How to read input shaper graphs:

a work in progress

Compilation by Reth (the original Reth)

Data taken from:

3D Printers & a whiteboard How to Read and Analyze Input Shaper Graphs Generated by Klipper – YouTube

Felix Boisselier (Frix_x): klippain/docs/input_shaper.md at main · Frix-x/klippain · GitHub

Reth's Voron Trident – serial 1190

Lots of members of the Voron Community

Version 8-8-2024

Introduction

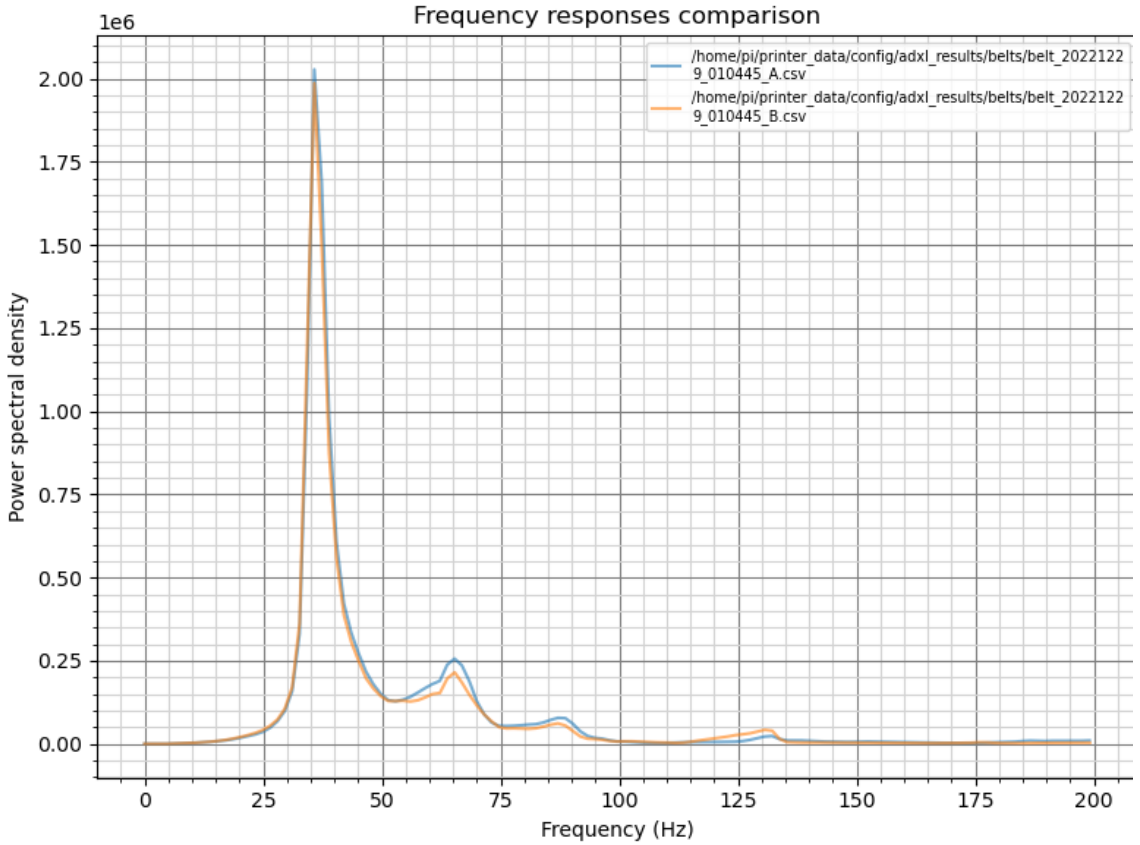
- The following graphs are only applicable to CORE XY printers. Bed slinger, delta, or other style printers will not necessarily be able to match the graphs to mechanical issues as the basic design of the printers are different.
- The purpose of these slides are to present different belt shaper and input shaper graphs with some suggestions on how to go about diagnosing and fixing the issue.
- These graphs were taken from 3D Printers & a whiteboard,Frix_x, my own Trident 350, and members of the Voron Community with annotations provided for clarity.
- Interpretation of input shaper graphs may not be straight forward and it is possible to have multiple issues happening at the same time
- Note: tighter belt tension is not always the answer. Tightening belts to much can lead to new, and not better, print artifacts.

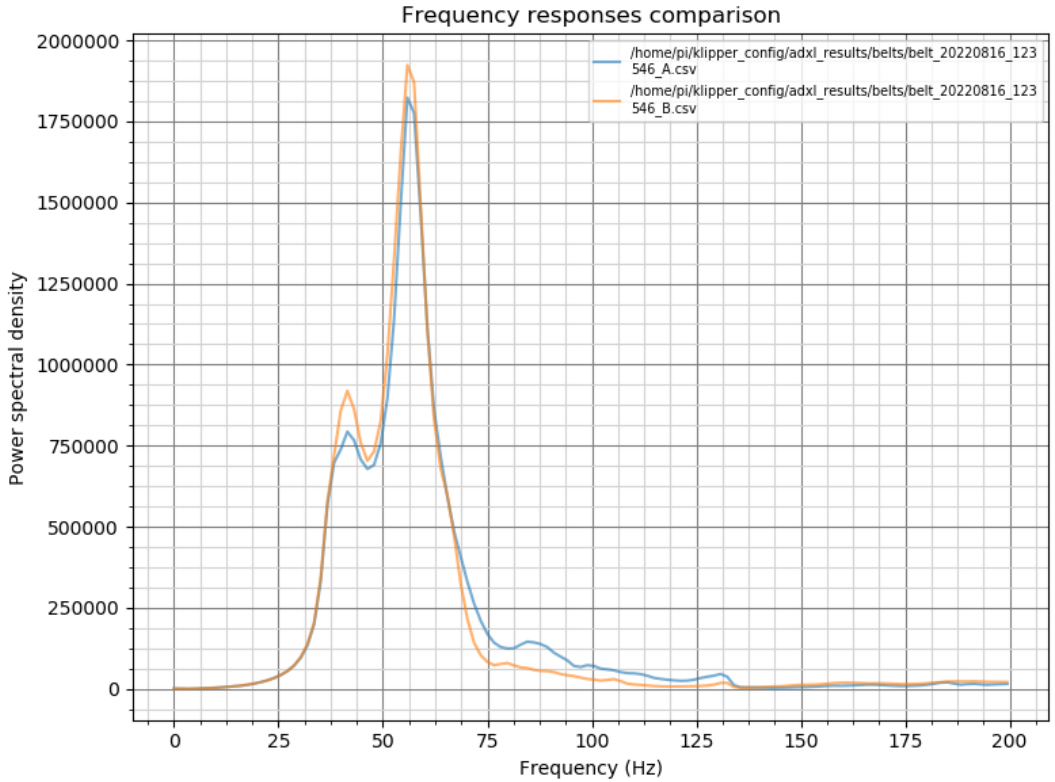
Common Issues

- Belts are showing two spikes, three spikes, one spike, etc.
  - “Ideally” you want belt shaper to have a single peak for A and B belts.
  - However, having two spikes, or even three spikes, may not be an issue.
  - Belt shaper is used mainly for determining if the belts have the same relative belt tension, and by itself is not a great troubleshooting tool for anything other than relative belt tension.
  - Need to run input shaper to confirm an issue.
- Belt shaper and/or input shaper shows a problem do I need to do a test print.
  - Begrudgingly yes. Why, sometimes input shaper can just be wrong. This is because input shaper is done by an ADXL and if the ADXL is not mounted correctly/tightly/ect. then it will not be able to produce good graphs. We need a print to verify the accuracy of what input shaper is reporting.
- Input shaper says I can do 1 million accel.
  - You are most likely looking at ZV. It is not recommended to use. This is because it is a really narrow shaper, basically only canceling the main peak. You might be thinking I have really great graphs I only have a main peak. This may not always be the case. Input Shaper only moves in a very small section of the toolheads total movement. There could be vibrations outside of this movement, belts could stretch overtime, the earths magnetic field could collapse. To be better safe than sorry Klipper recommends you use MZV. Further, I have yet to see a ZV shaper return 0% vibr.

Belt Shaper

Good belt graphs
peaks in freq are aligned





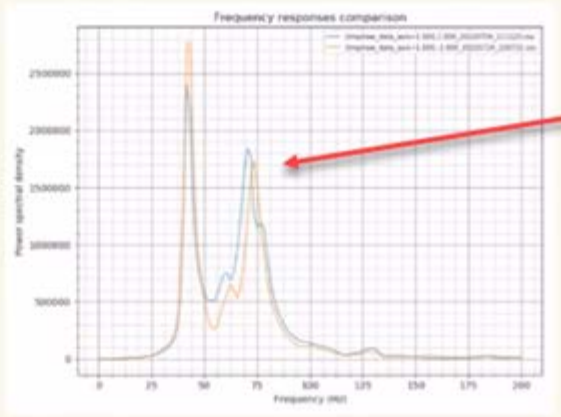
Belt Tension

Input Shaper Settings ✓

Absolute Belt Tension ✗

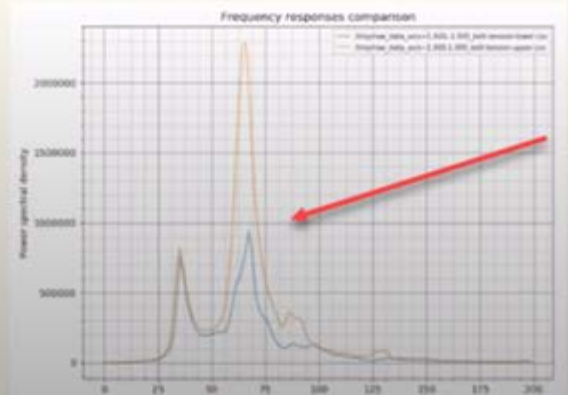
Relative Belt Tension ✓

Issues:
- binding
- loose bolts
- over-dampening
- loose belts
- wire loom issues
- printer design issues



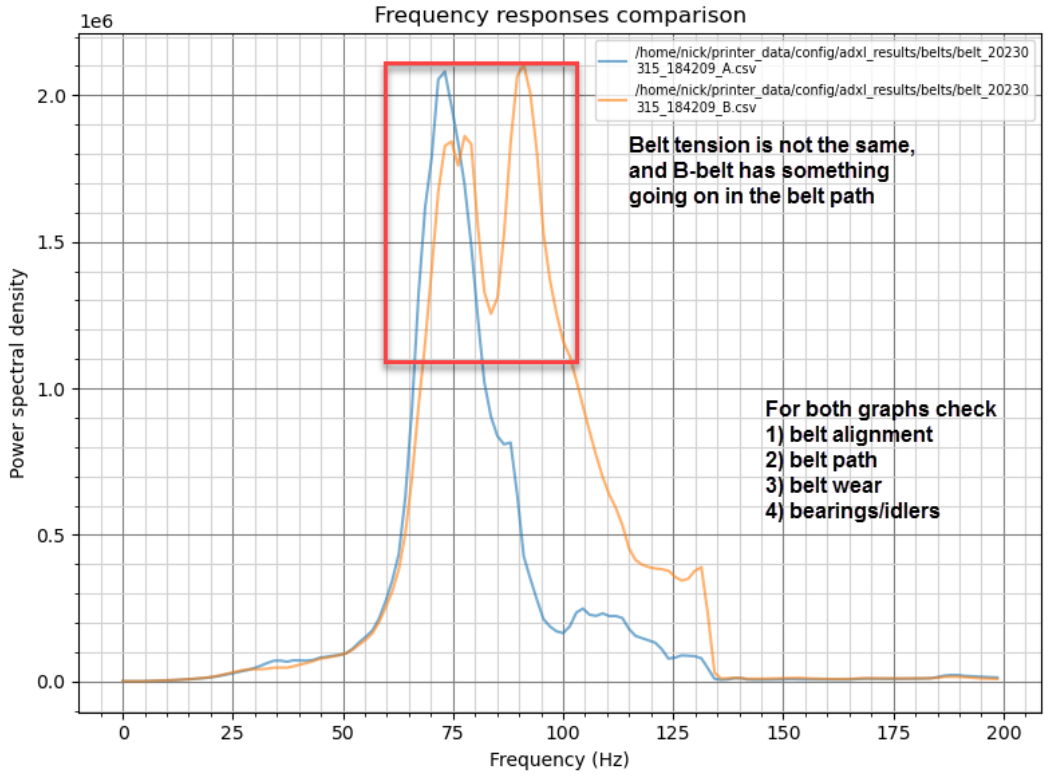
peaks not aligned

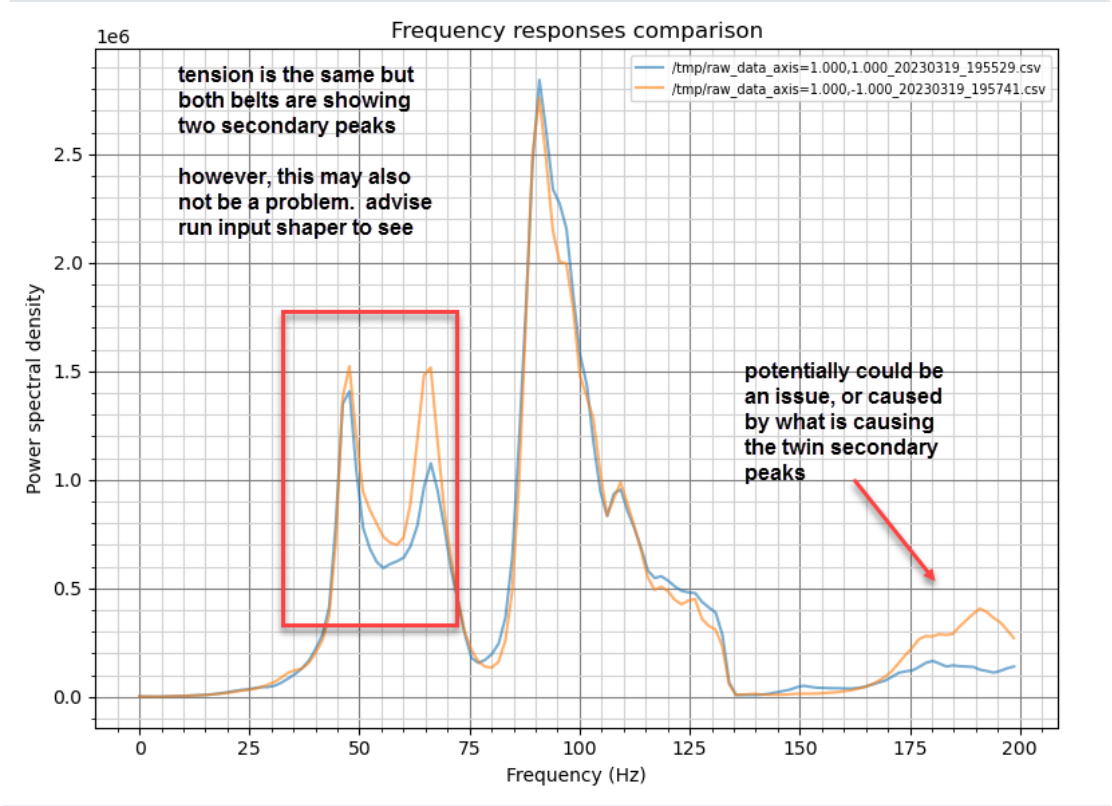
bad belt tension



Peaks are aligned, but amplitude is to low. generally indicates
1) belts were not cut the same length, or
2) belts length coming our of the x-carriage is not the same, or
3) something else in belt path

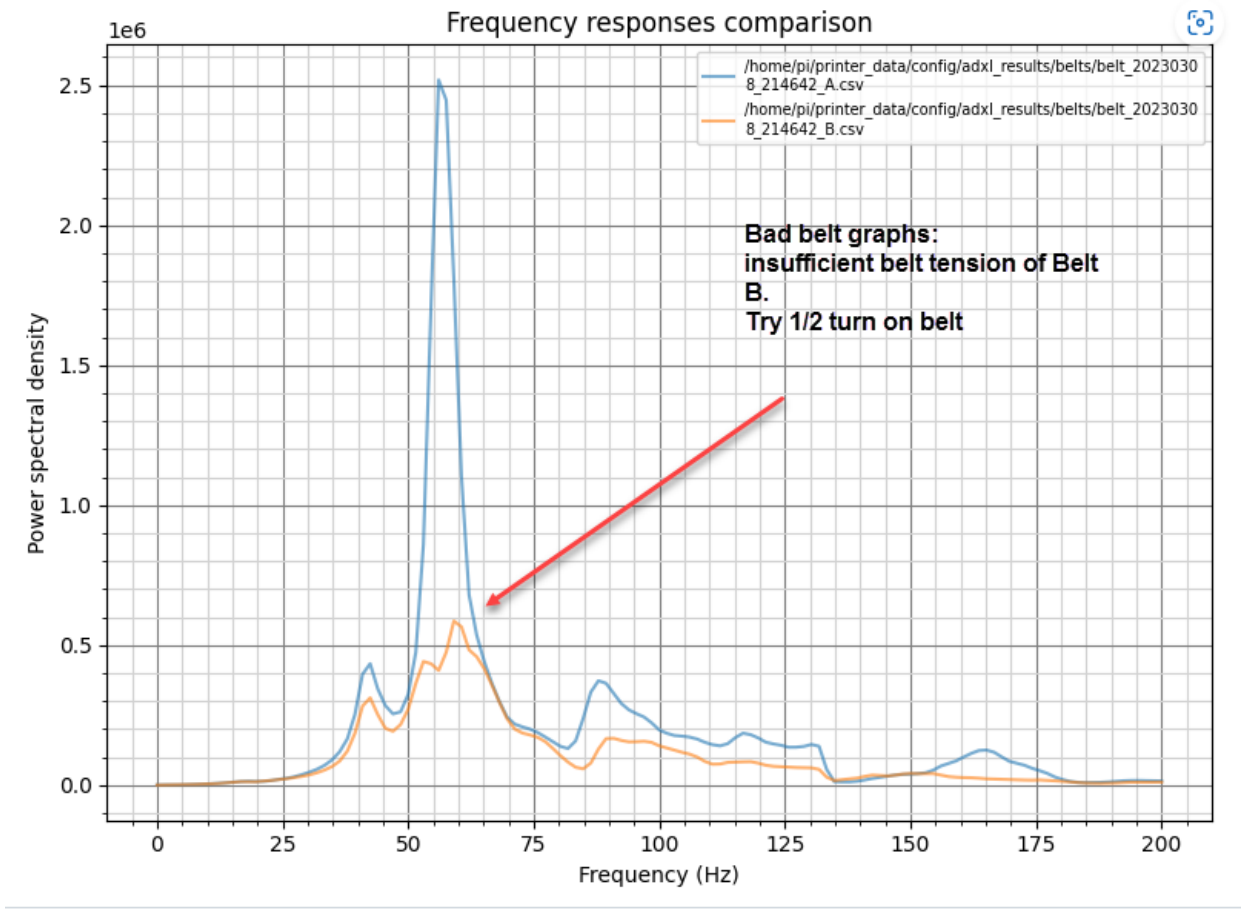
Belt Path problem



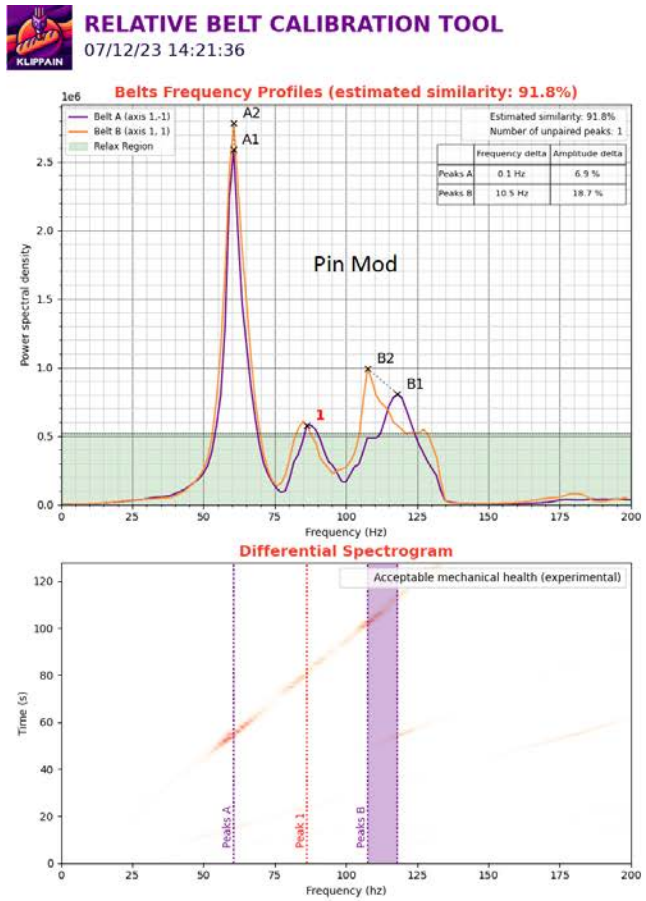


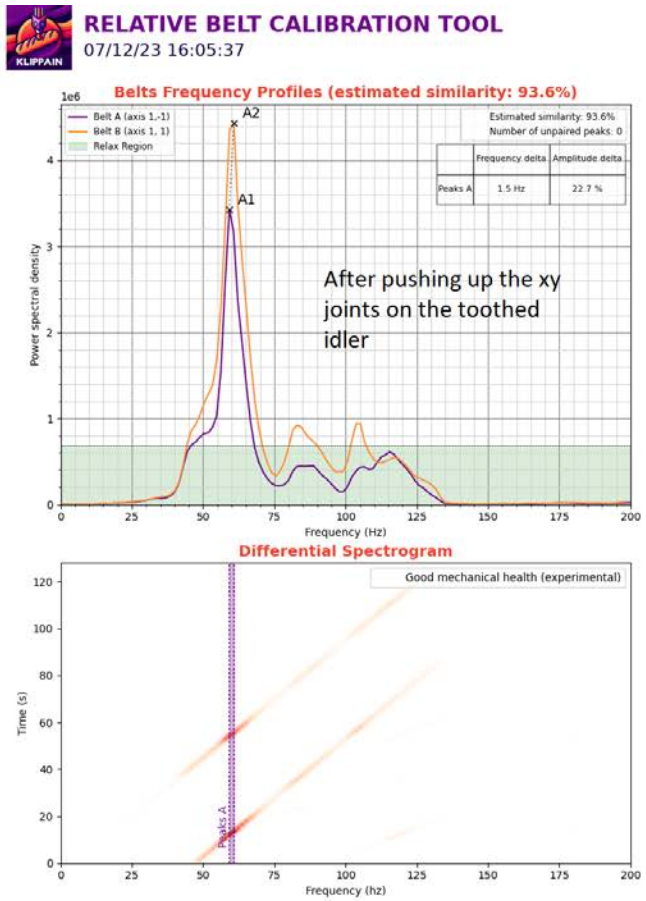
For graphs such as this it is recommended to run input shaper to troubleshoot any issues, and determine if the belt path is a problem

Belt Tension



Pin Mod: may need to push up the xy joint around the idler





What one can see here is that for the pin mod it is really easy to have the plastic around the toothed idler to contact the flange of the toothed idler thereby dampening is belt shaper

Input shaper

How to read input shaper graphs

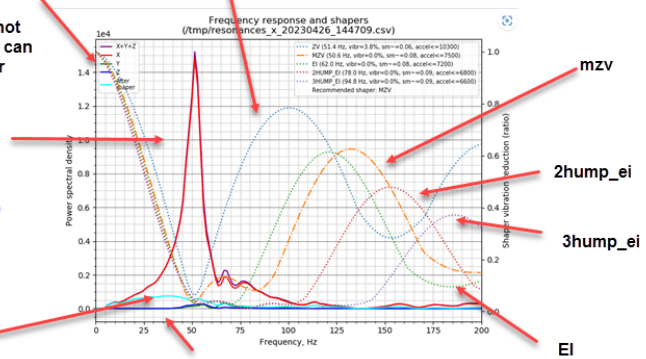
your measured resonance in x, y, and z.
Here x, y, and z refers to the orientation of your adxl and not necessarily to the printers x, y, and z.
If the adxl's x,y,z do not match machines you can change this in klipper

purple is the combination of all axis (x,y,z)

Red is x.

