

Onion Madder // messopedals.com · paper-circuit method after Peter Blasser / Ciat-Lonbarde

Build-up: a blank sheet folded in half and glued shut is the core. Glue the FRONT heart on one face, cut the core to its edge, then glue the BACK heart on the other face with its outline matching that edge. Lay it on a cardboard box and poke every hole from the front with pointed tweezers. Four layers: front, two core layers, back. The target marks are an extra check for the very careful.

Paper Crystal Beat Box

four crystal oscillator cans beating against each other in pairs, as a full heart-shaped paper circuit

This one uses up crystal oscillators. A crystal oscillator can runs at one fixed, very fast frequency, millions of times a second and far above hearing, but no two are exactly alike: two cans with the same number printed on them still differ by a few parts in a hundred thousand. Run two of them into an XOR gate, smooth what comes out, and what is left is the **difference** between them, which lands in the range you can hear.

Four cans give three of those differences: X1 against X2, X2 against X3, and X3 against X4. One 74HCT86 does all three and they are mixed into one output, so the box plays a three-note chord that nobody chose. Every set of four cans plays its own. There are no knobs but volume. It is a new design, drawn here first, and it has not been built yet.

What a paper circuit is

A paper circuit is a circuit board made of paper. The sheet you print is the board: the FRONT shows where every part sits, and the BACK is the same drawing mirrored, with the wiring on it. The printed front and back are glued to the two faces of a plain sheet folded in half, so the board is four sheets of paper thick, and every hole is poked through all four layers. The parts go in from the front, chips included, soldered straight to the paper. On the back, part legs bend along the printed lines, and bare wire covers the lines a leg cannot reach. Where one line has to cross another, an insulated wire hops over it. The power switch and the jacks hang off the board on wires. Nothing is etched and nothing is cut but paper: a printer, a glue stick, scissors, pointed tweezers, a cardboard box and a soldering iron are the whole kit.

The method is Peter Blasser's, from Ciat-Lonbarde. His paper circuits are a great idea, but they are complicated, full of unusual parts and hard to troubleshoot. This series takes circuits people already know, built from common parts, and makes a paper circuit something a beginner can try.

58 steps. Page 1 is the board itself; everything after it is the recipe.

Reading the sheet

Front: each part is drawn where it sits, with its value printed next to it. The faint dashed lines are only a preview of what connects on the back. The four squares marked OSC are the cans: each has a leg at every corner, and the dot marks pin 1. The ringed holes are for wires going off the board: PWR+ and PWR- for power; VOL TOP, VOL WIPER and VOL GND for the volume pot; OUT and OUT-G for the output jack. The three target marks are an extra check for the very careful: on the finished heart they sit on top of each other.

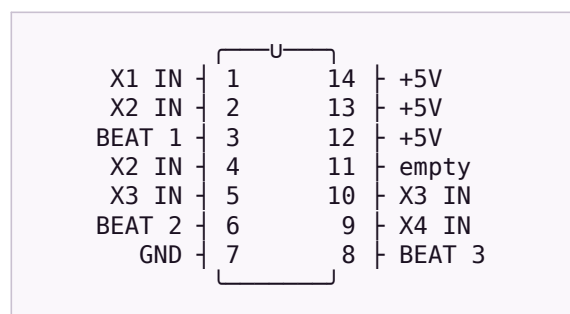
Back: every bold black line is bare wire or a bent part leg. The lines with a letter in a circle are bare wire, and the steps name them by that letter; the short unlettered ones are a part's own leg, bent along the line. Small pink numbers beside the chip and can holes are their pin numbers. Two long wires go all the way around the heart: J carries +5V and passes **under** each can, between its two rows of legs, and N is ground and runs outside each can. That is on purpose, so every can reaches both without a wire crossing another.

An XOR gate as a mixer for two clocks is the phase detector from every PLL datasheet, and two oscillators beating against each other is how a theremin makes its pitch. The paper-circuit method is Peter Blasser's / Ciat-Lonbarde's. This layout and the words are Onion Madder's.

