A CURIOSITY.DIY WORKSHOP TOOL

The Clever Contraptions Corner

Manual — designing and cutting real mechanisms

Cut a Gear Mesh Tester board before your first real machine — section 6.

1 · What this tool is

The Clever Contraptions Corner designs machines that **move** — gear trains, cams, cranks, linkages, drawing machines — and gives you laser-ready cutting files for them. You set the mechanism up on screen, watch it run, then download SVGs that are already nested onto your sheet and compensated for your laser's kerf.

There are two ways to work. **Single movements** builds one mechanism on its own — a gear pair, a cam, a rack. **Combining parts** chains several into one machine on a shared baseplate, using either the Composer Workbench (one layer) or the Complex Workbench (multiple layers, stacked gears, pens and arms).

Everything is cut from flat sheet. The tool assumes plywood or acrylic, bolts for shafts, and optional bearings and dowels.

2 · Before you cut: the numbers that matter

Four settings in the **Parameters** panel decide whether your machine runs sweetly or seizes. Get these right once for your laser and material, and everything afterwards just works.

`Wood thickness`	Your actual sheet, measured. Used for spacers, standoffs and stack heights.

`Kerf`	The width of material the laser beam burns away. Typically 0.10-0.25mm in ply. The tool grows outlines and shrinks holes by half of this, so finished parts come out on size.
`Gear mesh clearance`	Backlash between meshing teeth, set as a fraction of module. Default 0.08. This is the single most important setting for gears that turn freely.
`Bearings`	Whether gears get a bearing seat or a plain bolt hole, and the exact hole diameter to cut for a press fit.

Kerf is not the same as a hole fit

Kerf is the beam width — the same whether you cut a hole or a slot — and the tool compensates for it automatically. A **press-fit hole size** (for a bearing or a dowel) is a separate, tested number: an "8mm" bearing is rarely exactly 8mm, and wood compresses. Set kerf once for your machine; set hole sizes by testing.

Measuring your kerf

1. Cut a 50mm square with kerf set to 0.
2. Measure it with calipers. It will come out undersize, say 49.85mm.
3. The difference (0.15mm) is your kerf. Enter it in Parameters.
4. Re-cut and check: the square should now measure 50.0mm.

3 · Quick start

1. Pick a movement, or open Combining parts for a full machine.
2. Set the teeth counts, module and any lengths. Watch it run in 3D wood or 2D schematic.
3. In Parameters set wood thickness, kerf, gear mesh clearance and bearings.
4. Open **Cut sheets to laser** and check the nesting and the piece count.
5. Download each numbered sheet. Cut at your usual settings for the material.
6. Build it using the **Reference sheet** and the materials list, which tell you every part, bolt, bearing and dowel you need.

> *New to gears? Cut a Gear Mesh Tester board first (section 6). Twenty minutes there saves a whole sheet of gears that bind.*

4 · The movements

MOVEMENT	CONVERTS	NOTES
Spur gearing	rotary to rotary	Pairs and trains, 2-7 gears. Idlers set direction, not ratio.
Crank & connecting rod	rotary to reciprocating	The classic engine linkage; works both ways.
Cam & follower	rotary to reciprocating	Choose the motion law: heart, dwell, and others.
Rack & pinion	rotary to linear	Straight-line travel; rack length sets the stroke.
Ratchet & pawl	oscillating to intermittent	One-way motion, steps forward and holds.
Scotch yoke	rotary to sine reciprocation	Pure sine motion, fewer parts than a crank.
Internal ring gear	rotary to rotary	Same direction, compact centre distance.

MOVEMENT	CONVERTS	NOTES
Epicyclic / planetary	compound ratios	Big reductions in a small space; traces hypocycloid paths.
Four-bar linkage	rotary to complex curve	Coupler curves — the heart of drawing machines.
Composer Workbench	chained	Several movements on one baseplate, one crank.
Complex Workbench	chained, multi-layer	Stacked gears on shafts, plus pens and arms.

5 · Module, and why it matters

Module is tooth size: millimetres of pitch diameter per tooth. Two rules follow from it:

- A gear's pitch diameter = module x number of teeth.
- Two gears mesh at a centre distance of module x (teeth1 + teeth2) / 2.