Ideally we want purple to mimic the axis of the shaper. This graph is x so purple (combination) show match red (x). This is because when we measure the x-axis we only want to see x-axis resonance. Does this always happen no.

the legends recommended shaper



zv

Add text here

mzv

2hump_ei

3hump_ei

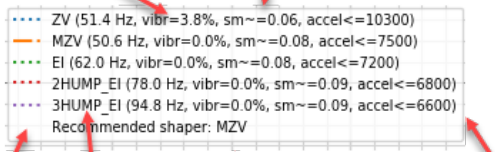
EI

y and z (so small can't even see them)

With input shaper you get one or the other.
More vibrations and less smoothing, or less vibrations and more smoothing.
No free lunch here.

In order to compensate for resonance klipper will smooth the acceleration of the toolhead. This smoothing will be noticed in the print. The amount of smoothing is SM. you can see this if you print a benchy and the lettering on the back is unreadable. Input shaper has smoothed that out to remove resonance in the rest of the print

Calculated vibration on print if this shaper is used we want zero vibrations



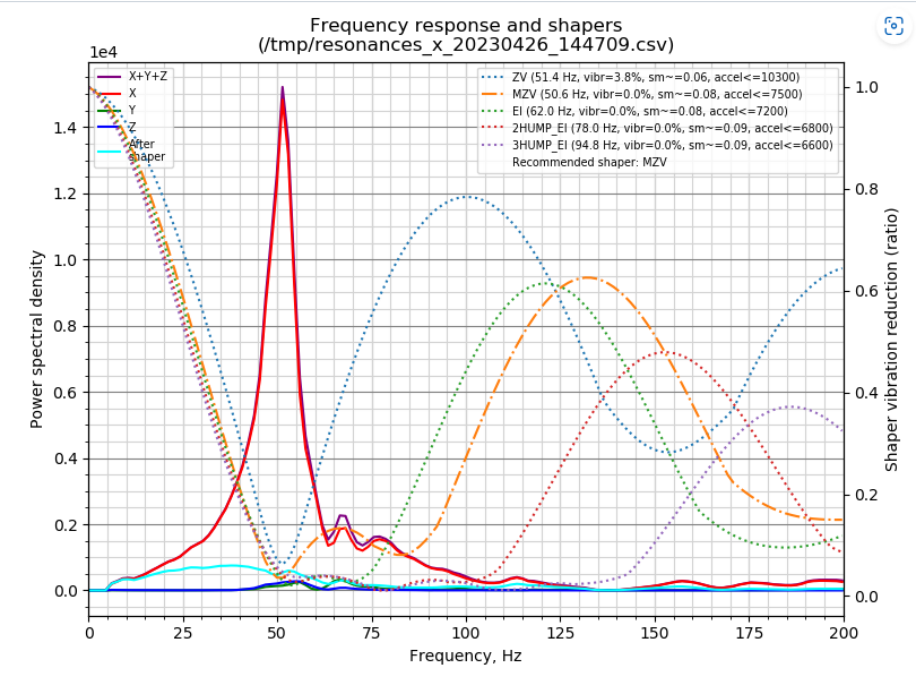
These represent the graphs of each of the input shapers

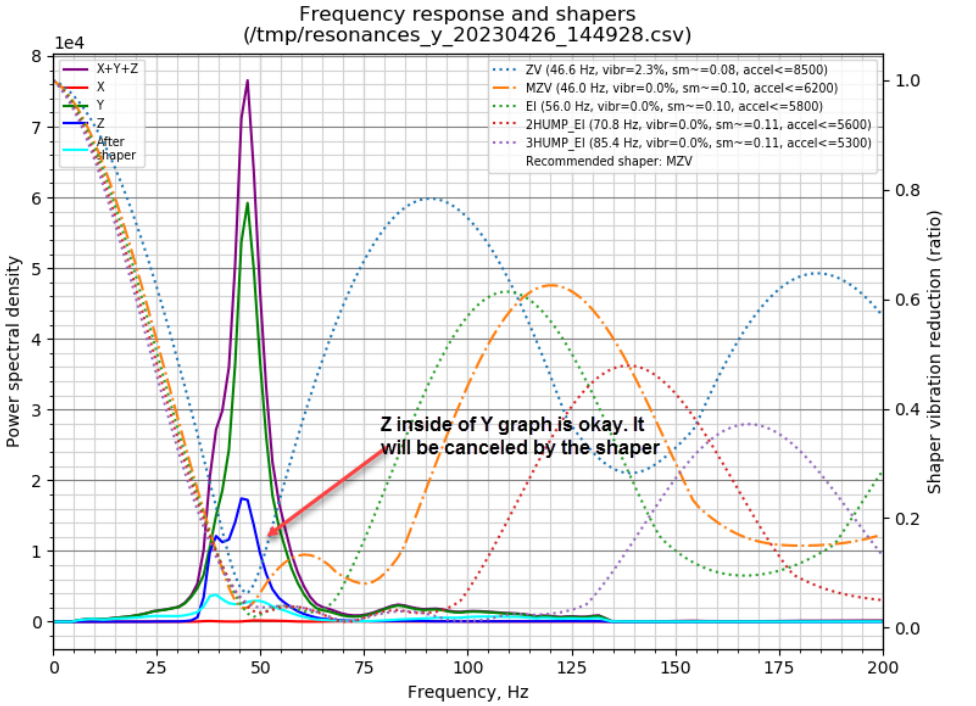
different input shapers

This is what Klipper thinks is best. On the graphs this is the blue lines

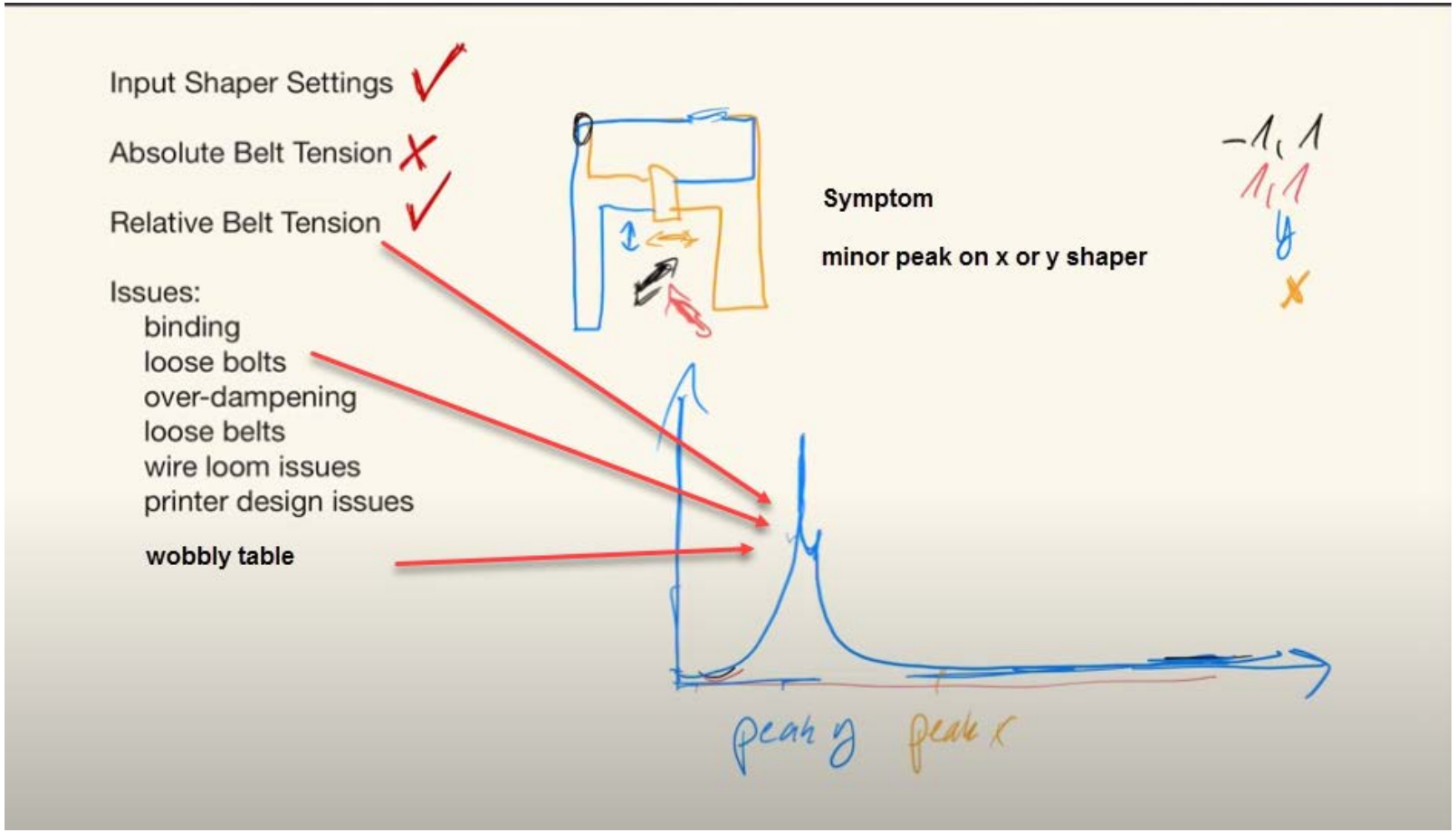
Recommended max acceleration.
Can treat this three ways.
1) set max acceleration in Klipper (printer.cfg) so no moves go faster than this.
2) set your perimeters (internal and external) to be alot less than this, while allowing infill and other non-visible print moves to be greater than this
3) do nothing, and accept that fact that you want to print fast, and a you aint's scared of not ghost[ing].

Good Graphs

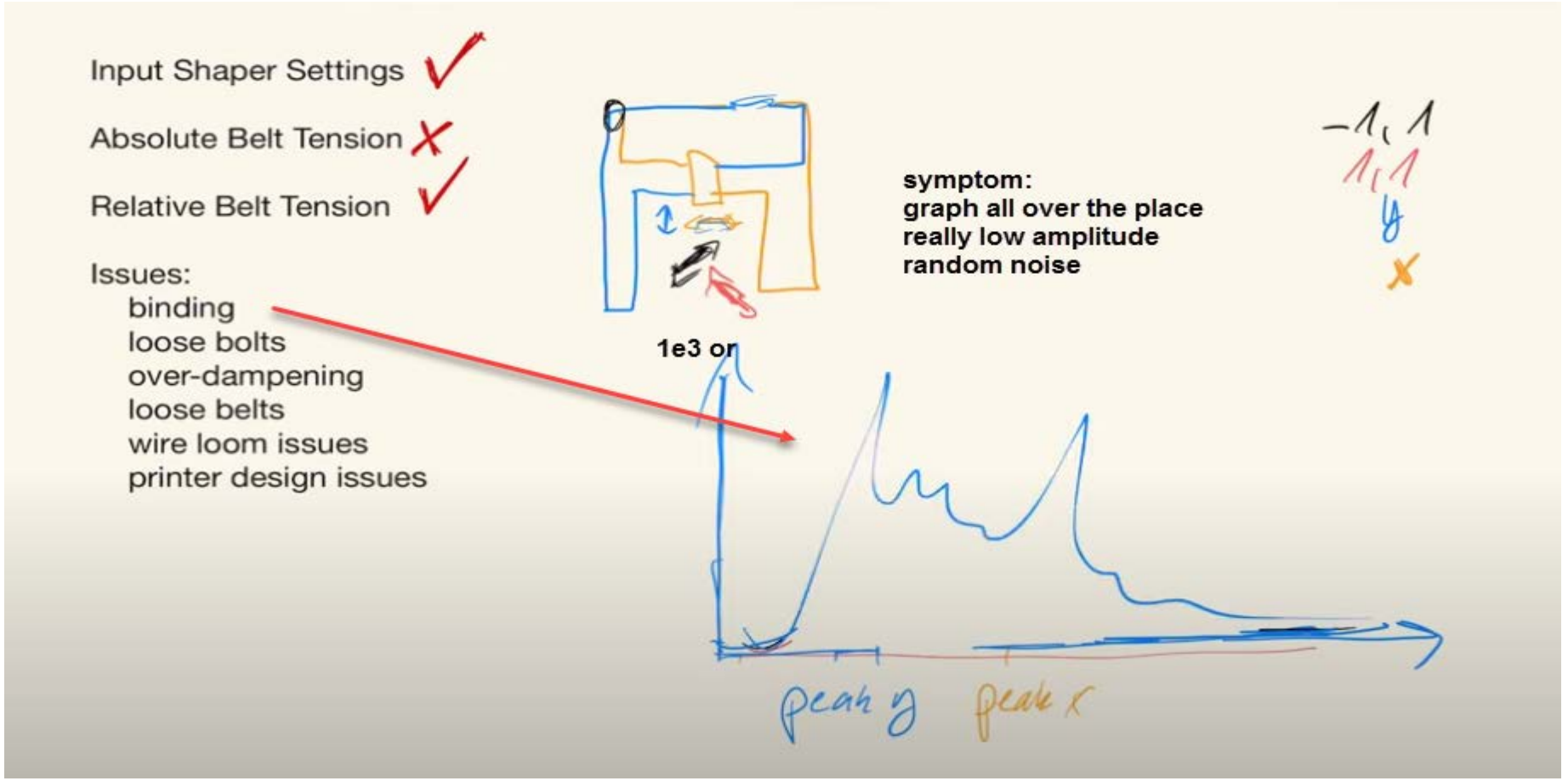

Frequency response and shapers
(/tmp/resonances_x_20230426_144709.csv)
1e4
X+Y+Z
X
Y
Z
After shaper
ZV (51.4 Hz, vibr=3.8%, sm~=0.06, accel<=10300)
MZV (50.6 Hz, vibr=0.0%, sm~=0.08, accel<=7500)
EI (62.0 Hz, vibr=0.0%, sm~=0.08, accel<=7200)
2HUMP_EI (78.0 Hz, vibr=0.0%, sm~=0.09, accel<=6800)
3HUMP_EI (94.8 Hz, vibr=0.0%, sm~=0.09, accel<=6600)
Recommended shaper: MZV
Power spectral density
Shaper vibration reduction (ratio)
Frequency, Hz


Frequency response and shapers
(/tmp/resonances_y_20230426_144928.csv)
1e4
X+Y+Z
X
Y
Z
After shaper
ZV (46.6 Hz, vibr=2.3%, sm~=0.08, accel<=8500)
MZV (46.0 Hz, vibr=0.0%, sm~=0.10, accel<=6200)
EI (56.0 Hz, vibr=0.0%, sm~=0.10, accel<=5800)
2HUMP_EI (70.8 Hz, vibr=0.0%, sm~=0.11, accel<=5600)
3HUMP_EI (85.4 Hz, vibr=0.0%, sm~=0.11, accel<=5300)
Recommended shaper: MZV
Z inside of Y graph is okay. It will be canceled by the shaper
Power spectral density
Shaper vibration reduction (ratio)
Frequency, Hz

Binding, Relative Belt Tension, Wobbly table

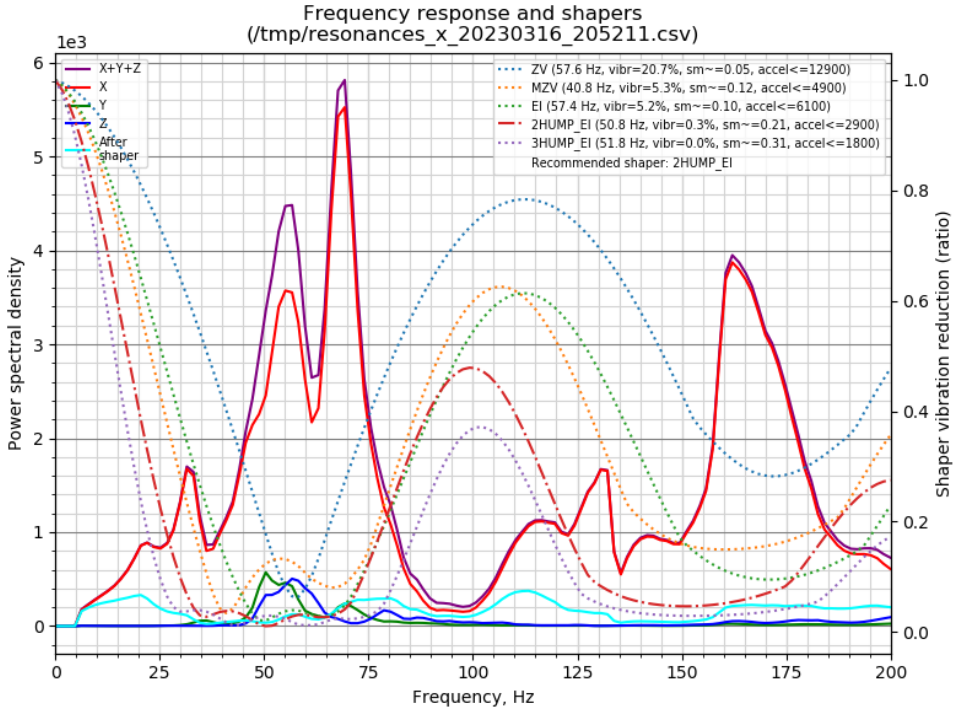


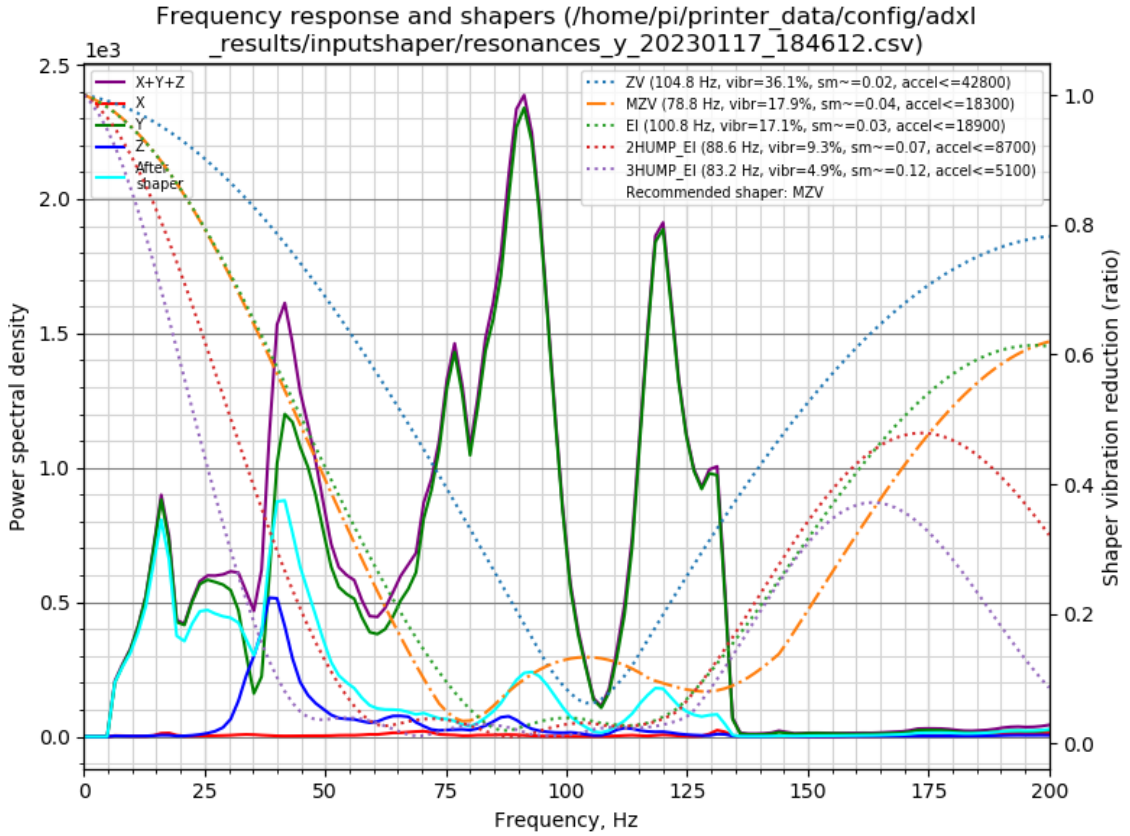
Binding


Input Shaper Settings
Absolute Belt Tension
Relative Belt Tension
Issues:
binding
loose bolts
over-dampening
loose belts
wire loom issues
printer design issues
1e3 or
symptom:
graph all over the place
really low amplitude
random noise
-1, 1
1, 1
peak y
peak x

