1. Theoretical Framework and System Control

1.1. Delta Kinematics: Parallel Robotics and Spatial Dynamics

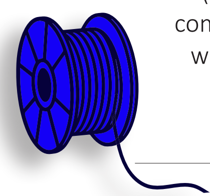
The ALT01d One operates on a Parallel Kinematic System (PKS), a design inspired by high-speed industrial robotics. Unlike “normal” (Cartesian) printers where each motor moves a single axis (X, Y, or Z) in a linear fashion, a Delta printer utilizes three vertical towers working in perfect synchronicity to position the end-effector.

Why Delta architecture is superior to “normal” Cartesian printers:

- Massive Reduction in Inertia: In a standard printer, the motors must move the heavy weight of the print bed or the entire X-axis gantry. In a Delta system, the heavy stepper motors are stationary on the frame. The only moving parts are the lightweight rods and the effector. This allows for extreme accelerations (4000 mm/s²) without losing precision.
- Fixed Print Bed: Because the bed never moves, there is no risk of the model “wobbling” or falling off due to rapid back-and-forth movements (a common issue called “bed slinging”). This results in much higher reliability for tall, thin prints.
- Superior Z-Axis Speed: To move vertically, a Delta printer uses all three motors simultaneously. This makes Z-axis travel just as fast as X and Y travel, whereas Cartesian printers are often limited by slow lead screws.
- Consistency: The symmetry of the three towers ensures that the mechanical forces are distributed evenly, leading to high-quality surface finishes and excellent reproduction of curved geometries.

1.2. The Mainsail Ecosystem: Distributed Control and Interface

The “brain” of the ALT01d One is managed through Mainsail, a high-performance web interface that serves as the primary Command and Control (C2) center for the Klipper firmware. It functions via a distributed computing model where a Raspberry Pi handles the heavy logic while the MCU executes the precise electrical pulses.



1.3. Real-Time Telemetry and Monitoring

Mainsail transforms the raw data of the printer into an industrial-grade dashboard for precise monitoring:

- Thermal Dynamics: It provides live, high-resolution telemetry for the PID (Proportional-Integral-Derivative) control loops. Users can monitor the stability of the nozzle and bed temperatures through interactive graphs, ensuring the material is extruded at a constant thermal state for perfect layer bonding.
- Kinematic Feedback: The interface tracks the effector’s spatial coordinates (X,Y,Z) and instantaneous velocity in real-time. This allows the operator to verify that the synchronized tower movements are executing correctly during high-speed operations.
- Hardware Health: It monitors CPU load, memory usage, and internal temperatures of both the Raspberry Pi and the BigTreeTech SKR Pico, ensuring the system never reaches a thermal or processing bottleneck.

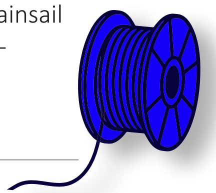
1.4. Advanced Operational Control and Diagnostics

Mainsail empowers the user with granular control that is impossible on standard “screen-only” printers:

- Bilinear Bed Mesh Mapping: Through the integrated Bed Mesh Visualizer, the system generates a 3D topographic map of the print surface based on a 9x9 probe grid. Klipper uses this map to subtly adjust the Z height in real-time, compensating for microscopic bed variances.
- On-the-Fly Adjustments: A critical advantage is the ability to adjust the Z-Offset, flow rate, and speed “live” during the first layer. This allows the user to fine-tune the “squish” of the plastic for perfect adhesion without restarting the print.
- G-Code Manager and Visualizer: Users can upload files wirelessly and use the built-in visualizer to inspect toolpaths layer-by-layer before the physical motors ever move, serving as a vital safety check for complex prints.

