PLA Recycler V1

Compact Non-Solvent Filament Reprocessing System
Concept, Parts List, Prototype Blueprint, and Step-by-Step Build Guide

Design goal	Convert sorted, clean, dried PLA scrap into reusable 1.75 mm filament using a small melt zone and an ultra-low-tension w
Core idea	The extruder creates filament; a gravity dancer buffers it; the spool only collects slack. The spool is never allowed to becor
Prototype target	1.75 mm filament, initially tuned manually; later goal +/-0.03 mm with optical diameter sensing.
Feedstock	Known PLA only. Avoid mixed plastics, fillers, unknown coatings, metal fragments, and wet material.

Safety scope: This is a bench prototype, not a certified appliance. Heated PLA can release ultrafine particles and volatile compounds. Use local exhaust or an enclosure with appropriate particulate/activated-carbon filtration, thermal cutoffs, guarded hot surfaces, fused power, and an emergency stop. Do not leave the prototype unattended until its failure modes are characterized.

1. Concept Architecture

The recycler is intentionally split into independent subsystems. The extrusion head determines material flow. Cooling stabilizes the filament. A gravity dancer stores a small amount of filament and reports whether the downstream reel is falling behind or pulling too hard. The spool motor responds only to dancer position, while a slip clutch physically limits the maximum tension.

A. Feed	B. Melt	C. Cool	D. Buffer	E. Wind
Dried PLA chips	Short heated auger barrel	Air tunnel / guide path	Gravity dancer arm	Slip-clutch spool + traverse

Locked design principle: the filament itself is not used as the mechanical transmission between the extruder and the take-up reel.

Operating Sequence

1. Sort, clean, and dry PLA scrap; granulate to roughly 3-6 mm pieces.

2. Feed granulate into a slow auger that meters it through a short heated barrel.

3. Extrude through a removable die and pass the strand through a controlled air-cooling path.

4. Route the cooled strand under a lightweight dancer roller.

5. The dancer position commands the reel speed. The reel only removes accumulated slack.

6. A slip clutch prevents reel torque from becoming high enough to neck or stretch the filament.

7. A leadscrew traverse lays filament side-to-side across the spool.

8. The user starts the first wraps manually, then switches winding to AUTO.

Why the Small Melt Chamber Matters

PLA is vulnerable to heat history and moisture-assisted hydrolysis. A small melt inventory reduces residence time, limits the amount of polymer repeatedly heated, and makes temperature corrections respond quickly. The prototype therefore avoids a large molten reservoir.

2. Prototype Blueprint - Overall Layout

Recommended bench footprint is approximately 600 mm wide x 300 mm deep x 350 mm high, excluding any extended cooling tunnel. The spool can remain external so different spool sizes can be accommodated.

HOPPER	AUGER + HOT ZONE	DIE	AIR COOLING	DANCER	TRAVERSE + SPOOL
PLA chips	60-100 mm heated length	1.8-2.0 mm trial bore	0.75-1.5 m path	150-250 mm arm	0-10 RPM take-up

Subsystem	Starting dimensions / specification	Purpose
Feed hopper	Approx. 100 x 100 x 120 mm; steep walls	Keep granulate flowing into auger.
Auger barrel	12-16 mm internal diameter; 100-160 mm total length	Meter chips and develop melt pressure.
Heated zone	60-100 mm	Keep melt volume small.
Die block	Removable; trial 1.8-2.0 mm bore	Form strand before draw-down.
Cooling path	0.75-1.5 m effective air path	Solidify strand before dancer tension.
Dancer arm	150-250 mm pivot-to-roller	Create gravity buffer and tension reference.
Spool shaft	Adjustable hub for common 250 g-1 kg spools	Support replaceable reels.
Traverse	Travel = usable spool width	Lay adjacent turns without piling.

Mechanical Winding Blueprint

Use a low-RPM gearmotor to drive a friction hub rather than a rigidly coupled spool. Place felt, cork, or another suitable friction washer between the driven plate and spool carrier. A spring washer and thumb nut set clutch preload. The clutch should slip before the take-up system can noticeably stretch the cooled filament.

The dancer should use a low-friction roller on a long, light arm. Prefer a counterweight over a strong spring so that the force is nearly constant through the useful travel. Begin testing in the range of roughly 10-40 grams effective pull, then reduce it if the strand is being stretched or made oval.

