PAPER WASP

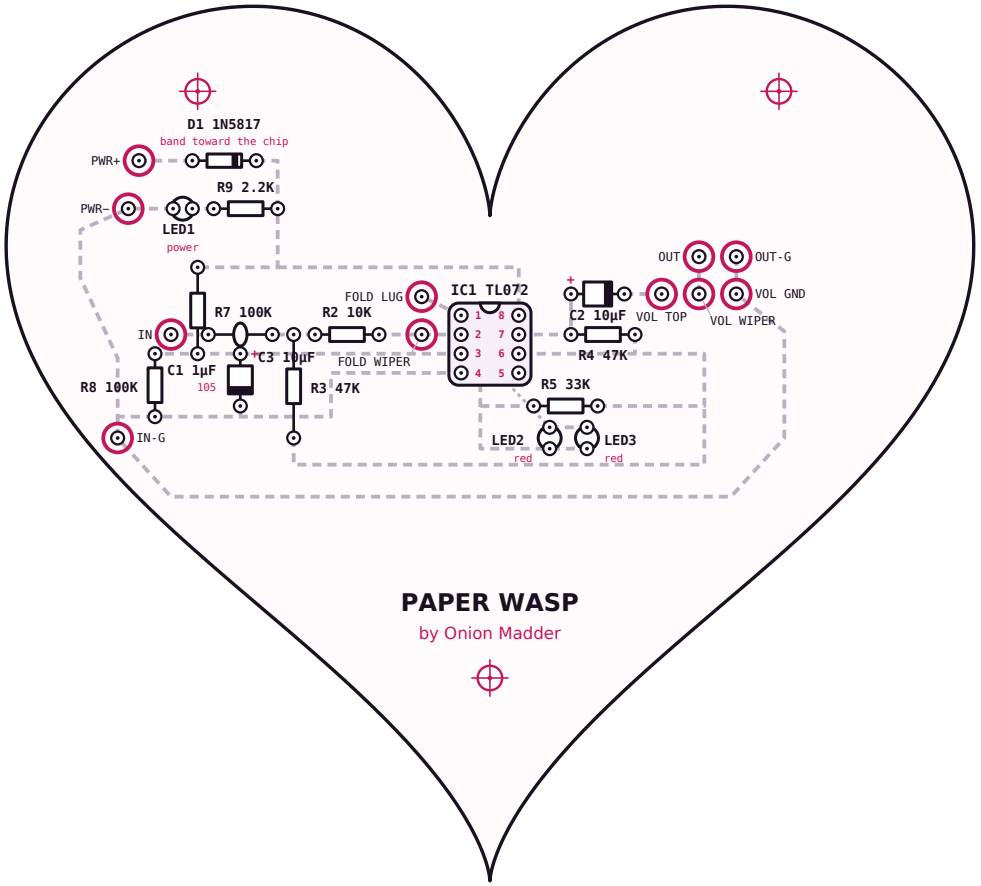
a one-chip wavefolder as a paper circuit · two hearts, print at 100% / Actual size

