70. I tend to get carried away with both techie and woodworking stuff – just ask my wife.

STEP2: Configuring and installing software.

1. The Raspberry Pi OS can be installed on the USB Flash Drive using Raspberry Pi Imager. This software is available for the Pi, Windows, Mac and Ubuntu. It can be downloaded here. Although much of the documentation talks about installing OS images to SD cards, it can also be used for installing to USB flash drives and SSD drives. For my use, I installed the standard Raspberry Pi OS (32-bit).
2. After the USB flash drive is completed, I would suggest booting it on your Raspberry Pi with a keyboard and mouse attached as well as a monitor. (do not have the dummy plug installed at this point)
3. Go through the same steps as in the first section - Installing UGS and getting it to run on a Raspberry Pi.
4. Make sure that you are doing this with the Wi-Fi enabled, since this is the way that it will be running on the CNC.

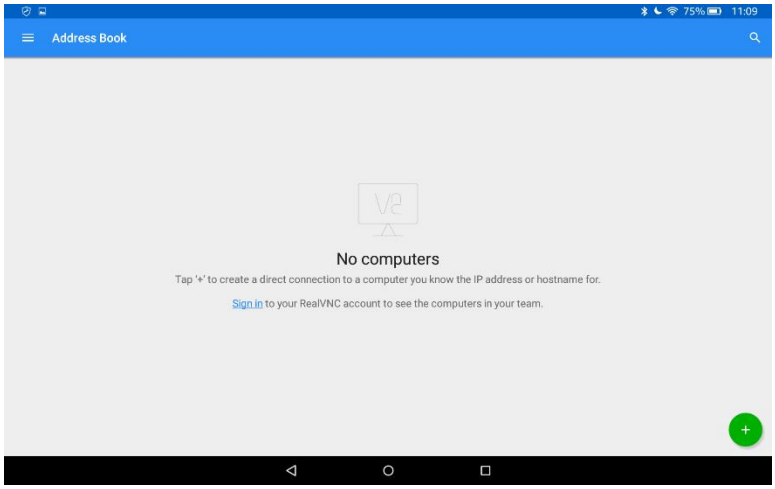
5. Open Terminal and type `ifconfig`



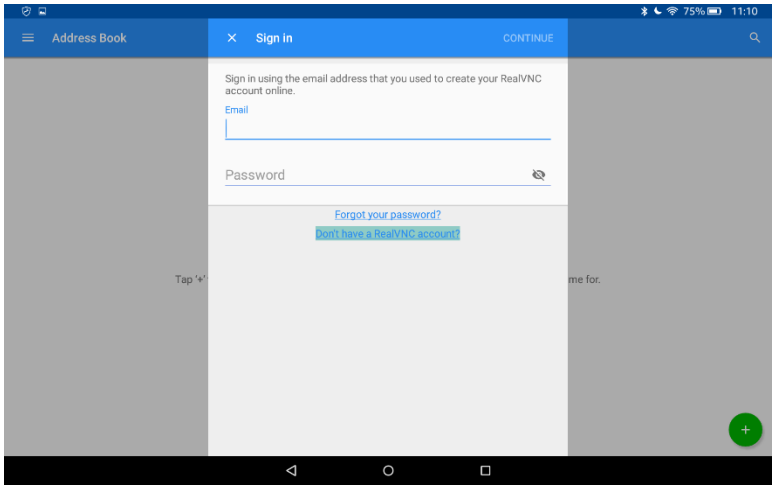
What we are looking for is the IP address of the Raspberry Pi – I have circled mine above. <u>This will be needed when we set up the VNC Viewer on the tablet, so write this down.</u>