What you'll need

- **4× crystal oscillator cans, all with the same frequency printed on them (X1-X4)** · *spot it:* square metal cans about 13 mm across with a leg at each corner; one corner is square or has a dot, and that is pin 1. Any frequency works as long as all four match, and they must be 5V types. Not the flat two-legged crystals: those need an oscillator built around them.
- **1× 74HCT86 quad XOR (IC1)** · *spot it:* 74HCT86 printed on top, notch at pin 1, 14 pins. A 74HC86 works too. A CD4070 or CD4030 will not: they are far too slow for the cans. It solders straight to the paper, no socket.
- **1× 7805 regulator (U1)** · *spot it:* the TO-220 kind, a black block with a metal tab and a hole: four cans can draw more than a little 78L05 gives
- **3× 47K resistors (R2, R3, R4)** · *spot it:* yellow-violet-orange. One from each beat into the mix.
- **6× 0.1 µF ceramic (C1, C3-C7)** · *spot it:* printed 104. One beside each can, one over the chip, one at U1's input.
- **1× 2.2 nF ceramic (C8)** · *spot it:* printed 222. It smooths the cans' hash away and leaves the beats.
- **2× 10 µF electrolytic (C2, C9)** · *spot it:* a little can, stripe marks the – leg
- **1× 1N5817 Schottky diode (D1)** · *spot it:* small black body, gray or silver band marks the cathode
- **1× LED (LED1) and a 2.2K resistor (R1)** · *spot it:* the power light. The LED's long leg is +, the flat side of the rim –; 2.2K is red-red-red
- **1× A100K pot (volume)** · *spot it:* marked A100K; A = log, the right taper for volume. It hangs off the board on wires.
- **1× SPST toggle** · *spot it:* for power; it hangs off the board on wires
- **1× jack** · *spot it:* the output, on wires
- **Bare tinned wire, and insulated wire** · *spot it:* bare for the traces on the back, insulated for every wire off the board
- **Power: a 9V pedal supply and a 2.1 mm DC jack, or a 9V battery and snap** · *spot it:* four cans drain a battery fast, so a supply is the better choice. The usual pedal supply is center-negative.
- **A second sheet of plain printer paper, a glue stick, scissors, pointed tweezers and a cardboard box** · *spot it:* the blank sheet becomes the core; the tweezers poke the holes and the box takes the points

The chip, from above



Drawn here notch-up, but on the sheet the chip lies on its side with the notch toward X1. Gate 1 (pins 1, 2, 3) is X1 against X2, gate 2 (pins 4, 5, 6) is X2 against X3, and gate 3 (pins 8, 9, 10) is X3 against X4. Gate 4 is spare: its inputs, pins 12 and 13, sit on +5V so they never float, and its output, pin 11, stays empty on purpose. Each can has a leg at every corner: pin 1 at the dot (left empty here), pin 4 ground, pin 5 the output, pin 8 +5V.

Before you start

Paper burns. Keep the iron moving, quick joints, and don't rest it on the sheet. Work over something that isn't flammable, and keep a damp sponge handy.

Chips and cans straight in. The 74HCT86 and the four cans solder straight to the paper with no socket. The cans are metal and soak up heat, so give their joints a moment longer than a resistor's, and no longer.

Four matching cans. All four must carry the same frequency marking, or the differences between them land far above hearing and the box is silent.

Fast chip only. A CD4070 in place of the 74HCT86 fits the same holes and will not keep up with the cans.

Mind U1 and the electrolytics. U1's metal tab faces the top of the heart, and the sheet marks each electrolytic's + hole.

Assembly

The sheet is the circuit board, four sheets of paper thick: the two printed hearts glued to the two faces of a plain sheet folded in half. Each heart is cut out on its own, and the back lines up with the front by its edge, so there is nothing to fold and nothing to misalign.

Print at 100% / "Actual size". Fit-to-page shrinks it and the holes stop matching the chips' legs.