Binding, racking, wobbly table, etc.

check every moving part
start by placing printer on a stable surface (floor)
then check belt path, then derack, then belt tension.
If problem persist consider relubing linear rails, replacing bearings/idlers

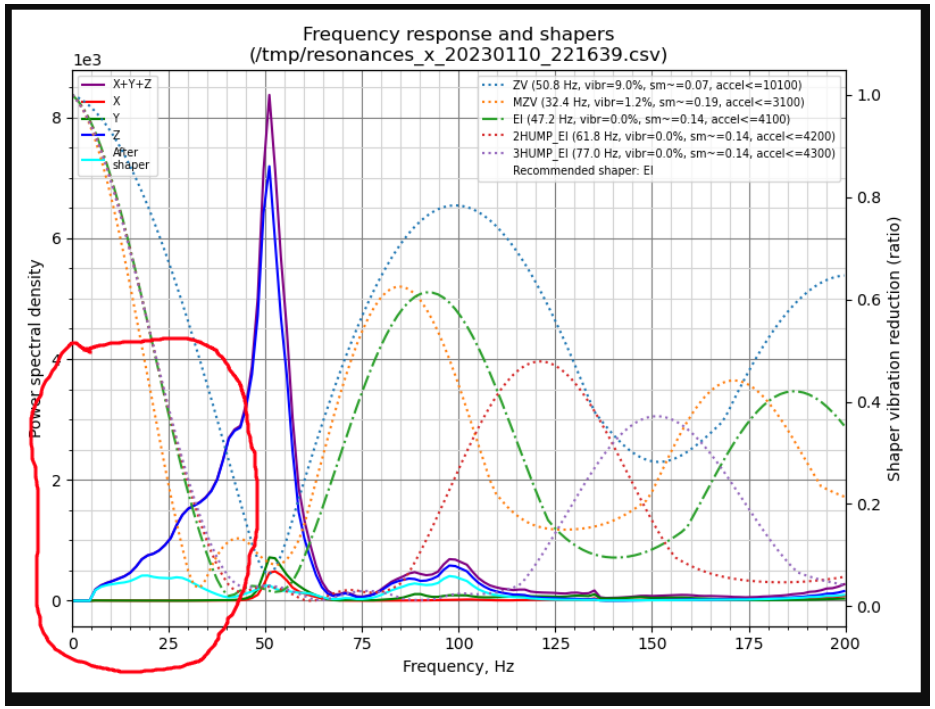


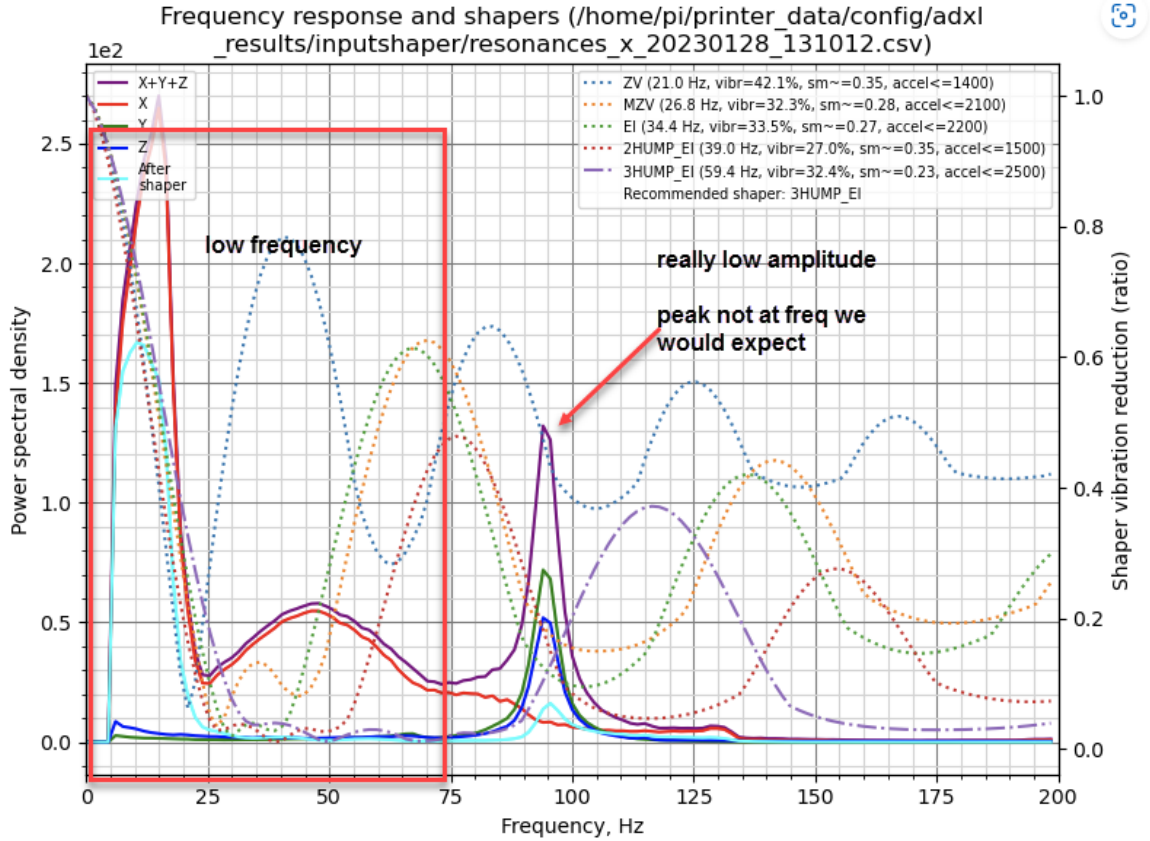


Low frequency – binding or grinding

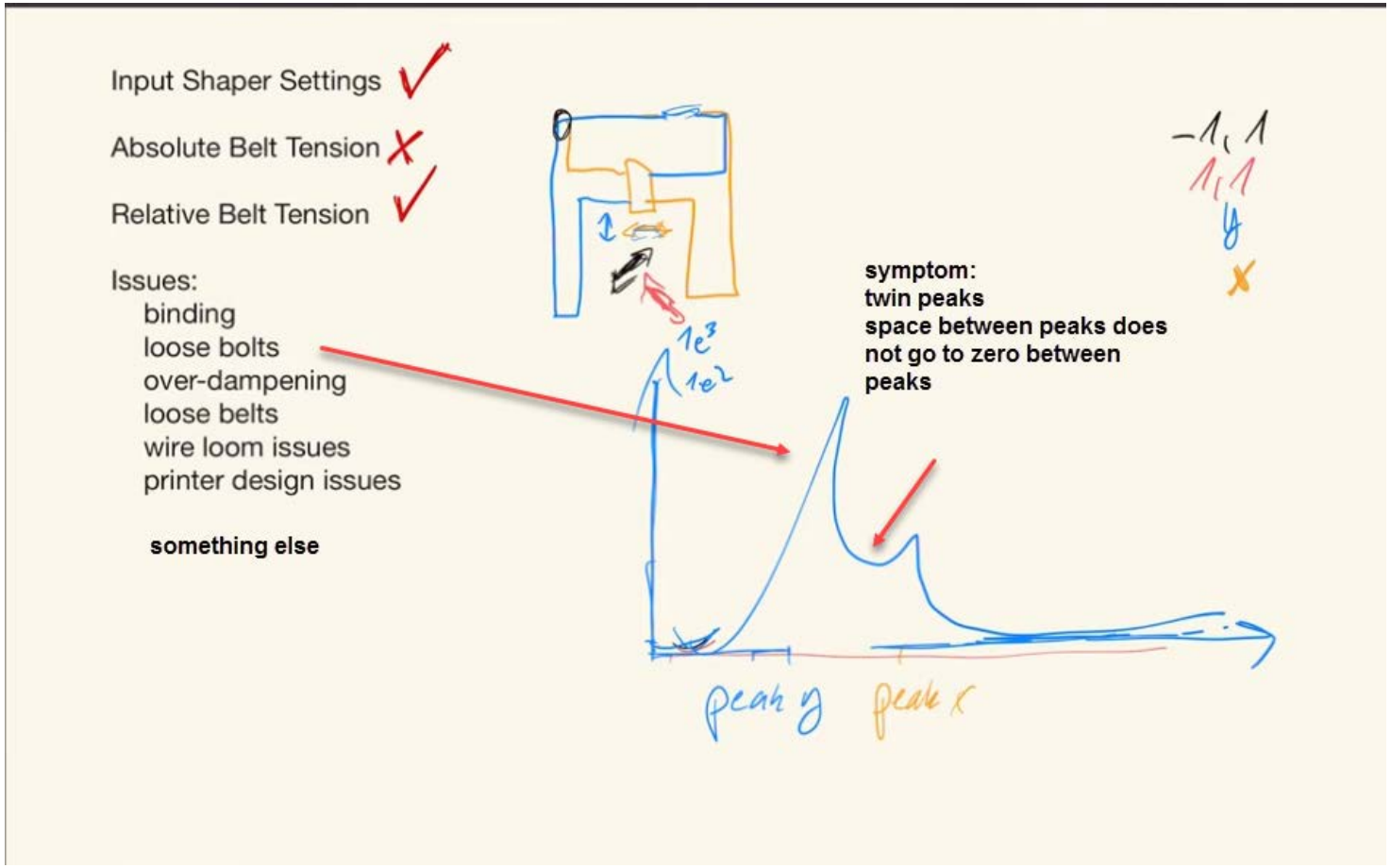
something is not moving freely

check belt alignment (make sure you have the belt in the middle of the bearings, and not riding on the flange. Make sure bearings have the flange on the outside of the belt bath)
Check linear rails, bearings, and idlers

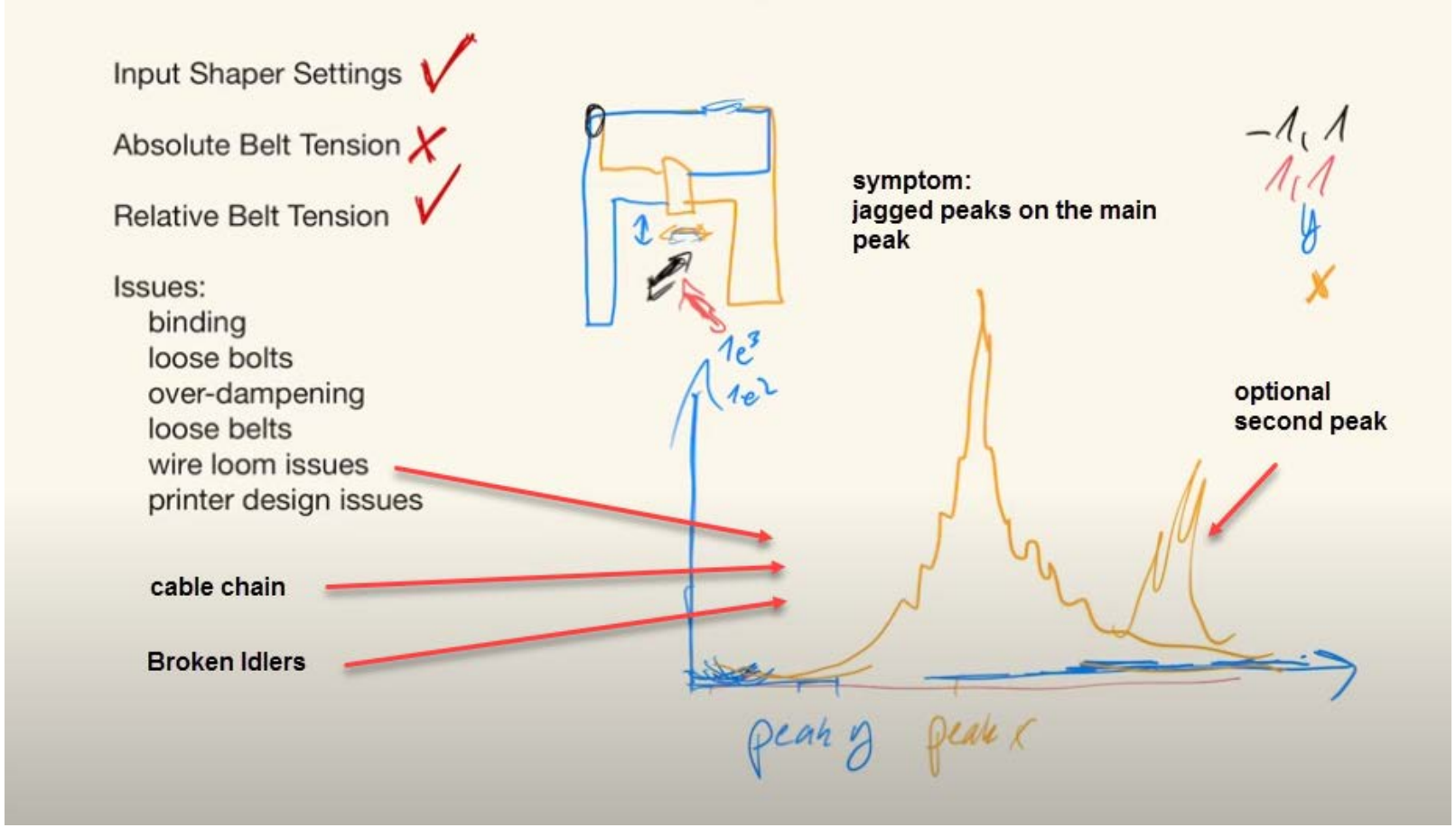




Loose Bolts


Input Shaper Settings
Absolute Belt Tension
Relative Belt Tension
Issues:
binding
loose bolts
over-dampening
loose belts
wire loom issues
printer design issues
something else
symptom:
twin peaks
space between peaks does not go to zero between peaks
peak y
peak x

Wireloom/cable chain, Broken Idlers



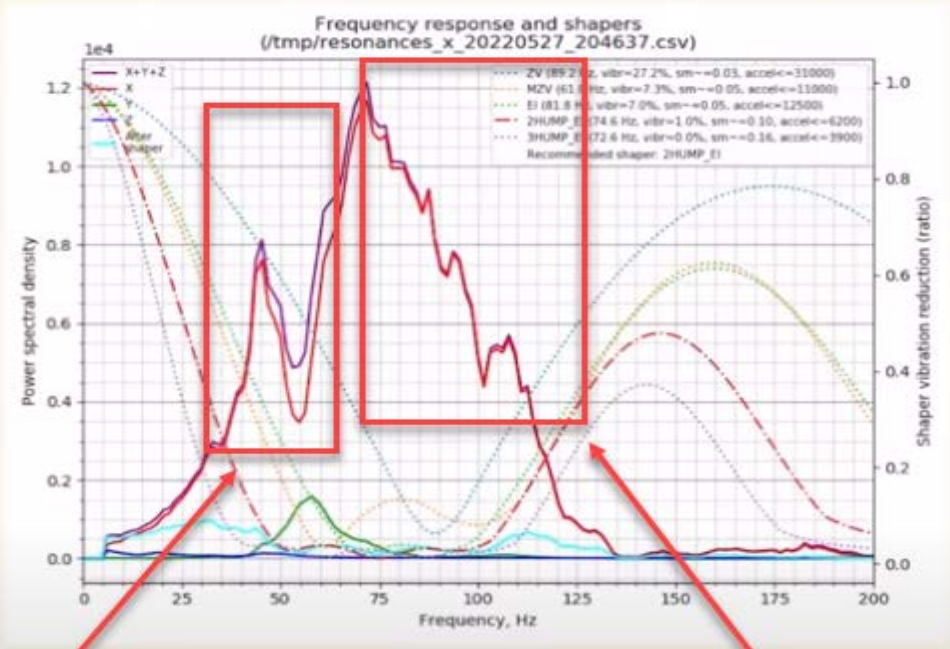
Wireloom and loose bolt

Input Shaper Settings ✓

Absolute Belt Tension ✗

Relative Belt Tension ✓

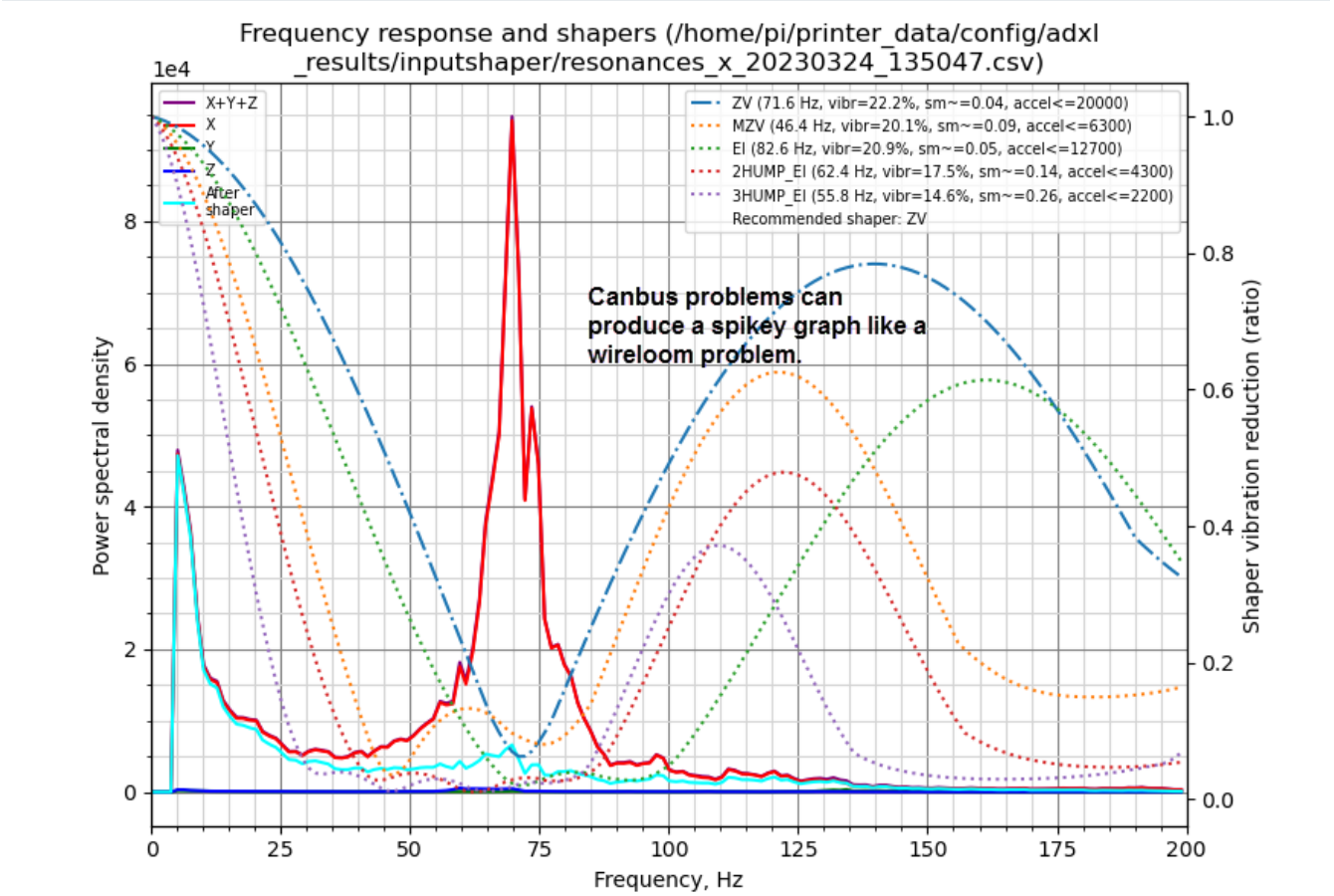
Issues:
- binding
- loose bolts
- over-dampening
- loose belts
- wire loom issues
- printer design issues



loose bolt: second peak

wireloom: jagged peaks

Canbus
increase canbus speed to 1M (1 million dollars)



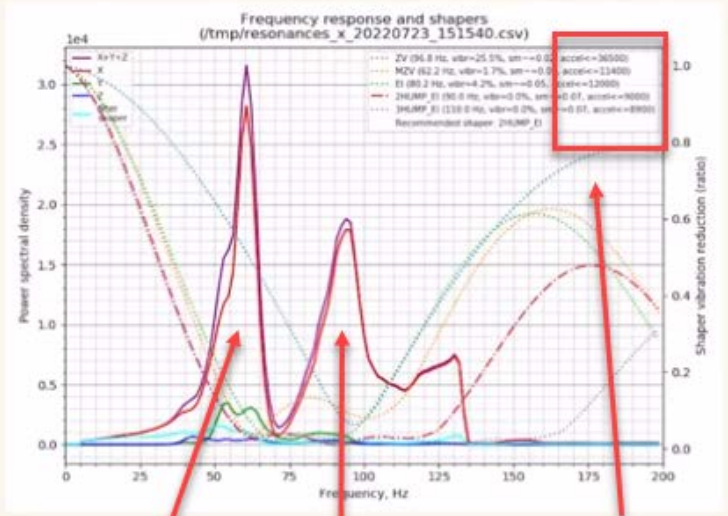
Wobbly table

Input Shaper Settings ✓

Absolute Belt Tension ✗

Relative Belt Tension ✓

Issues:
- binding
- loose bolts
- over-dampening
- loose belts
- wire loom issues
- printer design issues



wobbly table

wobbly table throws everything off

belt peak

difference really high between accelerations of different input shapers. Indicates a problem

don't believe input

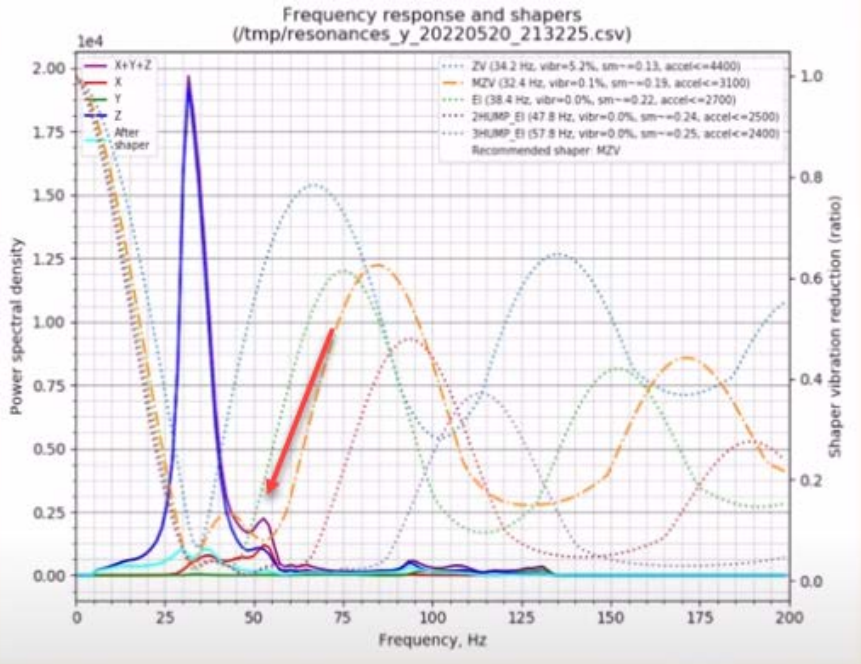
Potentially loose bolt or nothing at all

