DustCollector Design Document

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1. Overview

This project grew out of my original dust collection setup, which I had hacked with microswitches and a solid-state relay so that when I opened a blast gate, the dust collector would come on, and when I closed the gate the dust collector would go off. Since all the relays were ‘or-ed’ together, it would stay on as long as at least one blast gate was open.

This was easy to do, and reasonably effective. The dust collector itself, however, was not effective. I had an inexpensive 1.5 HP Delta machine with heavy felt filter bags. These clogged up quickly with fine dust from the lathe and heavier dust from the table saw, and when I measure it I was only getting about 350 CFM.

As the years went on, I developed *severe* allergy to some specific types of wood dust. These episodes could last for 3 days of pure misery. I faced a choice – either give up woodworking altogether or solve this dust issue.

As I put together a plan for salvaging some parts of the original collector and upgrading my filtering capacity, I decided that it would be really *cool* to do just a bit more automation, and have the blast gates operate automatically depending on what machines (e.g., tablesaw, drillpress) were running.

This would prevent me from being lazy and just using the tablesaw for a minute or two for a quick cut without walking the 3 steps to the blast gate. ;-) I did not realize at the time how much saving 3 steps would cost in both time and money.

1.1. Essential Goals

So, the *essential* goals are:

- Open and close appropriate blast gates automatically when any powered machine is running, and close them when none are running.
- Monitor the level of dust in the main collection bin and flash a visible warning of some kind if it should

be emptied soon.

- Monitor the amount of fine particulate matter in the air and turn on a *Corsi-Rosenthal* air filter that will run until the air has been ‘clean’ for some time.

- Ensure that the mechanism for opening and closing blast gates is timely (on the order of 2 seconds or so) and safe from jams (i.e., has timeouts and limit switches).

- The entire controller must fit inside a wall-mounted enclosure with a clear door for visibility.

1.2. Optional Goals

- Add displays to show internal states, opening and closing of gates, collection bin dust level, air pressure in ductwork, etc. Why not – they’re cheap and they don’t take up a lot of resources
- Monitor temperature inside the enclosure and be prepared to shut down if for some reason things get too hot.
- Add lots of digital I/O so I can set up switches for my grandchildren to push. Some of these may create spooky outer-space sounds, or activate a voice message or flash some crazy lights. Anything to amuse them and make them interested in what’s going on here.

2. The Big Picture – Physical System

The physical system consists of: - the recycled impeller, housing and motor from the original dust collection system.

- a ‘Dust Deputy’ cyclone to direct most of the heavy debris downwards to …

- a collection bin with a capacity of cubit feet

- a heavy duty pleated commercial filter rated MERV 15 that catches particles as small as 3 microns, which sits atop …

- a removable bucket fastened securely to it that holds dust released from cleaning the filter by banging on it **gently** while dousing it with **low-pressure** compressed air from the outside.

The operation of the impeller motor is controlled by a solid-state relay whose control input is governed by the

DustCollector controller.

The canister filter is rate MERV 15, comes from Wynn Environmental, and costs about $230. This high-efficiency filter traps over 95% of particles sized 3.0-10.0 microns, such as lint, dust, pollen, pet dander, and mold spores, as well as particles from coughs, sneezes, and smog. Here's a filter rating chart to give you more information.

At the bottom of the filter a collection bucket is attached with a "gamma seal" lid – it just twists off.