Bigger module means bigger, chunkier teeth — stronger and easier to cut cleanly in ply. Smaller module means finer teeth and a more compact machine. **Two gears can only mesh if they share the same module.** The machine scale buttons in the Complex Workbench change module: at half scale, module halves and every gear shrinks with it.

> *In ply, module 2 is about the finest worth cutting. Module 3 is a good general choice; module 4-5 is very forgiving.*

6 · Gear mesh clearance and the Gear Mesh Tester

A gear cut to perfect theoretical dimensions **will not turn**. Real teeth need backlash — a small gap between the driving and driven flanks — to allow for material roughness, char, and tiny errors. The **Gear mesh clearance** setting adds it by thinning each tooth very slightly, leaving centre distances exact so the motion stays true.

It is set as a fraction of module, which means the fit holds at any size. A machine that runs beautifully at half scale will run the same at full scale.

`0`	No clearance. Gears will almost certainly seize.
`0.05`	Tight. Precise, but stiff in plywood.
`0.08`	Good running fit for laser-cut ply. The default.
`0.12 - 0.15`	Free-running. A little lost motion, useful for rough material.
`0.20+`	Loose. Noticeable slack; fine for hand-turned toys, poor for drawing.

Using the tester

The Gear Mesh Tester (in the Combining menu, or the button at the top) cuts a small board of gear pairs at different clearances so you can feel the difference before committing a whole machine.

1. Press **match my machine** so the module matches what you are building.
2. Drag the clearance slider. The live close-up shows two teeth meshing, with the backlash gap shaded blue — watch it open as you go looser.
3. Set **also cut** to 5 to bracket your guess, or to 1 to test a single value.
4. Choose the shaft holes: match my machine, bearing seat, or bolt clearance.
5. Download and cut the board. Each pair is engraved with its clearance, centre distance and tooth count.

6 Mount each pair on its tile and turn them. Pick the one that turns freely without rattling.
7 Enter that number as your Gear mesh clearance in Parameters.

7 · Bearings, bolts and dowels

Rotating parts need something to turn on. The **Bearings** setting in Parameters offers three arrangements:

`None`	Every gear gets a bolt-clearance bore and spins directly on the bolt. Simplest, and fine for slow hand-turned machines.
`In gears`	Each gear gets a bearing seat; the baseplate keeps a smaller bolt hole. The bearing takes the load and the gear spins freely. This is the usual choice.
`In gears + rod pivots`	As above, plus bearings at linkage rod pivots. Smoothest, most hardware.

The **bearing hole diameter** is the size actually cut. Start at the bearing's nominal outside diameter and adjust by a tenth of a millimetre at a time until it presses in firmly without splitting the ply. **Dowel holes** work the same way for shafts and standoff posts.

> *Use the Kerf Hole Maker on curiosity.diy to test hole sizes quickly: it cuts a strip of holes in small increments so you can find the one that grips.*

8 · The Complex Workbench

The Complex Workbench builds multi-layer machines: gears stacked on shared shafts, driven from one crank, optionally carrying a pen.

Gears

- **Driver** is the input gear you turn. **Mesh** gears engage a chosen neighbour at an angle you set. **Stack** gears share a shaft with another gear, so they turn together.
- Each row shows the live tip diameter, so you can see the machine's real size as you work.
- Layers separate the gear trains vertically; spacers and standoffs are generated automatically.

Machine scale

The scale buttons resize the whole mechanism — module, arm lengths, pin radii — by an exact factor, relative to the original. Because clearance and hole fits are proportional or absolute as appropriate, a scaled machine still assembles correctly.

Pens and arms

- A **pen** can ride on a gear pin, a linkage joint, or part-way along an arm.
- **Arms** pivot on joints. A **branch** is glued rigidly to an arm — it is not a pivot — and carries the pen at its tip.
- The **pen collar** is a teardrop piece: the pen drops through the hole at the round end, and the narrow end bolts to the branch tip.
- The pen hole can be round or a 3-8 sided polygon, measured across the flats — so a hex hole grips a hex pencil.