STEP	DO
1	Print page 1 on plain printer paper at 100% / Actual size.
2	Measure the 100 mm bar at the top right of the sheet. If it isn't 100 mm, fix the print scale and print again.
3	Cut out the FRONT heart along its outline. Then cut out the BACK heart along its own outline. Don't fold the printed sheet and cut both at once: the two sides come out misaligned.
4	Fold a second, blank sheet of printer paper in half. Glue-stick the whole inside, close it, and press it flat. That's the core: two sheets thick.
5	Glue-stick the back of the FRONT heart.
6	Press the FRONT heart onto one face of the core, smoothing it flat from the middle out.
7	Cut the core away around the FRONT heart, following its edge, so the core is the same heart shape.
8	Glue-stick the bare side of the core.
9	Lay the BACK heart on it, printed side out, with its outline matching the edge all the way around, and press it flat. Now it's four sheets thick. The 3 target marks are there for the very careful: hold the heart up to a light and the targets on the two sides should sit on top of each other.
10	Let the glue set for a few minutes. Then lay the heart front side up on a cardboard box, and poke the 30 chip holes straight down through all four layers with pointed tweezers, held closed. The box takes the points.

- 11** Poke the other 40 dots and rings the same way. Check the back and open any hole that didn't come all the way through.
- 12** Check the fit: push each chip into its holes until its legs come through on the back. If a leg won't go, open that hole a little more.

The chip and the four cans

Everything builds outward from the chips. IC1 lies on its side in the middle, and each can's output runs to it. Two of the wires go in between the chip's two rows of legs: the steps say which pins each one touches.

Quick dabs only. Paper scorches if you sit on it: touch, flow, lift.

STEP	DO
13	Push the 74HCT86 into the IC1 holes from the front, notch toward X1 (the drawn notch). On the back, bend pins 1, 7, 8 and 14 outward slightly so the chip can't fall out.
14	Push the four cans into X1, X2, X3 and X4 from the front, each with its pin-1 corner on the drawn dot. On the back, bend one leg of each outward slightly to hold it.
15	Trace A: bare wire from X1's pin 5 straight across to IC1 pin 1. Solder at both.
16	Trace B: bare wire from X2's pin 5 down to the X1 end of the chip, in between the two rows of legs, along over pins 1, 2 and 3 without touching them, and down onto pin 4. Solder at X2's pin 5 and at pin 4.
17	Trace C: short bare wire from trace B straight down to pin 2. Solder at pin 2 and where it meets B.
18	Trace D: bare wire from X3's pin 5 down, then across above the chip's top row to pin 10, and on straight across between the rows to pin 5. Solder at X3's pin 5, pin 10 and pin 5.
19	Trace E: bare wire from X4's pin 5 across to above pin 9, then down onto it. Solder at both.
20	Check with a meter before going on: pin 3 must not beep to pin 2 or pin 4, and pin 11 must not beep to anything.

The three beats out to the mix

Each gate's output goes through a 47K into one line, MIX. C8 from MIX to ground smooths away the cans' fast hash, and what is left is the three beats, added together. C9 takes the sound out to the volume pot.

R2, R3 and R4 are all the same value, so the three beats come out even.

STEP	DO
21	Trace F: bare wire from pin 3 straight down to the R2's hole. Solder at pin 3.
22	Trace G: bare wire from pin 6 straight down to the R3's hole. Solder at pin 6.
23	Trace H: bare wire from pin 8 a short way out from the chip, then down to the R4's hole. Solder at pin 8.
24	R2, R3 and R4, 47K (yellow-violet-orange): legs into their a and b holes. Each lies across wires on the back; that's fine, the paper is between them. Solder each a leg where trace F, G or H ends.

- 25** Trace I, MIX: bare wire from R2·b straight down through R3·b and R4·b to the C8·a hole. Solder at R2·b, R3·b and R4·b.
- 26** C8, 2.2 nF (222): legs into C8·a and C8·b. Solder C8·a on trace I. C8·b waits for the ground line.
- 27** C9, 10 μ F: long + leg into C9·+, striped leg into C9·-. Bend C9·+'s leg onto trace I and solder. Bend C9·-'s leg to the VOL TOP pad and solder at both.