Input Shaper Settings ✓

Absolute Belt Tension ✗

Relative Belt Tension ✓

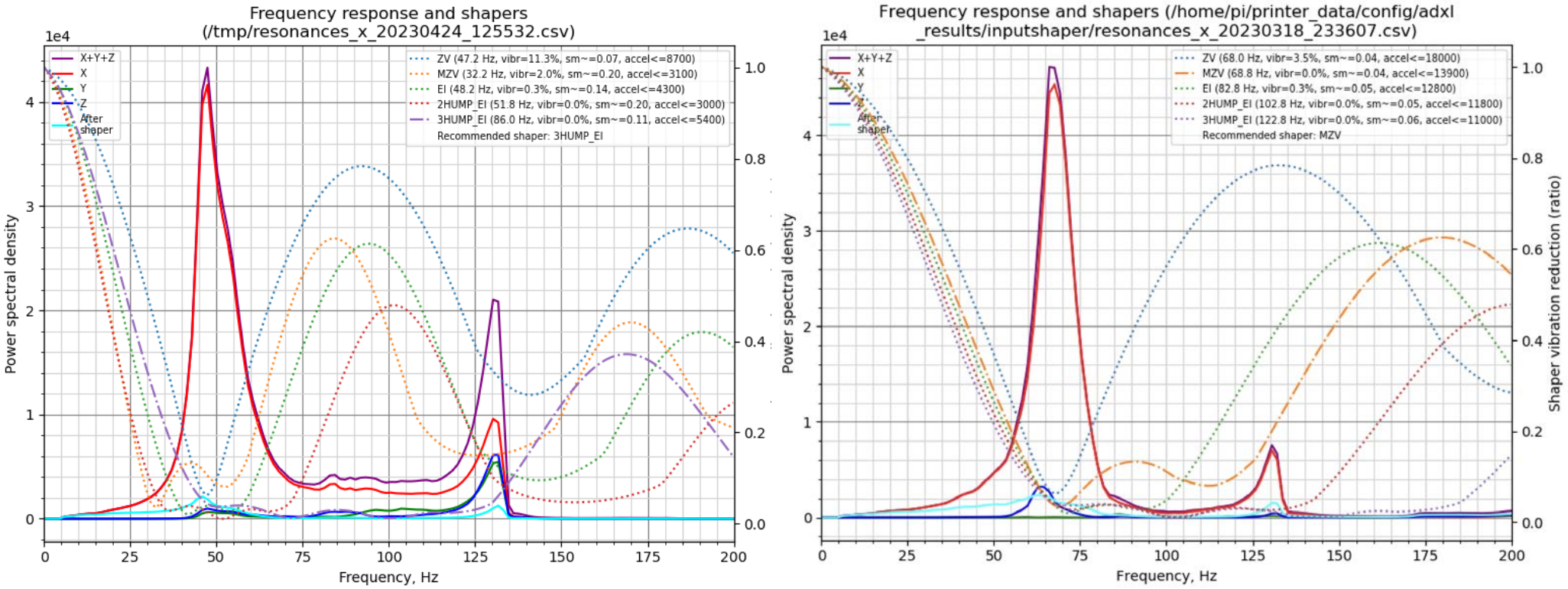
Issues:
- binding
- loose bolts
- over-dampening
- loose belts
- wire loom issues
- printer design issues



The side peak could 1) not matter, or 2) does matter.
For this graph it was a loose bolt. This issue would only manifest in larger movements than input shaper does (e.g. prints)

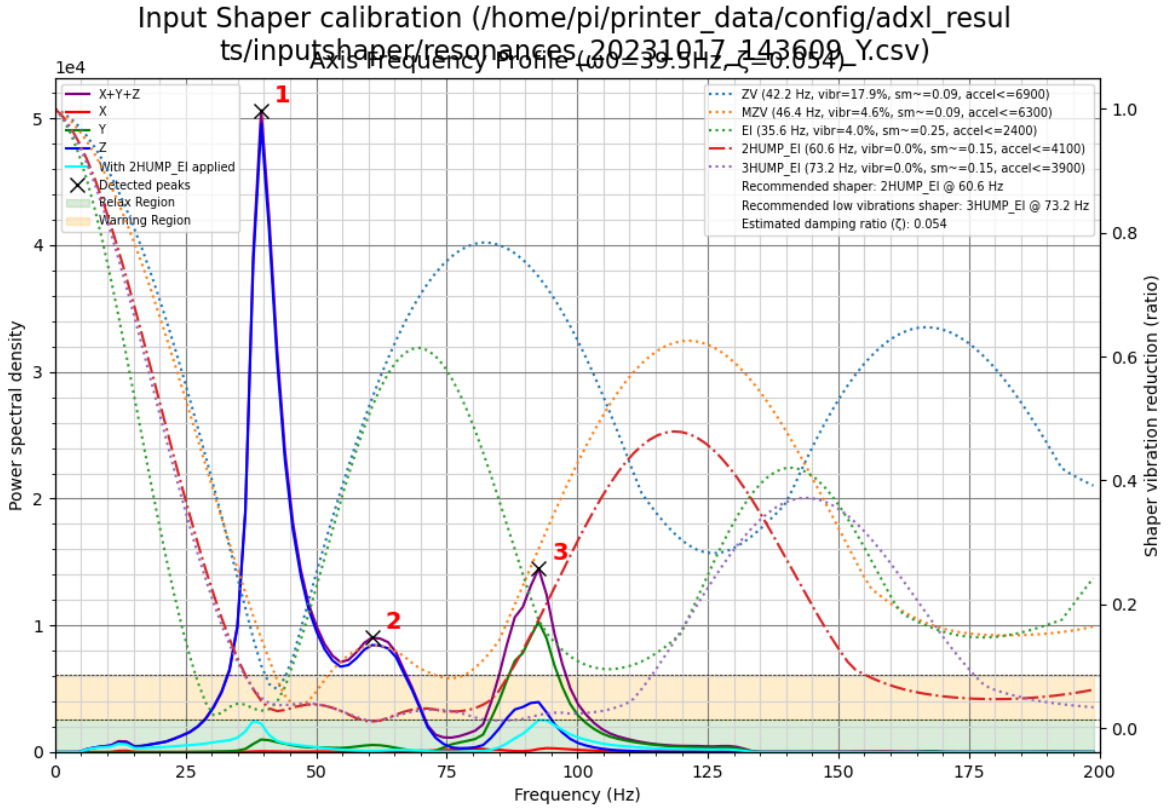
Investigate bolts to make sure all are snug

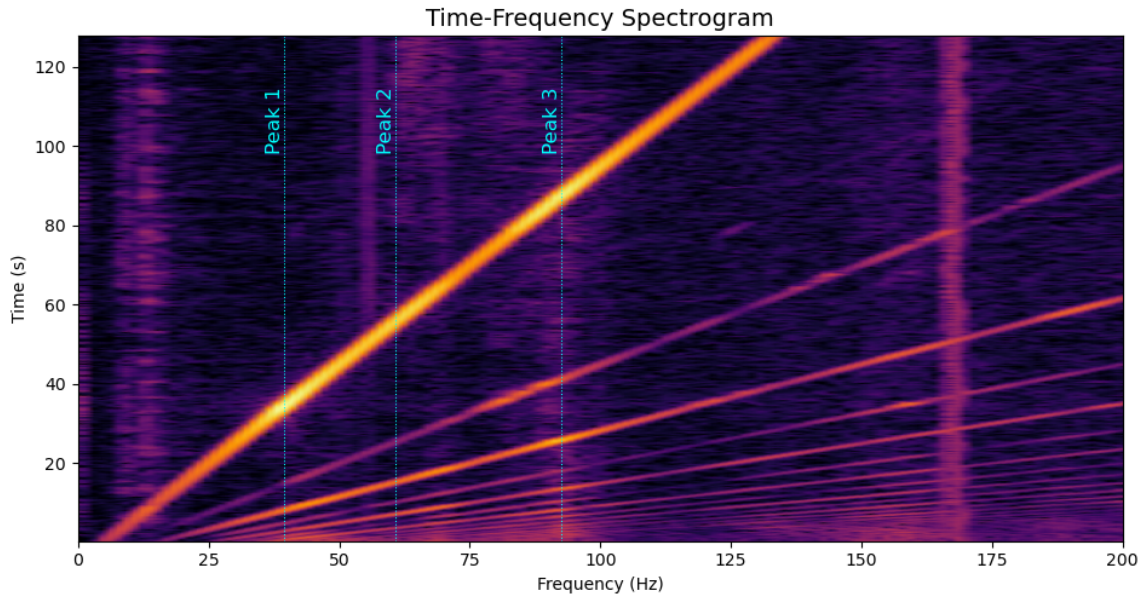
TAP Wobble toolhead in general



TAP issues are generally around 125hz and have the general shape shown above.
Toolhead issues are also associated with, but not exclusive to, 125hz.
If you see 125hz investigate the toolhead – break it down, and make sure all screws are tight, and your tap magnets are engaged.
Can have 125hz on non-tap machines also

Canbus cable, or TAP linear rail





peak 3
this could be the canbus umbilical cable, or
this could be the tap linear rail

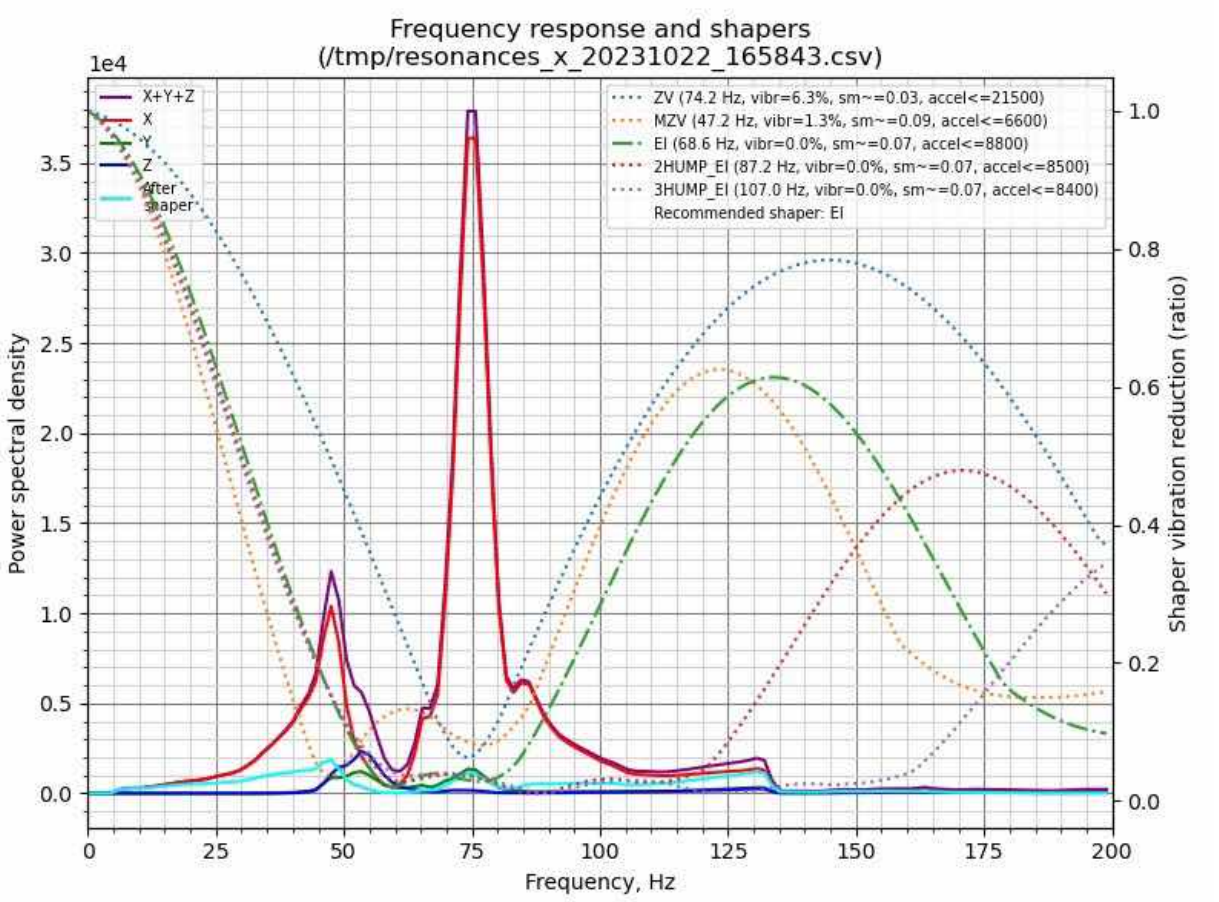
The effect as seen is that there is a z excitation. This can be interpreted as an RX (rotation on the x axis) or as something pulling up on the tool head.

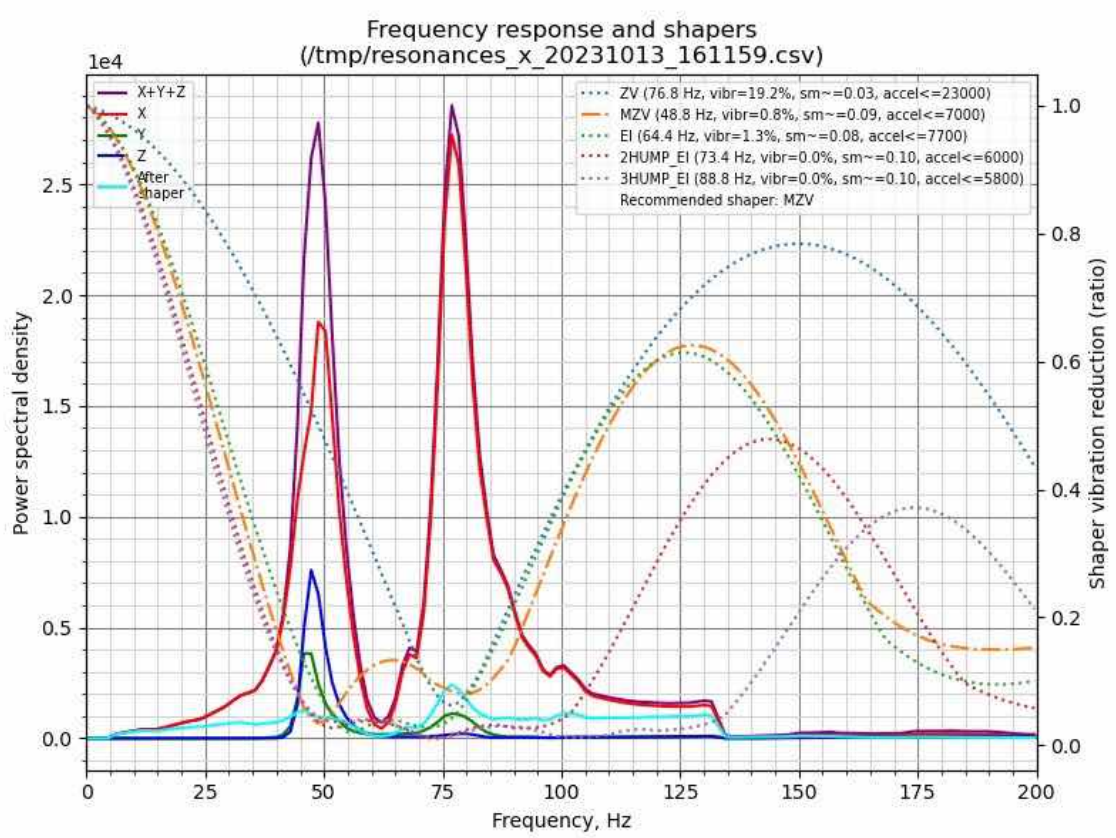
A canbus umbilical can pull on the toolhead, also the tap rail may not be good enough and allows for Rx rotation

Notice that peak 3 goes to zero on the left and right of it

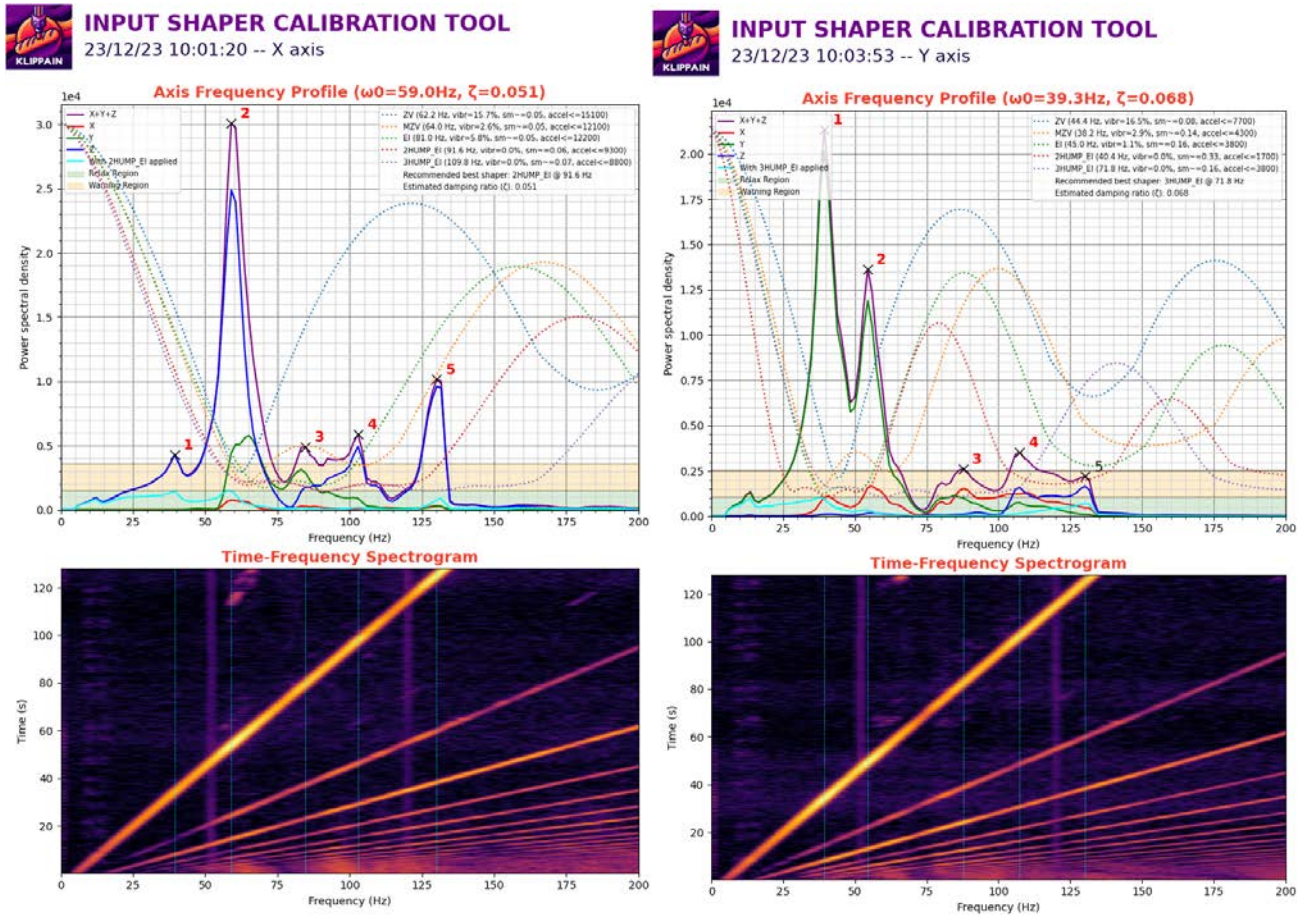
Potential Bearing issue

What you see here is two peaks with a valley between then and the valley goes to zero.
This is very similar to the canbus, tap, or linear rail.
The difference is the amplitude of the 75 hz spike is equal to or greater than the real freq of around 50hz.
-graphs by rafs2921



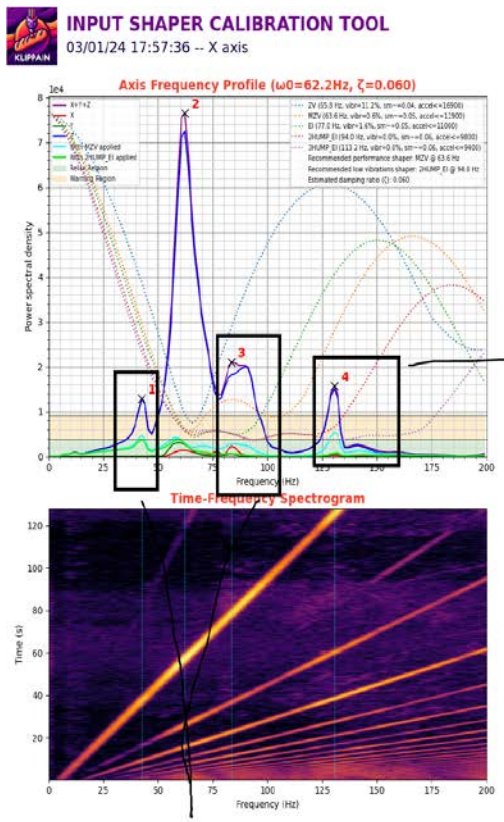


Not using all four screws to secure tap to the x-linear rail – missing two screws.
Likely similar if screws are loose.