6. The IP address is assigned by your network router. Under normal conditions (DHCP), any address in the router's range could be assigned to the device. On most networks, you are usually pretty safe that the same IP address will be assigned each time the device reconnects but, to be sure, the device can be assigned a static IP address so that you are guaranteed to have the same IP address. This can be done either on your router (the surest way), or can be done in the configuration of the Raspberry Pi. Setting up a static IP address is beyond the scope of this document. You can consult your router instructions to do it that way or, if you want to assign it on the Pi, here are the official directions from Raspberrypi.org.
7. Now is time to set up the tablet to access the Raspberry Pi and test it – this can (and should) be done while the Pi is still connected to the monitor.
8. The VNC Viewer software can be downloaded from the Google Play Store and the Apple App Store. It is not in the Amazon App Store. In order to get it, I used these instructions to load the Google Play Store on my Fire Tablet. I actually used the second set of directions by connecting it to a Windows PC.
9. You do have to create a free account with RealVNC in order to us the software. There is no cost for using it. Screenshots following are shown from an Android tablet, but the others are very similar.

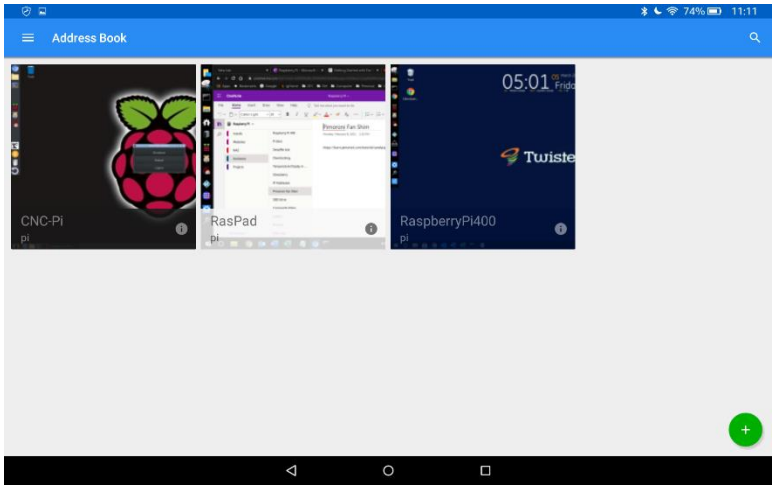
10. When you first start the VNC viewer, you should see a screen like this:



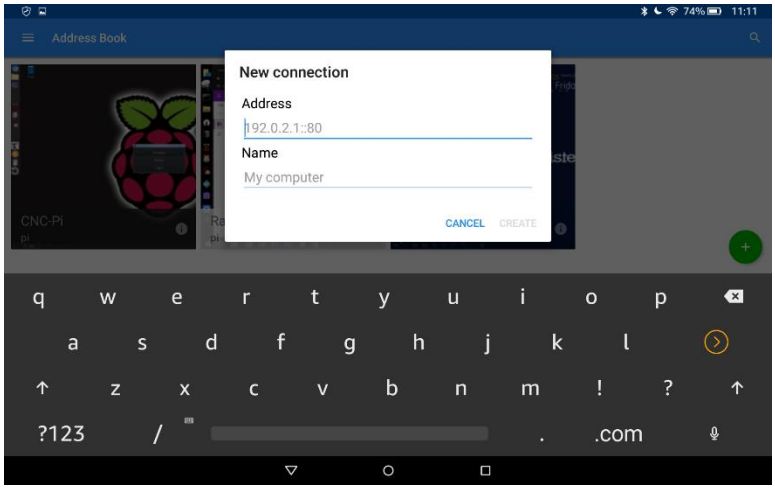
11. Click the Sign In hyperlink, and you will get a sign in dialog like this:



12. Sign in if you already have an account, or click the “Don’t have a RealVNC account?” Hyperlink and sign up on line.
13. After you get logged in, you will see a window something like this. You won’t have any computers listed yet, as you can see, I like having access to multiple computers.