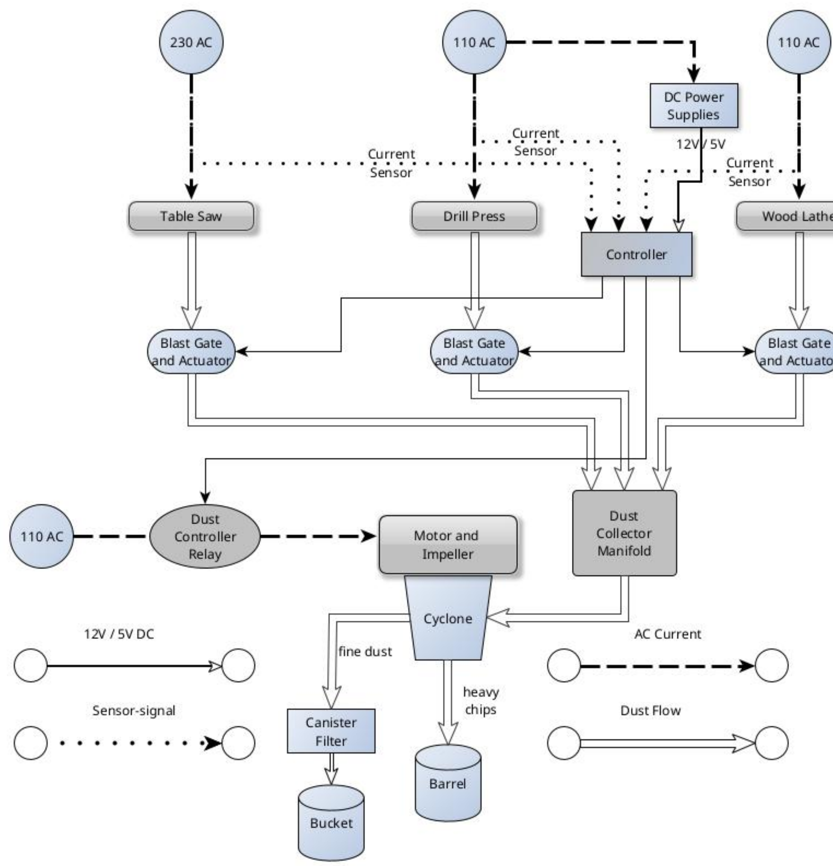


Figure 1: alt text

2.1. The Processor

I settled on a Raspberry Pi 4b for the CPU, with 8GB of ram and a 250G solid state drive. It is programmable in Python, has sufficient GPIO pins for my needs, support for I2C and very fast serial communications.

It also has direct support for an HDMI monitor, USB keyboard and mouse, and sound output. Cool – I can do a lot with that.

3. Project Directory Structure

```
├── docs
│   └── images
├── hardware
├── notebooks
├── obsidian-vault
├── src
│   ├── dustcollector
│   └── hardware
└── tests
```

- The ‘docs’ directory holds the formal documentation (like this document).
 - Its ‘images’ subdirectory contains any images generated by tools such as GraphViz (yEd), WireVix, or Dot.
- The ‘hardware’ directory holds hardware specific code such as drivers for specific LCDs, a/d converters, digital I/O expander boards and so on.
- The ‘notebooks’ directory is intended for jupyter things like experiments, informal tests, etc.
- The ‘obsidian-vault’ directory holds obsidian docs for recording design decisions along the way, miscellaneous notes and perhaps some maintenance tips (e.g., how to install a new DRV8825 and not blow things up by forgetting to adjust the current. You’re welcome.)
- The ‘src’ directory holds the primary source files (python, config files, etc.). - Its ‘hardware’ subdirectory holds modules that are dedicated to specific low-level devices such as MCP23017 I2C expanders, PCF8574 digital I/O expanders and so on.

4. Software Architecture

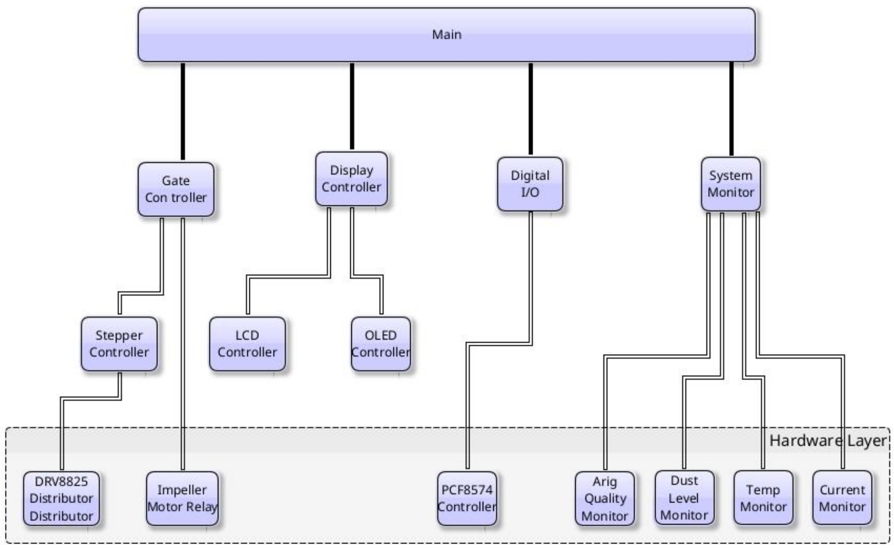


Figure 2: a picture

5. Key Subsystems

5.1. The Motor Subsystem

There are currently 4 motors planned, one of which is not yet implemented and is being saved for possible use by the router (mounted under the table-saw wing) or as an auxiliary port for the small vertical belt sander..