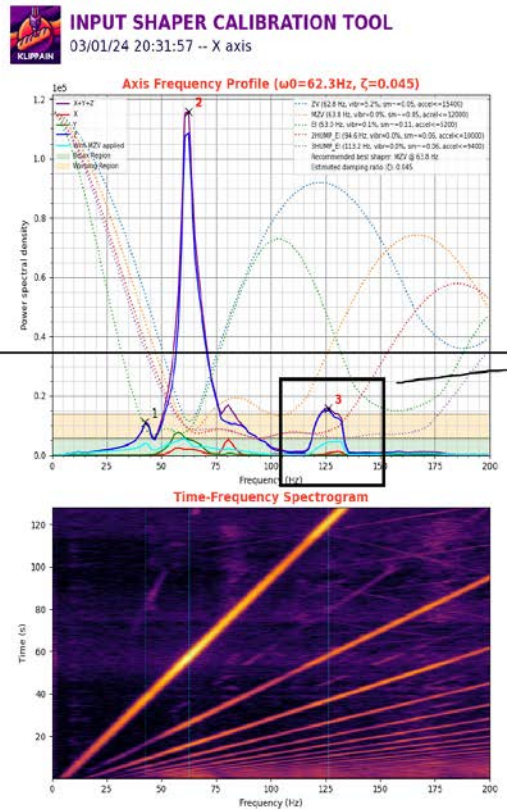


What a bad x-linear rail looks like.

Part 1: 125hz is not the x-linear rail

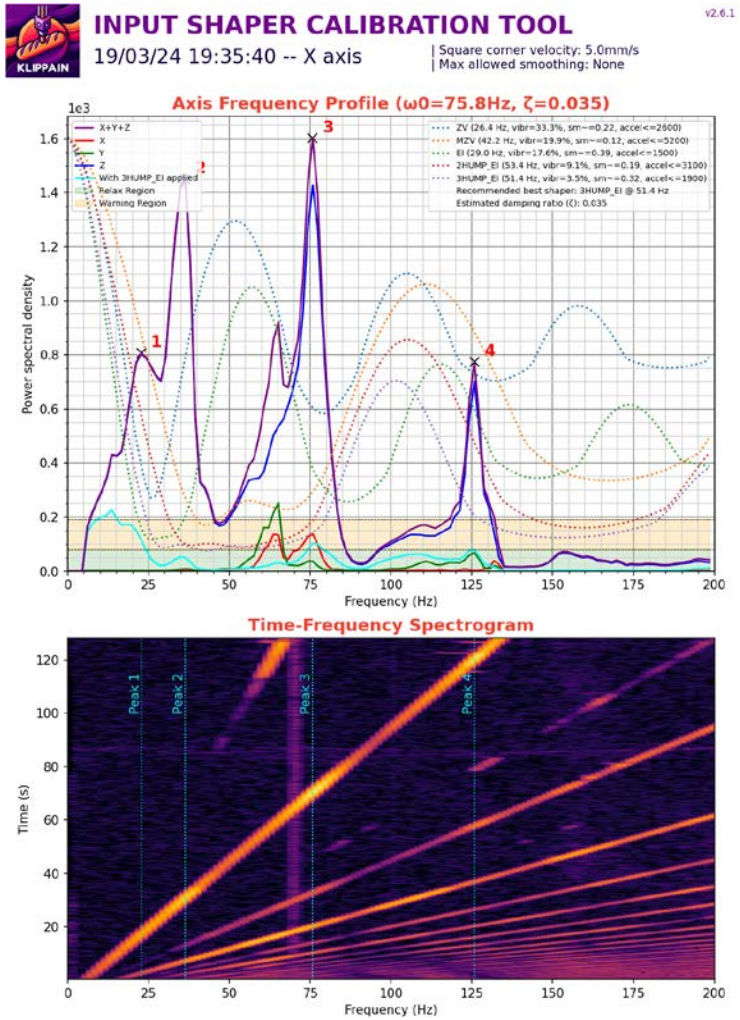


Bad linear rail - missing bearings



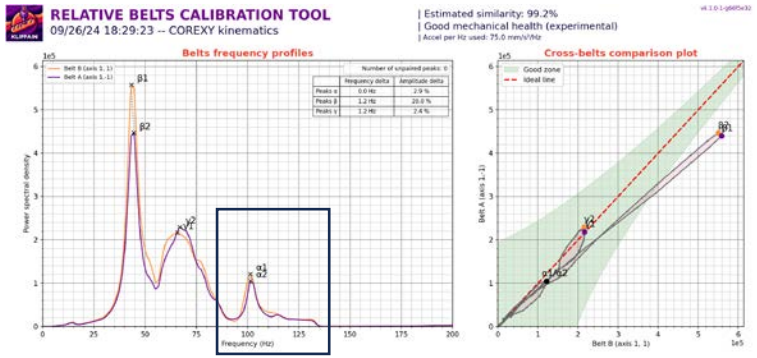
Good linear rail

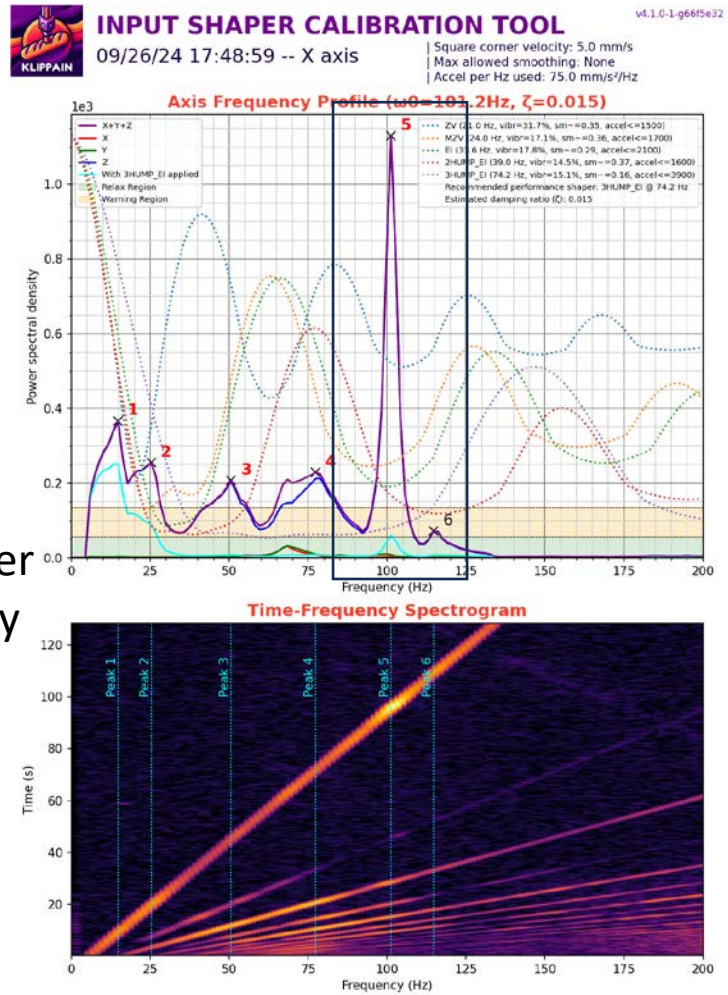
Tap:
using mellow tap.
likely umbilical is causing some of this.



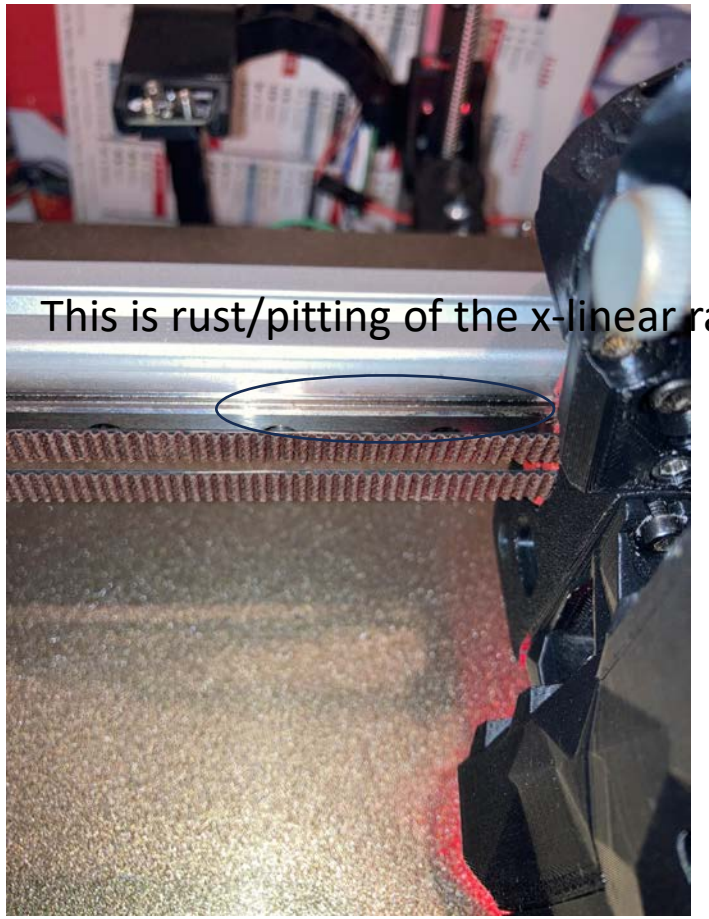
What a bad x-linear rail looks like.

Part 2



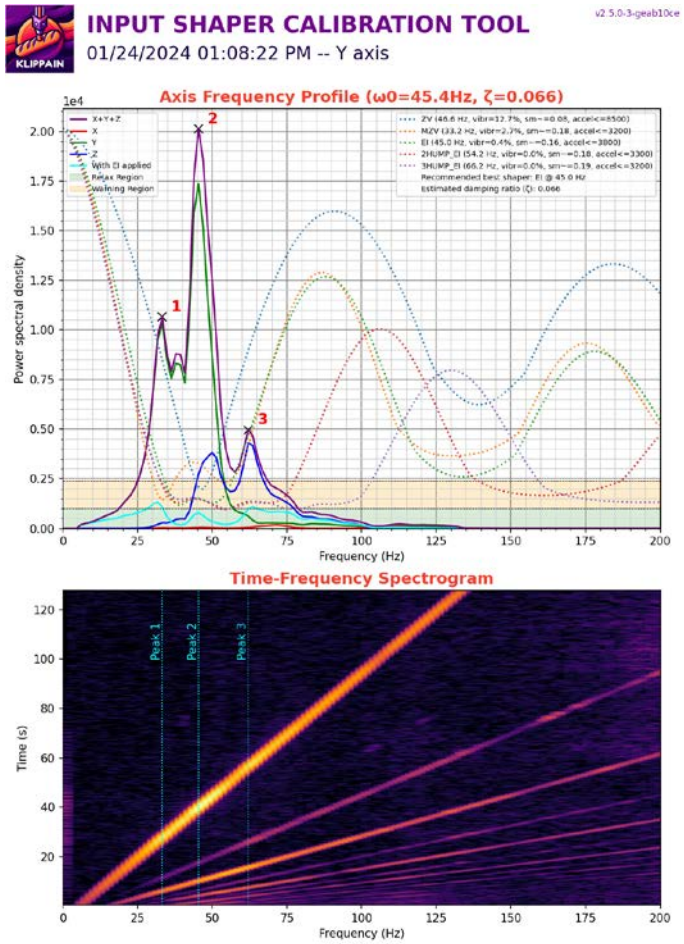


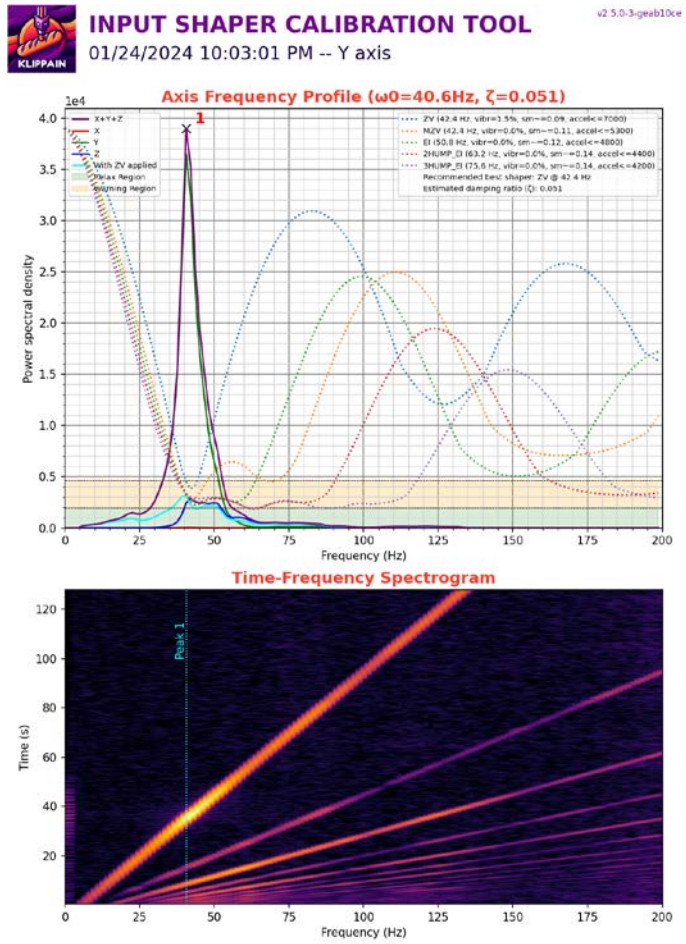
The 100hz spike in belts and x-shaper
Is due to a rusted (pitted) potentially
Twisted x-linear rail



This is rust/pitting of the x-linear rail

Printer wobbled on floor.
Added dampers to the printer feet



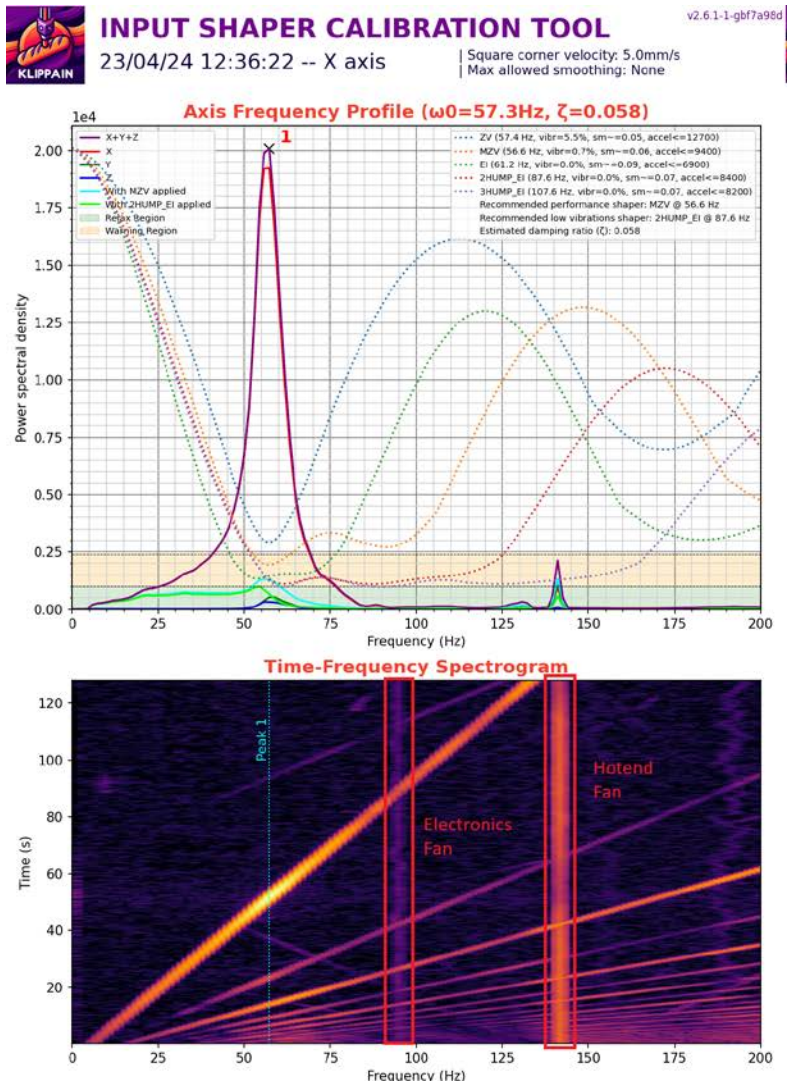


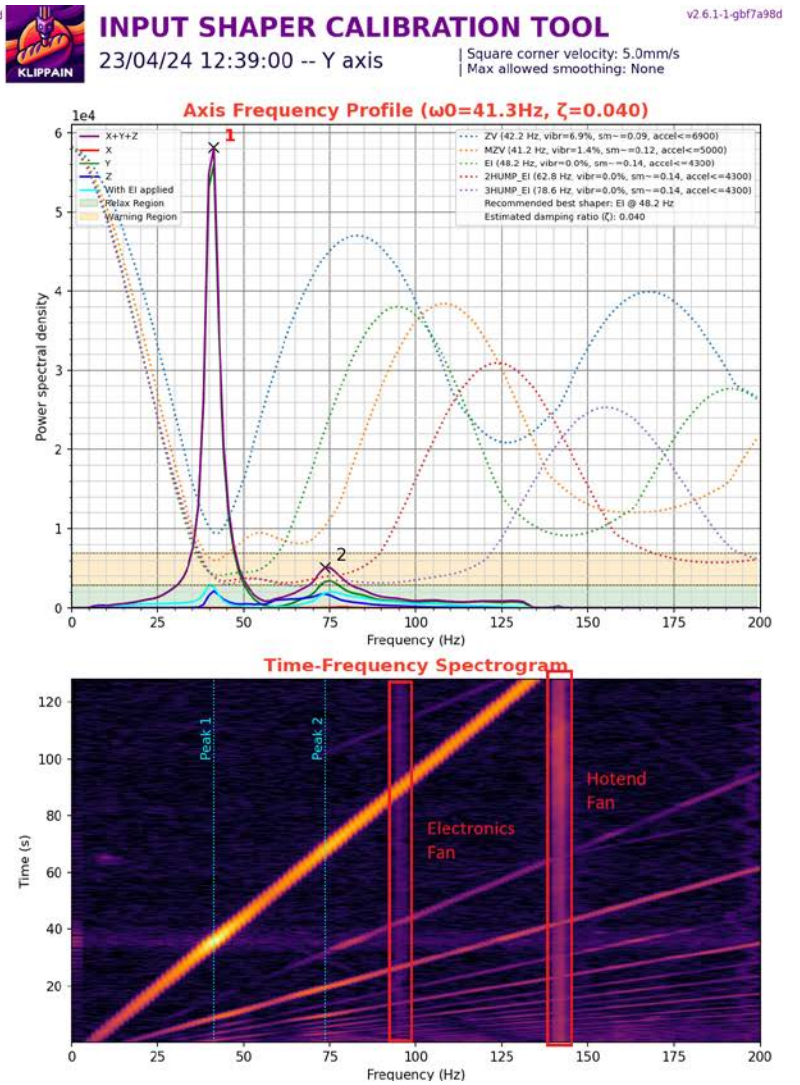
Ioannis_gi V2.6589
Used: Raise It Isolation Feet for Speaker Vibration/Ventilation