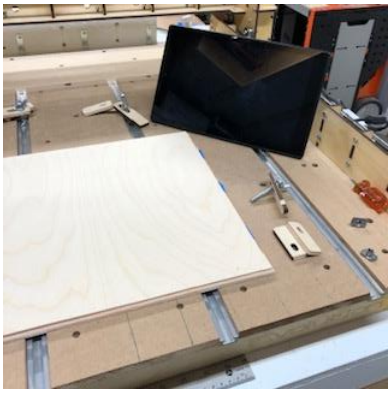


14. Click the plus key to add a new connection.



15. Type the IP address that you obtained from the Raspberry Pi ifconfig, and give the connection a name. Hit create.
16. At this point, you should be able to connect by clicking or double-clicking on the connection icon, and you should be presented with a full-screen view of the Raspberry Pi desktop.
17. Please read the instructions about how to use the touch screen on the tablet. It is not a direct touch and tap like it is with normal tablet functions. You have to put your finger down (anywhere on the screen) and it will drag the cursor from its current position. It's like using the entire screen as a touchpad. When you get the cursor where you want, tap or double-tap the screen anywhere to execute those "mouse" actions. Please consult the instructions for right-click and other options.
18. As I noted above, I bought a Bluetooth keyboard with a touchpad. It makes things easier when typing text (although you can pull up an onscreen keyboard that works quite well). It all comes down to personal preference. I go back and forth depending on what I am doing.
19. I tend to leave the tablet on its stand when doing normal operation, put if I am jogging or doing something that I want to be closer to the "action", I will pick up the tablet and take it with me. I also bought a tablet hand strap that helps me to maintain control of the tablet, but also works as stand if I want to set it down on the work surface.



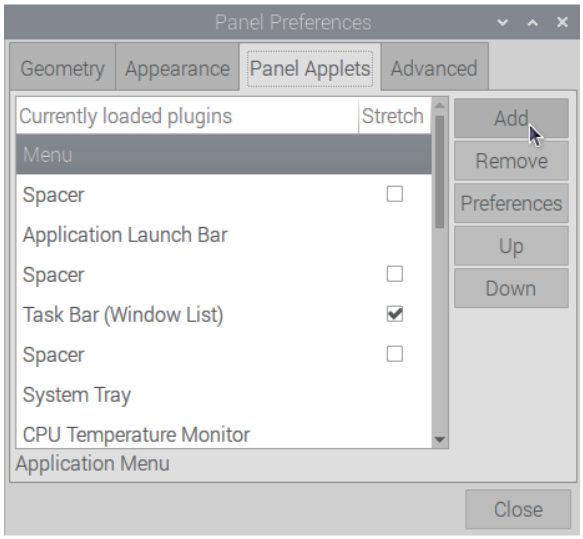


20. That pretty much concludes he software setup.

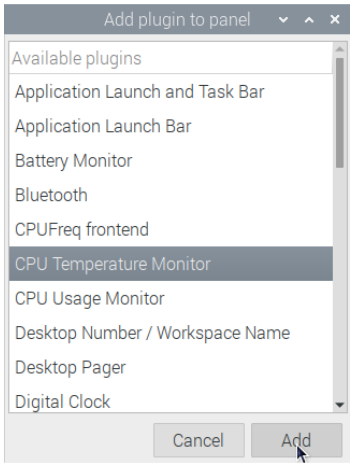
STEP 2A: Bonus software suggestions

There are a few other suggestions, or just things that I prefer to do with all of my Raspberry Pi software setups.

1. First, and I would suggest this highly, is to put a temperature monitor in the panel. Raspberry Pi OS sets the panel position to the top of the screen (like most Linux versions), but I prefer to have it on the bottom, since it is where I am used to having it. To change it, right-click on the panel and select Panel Settings. Then on the dialog that pops up and on the Geometry tab, you can select where on the screen you would like it to appear. While we are on that dialog, click on the Panel Applets tab. Click Add.