The primary machines are: - the table saw - the lathe - the drill press

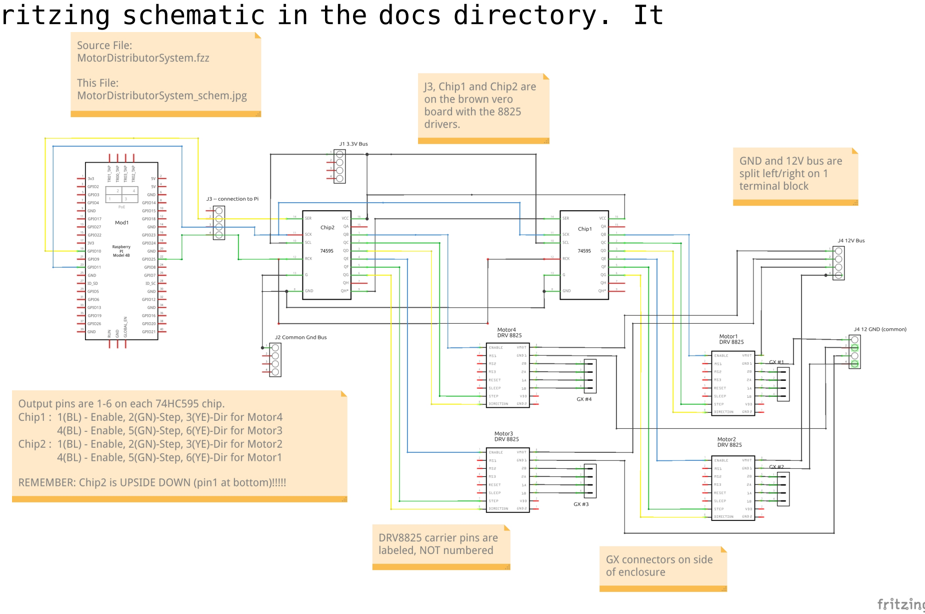
Each of these has a 5-inch duct connecting it to the intake of the dust collector. At some point on the ductwork leading to each machine there is a blast gate that controls the flow of air into the dust collector.

Each blast gate has a stepper motor mounted on it to move the gate opened and closed. Momentary-contact limit micro-switches are mounted at each end of travel to tell the controller that the blast gate has reached the desired position. [Note – a timeout will occur if this hasn't happened in a reasonable amount of time, and a warning of some sort will be issued.

The stepper motors are Nema 17 Bipolar, 2A, 59Ncm. These are more than powerful enough to overcome any friction in the blast-gate slide mechanism.

5.1.1. The Distributor The requirement to run the steppers fast enough to satisfy a 2-second open/close time was difficult to handle with plain old I2C expanders like the MCP23017 – the bus was just too slow. I opted for creating a new sub-sub-system called the 'distributor' which uses a pair of 8-bit shift registers and the SPI bus to squirt out enable/step/dir signals to 4 motors quite rapidly. There is a detailed breakdown in the Wiring section to show how this is mapped to individual motors.

There is also a fritzing schematic in the docs directory. It



looks like this:

Yes, it's small. Use fritzing if you really want to explore it.

A Picture is Worth a Thousand Words

If you find it necessary to replace a Jeanoko DRV8825 board, be sure to reconnect it as shown here. The upper portion of the picture clearly shows the connects that control the chip, and the lower portion clearly shows the connections to the motor cable. **Do NOT mess this up!**

Also – before messing with cables to motors, **please** disconnect that little red wire that runs from the 12V bus to the red 3-pin connector labeled ‘V’. You’ll be glad you did.