1.5. Conclusion of Software Synergy

By combining the high-speed mechanical advantages of Delta kinematics with the advanced processing power of the Klipper/Mainsail stack, the ALT01d One transcends the limitations of hobbyist-grade machines. It utilizes algorithms like Input Shaping to



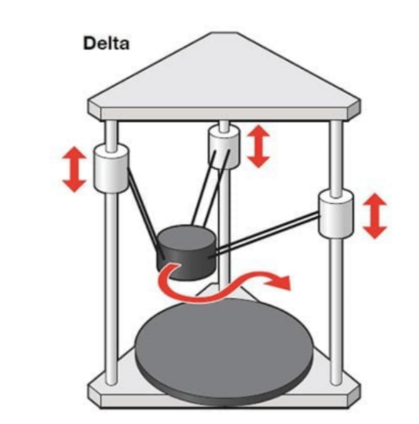
cancel out vibrations and Pressure Advance to control plastic flow, resulting in industrial-grade parts produced at speeds that traditional printers simply cannot match.

2. Hardware

2.1. Architectural Concept and Structural Framework

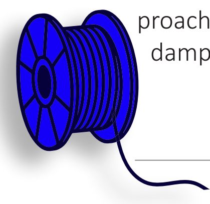
The ALT01d One is a high-performance 3D printer based on a Delta (Parallel Kinematic) architecture. It redefines the entry-level segment by implementing sophisticated mechanical engineering solutions usually reserved for industrial-grade machines. The operational envelope is characterized by a “dome” or “mushroom” volume, featuring a 150 mm base diameter and a 200 mm peak vertical reach.

The system is designed with a modular and scalable topology. While the current iteration is optimized for a compact footprint, the structural design allows for the extension of vertical profiles and diagonal linkages. This enables a significant increase in the build volume without necessitating the redesign of structural nodes or the linear motion assembly.



2.2. Materials Engineering: The Hybrid Chassis

The frame of the ALT01d One utilizes a strategic multi-material approach to balance structural rigidity, low inertial mass, and vibration damping.



2.2.1. Acoustic Damping via Wood Substrate

In contrast to traditional metallic frames that act as resonators for motor frequencies, the ALT01d utilizes 24 cm wooden base plates. This organic substrate provides:

- Acoustic Insulation: It effectively absorbs high-frequency micro-vibrations generated by the NEMA 11 stepper motors.
- Mass Stability: The intrinsic density of the wood anchors the machine to the workspace, providing a stable center of gravity that prevents “frame walking” during high-acceleration maneuvers.

2.2.2. Vertical Support Columns (Structural Reinforcement

The defining element of the ALT01d One’s structural integrity is its vertical reinforcement system. Each of the three towers is stabilized by a dual-column aluminum tube configuration.

- Compressive Spine: These tubes manage the mechanical compression stress between the top nodes (motor mounts) and the base nodes.
- Torsional Rigidity: The parallel dual-tube design eliminates lateral twisting and structural bowing under the high tension of the GT2 drive belts.
- Z-Axis Scalability: These columns serve as the primary interchangeable component for scaling the build volume on the Z-axis, allowing the “One” to be extended vertically while maintaining geometric fidelity.

2.2.3. Precision Guidance Rails (13x13 mm Aluminum Profiles)

Separate from the structural support tubes, the motion system utilizes 13x13 mm square aluminum profiles. These serve exclusively as the linear guidance pathways for the carriages. The anodized finish provides a high-surface hardness resistant to frictional wear, ensuring long-term verticality.

2.2.4. High-Temperature Structural Nodes (ABS/PETG)

The critical junctions connecting the wooden base to the aluminum extrusions are fabricated from high-performance polymers (ABS/PETG). These nodes are engineered to withstand the thermal radiation of the motors, preventing creep or deformation that would otherwise compromise tower alignment

2.3. Motion System: Ball-Joint Kinematics and Aluminum Linkages

The ALT01d One excels in mechanical precision by replacing traditional printed hinges with professional-grade articulated joints.

2.3.1. Aluminum Linkage Rods

The diagonal arms supporting the end-effector are constructed from high-strength aluminum tubing.

- Thermal Expansion Matching: Using aluminum for both the frame and the linkages ensures a uniform thermal expansion coefficient across the machine, maintaining calibration during long prints in varying ambient temperatures.
- Structural Durability: Unlike carbon fiber rods, which may suffer from delamination at the glue points under cyclic stress, aluminum linkages offer superior fatigue resistance.