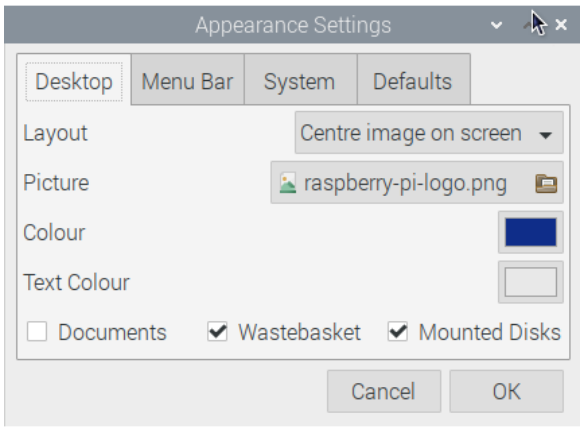
Choose CPU Temperature Monitor and Click Add.



This will add the temperature monitor at the right side of the panel and return you to the list of installed panel applets. At this point, you can highlight the CPU temperature monitor and move it (with the up and down buttons) to wherever you like it in the panel.

As you can see, the temperature on this Pi is currently at 34°C. Without a fan but with the aluminum case, I find that mine Piggy-Back Pi on the CNC runs around 55-60°C. If the temp gets up to 80°C, the Raspberry Pi automatically starts throttling itself to reduce the heat generation. You should not get anywhere near that if you have followed my instructions.

2. I don't particularly care for the default wallpaper that comes installed on Raspberry Pi OS. If you want to change it you can right-click on the desktop, choose desktop preferences and you'll get this dialog:



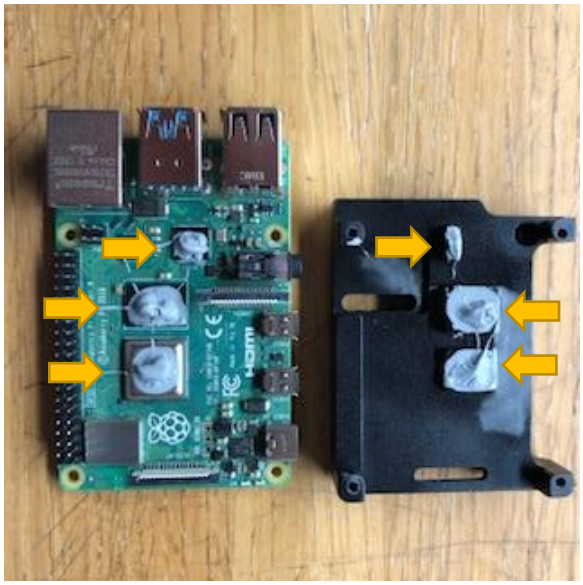
   If you click on the little file icon next to the name of the wallpaper, you can play with several of the wallpapers that come with the Raspberry Pi OS. As you can see, I have selected the Raspberry Pi Logo, I have centered it on the desktop and I have changed the background color to dark blue. Make it whatever you want.
3. There is a great app to install that allows you to, in turn, install a bunch of other great apps. It's called Pi Apps. To install it, please visit this website. Scroll down to the section about installing and cut-and-paste that command into your Terminal Window. Pi Apps will then be available in the Start-Accessories menu. Open it up and you will see that Botspot has included a lot of cool open-source programs ready to install and you know they are going to work with Raspberry Pi OS.
4. Within Pi Apps - Tools, I would first install Commander Pi. While there are some other useful utilities, I find Commander Pi to be the easiest way to overclock the Raspberry Pi. A standard Pi 4 is clocked at 1.5GHz, and the Pi 400 is clocked at 1.8Ghz. For the Piggy-Back Pi, I recommend not exceeding the Commander Pi's recommended values of:
   a. CPU Speed: 2000
   b. GPU speed: 600
   c. Voltage Adjustment: 6

   Enter and set those settings and then click Apply and Reboot. Your Pi will now be just a little faster.
5. The second program that I would install, also under tools is PiGro. This program gives you quick and easy access to many system tools, like Raspi-Config. There are a lot of things that you can do "under the hood" with PiGro. Just be cautious – you could also seriously mess up your operating system. Luckily, I haven't found anything that actually damages the Pi itself. Worst case is you erase the SD card or USB drive and reinstall and start over.