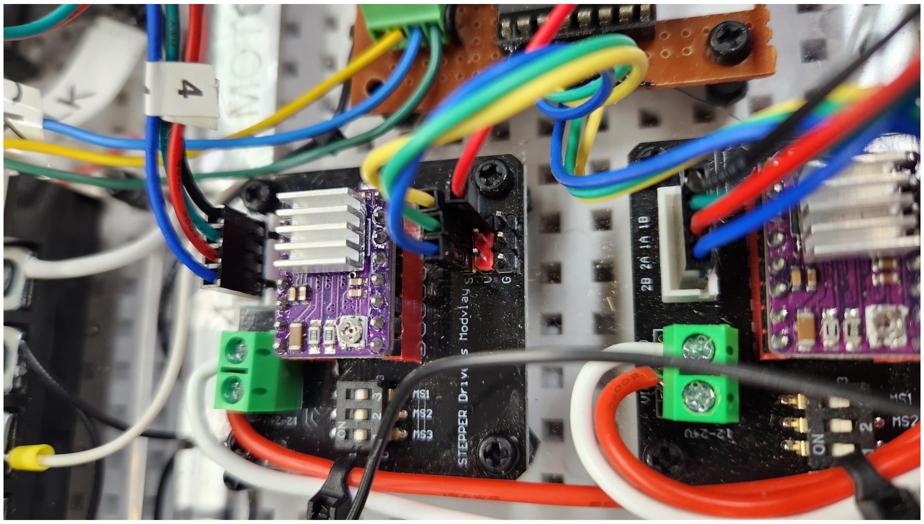


Figure 3: see!

5.2. The Digital I/O Subsystem

The digital I/O is almost entirely managed by a set of PCF8574 I2C-based 8-bit expander boards. 5 of them ganged together gives 40 I/O bits, which are periodically read into a 40-bit buffer. See the section on Digital I/O Pin Map for details.

[Yes, this is excessive. I don’t care. I like lots of switches and buttons.]

5.3. The Current Sense Subsystem

The ‘on’ or ‘off’ state of a given machine such as the table saw is determined by detecting the presence or absence of current in a split-coil transformer wrapped around the ‘hot’ line going to the saw. This output is fed to a sensor module. The output of that module is fed to an ADS1115 4-channel a/d converter and read over the I2C bus.

5.4. The Gate Control Subsystem

The gate control system is responsible for sensing machine state (On or Off), opening/closing the appropriate blast gate[s] and turning on (or off) the dust collector impeller motor.

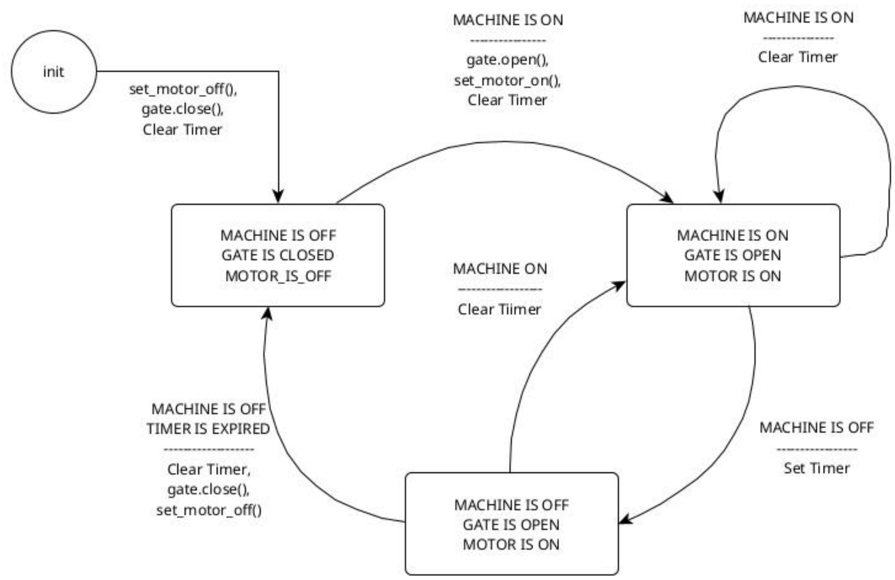


Figure 4: Gate States

There is currently a provision for a delay after turning off all machines and turning off the dust collector impeller motor. This is to allow any remaining dust to be sucked out of the system. It may turn out that this is unnecessary due to the high velocity of the air in the ducts (estimated to be over 80 MPH).