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

this bar must measure 100 mm

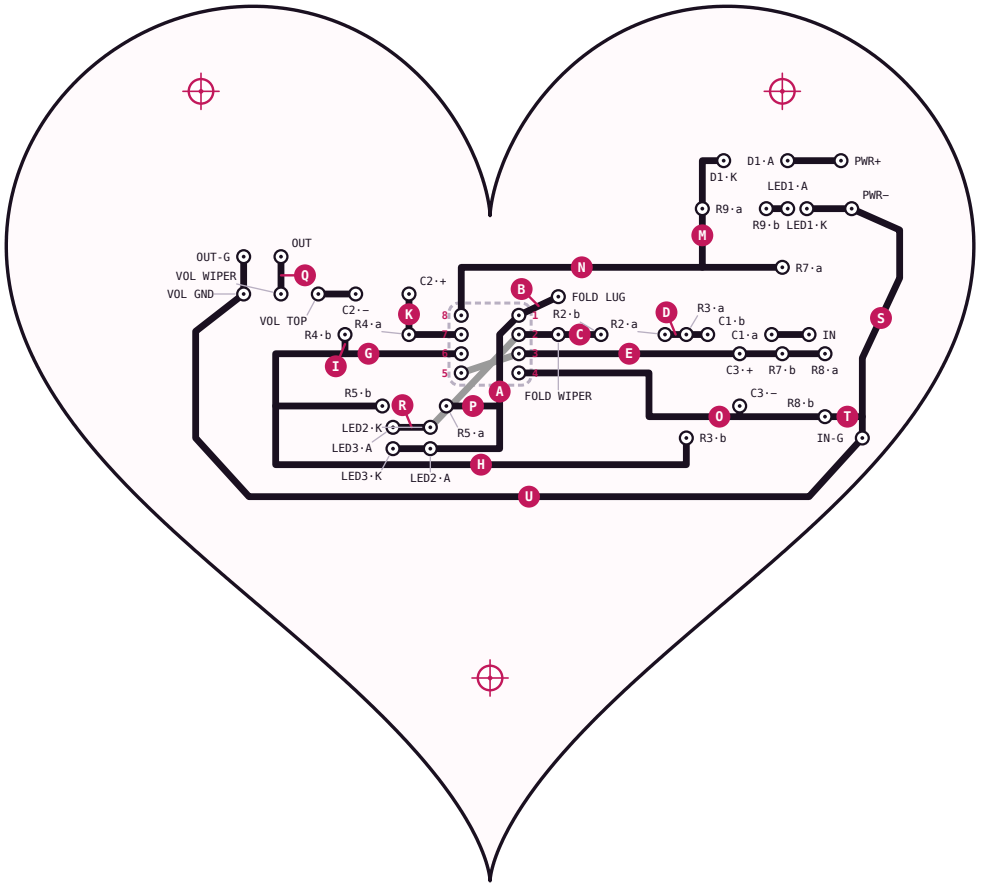
FRONT - parts side

parts go in from this face · the fold and volume pots, the jacks and power on wires



BACK - solder side

glued behind the front · mirror image · bare wire along every line



Cut each heart out on its own outline. Never fold this sheet and cut both at once: the two sides come out misaligned.

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 Wasp

a one-chip wavefolder that turns a smooth wave's peaks back on themselves, as a full heart-shaped paper circuit

This one is a **wavefolder**, an effect for smooth waves. Plug in a sine or a triangle and turn FOLD up: past a certain level the top of the wave, instead of going higher, turns back down, and the further you push it the earlier in the wave the fold starts. The fold adds harmonics, so a plain hum turns bright and buzzy.

One TL072 does it. The first half is a gain stage set by the FOLD knob, and two red LEDs across that knob cap its output at a little under two volts either way. The second half takes the dry signal away from that capped copy: while the copy is still rising it wins, and once it hits the cap the dry signal keeps going and pulls the wave back down. That is the fold. The two LEDs glow faintly while it folds. It is made for smooth waves, the Paper Water Strider's sine and triangle or any synth's triangle out; a square wave has nothing to fold.

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 ringed holes are for wires going off the board: PWR+ and PWR− for power; IN and IN-G for the input jack; FOLD LUG and FOLD WIPER for the fold pot; 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.

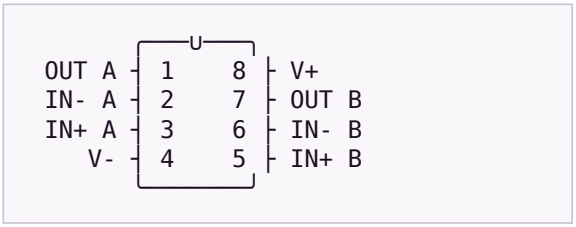
Back: every bold black line is bare wire or a bent part leg. The lines with a letter in a circle are bare wire, and the steps name them by that letter; the short unlettered ones are a part's own leg, bent along the line. The two lighter, thicker lines are J1 and J2, the insulated wires. Small pink numbers beside the chip holes are its pin numbers. R3 stands across two bare wires on the back: they run between its legs, and the steps say so.

Folding a wave by taking it away from a diode-clipped copy of itself is an old analog synth trick. The paper-circuit method is Peter Blasser's / Ciat-Lonbarde's. This layout and the words are Onion Madder's.

What you'll need

- **1× TL072 dual op amp (IC1)** · *spot it:* TL072 printed on top, notch or dot at pin 1, 8 pins. It solders straight to the paper, no socket.
- **Resistors: 2× 47K (R3, R4), 33K (R5), 2× 100K (R7, R8), 10K (R2), 2.2K (R9)** · *spot it:* 47K yellow-violet-orange, 33K orange-orange-orange, 100K brown-black-yellow, 10K brown-black-orange, 2.2K red-red-red.
- **1× 1 µF film (C1)** · *spot it:* printed 105, a small box. The input coupling cap; it goes in either way around.
- **2× 10 µF electrolytic (C2, C3)** · *spot it:* little cans; the stripe marks the − leg. C2 is the output's DC blocker, C3 holds the half supply still.
- **3× LEDs: 2 red (LED2, LED3) and 1 for power (LED1)** · *spot it:* the two red ones are the fold: they cap the FOLD stage and glow faintly while it folds. Long leg +, flat side of the rim −.
- **1× 1N5817 Schottky diode (D1)** · *spot it:* small black body, gray or silver band marks the cathode
- **2× pots: B100K for FOLD, A100K for volume** · *spot it:* B is linear, A is log. They hang off the board on wires, so any style fits. FOLD uses two lugs, volume all three.
- **1× SPST toggle, 2× jacks** · *spot it:* power, the input and the output, on wires
- **Bare tinned wire, and insulated wire** · *spot it:* bare for the traces on the back, insulated for J1, J2 and every wire off the board
- **Power: a 9V battery and snap, or a 2.1 mm DC jack and a 9V pedal supply** · *spot it:* 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



The chip sits on the sheet exactly like this, notch toward the top edge. Half A (pins 1, 2, 3) is the FOLD gain; half B (pins 5, 6, 7) adds the dry and folded signals. Pins 3 and 5 both sit at half the supply, joined by J1.