2.3.2. Professional Ball-Joint Articulation

The system implements professional-grade spherical joints, a significant upgrade over DIY-style printed joints.

- Zero Backlash (No Slop): These joints facilitate fluid multi-axis rotation without mechanical play.
- Direct Force Transmission: Mounted directly to the carriages, they ensure that the kinetic energy from the belts is transmitted instantaneously to the effector with zero hysteresis.

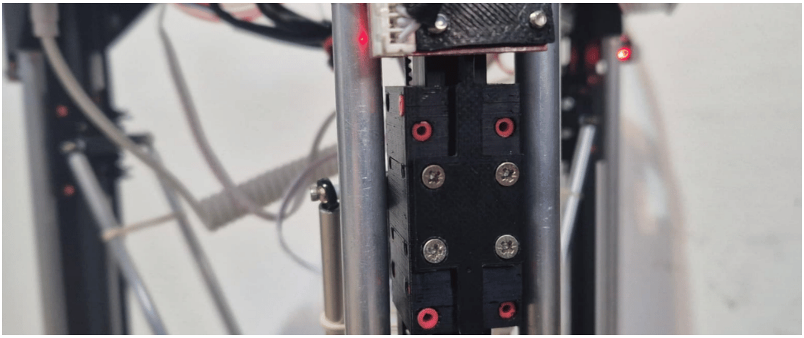
2.3.3. Anti-Backlash Pre-Tensioning

The rod pairs are grouped and connected via a precision elastic tensioning system. This maintains a constant pre-load on the ball joints within their sockets, effectively neutralizing mechanical backlash and ensuring sub-millimeter positioning accuracy.

2.4. “Low-Friction” PTFE Linear Motion Technology

To minimize maintenance and reduce the costs associated with recirculating ball bearings, the ALT01d utilizes a custom Low-Friction guidance system:

- PTFE (Teflon) Inserts: The printed carriage “wraps” around the 13x13 mm aluminum profile, utilizing 4 mm PTFE tube segments as the contact interface.
- Dry-Lubrication: The Teflon-on-aluminum interface provides an exceptionally low coefficient of friction, allowing for rapid movements of up to 540 mm/s.
- Acoustic Signature: This system eliminates the metallic noise inherent in steel-ball linear rails, resulting in near-silent operation.



2.5. Propulsion and Transmission Topology

- NEMA 11 Stepper Motors: Strategically located at the apex of the frame, these motors drive the GT2 timing belts. This top-mounted configuration reduces the moving mass of the effector and isolates the motors from the thermal radiation of the heated bed.
- GT2 Drive System: High-precision belts transmit motion from the motor pulleys to the carriages. Tension is managed at the base via adjustable idler pulleys equipped with dual ball bearings for minimal resistance.

2.6. Thermal Substrate and Operational Envelope

- Heated Bed: A circular 150 mm diameter thermal substrate.
- “Mushroom” Volume Geometry: The build volume is a 200 mm high cylinder with a curved hemispherical top. This geometry is a function of the Delta linkage limits: as the effector reaches the radial extremes, the angle of the aluminum arms constrains the maximum Z-height, resulting in the characteristic curved operational profile.

3. Software Architecture

3.1. Klipper Firmware Ecosystem

The ALT01d One utilizes Klipper, a high-performance 3D printer firmware known for its unique distributed computing architecture. Unlike traditional firmware that performs all calculations on a 3-bit or 32-bit microcontroller (MCU), Klipper delegates heavy mathematical computations specifically Delta Kinematics transformations to a host computer, in this case, a Raspberry Pi.

The Raspberry Pi processes the G-code and calculates the precise timing of stepper pulses, which are then transmitted to the BigTreeTech SKR Pico MCU for execution. This separation of concerns allows the ALT01d One to achieve significantly higher step rates and smoother motion profiles without the risk of "processing bottlenecks" common in standalone MCUs.