6. The Top Level Software Structure

Although this is not a 'hard real-time' problem, there are many things to keep track of in a timely manner. 'Bob'[1] suggested using Python's asyncio package to help with this, and I agree wholeheartedly. This enables the top-level structure of the program to be divided cleanly into separate tasks that will not step on each other.

[1]This is the name I gave to my ChatGPT agent. We're good friends now.]

7. Enclosure

The enclosure is an “ABS Electrical Junction Box, Ventilated Design, with Cable Grommets, IP65 Waterproof Enclosure, Indoor/Outdoor Use with Mounting Panel.. (Clear Cover, 17.7”x13.7”x7.9”) ” from Amazon.

Connections to the outside world are run via pass-through connectors, so the entire enclosure can be easily removed from its wall-based mounting panel for benchwork.

8. The Monitor Subsystem

This subsystem is a catch-all for anything I can think of to measure the system to provide useful information.

Some candidates are: - temperature at various places in the enclosure (e.g., the Pi computer chip, the motor driver heat-sinks, etc.) - current draw for 3.3V, 5V and 12V busses. - level of dust in the collection bin - failure to open or close a blast-gate in time

It is likely that some temperature information may be used to turn on PC fans to vent the enclosure more thoroughly.

9. Wiring

Yes, there are lots of wires here. Many of the cables are custom-made for these reasons:

1. Length considerations
2. Connector type mismatches
3. Connector pin assignments don’t match.

For example, some I2C boards have signals in the order [vdd, gnd, scl, sda], while others switch vdd and ground, and scl and sda. These cables are labeled and clearly marked as CUSTOM, and usually have a bit of whiteout to help show what goes to what.

I tried to maintain a consisten color coding scheme for wiring, but did not succeed completely. In general, however, for power wiring, I have followed this scheme:

A/C: Neutral – White (referred to as Gnd on the board) Hot – Black Ground – Green.

D/C: 5V – Orange 3.3V – Black 12V – Red Gnd – White

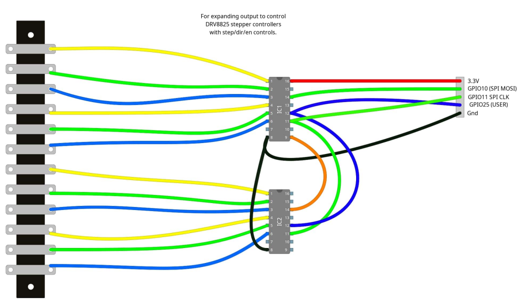
All Ground connections are tied together on the board.

For some cables, in particular those that carry I2C data, I used off-the-shelf premade Dupont cables. In many (most) cases I had to rewire one end to straighten out the different sequence of connections from different manufacturers. Be careful if you disconnect and reconnect anything – make sure you know what you're doing.

____Remember – this is not guaranteed! Look at where the wires go to be sure.____

9.2. The Distributor

This custom circuit board is mounted with the 4 stepper driver boards. It consists of two 74HC595 8-bit shift registers fed by the fast SPI interface.



his custom circuit board holds 4 identical circuits to convert a 0-100 mA current from a transformer into a small voltage that a 4-channel ADS1115 a/d converter can read. Yes, I know the picture is tiny. If you can't read it look at the .jpg image here in the docs directory.

This is explained in great detail here since it took me a while to figure it all out and get it straight.

74HC595 Chaining and Bit-to-Pin Mapping You have chip1 and chip2. As you look at the board, chip1 is on the left. **Note carefully that the chip on the right (chip2) is upside down, with pin 1 at the bottom right.**] Here is a detailed breakdown to show how this is mapped to individual motors.

Each 74HC595 has 8 outputs: Q0–Q7 (pins 15, 1, 2, 3, 4, 5, 6, 7). You are using pins 1-6 (Q1–Q6) on each chip for step/dir/enb. You’re sending 2 bytes over SPI: byte1, byte2.

Critical Fact About Chained 595s: The first bits shifted out land furthest down the chain. The last bits shifted out stay closest to the Pi.