3. Parts Needed to Build V1

Qty	Part	Suggested starting spec	Notes
1	Controller	Arduino Nano or equivalent	Reads temperature, dancer, limits; drives outputs.
1	Power supply	12/24 V DC, sized for motors/fans	Heater may use separate appropriate supply.
1	Heater	100-150 W cartridge heater	Match voltage and heater block.
1	Temperature sensor	100K thermistor, PT100, or thermocouple	Use compatible interface.
1	Thermal cutoff	Independent high-limit cutoff	Fail-safe, not software-only.
1	Hot barrel	Stainless or suitable metal, 12-16 mm ID	Short hot zone.
1	Auger/screw	Custom or adapted metering screw	Slow feed; avoid excessive shear.
1	Auger drive	Gearmotor or stepper, ~1-10 RPM effective	High torque, low speed.
1	Heater block / die block	Machined aluminum or suitable metal	Insulated from frame.
3-5	Melt screens	Fine stainless mesh discs	Catch debris before die.
1	Removable die	Start around 1.8-2.0 mm bore	Tune empirically.
2-4	Cooling fans	Small brushless fans	Air-cool before dancer.
1	Dancer arm	150-250 mm light arm	Pivot on bearing/bushing.
1	Dancer roller	PTFE/Delrin/aluminum grooved roller	Low friction.
1	Dancer sensor	Hall-angle sensor + magnet or potentiometer	Measures arm position.
1	Counterweight set	Small adjustable mass	Sets very low line tension.
1	Spool gearmotor	12 V gearmotor, roughly 0-10 RPM output	PWM controlled.
1	Slip clutch	Friction discs + spring washer + thumb nut	Mechanical torque limiter.
1	Spool shaft/hub	Adjustable hub	Accept several spool widths/bores.
1	Traverse motor	Small reversible gearmotor/stepper	Low-speed lateral motion.
1	Traverse leadscrew	6-8 mm screw + nut	Travel equals spool winding width.
1	Linear guide	Rail/rod for traverse carriage	Prevents rotation.
2	Traverse limit switches	Left and right end stops	Reverse traverse.
1	Filament guide eye	PTFE/ceramic smooth guide	Mounted on traverse.
1	Emergency stop	Latching mushroom switch	Cuts hazardous power.
1	Main fuse/breaker	Correctly rated	Protect wiring and supply.
1	Enclosure / guard	Metal around hot zone	Prevent accidental contact.
1	Local exhaust / filter provision	Particulate + activated carbon or vented exhaust	Reduce exposure to hot-polymer emissions.
As req.	Wire, terminals, ferrules, connectors	Temperature-rated near hot zone	Use strain relief.
As req.	Frame hardware	Aluminum extrusion, sheet metal, or rigid frame	Keep hot zone noncombustible.

4. Electrical / Control Architecture

Keep heater power, motor power, and logic wiring physically organized. The controller should command the heater through an appropriately rated switching device, but a separate thermal cutoff should be able to remove heater power without relying on software.

Input to controller	Output from controller
Extrusion temperature	Heater control
Dancer position	Spool motor PWM
Traverse left limit	Traverse direction
Traverse right limit	Cooling fans
Emergency / fault status	Auger enable
Optional diameter sensor	Alarm / display

Dancer Logic

Dancer position	Spool response
Very high / low slack	OFF
Slightly high	Very slow
Centered	Nominal
Low	Faster
Very low	Maximum safe take-up + warning

Important: V1 should not use spool speed to control extrusion rate. Keep extrusion and winding loosely coupled. The dancer is a buffer, not a demand signal to make more plastic.

Traverse Ratio

A useful starting target is about 1.75-2.0 mm of lateral guide travel per spool revolution for nominal 1.75 mm filament. This does not need to be perfect on V1; avoiding repeated overlap is more important than producing a factory-perfect spool.

5. Step-by-Step Prototype Build Guide

1. Build the rigid frame

Mount the extruder, cooling path, dancer pivot, traverse, and spool shaft to a rigid base. Keep the hot-zone structure metallic or otherwise heat-safe. Leave enough access to remove the die and melt screen.

2. Fabricate the short extrusion barrel

Use a metal barrel around 12-16 mm internal diameter. Keep the heated section around 60-100 mm. Provide a cold-side bearing/support so the auger drive is not exposed to melt-zone heat.

3. Fit the auger and drive

Couple the auger to a geared motor or stepper capable of very slow motion. Design for roughly 1-10 RPM effective auger speed. Verify by hand that nothing binds before heating.

4. Build the removable melt-screen/die section

Place a replaceable stainless screen before the die. Make the die removable for cleaning. Start with a trial bore around 1.8-2.0 mm and expect to tune it.

5. Install heater and temperature sensing

Clamp or insert the heater into the heater block with the temperature sensor close to the melt path. Add insulation around the hot block while keeping the electrical terminations protected.