As additional vibration damper

Fans effects on graphs

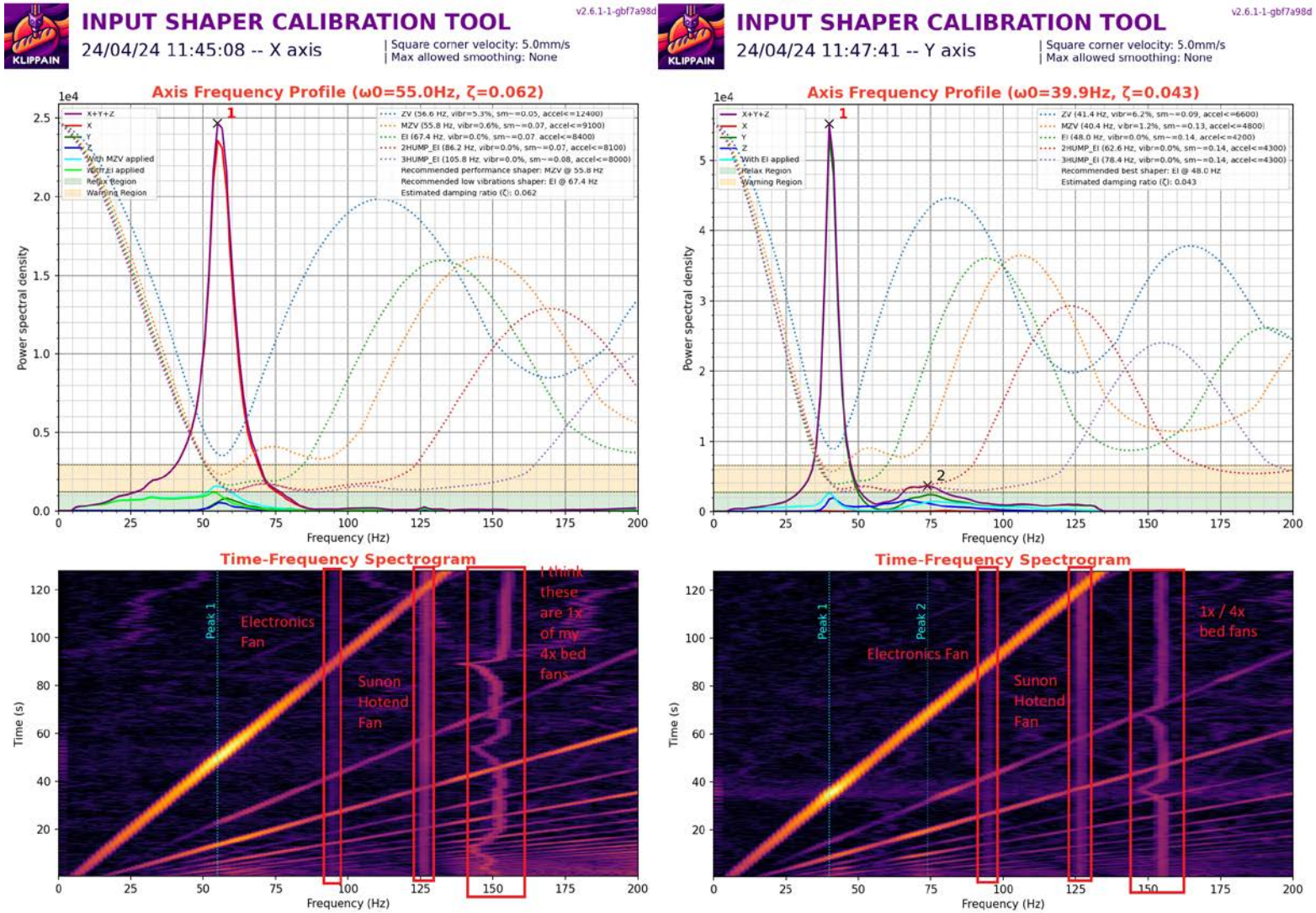
by Nick|VS|V0|V2





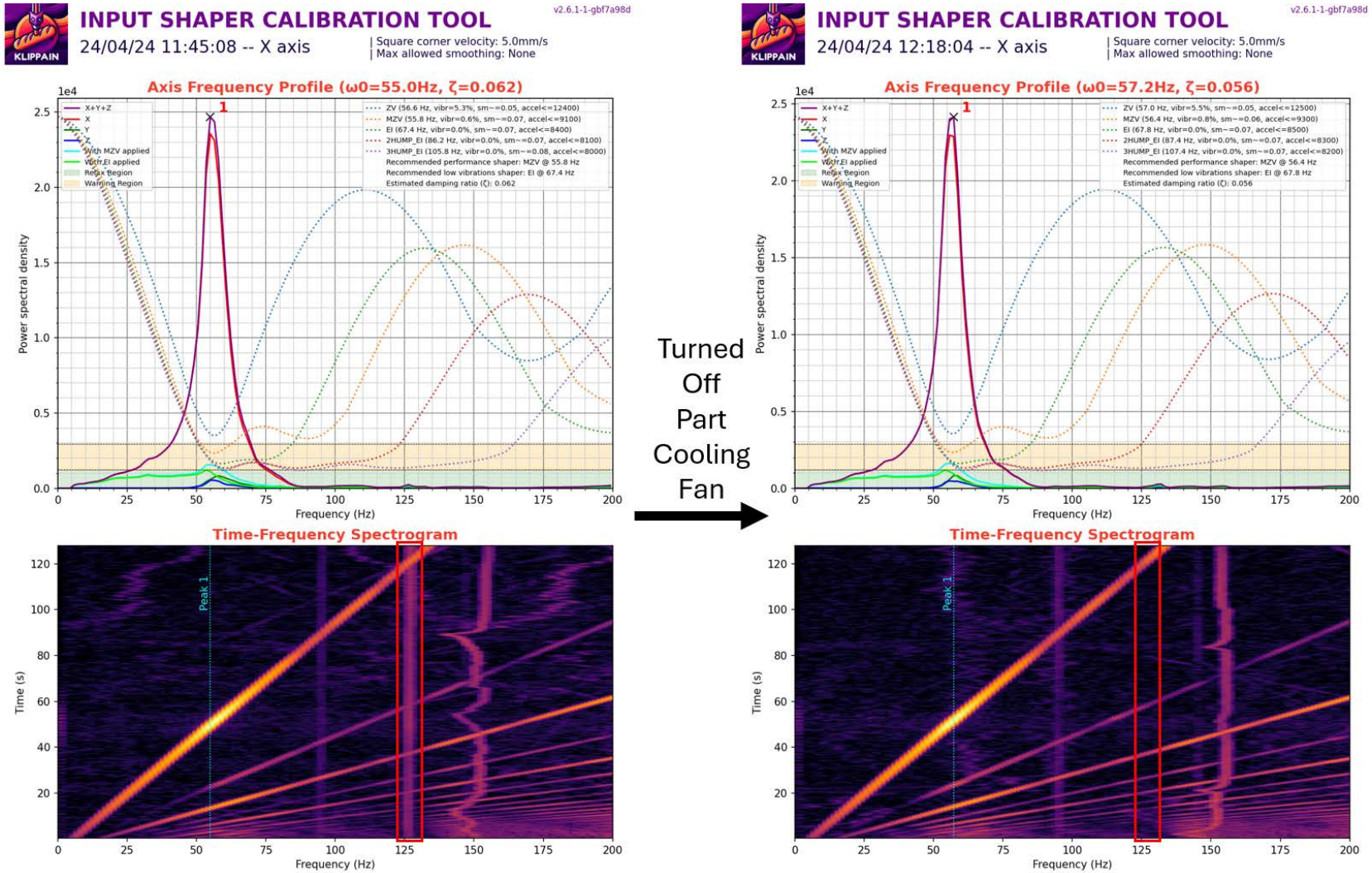
Fans effects on graphs

by Nick|VS|V0|V2



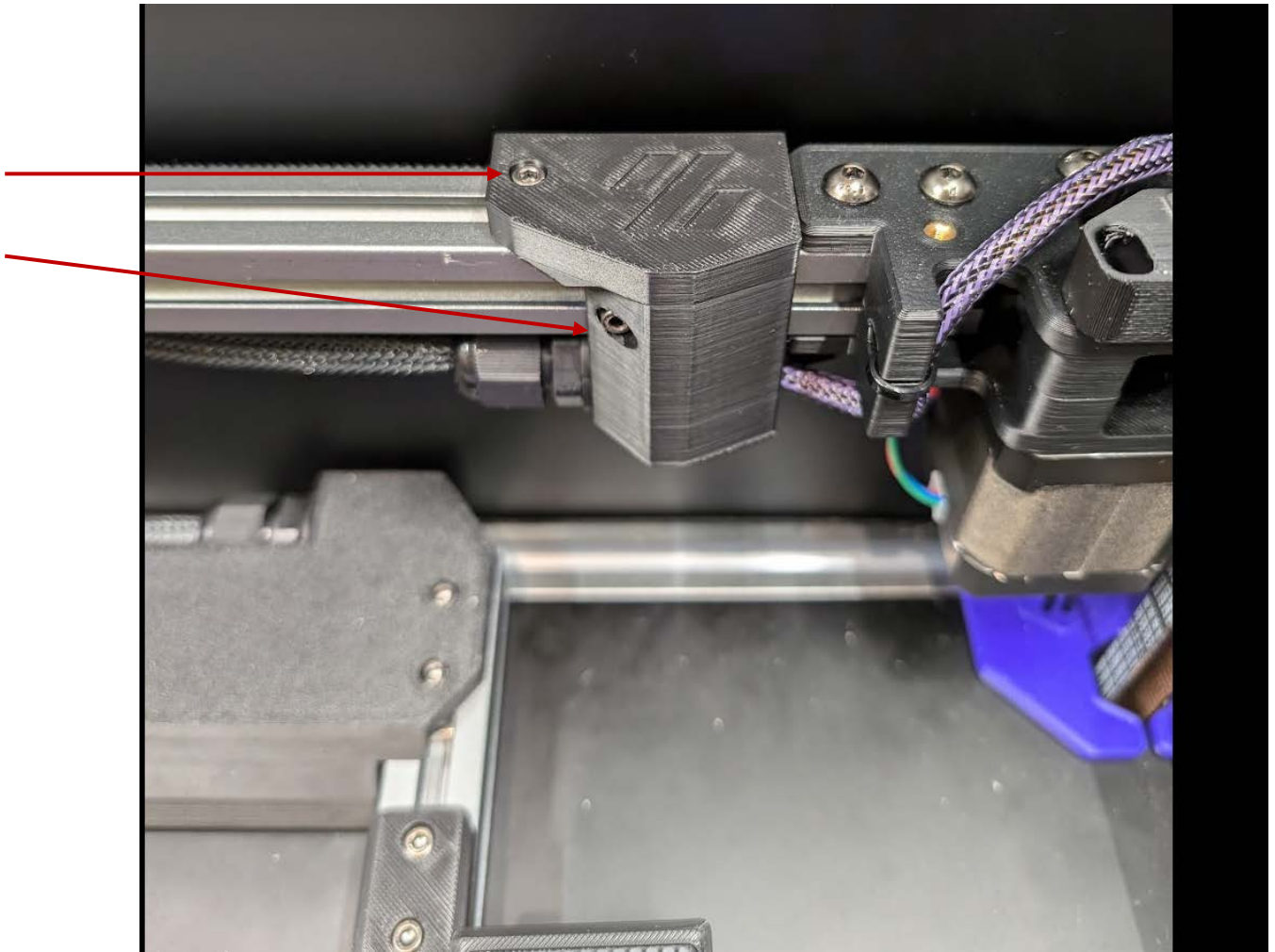
Fans effects on graphs

by Nick|VS|V0|V2



Loose Z-mod screw (or missing screw)

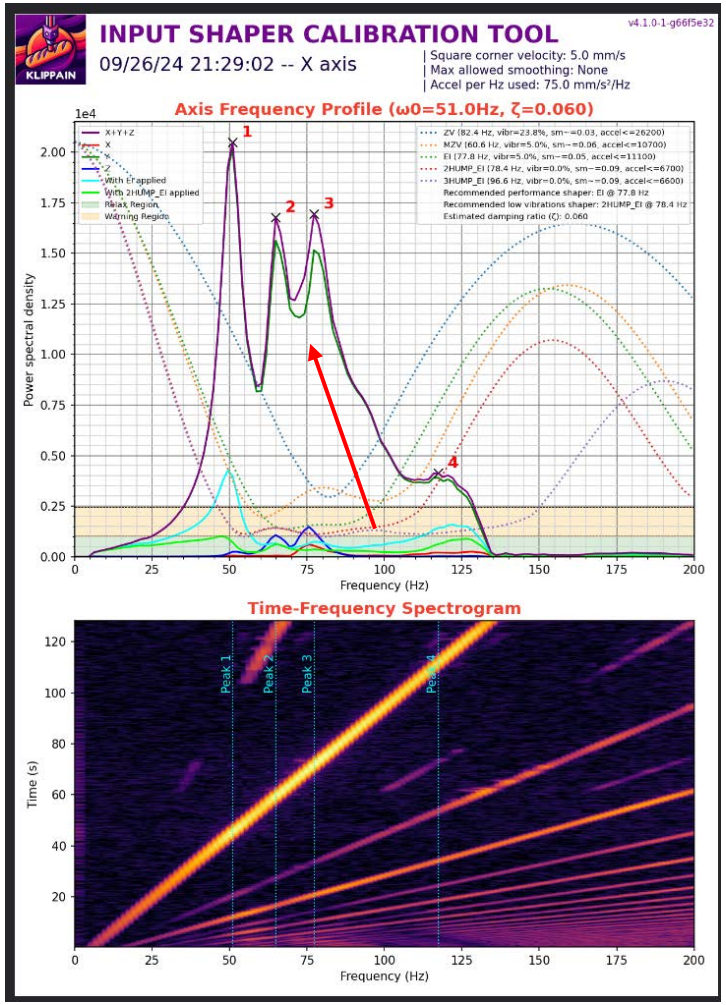
by Maverick



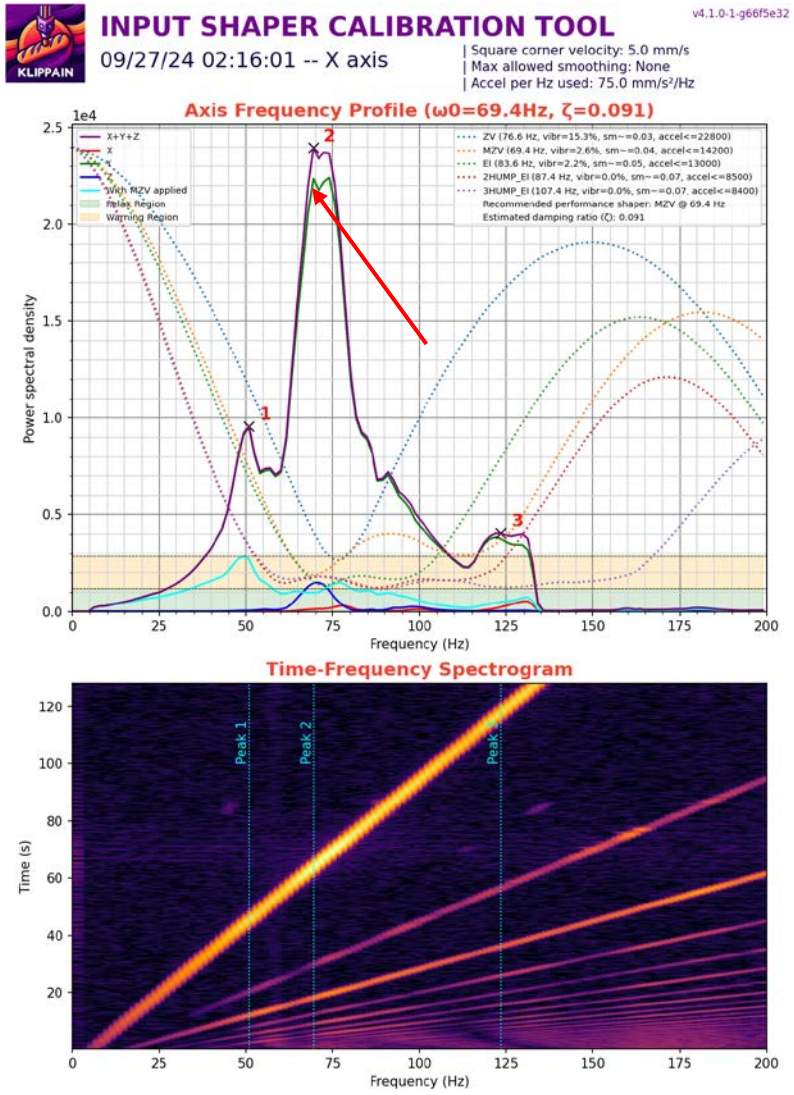
Loose Z-mod screw (missing screw)

by Maverick

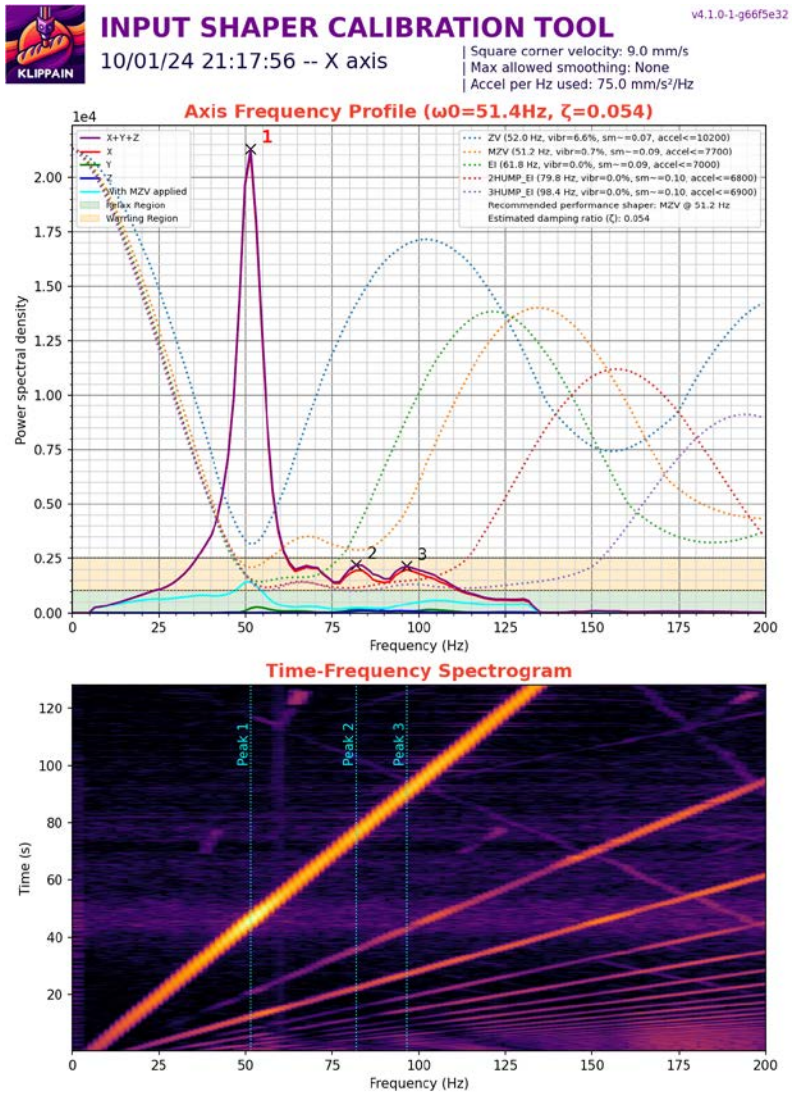
Before



Before



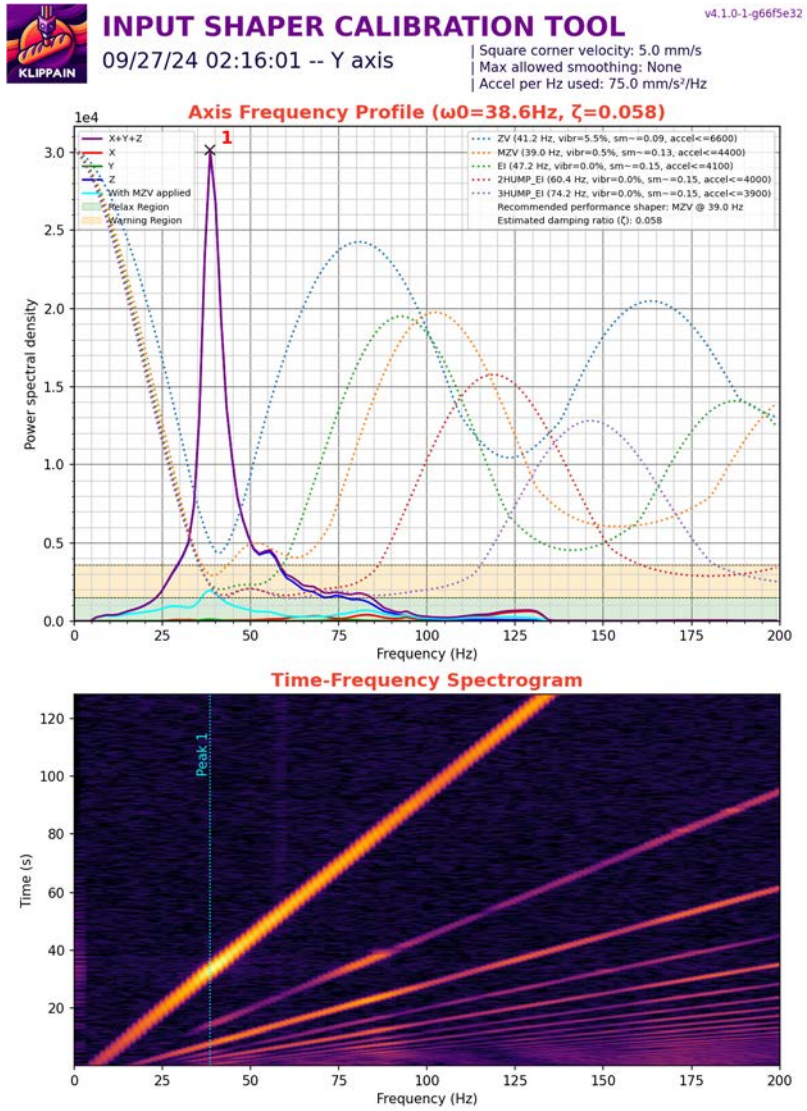
After



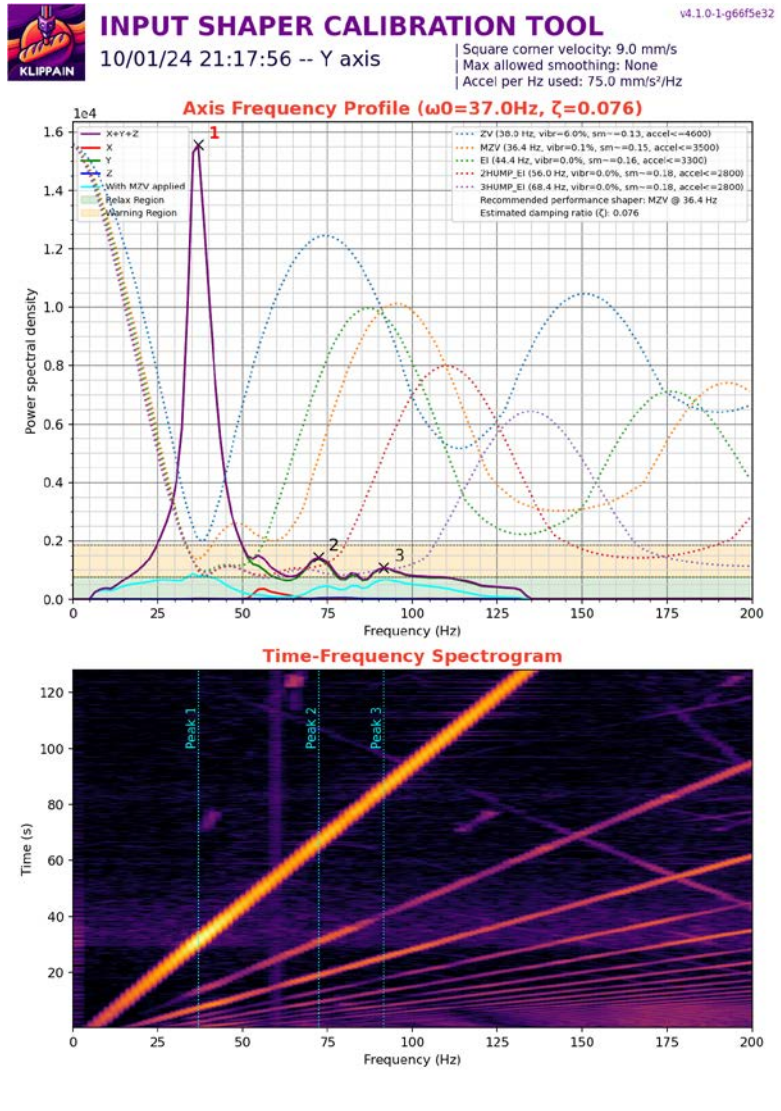
Loose Z-mod screw (missing screw)

