Construction of a high-speed extrusion-based 3D printer

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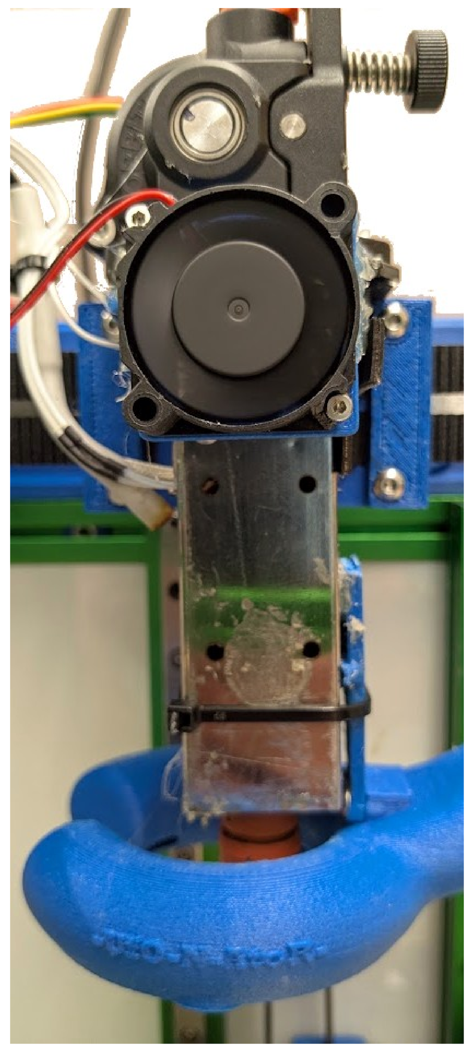
Abstract

*Maximizing speed of an extrusion-based 3D printer depends on tuning the **extrusion**, **cooling**, and **motion systems**.*

Extrusion system – easy

Fast printing requires a high flow rate for plastic being extruded from the nozzle. Increasing the length of the melt chamber feeding the nozzle gives the heating element more time to liquefy the plastic for extrusion. To control the extrusion rate, a motor directly drives plastic filament into the top of the melt chamber.