Thus: - byte1 → chip2 - byte2 → chip1

Bit-to-Pin Layout (directly from the code)

```
Bit layout is based on physical pin mapping:
- High byte (bits 15–8) → Chip2 (rotated 180°)
- Low byte (bits 7–0)     → Chip1 (upright)
- Data sent MSB first (bit 15 down to bit 0)



MOTOR_MAP = {
        1: {'en': 12, 'step':  13, 'dir': 14},
        2: {'en': 9,  'step':  10, 'dir': 11},
        3: {'en': 4,  'step':   5, 'dir': 6},
        4: {'en': 1,  'step':   2, 'dir': 3},
}
```

Practical Summary:

- byte1 → fills chip2 (the far one)
- byte2 → fills chip1 (the near one)
- Pins 1-6 on each chip will reflect bits 1-6 of each respective byte.
- MSB (bit 7) and LSB (bit 0) could be unused or reserved.

Visual Sketch:

SPI –> [byte2][byte1] | | | +–> chip2 (pins 1-6) +——> chip1 (pins 1-6)

Practical Tip for Code:

When sending: spi.xfer2([byte2, byte1]) # byte2 first for chip1, byte1 second for chip2

If you're building bytes on the fly: byte2 = (enb4 « 1) | (dir4 « 2) | (step4 « 3) | (enb3 « 4) | (dir3 « 5) | (step3 « 6) byte1 = (enb2 « 1) | (dir2 « 2) | (step2 « 3) | (enb1 « 4) | (dir1 « 5) | (step1 « 6)

Final Word:

Pin 9 (QH*) serial out is ONLY used between chips. After two chips, if you don't add more, you can ignore it.

The Net Result This organization means that it is easy to spot the 3 signals need for each motor. Take a look at the circuit board and you'll see that E(enable), S(step) and D(dir) are grouped for each motor. Look at the two shift-register chips. For chip 1 (left) pins 1, 2 and 3 are ESD for motor 4 (the nearest motor. For chip 2 (right) pins 4, 5 and 6 are ESD for Motor 1 (the nearest motor). You get the idea. Cool.

10. Power Supplies

I decided not to use the Raspberry Pi 4b plug-in power input for these reasons:

1. I didn't know at the beginning how much current I might need
2. I needed an external 12-volt supply anyway.

Both supplies were furnished by Amazon: - [5V supply] (https://www.amazon.com/dp/B07PPPF1R5?ref_=ppx_hzsearch_conn_dt_b_fed_asin_title

Description: 5V 5A Power Supply,25W Universal Regulated Switching

- [12V supply] (https://www.amazon.com/dp/B00M8TBJLK?ref_=ppx_hzsearch_conn_dt_

Description: LRS-150-12 150W 12V 12.5 Amp Enclosed Switchable Power

These power supplies are mounted on a separate board that is detachable from the main mounting board. They are fed from a common A/C source via GX connectors, and routed into the enclosure with replaceable fuses in-line.

10.1. Reboot, Shutdown and Restart

Both power supplies run through an emergency shutoff switch with a plastic cover. You probably should not lock the plastic cover – it’s just there to prevent you from using it as an ordinary shutdown. When the button is pressed, it shuts off all power to the controller, and this also cut power to the relay that controls the impeller motor.

The preferred way of shutting down the system is to press the little button below the emergency shutoff labeled “reboot / shutdown”. If you press for 1 second or less, it will reboot. If you hold it for more than 2 seconds, it will just shutdown the Raspberry Pi. In **neither** case will it shut off the power supplies. To restart the system, push the big red button, then release it by twisting clockwise.

11. Digital I/O Pin Map

Digital I/O is handled via a 40-bit map in software. A single board contains 5 instances of PCF8574 8-bit digital I/O expanders connected to the I2C bus.

The map currently looks like this (not all bits are assigned yet – this mapping shows the assigments for connectors J1 and J2):

	Connector	Pin #	Bit# (0-39)	Manual Function	Auto Function
0	DB-25 J1				
1		1	32	Motor 1 ON	Same
2		3	33	Gate 1 OpenLImit	Same
3		5	34	Gate 1 Clos-edLimit	Same
4		7	35	Motor 2 ON	Same
5		9	36	Gate 2 OpenLImit	Same
6		11	37	Gate 2 Clos-edLimit	Same

	Connector	Pin #	Bit# (0-39)	Manual Function	Auto Function
7		14	38	Motor 3 ON	Same
8		16	39	Gate 3 OpenLImit	Same
9		18	24	Gate 3 Clos-edLimit	Same
10		20	25	Motor 4 ON	Same
11		22	26	Gate 4 OpenLImit	Same
12		24	27	Gate 4 Clos-edLimit	Same
13					
14	DB-25 J2	1	28		
15		3	29		
16		5	30		
17		7	31		
18		9	16		
19		11	17		
20		14	18		
21		16	19		
22		18	20		
23		20	21		
24		22	22		
25		24	23		

12. Maintenance Hints

This section contains advice to my future self for likely maintenance / upgrade / repair events.