by Maverick

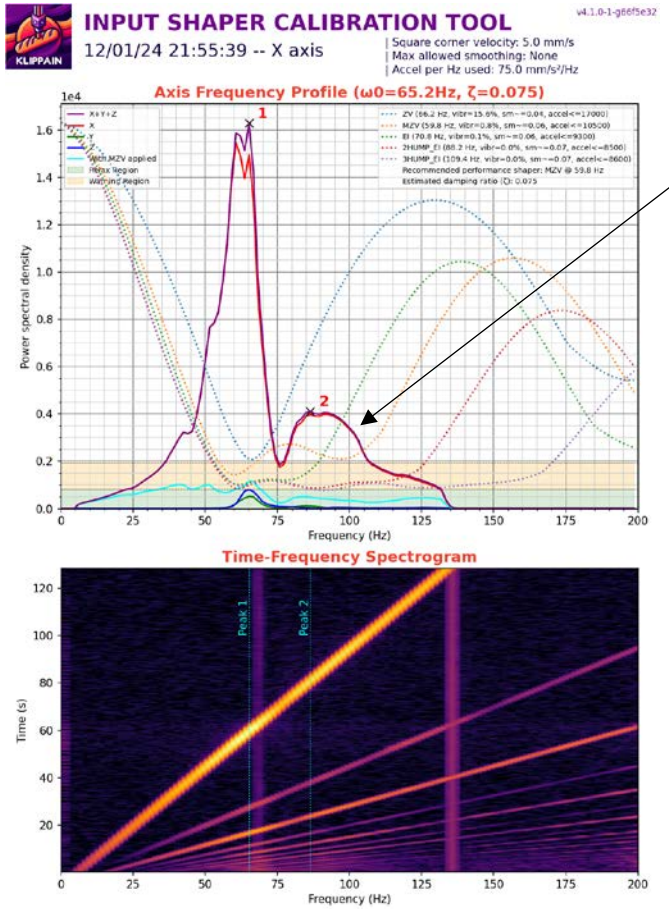
Before

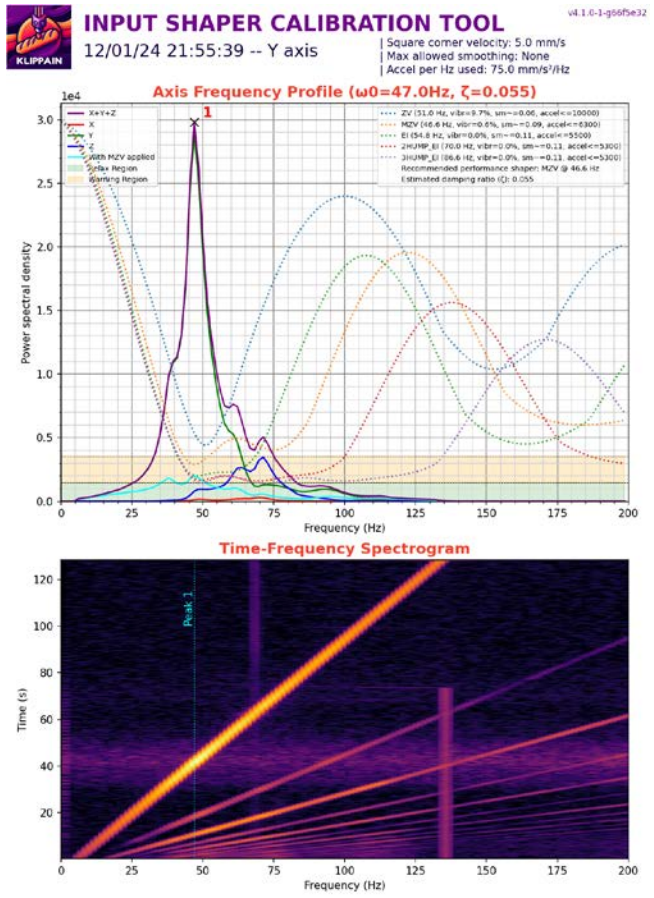


After

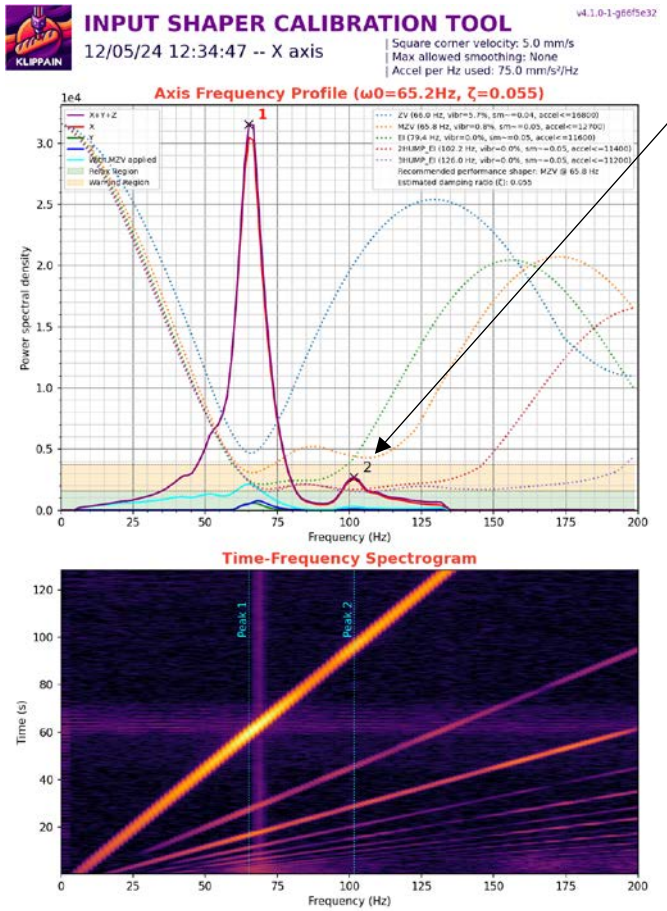


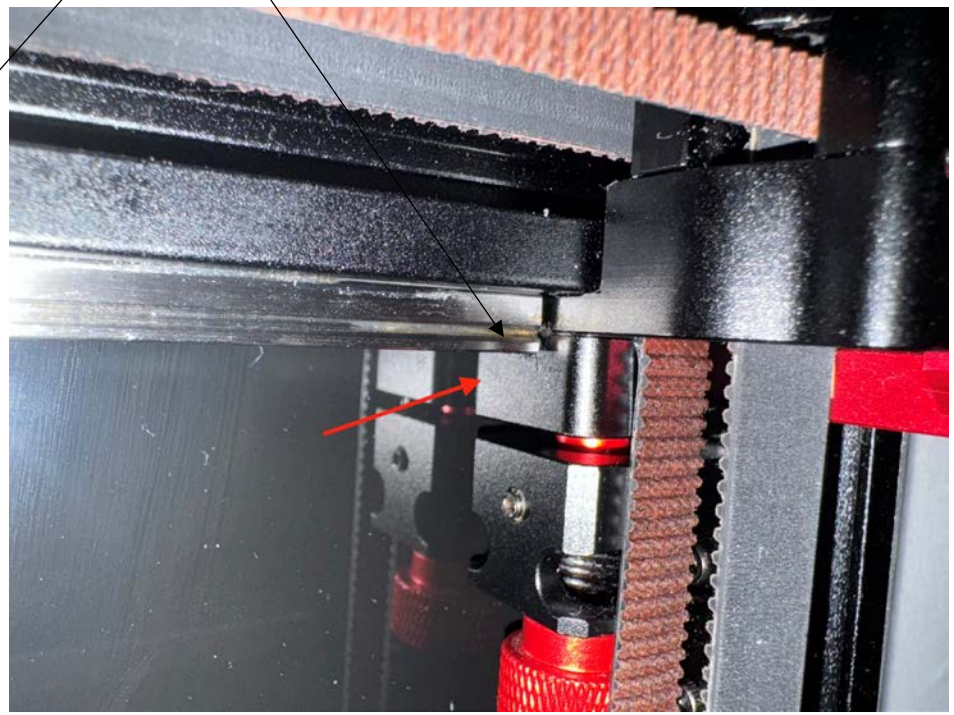
Loose Z-gantry screw (Igiannakas)

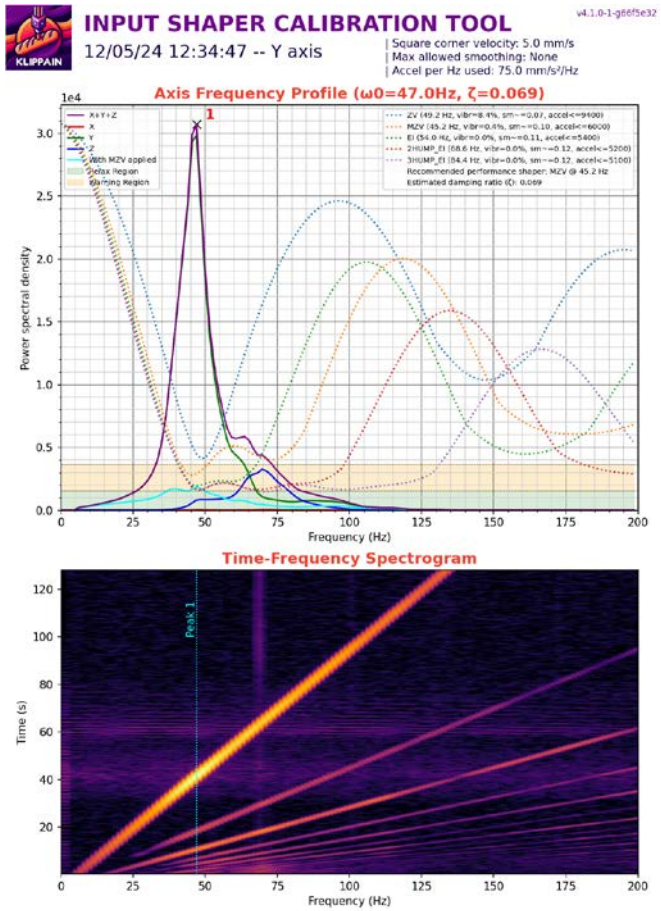




Loose Z-gantry screw (Igiannakas)







Loose Z-gantry screw (Igiannakas)

Troubleshooting

1. **Replaced belt and toothed idlers on the gantry last night.**

I was kind of hoping this would have fixed it, but nope! Absolutely 0 change. Maybe even ever so slightly worse due to the belts not being run in yet. You can imagine my face when i saw those results... (results removed they were not improved)

2. Then last night and until 2 in the morning I went down a rabbit hole

Removed the extruder, replaced its X carriage mount with a new one just in case the old one was worn and was vibrating. Replaced the revo mount with a new one too. Again, absolutely no change whatsoever.

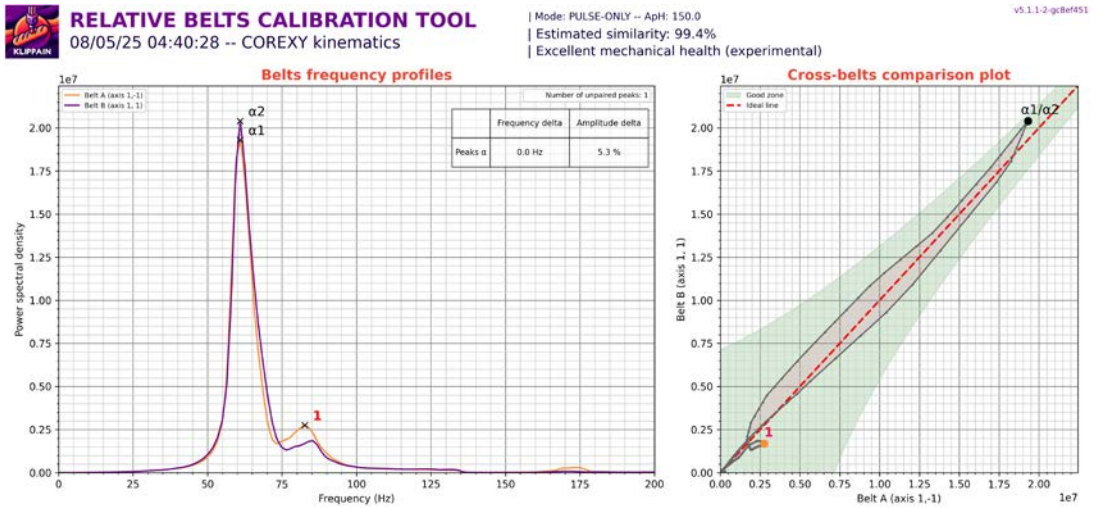
3. This morning I decided to re-inspect the motion system.

I was battling slightly off belt tension with the new belts and thought I had not cut them to exact same size. But that was not the case. I took apart the panels, re-squared the gantry and validated with my machinists square. Then when I was inspecting the Z pins for alignment I noticed that the **bottom belt clamp was not tight on any of the 4 corners.**

Toolhead screws hitting x-linear rail carriage (MxBrnr)

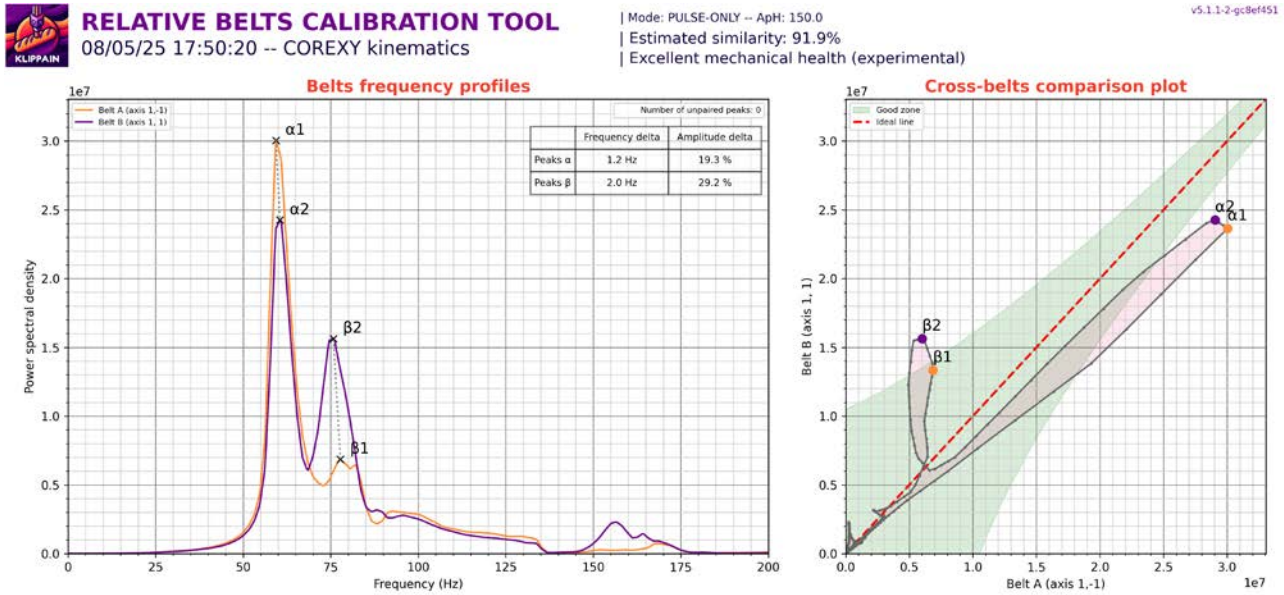
- During Input Shaping calibration after rebuilding the gantry and toolhead, notice the X-axis graph had an abnormally low PSD value and sporadic graph image.
- Since the low PSD was occurring only in the X-axis, possible causes would have to be potentially exclusive to that axis.
- General visual inspection showed that all belts, gears, and pulleys were properly aligned.
- Tactile investigation found the toolhead being slightly more difficult to move by hand along the X-axis compared to the Y-axis.
- Detailed visual inspection of the toolhead (Dragon Burner) found that the front-facing cowl-to-carriage mount screws were extending through the mount and contacting the rail carriage.
- The screws in use at that time were M3x40mm; they were then changed to M3x35mm.
- No other changes were performed. Hand movement of the toolhead verified equal effort in both X and Y axes, and input Shaper calibration was re-run with drastically improved results.
- Conclusion: the incorrectly sized screws (my own fault) were pinching the X-axis rail carriage and causing slight binding in only that axis.

Toolhead screws hitting x-linear rail carriage (MxBrnr)



Before

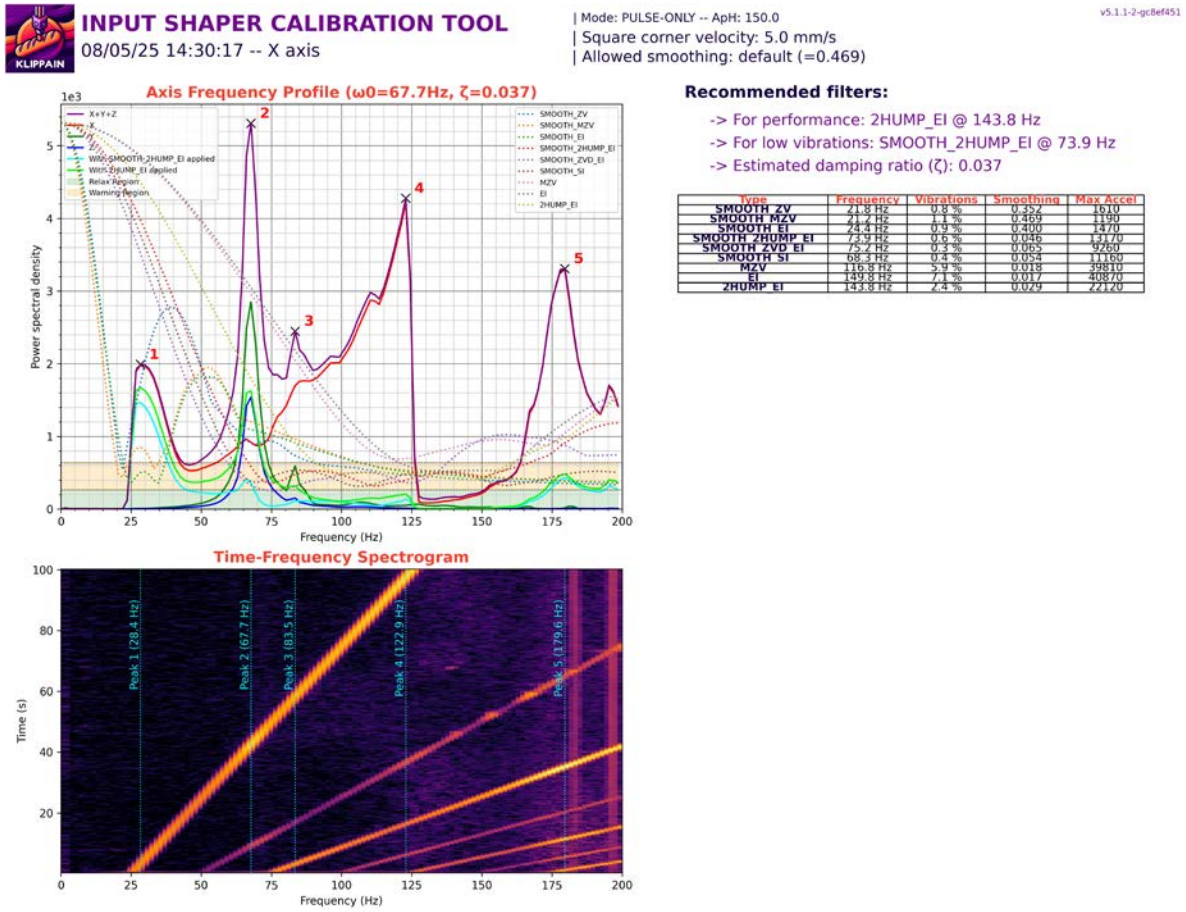
After



Note: The belts are not showing an issue. This is likely due to the fact that the belts test acts upon both the x and y axis (diagonal moves)

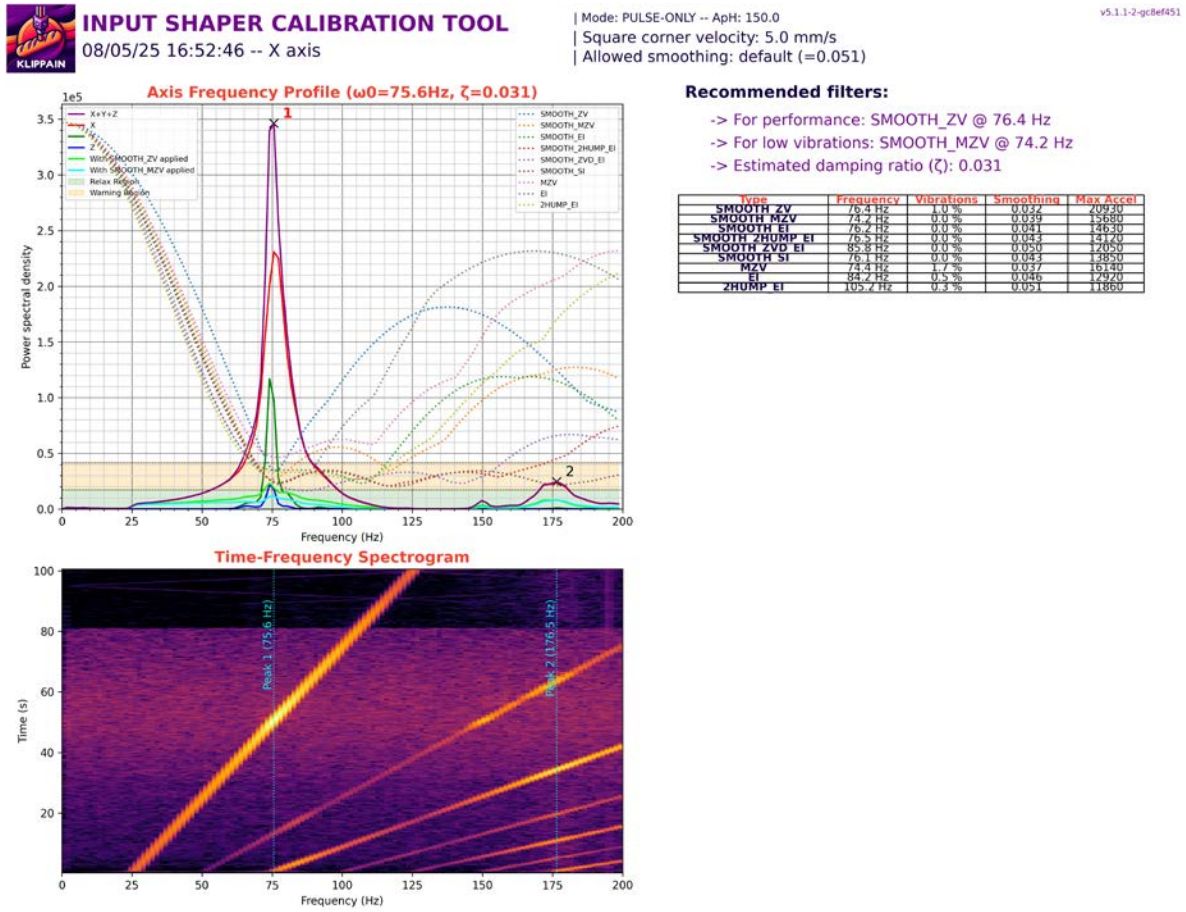
Toolhead screws hitting x-linear rail carriage (MxBrnr)