That's it for my personal preferences and recommendations.

STEP 3: Build Up the hardware and mount it on the gantry.

1. Apply thermal paste liberally to both the Raspberry Pi and the case contact points. The case is designed to contact three of the chips on the board to dissipate heat. In some testing that I did, a good application of thermal compound lowered the temperature of the CPU by 5-10^{o}C, which is substantial.

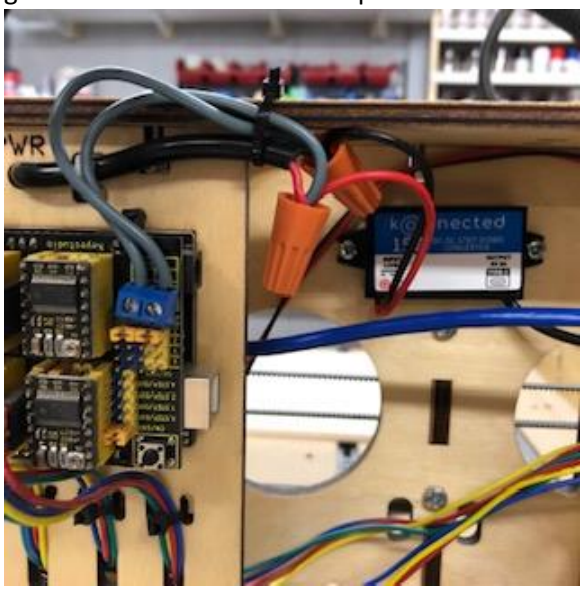


2. Carefully assemble the top and bottom of the case around the Raspberry Pi using the four screws provided. Make sure the screws are good and snug, but don't over-tighten.

3. Plug the dummy HDMI plug into the micro-HDMI to HDMI cable and plug into the micro-HDMI port closest to the power connector. By the way, this cable and dummy plug are crucial to the VNC software working correctly. It tricks the Raspberry Pi into thinking it has a monitor attached so that it will generate the screen that you ultimately see on the tablet. If you don't have this, the Raspberry Pi will not generate a screen image. Plug the 18" USB A-B Cable into one of the USB2 ports (farthest away from the Ethernet connector). Plug the USB flash drive into one of the USB3 ports (with the blue plastic in the connector).

4. Insert dust plugs into left over USB ports, Ethernet connector and audio plug port. Unfortunately, the kit I bought did not have a plug for the second micro-HDMI port.

5. Mount and connect the 12V to 5V USB Type-C Step-Down Power Converter. I tried to just loosen the screw connectors for the 12V input on the Arduino and slip the wires from the power converter, but those connectors really didn't like trying to clamp two different wire sizes. As a result, I had to make a couple of jumper wires and use wire nuts to tie the three wires together for each of the power and ground wires. I mounted the power converter to the gantry with a couple of screws.



6. Mount the Raspberry Pi and make the final hookups. Plug the USB cable into the Arduino and plug the power cable into the Pi. Tuck the HDMI cable into the gantry.

STEP 4: Running it.

Well, I pretty much covered getting VNC hooked up in the software section. It will take some time to get used to controlling the Raspberry Pi with the tablet. Once you've got the hang of it though, it's just like running UGS from a regular computer.

One of the enhancements I have already decided to do, is to put a switch on the 5V power supply. There is constant power to the 12V so that means the only way to turn off the Pi is to unplug it, which is less than optimal. Other than that, I am very happy with the setup. Even using the little clamp as the mounting method – it makes it easier if I have to take the Pi off the Gantry for any reason.

I hope this has given you some useful information on using a Raspberry Pi in conjunction with your CNC.