3.2. Technical Configuration (printer.cfg)

The system's behavior is governed by the printer.cfg file, allowing for real-time adjustments without the need for firmware recompilation. Key delta-specific parameters include:

- L (Arm Length): The precise physical length of the diagonal aluminium Rods.
- Delta Radius: The horizontal distance from the center of the effector to the center of the towers when the effector is at [0, 0]
- Angle Adjustments: Fine-tuning the 120° positioning of the towers to compensate for structural tolerances.

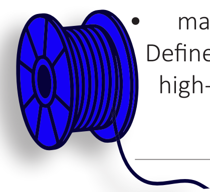
Section Definitions: The kinematic limits define the operational envelope and safety margins of the machine:

- kinematics: delta

Invokes the specialized delta transformation matrix. Every move in the Cartesian space (X, Y, Z) is translated into synchronized movements across the three vertical towers (A, B, and C).

- max_velocity: 300 mm/s

The theoretical upper bound for XY travel moves. While actual print speeds depend on material flow, this high limit showcases the agility of the lightweight delta effector.



- max_accel: 3000 mm/s²

Defines the rate of velocity change. This value is optimized to balance high-speed direction changes with the structural damping of the frame, minimizing mechanical resonance (ringing).

- max_z_velocity: 300 mm/s

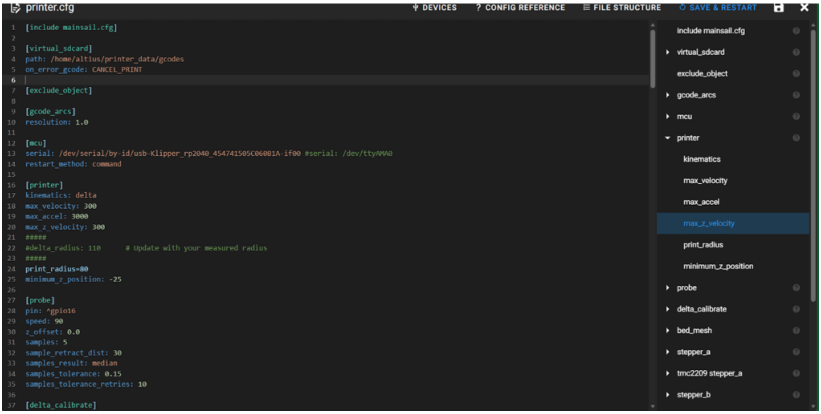
In delta printers, vertical movement utilizes all three stepper motors simultaneously, allowing Z travel speeds to match XY speeds—a major advantage over Cartesian "lead-screw" systems.

- print_radius: 80 mm

Defines the cylindrical reach of the effector, resulting in a 160 mm total build diameter.

- minimum_z_position:-25 mm

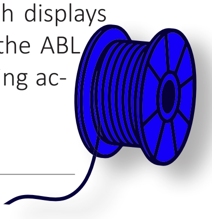
Provides the necessary "headroom" below the zero-plane for the Auto Bed Leveling (ABL) routine and Z-offset calibration.

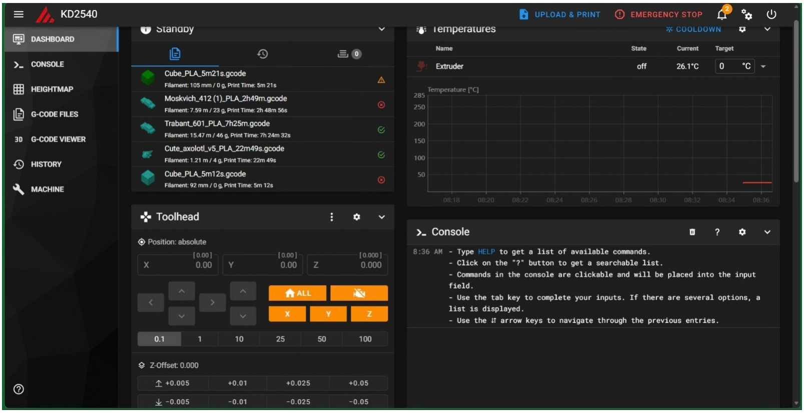


3.3. Mainsail: The Web Interface and OS

Mainsail serves as the primary operating interface for the ALT01d One. It is a lightweight, responsive web-based GUI (Graphical User Interface) that communicates with Klipper via the Moonraker API.