The +5V line

One long bare wire carries +5V around the heart. Under each can it runs between the can's two rows of legs and touches none of them; each can's pin 8 leg bends over onto it.

If a can's pin 8 leg is too short to reach, a scrap of bare wire from the leg to trace J does the same job.

STEP	DO
28	Trace J, +5V: bare wire from the U1·O hole, along under X1's output line, up between X1's two rows of legs, around the X2 lobe and between X2's rows, down under the dip of the heart, up around the X3 lobe and between X3's rows, and down between X4's rows to its end. It passes the C3·a, C4·a, C7·a, C5·a and C6·a holes: those get soldered as their caps go in.
29	Bend X1's pin 8 leg along its drawn line onto trace J and solder it there. Do the same for X2, X3 and X4. Trace J's far end is soldered with X4's.
30	Trace K: bare wire from trace J under the dip straight down to pin 14, then along the top row through pin 13 to pin 12. Solder at pins 14, 13 and 12 and where it meets J. That powers the chip and holds the spare gate still.
31	Check with a meter: trace J must not beep to pin 1, 4 or 5 of any can.

The power corner

Power comes in on two pads at the bottom left. D1 only lets current through one way, so power hooked up backwards does nothing. U1, the 7805, turns the 9V into the steady 5V the cans and the chip need; C1 and C2 keep it calm, and the LED says it's on.

D1's band goes in D1·K, toward U1.

STEP	DO
32	D1, 1N5817: band end into D1·K, plain end into D1·A. Bend D1·A's leg to the PWR+ pad and solder at both.
33	U1, 7805: legs into U1·I, U1·G and U1·O with the metal tab facing the top of the heart (the heavy line on the sheet) and the printed face toward the bottom. Solder U1·O where trace J starts.
34	Trace L: bare wire from U1·I down to the C1·a hole, across to D1·K, and down to the R1·a hole. Solder at U1·I and D1·K.
35	C1, 0.1 μ F (104): legs into C1·a and C1·b. Solder C1·a on trace L.
36	C2, 10 μ F: long + leg into C2·+, striped leg into C2·-. Bend C2·+'s leg to U1·O and solder at both.
37	Trace M: bare wire from C2·- across to C1·b. Solder at both.

- 38** R1, 2.2K (red-red-red): legs into R1·a and R1·b. Solder R1·a on trace L.
- 39** LED1: long leg into LED1·A, short leg into LED1·K. Bend R1·b's leg to LED1·A and solder at both. LED1·K waits for the ground line.

The ground line

Ground goes around the outside of the cans, the other side from +5V, and a second run comes down from pin 7 to the bottom, out to U1 and up the X4 side to meet it. The five 0.1 μ F caps sit across the two long wires, one beside each can and one over the chip, to keep each can's supply quiet.

STEP	DO
40	Trace N, ground: bare wire from the X4 side, up outside X4, around the X3 lobe outside X3, across under the dip just above trace J without touching it, around the X2 lobe outside X2, and down outside X1 to beside X1's pin 4.
41	Bend each can's pin 4 leg onto trace N and solder it there: X1, X2, X3 and X4.
42	C3, C4, C5, C6 and C7, 0.1 μ F (104): legs into their a and b holes. Each a hole is on trace J and each b hole is on trace N. Solder each at both.
43	Trace O: bare wire from pin 7 straight down to the bottom, along the bottom to under U1, and up through C1·b to U1·G. Solder at pin 7, C1·b and U1·G.
44	Trace P: bare wire from where trace O reaches the bottom, along the bottom through C8·b, then up the X4 side to meet trace N. Solder at C8·b, where it meets O and where it meets N.
45	Bend LED1·K's leg down onto trace O and solder.
46	Trace Q: bare wire from the PWR— pad straight down to trace O. Solder at both.