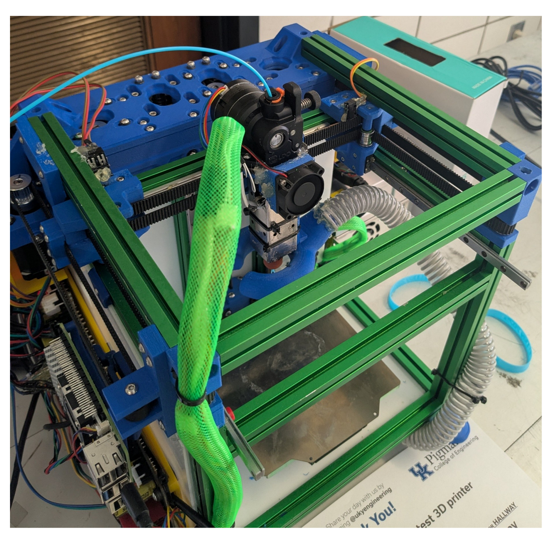
Cooling system – easy

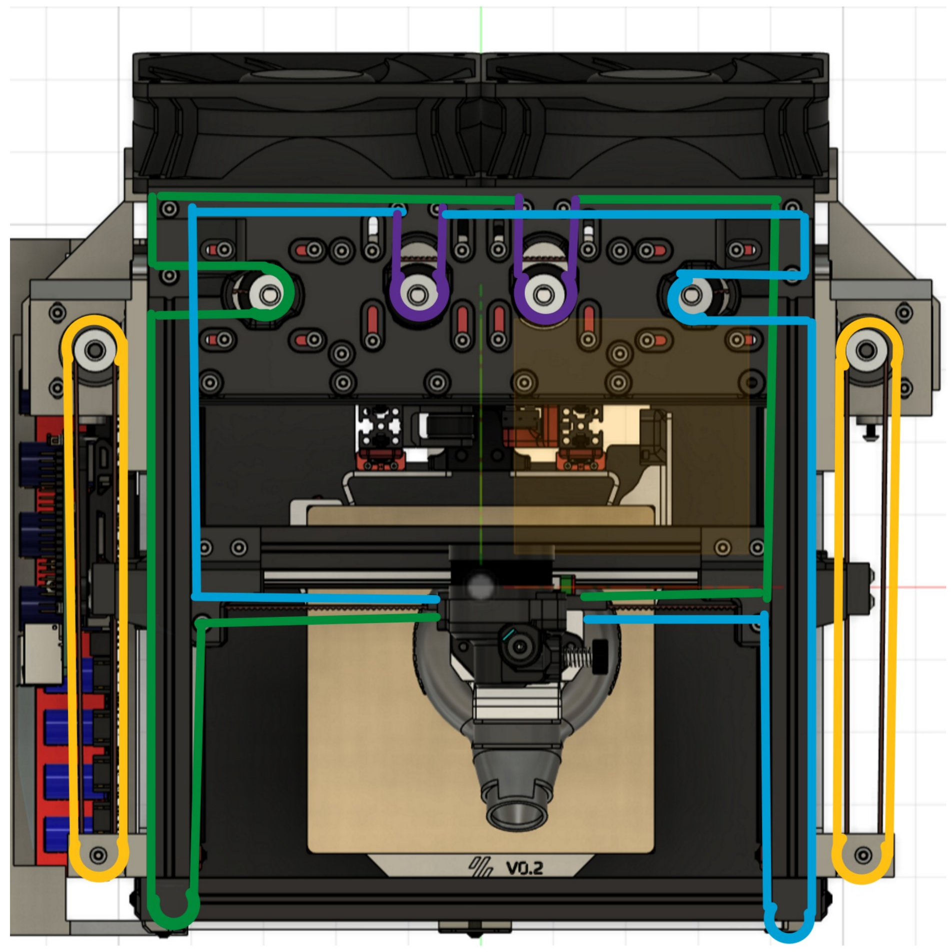
An extruded line of plastic takes some time to cool and harden. If additional material is extruded too quickly, the printed shape will deform. To speed cooling, a high-volume blower directs air through tubing and ducts precisely at the fresh extrusion.

Motion system – hard!

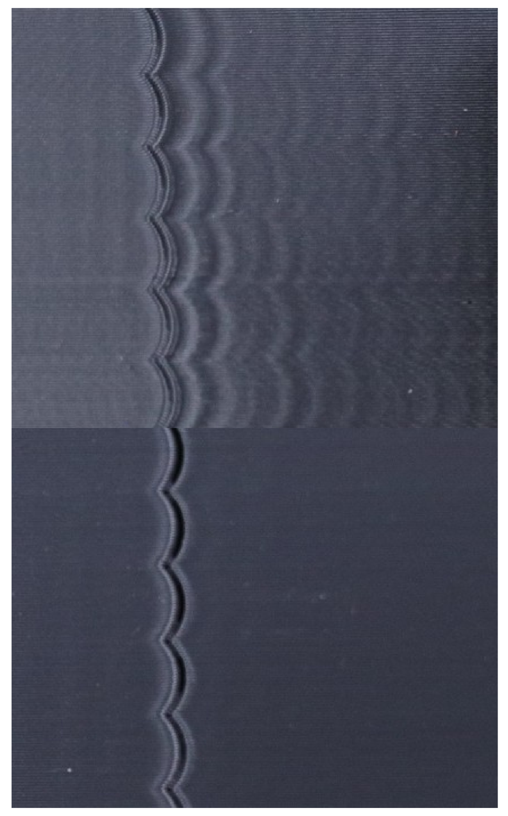
The motion control system must be able to precisely control the position of the nozzle during each extrusion. With air flow routed so that the cooling system blower does not need to move with the nozzle, a direct-drive extrusion system with a long melt chamber unfortunately still has significant mass. It takes strong drive motors to quickly move that mass, and the vibrational modes of the mass can cause errors in the time-varying position of the nozzle that result in prints with ringing artifacts.