Before replacing screws



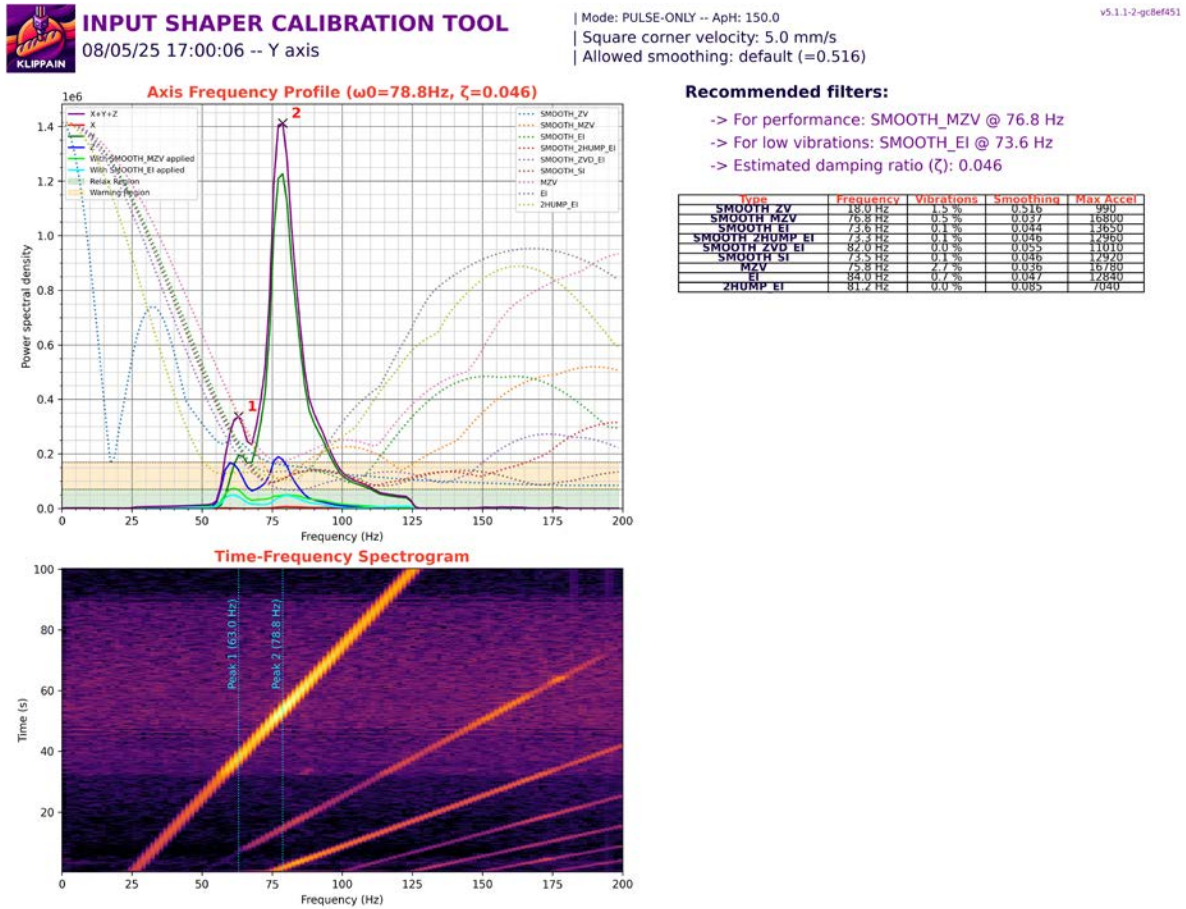
Type	Frequency	Vibrations	Smoothing	Max Accel
SMOOTH_ZV	21.8 Hz	0.8 %	0.357	1010
SMOOTH_MZV	21.2 Hz	1.1 %	0.469	1190
SMOOTH_EI	24.4 Hz	0.9 %	0.400	1470
SMOOTH_2HUMP_EI	73.9 Hz	0.6 %	0.046	12170
SMOOTH_ZVD_EI	75.2 Hz	0.5 %	0.065	9260
SMOOTH_SI	68.3 Hz	0.4 %	0.054	11160
MZV	116.8 Hz	5.9 %	0.015	39810
EI	149.8 Hz	7.1 %	0.017	40870
2HUMP_EI	143.8 Hz	2.4 %	0.029	22120

After replacing screws



Type	Frequency	Vibrations	Smoothing	Max Accel
SMOOTH_ZV	76.4 Hz	1.0 %	0.032	20930
SMOOTH_MZV	74.2 Hz	0.0 %	0.039	15680
SMOOTH_EI	76.2 Hz	0.0 %	0.041	14630
SMOOTH_2HUMP_EI	76.5 Hz	0.0 %	0.043	14170
SMOOTH_ZVD_EI	85.8 Hz	0.0 %	0.050	12050
SMOOTH_SI	76.1 Hz	0.0 %	0.043	13850
MZV	74.4 Hz	1.7 %	0.037	16140
EI	94.2 Hz	0.3 %	0.046	12920
2HUMP_EI	105.2 Hz	0.3 %	0.051	11860

Toolhead screws hitting x-linear rail carriage (MxBrnr)



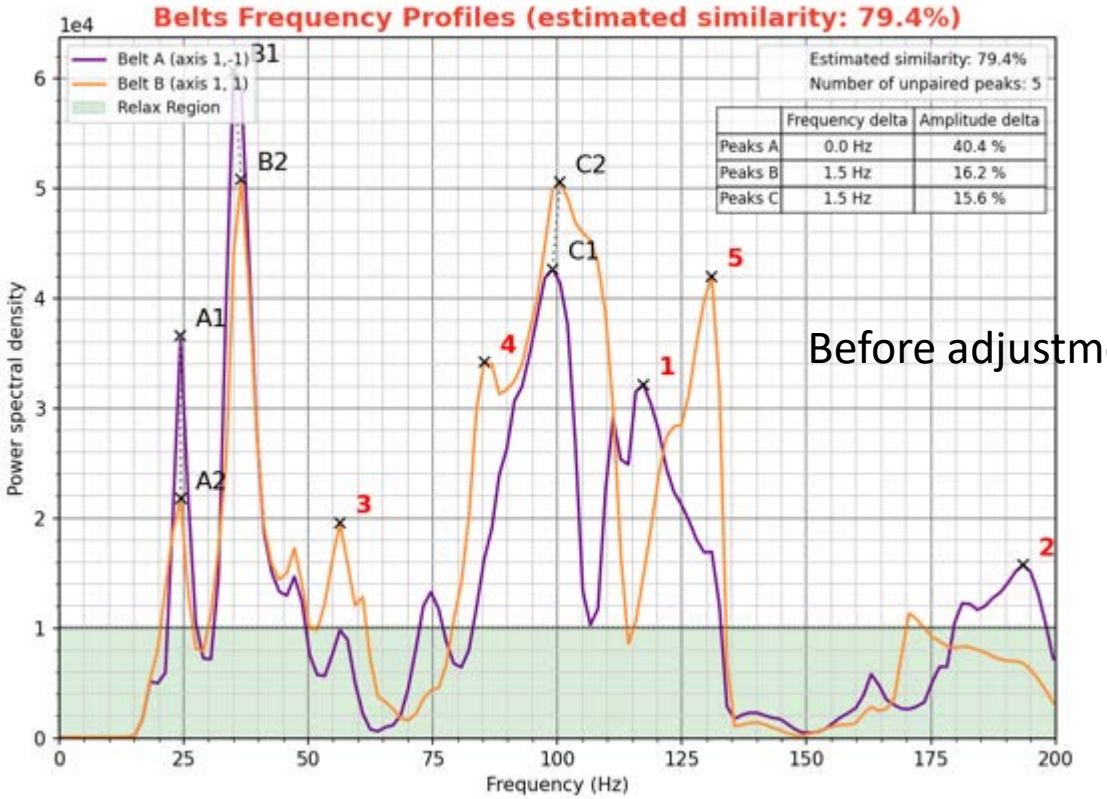
Type	Frequency	Vibrations	Smoothing	Max Accel
SMOOTH_ZV	18.0 Hz	1.5 %	0.516	990
SMOOTH_MZV	76.8 Hz	0.5 %	0.037	16800
SMOOTH_EI	73.6 Hz	0.1 %	0.044	13650
SMOOTH_2HUMP_EI	73.3 Hz	0.1 %	0.046	12960
SMOOTH_ZVD_EI	82.0 Hz	0.0 %	0.055	11010
SMOOTH_SI	73.5 Hz	0.1 %	0.046	12920
MZV	75.8 Hz	2.7 %	0.036	16780
EI	84.0 Hz	0.7 %	0.047	12840
2HUMP_EI	81.2 Hz	0.0 %	0.085	7040

Y-axis after, before it looked very similar

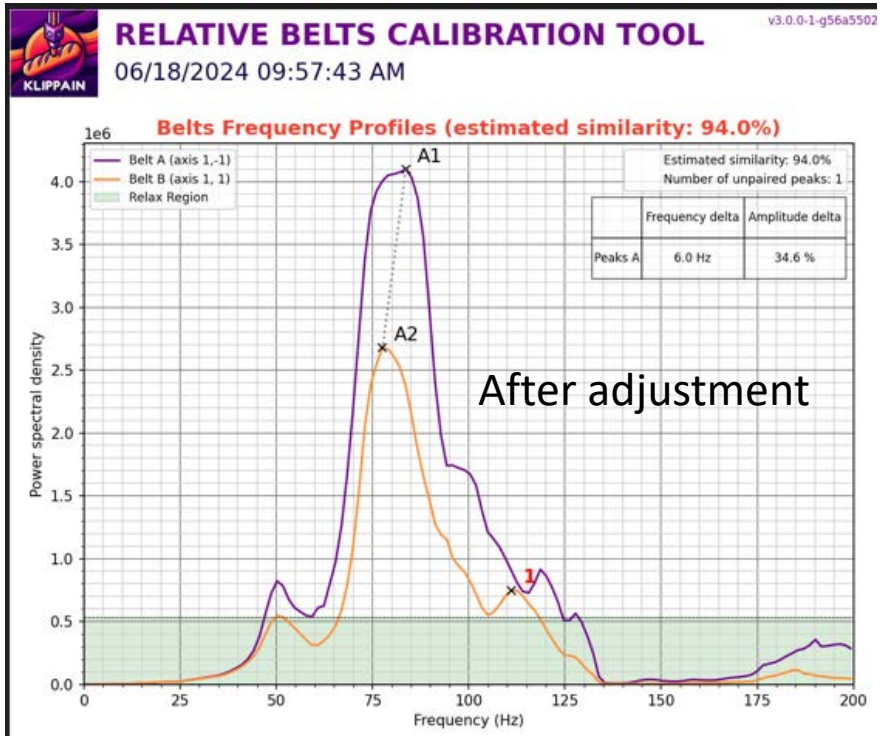
StealthChanger - specific

- Thank you to all the folks at Draft Shift Design (DSD) for their help in bringing this to the communities attention.
- Thank you

StealthChanger – Tap Screws



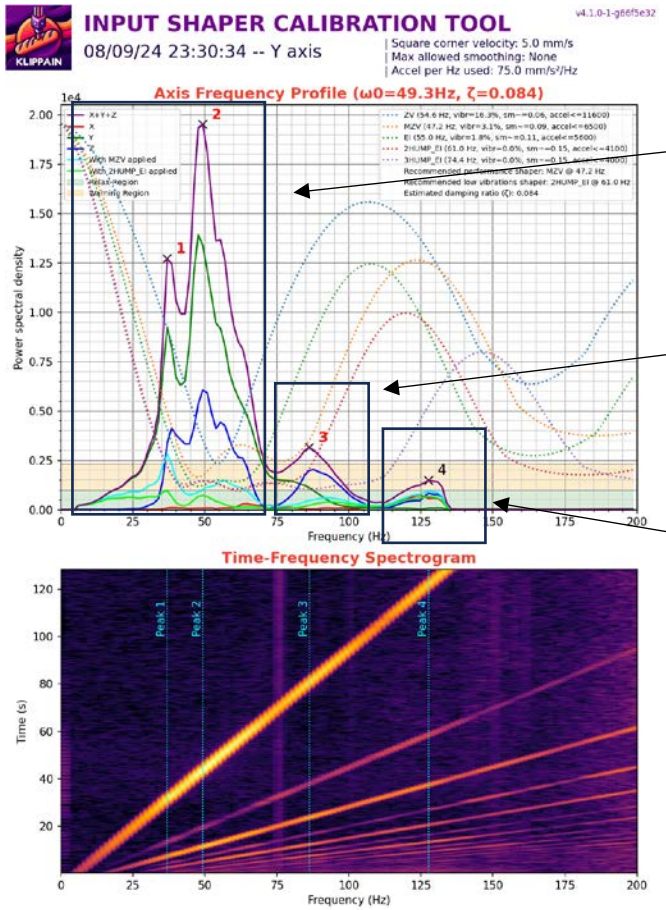
Before adjustment



After adjustment

Data by B*ttSlark:
belts show issue with the tap preload screws (screws connected to tap magnets)
Use the paper test to adjust preload screws to correct length

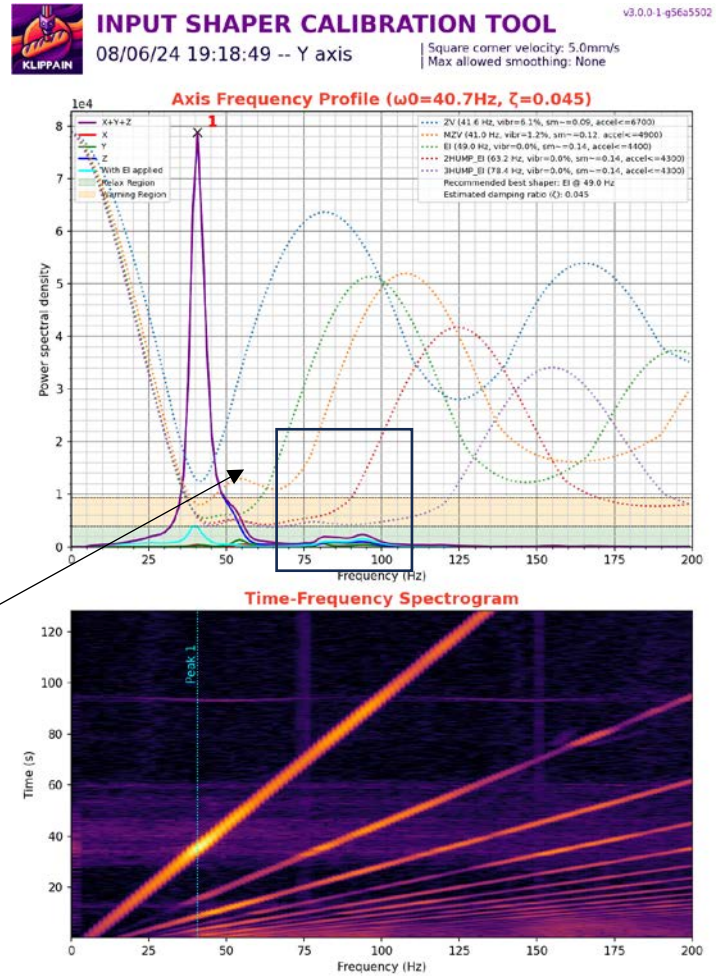
StealthChanger – specific issues



Optional junk you may or may not see with issues with the preload screws

Stealthchanger tap preload screws (attach to tap magnets)

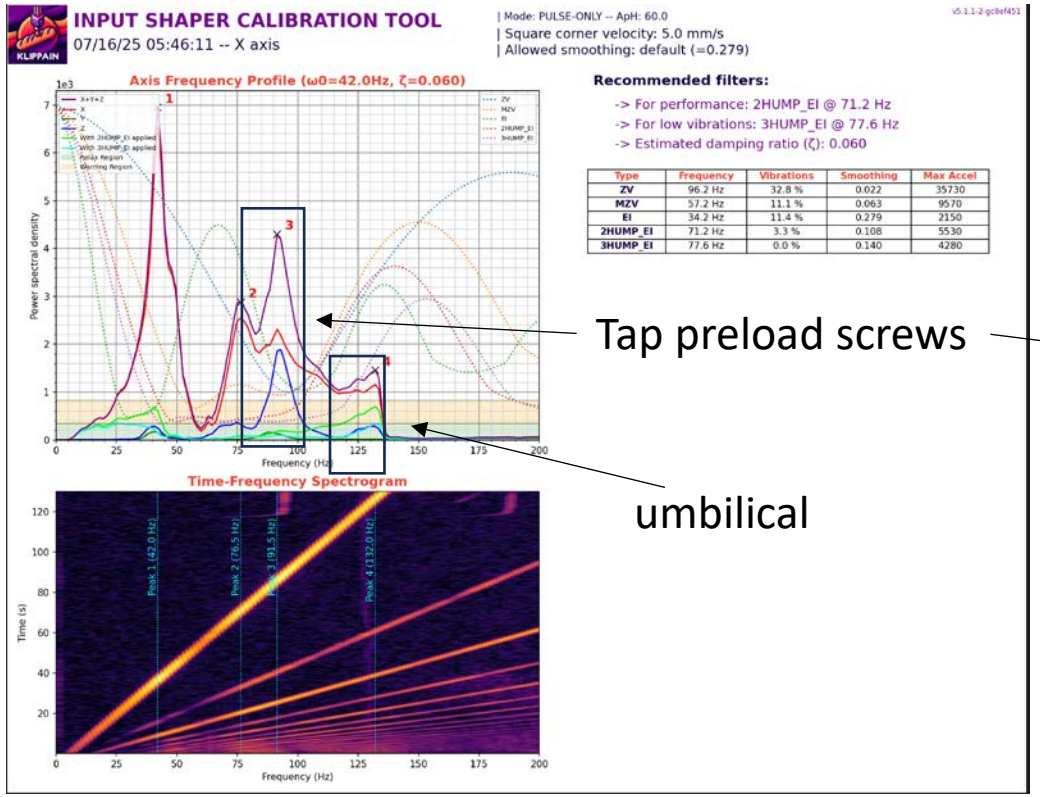
Mainly the umbilical



Stealthchanger tap preload screws
This is tiny and probably should not worry about it

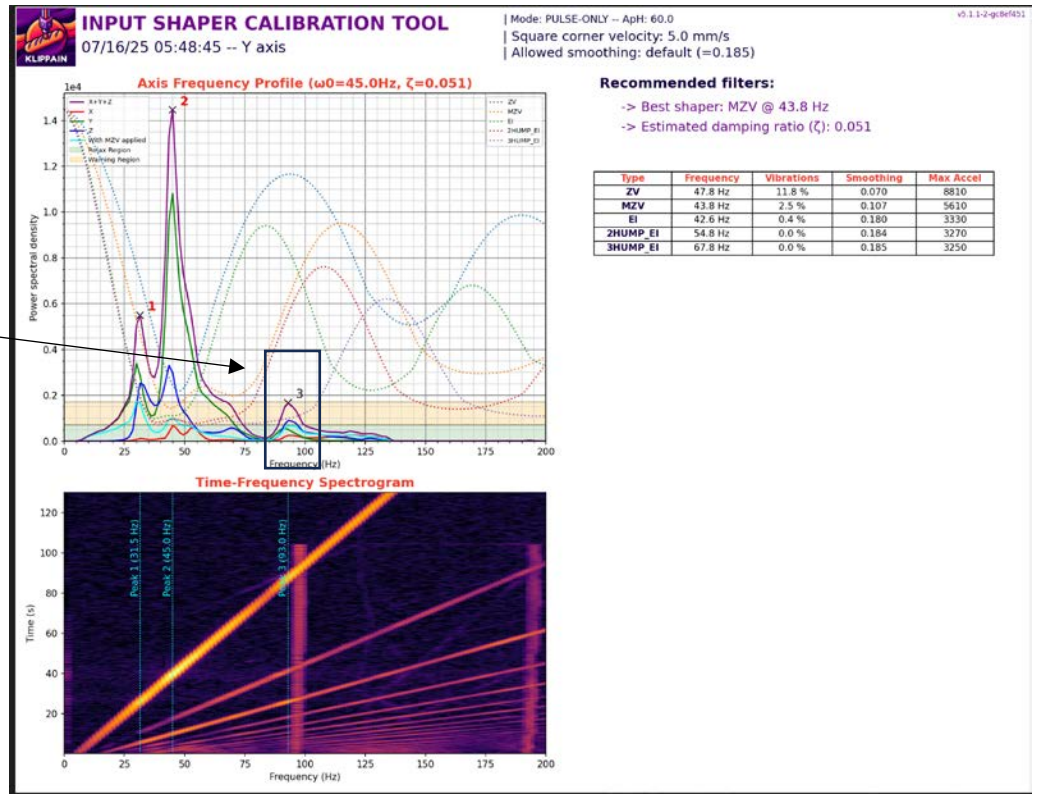
Data by Broncosis

StealthChanger – specific issues



Tap preload screws

umbilical



The rest of the junk on the graph is likely/probably due to the tap preload screws not be secured enough to the tap magnets