12.1. Stepper Drivers

There are 4 stepper motor DRV8825 driver boards mounted on an acrylic plate, labeled 1, 2, 3 and 4. In the center of those is a custom-made circuit board called ‘The Distributor’ which uses the SPI bus to squirt control bits very rapidly.

The DRV8825 chips are mounted on [Jeanoko DRV8825/A4988 Stable 42 Stepper Motor Driver Expansion Boards](https://www.amazon.com/dp/B0C4P8997M is to press the little button below the emergency shutoff labeled “reboot / shutdown”. If you press for 1 second or less, it will reboot. If you hold it for more than 2 seconds, it will just shutdown the Raspberry Pi, In *neither* case will it shut off the power supplies. To restart the system, push the big red button, then release it by twisting clockwise.dt_b_fed_asin_title_1). Each board has a very tiny potentiometer for adjusting the current limit. You ____must____ adjust these if you replace them or you run the risk of frying something important.

Safe VREF Setup Without Motor Connected (Courtesy of Bob)

Purpose:

Prevents the chance of slamming full current into the motor during first power-up.

Avoids a damaged motor, a fried driver, or accidental runaway heating.

Steps:

Install the new DRV8825 board, BUT DO NOT connect the motor coils yet.

Leave the motor wiring unplugged.

Only connect logic (VDD, GND, STEP, DIR, ENABLE) and motor power (VMOT, GND).

Power up the system (logic and VMOT live).

Measure VREF at the trimpot just like before:

Black multimeter probe to GND.

Red probe to the metal top of the potentiometer.

Adjust VREF carefully:

Clockwise to increase, counterclockwise to decrease.

Set VREF based on the formula: VREF=0.5×Desired Motor Current (A) VREF=0.5×Desired Motor Current (A)

Confirm the VREF is in the right ballpark (e.g., 0.60V for 1.2A motor current).

Power down the system.

Connect the motor coils properly:

Double-check you know which motor wire pairs are each coil.

(If not sure, I can give you a 10-second multimeter method.)

Power back up and test the motor gently (slow step pulses first).

I recommend that you use a very, very tiny phillips screwdriver to do the adjustment. If you use one that is too large, it will not engage but will *look* like its engaged, and nothing will happen (how do I know this?). The potentiometer is very sensitive, so make tiny adjustments as you get close.

12.2. Power Supplies

If you have to replace a power supply, try to get an identical replacement. Be sure to adjust the voltage output before connecting it.

13. Implementation Notes

13.1. Scripting

There are some details about startup that bear mentioning here.

This section cannot be filled in until we actually figure out what goes here.

13.2. Coding

The coding is all in Python. The code is mostly (but not entirely) generated by Bob according to my prompts and editing suggestions.

This is not a professional project, soI have not bothered to create pydoc-style comments for everything. It’s just for me and whoever the hell happens to be reading this.

The style guide is:

- pycodestyle compliant
- flake8 compliant
- black -l 79 compliant

There are minor exceptions for a few cases where it just doesn’t make sense to go to great lengths to wrap things.

13.3. A Note on Using AI to Generate Code

An LLM like Bob (aka ChatGPT) does a remarkably good job of generating code. Most of the time. What I've learned is that once you've given a spec in a prompt and then had him edit the code repeatedly to make small name changes, add or modify features and so on, he gets confused.

The reason for the confusion is that he's editing the code based on *pattern matching*, so he sometimes does not take into account the larger context of the entire program.

In such cases, when we started to flounder through repeated edits that were not getting any closer to correct, it was useful to have the original spec, update it to reflect the new/modified requirements, and have Bob generate the code explicitly from scratch.