The pot and jack pads

Three short wires finish the board.

STEP	DO
47	Trace R: bare wire from the VOL GND pad straight down to trace P. Solder at both.
48	Trace S: bare wire from the OUT-G pad straight down to trace P. Solder at both.
49	Trace T: bare wire from the VOL WIPER pad to the OUT pad. Solder at both.
50	Snip every leg tail that sticks past its joint.

Off the board

The volume pot, the jack, the toggle and the power hang off the pads on insulated wire.

If the volume knob feels backwards, swap its two outer wires.

STEP	DO
51	Volume pot: one outer lug to VOL TOP, the middle lug (the wiper) to VOL WIPER, the other outer lug to VOL GND. No pot? A short wire from VOL TOP to VOL WIPER and it plays at full volume.
52	Output jack tip to OUT, sleeve to OUT-G.

- 53** A wire from one lug of the power toggle to the PWR+ pad.
- 54** DC jack for a center-negative 9V pedal supply: the jack's sleeve (+) lug to the toggle's other lug, its center-pin (−) lug to PWR−. Or a battery: the snap's red (+) wire to the toggle's other lug, its black (−) wire to PWR−.

Check, then play

Meter it before you play it. These readings come from the design, not from a built board.

STEP	DO
55	Plug the supply in or clip the battery on, and toggle on. LED1 should light.
56	Meter U1·O to PWR−: 5 V. If it isn't, toggle off and check U1 before anything else.
57	Meter each can's pin 5 to its pin 4: somewhere around 2 to 3 V. A can that reads a steady 0 V or 5 V there is not running.
58	Turn the volume down and the amp low, then bring the volume up slowly: three tones at once that nobody tuned.

Voltage check

METER BETWEEN	EXPECT (toggle on, from the design)
PWR+ pad → PWR− pad	supply voltage
U1·I → PWR−	supply voltage minus about 0.3 V
U1·O → PWR−	5 V, give or take 0.2
IC1 pin 14 → pin 7	5 V
each can: pin 8 → pin 4	5 V
each can: pin 5 → pin 4	about 2 to 3 V: a fast square wave, averaged by the meter
pins 3, 6 and 8 → pin 7	about 2.5 V, or wandering slowly if that pair's beat is slow
C8·a → pin 7	about 2.5 V

If it won't sing

SYMPTOM	CHECK
Dead, LED dark	D1 in backwards (the band goes in D1·K), the power wires reversed, or the toggle not between the supply's + and PWR+.
LED lit, but U1·O isn't 5 V	U1 in backwards (the tab faces the top of the heart), or +5V touching ground somewhere: toggle off and meter trace J to trace N, which must not beep.
U1 gets hot	Warm is normal: four cans draw a fair bit and U1 burns off the difference. Too hot to touch means something on +5V is shorted to ground.

SYMPTOM	CHECK
Silent, and a can reads a steady 0 V or 5 V on pin 5	That can is not running. Check its pin 8 and pin 4 read 5 V between them. Some cans use pin 1 to switch on: try a short wire from that can's pin 1 to its pin 8 (untested).
Silent, every can running	Their markings must match: two different frequencies beat far above hearing. Then traces F, G and H and the 47Ks into trace I, C9 to VOL TOP, and the volume pot (or the wire from VOL TOP to VOL WIPER).
Only one or two notes, or a slow thump	Normal for some sets of cans: a pair that sits very close together beats too slowly to be a note, and a pair far apart can beat above hearing. Every set of four plays its own chord.
Paper scorched or a hole tore	Glue a scrap of paper over the back, re-poke, carry on. It is paper.

Things to try

- **Warm a can with a fingertip.** A crystal drifts a little with temperature, so the beats it is part of should bend while you hold it. Untried.
- **Change C8.** A 4.7 nF (472) for a darker chord, a 1 nF (102) for a brighter one with more hash in it. Untried.
- **Into the Paper Ring Mod.** The beat box on one input and a Paper Mosquito Mk II on the other. Untried.