- Real-time Monitoring: Provides live telemetry for nozzle and bed temperatures through PID-tuned graphs, as well as effector positioning and print progress.
- Dynamic Control: Users can adjust feed rates, flow percentages, and Z-offsets "on the fly" during the first layer for perfect adhesion.
- G-Code Visualization: Includes a built-in file manager for G-code uploads and a visualizer to inspect toolpaths before execution.
- Diagnostic Tools: Integrates the Bed Mesh visualizer, which displays a 3D topographic map of the print surface generated by the ABL system, ensuring the user can verify bed flatness and leveling accuracy.

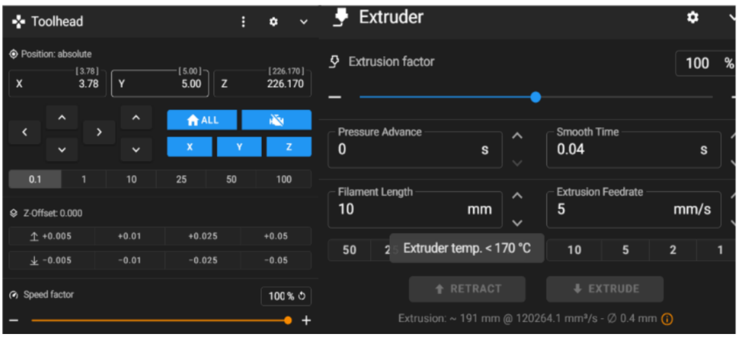


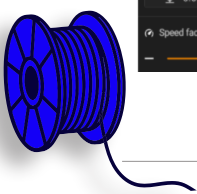


3.4. Motion Control and Advanced Features

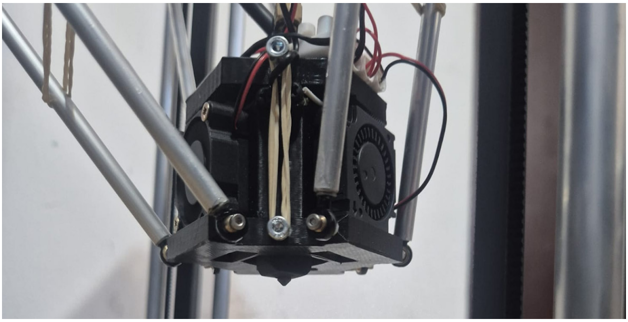
The integration of Klipper on the SKR Pico allows the ALT01d One to utilize advanced motion algorithms that are typically too computationally expensive for standard firmware:

- Pressure Advance: Predicts the pressure build-up inside the hotend to reduce oozing during decelerations and under-extrusion during accelerations.
- Input Shaping: (Optional implementation) Uses frequency measurements to cancel out mechanical vibrations, allowing for even higher accelerations without sacrificing surface quality.
- Closed-Loop Thermal Control: The PID algorithm ensures that the 24V heater cartridge maintains thermal equilibrium, which is critical for consistent extrusion widths and structural integrity of the printed layers.





4. The Toolhead (Print Head)



4.1. Concept and Modular Architecture

The toolhead of the ALT01d One is the central mobile assembly of the delta system. In delta kinematics, the effector's mass is critical; a lightweight head allows for higher accelerations and reduces vibrations that cause "ghosting." To balance performance with maintenance, the toolhead features a modular design split into two parts:

- The Effector Base: Connects directly to the six diagonal arms. It ensures structural rigidity and precise kinematic alignment.
- The Lift Module: A detachable unit containing the hotend, extruder, and electrical components. This allows for rapid servicing or hotend swaps without disturbing the arm geometry.

4.2. Direct Drive Extrusion

The ALT01d One utilizes a Direct Drive system integrated into the toolhead. By mounting the extrusion motor directly above the hotend, the filament path is significantly shortened compared to Bowden systems.

- Precision: Provides immediate response to extrusion and retraction commands.
- Material Versatility: Specifically designed to handle flexible filaments (like TPU) and high-speed printing with minimal risk of buckling or slipping.
- Stringing Control: The proximity of the drive gears to the melt zone allows for very short retraction distances, effectively eliminating stringing and oozing.