Reading the drawing

A **closed** figure repeats after a set number of turns. An **open** figure never quite closes, so it weaves denser the longer it runs — set **run for N turns** to control how much it fills in.

Splitting the baseplate

If the baseplate is bigger than your sheet, use **Split the baseplate** to tile it into sheet-sized pieces with alignment features.

9 · Cut sheets and downloads

There are two different files, and they do different jobs.

`Reference sheet (annotated)`	One long drawing with every part named, dimensioned and annotated — which hole is which, what glues where. Print it or keep it on screen while you build. Not intended for cutting.
`Cut sheets to laser`	The numbered sheets you actually cut. Tightly nested to your sheet size, kerf compensated, one SVG per sheet.

Options

`Sheet outline`	Draws the sheet border. Turn it off if your laser software places jobs itself.
`0,0 marker`	A crosshair at the origin for lining the job up on the bed. Handy with the outline off.
`Engrave part labels`	Engraves each part's number and tooth count. Off by default, since engraving adds machine time.
`Zoom / fit width`	Inspect the nesting before committing.

Colours

Red lines are cuts. **Blue** lines are engraving or scoring. Map these to your laser's layers as cut and raster/score.

> *If a piece is larger than your sheet, a red warning appears above the downloads. Choose a bigger sheet size or split the baseplate — otherwise that piece will be cut short.*

10 · Building it

1. Weed and de-soot the parts. Wiping cut edges with methylated spirits removes char, which is a surprisingly large source of friction.
2. Press bearings into the gears. They should need firm thumb pressure, not a hammer.
3. Fit shafts and standoffs to the baseplate. Dowels glue in; bolts pass through.
4. Stack the layers in order, using the generated spacers to set the gaps.
5. Check each gear turns freely on its own before adding the next.
6. Fit arms and linkages. Branches are glued rigidly; joints must stay free.
7. Bolt the pen collar to the branch tip and drop the pen through.
8. Turn the crank slowly by hand for a full cycle before running it properly.

> *A candle or paste wax rubbed on tooth flanks makes a real difference to how freely wooden gears run.*

11 · Troubleshooting

SYMPTOM	LIKELY CAUSE	FIX
Gears bind or lock up	Not enough mesh clearance	Raise Gear mesh clearance to 0.10-0.12; de-soot and wax the teeth
Gears rattle, drawing looks fuzzy	Too much clearance	Lower to 0.05-0.06 and re-cut
Gear wobbles on its bolt	No bearing, or hole too large	Switch Bearings to 'In gears', or reduce the bearing hole
Bearing falls out	Hole cut too big	Reduce the bearing hole diameter by 0.1mm and re-cut
Bearing won't go in	Hole too small	Increase by 0.1mm; do not change kerf to fix this
Parts come out undersize	Kerf set too low	Measure a test square and correct the kerf
A piece is cut short at the edge	Piece exceeds the sheet	Bigger sheet size, or split the baseplate
Pen slips in the collar	Pen hole too large	Reduce the pen hole size, or match the shape to the barrel
Drawing never repeats	Open figure	Expected — set run for N turns to control the density
Screen looks unchanged after an edit	Cached page	Hard reload, adding ?v=2 to the address

12 · Glossary

Module	Tooth size: mm of pitch diameter per tooth. Meshing gears must share it.
Pitch circle	The imaginary circle where two gears effectively roll on each other.
Centre distance	Distance between two meshing gear centres: module x (T1 + T2) / 2.
Backlash	The small gap between meshing tooth flanks that lets gears turn freely.
Kerf	The width of material removed by the laser beam.
Kerf compensation	Growing outlines and shrinking holes by half a kerf so finished parts are on size.
Involute	The tooth curve that gives a constant speed ratio through the mesh. All gears here are involute.
Across flats (A/F)	The width of a polygon measured flat-to-flat, not corner-to-corner. How hex pencils and bolts are sized.
Press fit	A hole slightly smaller than the part, so it grips without glue.
Coupler curve	The path traced by a point on the connecting link of a four-bar linkage.
Hypocycloid	The path traced by a point on a circle rolling inside another circle, as in planetary gearing.

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