6. Add independent thermal protection

Install an independent high-temperature cutoff in the heater power path. The emergency stop should remove heater and drive power appropriate to the design.

7. Build the cooling path

Provide 0.75-1.5 m of effective air-cooling travel using smooth guides and small fans. Do not route the filament into the dancer until it has become dimensionally stable.

8. Build the dancer

Use a 150-250 mm lightweight arm on a low-friction pivot. Mount a smooth grooved roller at the end. Add a small adjustable counterweight so the effective filament pull begins around 10-40 grams.

9. Sense dancer position

Fit a magnet/Hall angle sensor or potentiometer at the pivot. Record the sensor values for top, center, and bottom positions.

10. Build the slip-clutch spool hub

Drive a plate from the gearmotor, then couple that plate to the spool hub through friction washers and a spring-loaded thumb nut. Tune it to slip under very small excess tension.

11. Build the traverse

Mount a carriage on a linear guide and move it with a 6-8 mm leadscrew. Add left and right limit switches. Mount a smooth filament guide on the carriage.

12. Wire the controller

Connect temperature input, dancer input, traverse limits, auger drive, heater switching, spool PWM, traverse motor, cooling fans, emergency stop, and fault/alarm indication.

13. Dry-run the mechanics

With the heater disabled, verify auger rotation, traverse reversal, dancer sensing, spool clutch slip, spool speed range, and emergency-stop behavior.

14. Heat and purge

With ventilation operating, heat the empty extrusion head to an appropriate PLA processing temperature and feed a small amount of known clean PLA. Purge until the extrusion is uniform.

15. Establish the strand

Manually guide the emerging strand through the cooling path. Measure it with calipers after it is fully cooled. Adjust temperature and auger rate conservatively until the strand is stable.

16. Thread the dancer and spool

Route cooled filament under the dancer roller and through the traverse guide. Wrap the spool two or three turns by hand, secure it, then enable AUTO winding.

17. Tune only the take-up behavior

Adjust dancer counterweight, spool PWM limits, and clutch preload until the reel quietly follows the filament without visibly stretching it. The dancer should spend most of its time near mid-travel.

18. Tune the traverse

Adjust traverse speed so adjacent filament turns lay beside one another. Reverse cleanly at both spool edges without striking the flange.

19. Run a short qualification spool

Produce a small test length first. Record filament diameter at regular intervals and in two perpendicular directions. Also note brittleness, surface quality, and winding consistency.

20. Print-test and iterate

Use the recycled filament in a controlled test print. If diameter or brittleness varies, correct drying, temperature, residence time, feed consistency, or blend ratio before increasing spool size.

6. Initial Calibration Targets

Parameter	Starting target	What to watch
PLA dryness	Dry before every recycle run	Steam, bubbles, rough surface, brittleness.
Hot zone	Approx. 170-210 C adjustable	Use the lowest stable temperature that extrudes consistently.
Auger speed	Approx. 1-10 RPM effective	Surging, starvation, excessive pressure.
Dancer pull	Approx. 10-40 g effective	Necking, oval filament, dancer oscillation.
Spool speed	0-10 RPM range	Must follow dancer rather than impose pull.
Traverse advance	Approx. 1.75-2.0 mm/rev	Overlap, gaps, flange collisions.
Filament diameter	1.75 mm nominal	Measure after full cooling.
Future diameter goal	+/-0.03 mm	Requires closed-loop optical sensing for reliable consistency.

Acceptance Test for V1

- No uncontrolled heater rise when the controller is disconnected or faulted.

- Emergency stop reliably removes hazardous motion/heat power as designed.

- Spool clutch slips before the filament is visibly stretched.

- Dancer can absorb short extrusion-rate variations without hitting either stop.

- Traverse reverses reliably at both spool edges.

- Filament remains continuous and printable over a short qualification spool.

- Diameter is recorded at multiple positions and in two axes before claiming usable filament.

7. Recommended V2 Upgrades

Once V1 winds reliably, the next upgrade should be diameter measurement rather than adding more spool torque. Use two perpendicular optical measurements so both diameter and ovality can be observed. Closed-loop control can then trim puller/take-up behavior while preserving the dancer as the low-tension buffer.

- Two-axis optical filament gauge.

- Melt-pressure sensing ahead of the die.

- Automatic spool-full detection.

- Recipe memory for PLA blends and colors.

- Logged temperature, auger speed, dancer position, and diameter data.

- Interlocked enclosure and extraction-fan verification.

- Controlled blend hopper for recycled/virgin PLA ratios.

Prototype thesis: make extrusion steady, keep the molten inventory tiny, let gravity buffer the product, and make the spool mechanically incapable of pulling hard enough to damage the filament.