To better understand how to minimize positioning errors while maximizing speed, **we created a printer that easily can be switched between four versions of CoreXY kinematics.** Using layer-based extrusion orders, Z motions are small and rarely problematic. CoreXY provides direct support for X axis travel, so vibration is mechanically constrained. Thus, resonance on the Y axis is the primary issue.





No Input Shaper



Input shaper

CoreXY (in figure above: blue, green)

A traditional Core XY system has two motors, where each motor moves the print head to either the left or right corner, using the motors in combination allows the printhead to move anywhere on the desired plane.

4WD Core XY (blue, green, purple)

Works like a traditional CoreXY system but uses four motors (4 wheel drive) instead of two to drive the X and Y axis, this provides more total power evenly distributed across both axis.

Extended Core XY (blue, green, yellow)

4 motors are used, 2 drive a traditional Core XY system while the other 2 drive only the Y-axis. This helps counter the weight of the X-beam which is the main limiting factor for speed in a traditional core XY system.

Extended 4WD Core XY (blue, green, yellow, purple)

A combination of both 4WD Core XY and Extended CoreXY allows for more total power in the motion system while also better constraining the printhead.

How to read Input shaping graphs

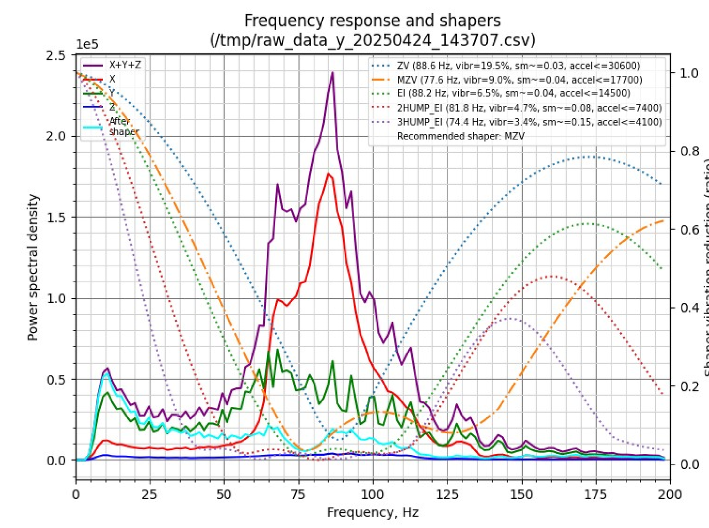
X-Axis (***Frequency***, Hz): Shows vibration frequencies measured during the test.

Y-Axis (left, ***Power Spectral Density***, PSD): Measures the strength of vibrations at each frequency. A higher peak means stronger resonance at that frequency.

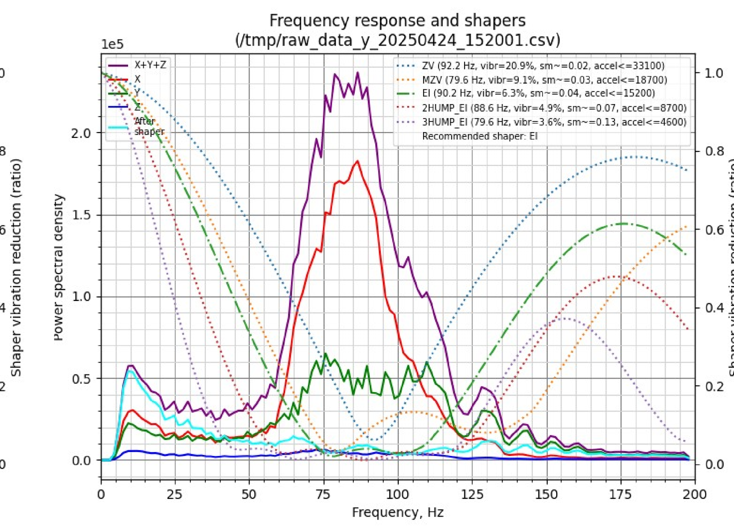
Y-Axis (right, ***Shaper Vibration Reduction Ratio***): Shows how effective a given shaper is at reducing vibrations at each frequency.