4.3. Hotend and Thermal Management

The hotend is designed for high-performance thermal stability, operating at 24V and controlled via Klipper firmware

- PID Calibration: Uses a Proportional-Integral-Derivative algorithm to maintain a constant temperature with minimal fluctuation, ensuring a uniform flow rate.
- Specifications: Supports a maximum temperature of 275°C, a standard 0.4 mm nozzle, and 1.75 mm filament.
- Reliability: The heat break is specifically engineered to maintain a sharp thermal transition between the melting zone and the cold section.

4.4. Triple-Fan Cooling System

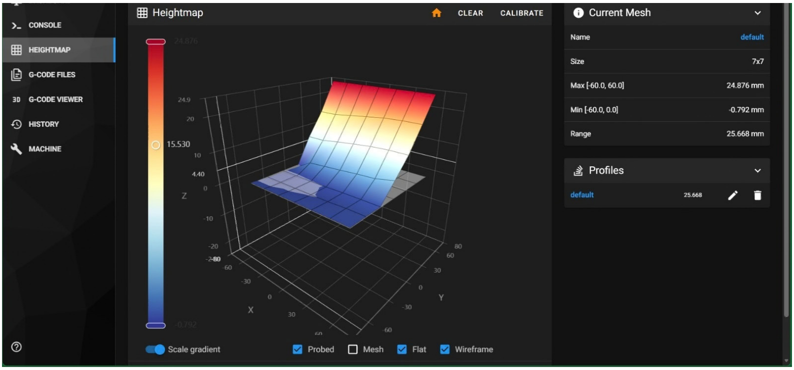
Thermal control is managed by a specialized three-fan configuration:

- Heat Sink Fan (1 unit): Automatically activates when the hotend exceeds 50°C. Its sole purpose is to cool the "cold side" of the toolhead to prevent "heat creep" and subsequent nozzle jams.
- Part Cooling Fans (2 units): These high-static-pressure fans are positioned to provide symmetrical airflow to the printed part. By rapidly solidifying the plastic as it leaves the nozzle, they prevent stringing and enable the printing of complex bridges and steep overhangs. The airflow is ducted to avoid cooling the heater block, which would otherwise cause thermal instability.

4.5. Integrated Auto Bed Leveling (ABL)

The toolhead functions as its own Z-probe through a mechanical-electrical system.

- Mechanism: The effector utilizes three electrical contacts held in place by precision elastics.
- Detection: Under normal conditions, the circuit is closed. When the nozzle physically touches the print bed, the slight upward force opens the contacts and breaks the circuit.
- Accuracy: Klipper registers this break as a precise coordinate. By probing multiple points, the system creates a digital map of the bed surface, allowing the printer to compensate for any tilt or warping automatically. This eliminates the need for heavy, external inductive or optical sensors.



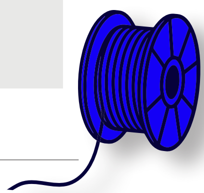
5. How to print with OrcaSlicer

5.1. Selecting the Base Profile

- In OrcaSlicer, follow these steps to "borrow" the FLSun settings:
- Go to Printer Settings-> click on the settings icon (the gear wheel).
- In the list of predefined printers, look for FLSun.
- Select FLSun SR (Super Racer) or FLSun Q5. (These are the closest to your dimensions.)
- After it loads, press the Save As button (floppy disk with a pencil) and rename it: ALT01d One.

5.2. Editing Parameters (Customization)

Now that you have the Delta profile activated, you need to enter the exact dimensions of your project:



5.2.1. Tab: Basic Information

- Printer Type: Make sure it stays on Delta.
- Bed Shape: Circular.
- Printable Area (Diameter): Change the value to 150 mm (for your radius of 7.5 cm).
- Printable Height: Change the value to 200 mm.
- Origin: Must be 0,0 (center of the circle).