Input Shaping Graphs

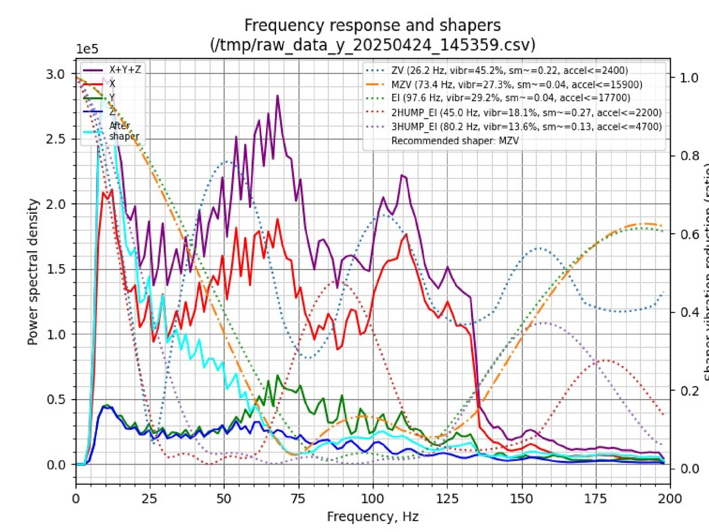
CoreXY



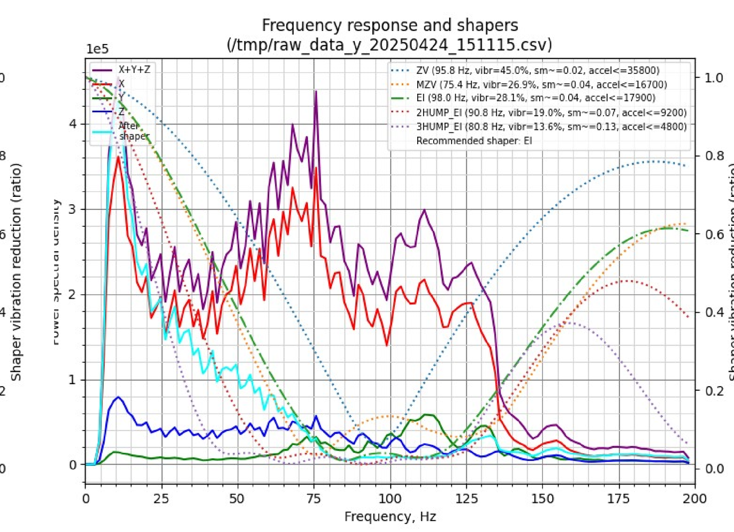
4WD CoreXY



Extended CoreXY



Extended 4WD



	• VZ	• MVZ	• EI	• 2Hump_EI	• 3Hump_EI
• 1	• 30600	• 17700	• 14500	• 7400	• 4100
• 2	• 33100	• 18700	• 15200	• 8700	• 4600
• 3	• 2400	• 15900	• 17700	• 2200	• 4700
• 4	• 35800	• 16700	• 17900	• 9200	• 4800

Analysis

Focusing on the solid green line (Y-axis resonance), all four graphs have a similar PSD (note the different scale of the graphs). The light blue line shows the PSD after using the recommended input shaping profile.

The table shows recommended accelerations for different input shaping profiles. While each profile is best for certain frequencies, basing results on the recommended profile will be the most beneficial. Highlighted will give the best print quality.

The **Extended 4WD CoreXY has the highest recommended acceleration**, thus, it is the best motion system for achieving good quality at high print speeds.