5.2.2. Tab: Machine Ability (Speeds and Accelerations)

- Since you replaced the carbon with aluminum arms and installed ball joints, your printer is more rigid, but has a slightly larger arm mass than a standard FLSun.
- Max Velocity: Set 400- 500 mm/s (the limit of your Teflon slides).
- Max Acceleration: Set 3000 mm/s^2 to start. If the structure with double vertical tubes is very rigid, you can go up to 5000 mm/s^2.

5.2.3. Tab: Extruder

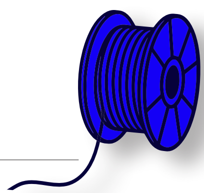
- Retraction Length: Since the NEMA 11 motors are on top (Bowden), set 5 mm.
- Retraction Speed: 45- 50 mm/s.
- Nozzle Diameter: 0.4 mm.

5.3. Why is it better to start from FLSun?

- By selecting an FLSun model, OrcaSlicer automatically enables some hidden settings that are vital for you:
- Delta Geometry: The software knows that Z movement is done by the simultaneous movement of the 3 slides on the 13x13 mm profiles.
- Circular Bed Mesh: The bed leveling algorithm will generate probing points in a circle, not a square, avoiding corners where the print head cannot physically reach.
- Endstop Logic: Deltas always “Home” at the top, towards the motors, not down on the bed.

6. Prices and materials used

Component Category	Details	Estimated Cost (EUR)
Metal Structure	Square profiles (3 pcs) and round tubes (6 pcs)	24
Motion System	NEMA 11 motors (4 pcs), GT2 belts and pulleys	25
Control Electronics	Raspberry Pi 3 and SKR Pico MCU	47
User Interface	Touch LCD	10
Power Source	24V / 300W Power Supply	8
Extrusion System	Hotend (BambuLab type) and Heated Bed	20
3D Components (BOM)	Set of printed parts (ABS/PETG)	10
Sensors and Wiring	Endstops, ABL sensors and electrical wires	10
Consumables/Misc	PTFE tube, fans, screws	11
TOTAL GENERAL		175 EUR



Part ID	Component Name	Qty (pcs)	Functional Description
a_frame	Lower Corner	3	Anchors the wooden base to the vertical aluminum support columns.
b_frame	Motor Corner	3	High-load mounts for the NEMA 11 stepper motors at the apex.
c_frame	Inner Corner	6	Structural gussets providing internal tower rigidity.
d_endstop	Holder	3	Stationary mount for the optical endstop sensors.
e_endstop	Mobile Sensor	3	Actuation flag mounted to the linear slider for position sensing.
f_linear	Carriage	3	Main slider body containing the PTFE low-friction inserts.
g_carriage	Adapter	3	Mechanical interface between the slider and the spherical joints.
h_belt	Tension Base	3	Static housing for the belt tensioning mechanism at the base.
i_belt	Tension Lift	3	Moving carriage for dynamic GT2 belt adjustment.
j_belt	Tension Knob	3	Manual adjustment nut for fine-tuning belt resonance.
k_effector	Base	1	Central effector platform containing the tri-fan cooling array.
l_effector	Lift	1	Secondary mount for the BambuLab-style hotend and wiring.

Category	Component / Specification	Qty	Estimated Cost (EUR)
Structural	Aluminum Square Profile (13x13 mm)	3	12
Structural	Aluminum Round Tube (10 mm)	6	12
Structural	Timber Base Sections (24 cm)	1 set	(included)
Motion	NEMA 11 Stepper Motors	4	20
Motion	GT2 Belts + Pulleys	1 set	5
Motion	Spherical Ball Joints (No-Slop)	1 set	10
Control	BigTreeTech SKR Pico (RP2040 MCU)	1	22
Control	Raspberry Pi 3 (Host Computer)	1	25
Interface	LCD Touch Screen	1	10
Power	24V / 300W DC Power Supply	1	8
Extrusion	Hotend (BambuLab Replacement Style)	1	10
Extrusion	Heated Bed (Hotbed)	1	10
Sensors	Optical Endstops	1 set	5
Misc	PTFE Tubing (4 mm), Fans, Screws, Cables	1 set	26
TOTAL			175 EUR