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.

Chip straight in. The TL072 is soldered straight to the paper with no socket, and a bare wire runs between its two rows of legs on the back. Keep each joint quick: touch, flow, lift.

LEDs back to back. LED2 and LED3 point opposite ways between the same two wires, so the wave folds on both its top and its bottom. The sheet marks each A hole.

Mind the cans. C2 and C3 are polarized: the stripe is the − leg, and the sheet marks each + 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 8 chip holes straight down through all four layers with pointed tweezers, held closed. The box takes the points.
11	Poke the other 39 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.

Start in the middle: the chip and the wire under it

Everything builds outward from the chip. Half A’s output leaves pin 1 down between the rows and out under the chip.

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

STEP	DO
13	Push the TL072 into the IC1 holes from the front, notch toward the top edge (the drawn notch).
14	On the back, bend pins 1, 4, 5 and 8 outward slightly so the chip can’t fall out.
15	Trace A: bare wire from pin 1 a little way in between the rows, down past pins 2, 3 and 4 without touching them, out under the chip and across through the LED2·A hole to LED3·K. Solder at pin 1; the far end gets soldered as the LEDs go in.
16	J1: an insulated wire from pin 3 to pin 5, across the back of the chip. It crosses trace A, which is why it is insulated. Strip just the ends and solder at both pins.
17	Check with a meter: trace A must not beep to pins 2, 3 or 4.

The left side: the input and the FOLD gain

The input comes in through C1. R2 and the FOLD pot set half A’s gain, and R3 carries the dry signal down to half B’s summing node.

STEP	DO
18	Trace B: bare wire from pin 1 up and out to the left to the FOLD LUG pad. Solder at both.
19	R2, 10K (brown-black-orange): legs into R2·a and R2·b.
20	Trace C: bare wire from pin 2 out to the left through the FOLD WIPER pad to R2·b. Solder at all three.
21	C1, 1 µF film (105): legs into C1·a and C1·b. Bend C1·a’s leg to the IN pad and solder at both.
22	R3, 47K (yellow-violet-orange): legs into R3·a and R3·b. It stands across two wires that go in later: they run between its legs on the back.
23	Trace D: bare wire through R2·a, R3·a and C1·b. Solder at all three.

Half the supply

R7 and R8 split the supply in half and C3 holds it still. That half-supply, VREF, is what both + inputs sit on.

> C3’s stripe goes toward the bottom of the heart.

STEP	DO
24	R7, 100K (brown-black-yellow): legs into R7·a and R7·b. C1’s bent leg runs between its legs on the back.
25	R8, 100K: legs into R8·a and R8·b.
26	C3, 10 µF: long + leg into C3·+, striped leg into C3·−.

27	Trace E, VREF: bare wire from pin 3 straight out to the left, between R3's legs, through C3·+ and R7·b to R8·a. Solder at all four.
28	Trace O, ground: bare wire from pin 4 out to the left, down, and along between R3's legs to R8·b. Solder at pin 4 and R8·b. Bend C3·−'s leg down onto it and solder.

Under the chip and right: the fold

The two red LEDs go between pin 1's wire and pin 2's, pointing opposite ways: they cap half A at a little under two volts. R5 carries the capped copy to half B's summing node, pin 6, where the dry signal takes it away again: the fold.

> LED2 and LED3 must point opposite ways: check each flat side against the sheet. Meter pin 1 to pin 2 with the power off: trace A must not beep to J2's line.

STEP	DO
29	LED2: long leg into LED2·A (the lower hole), short leg into LED2·K. LED3: long leg into LED3·A (the upper hole), short leg into LED3·K. They point opposite ways. Solder LED2·A and LED3·K where trace A ends.
30	Trace R: bare wire from LED2·K across to LED3·A. Solder at both.
31	J2: an insulated wire from pin 2 across the back to LED2·K. It crosses trace A and J1, which is why it is insulated. Strip just the ends and solder at both.
32	R5, 33K (orange-orange-orange): legs into R5·a and R5·b.
33	Trace P: bare wire from trace A, where it comes down between the rows, across to R5·a. Solder at R5·a and where it meets A.
34	Trace G, the summing node: bare wire from R5·b across and up the right side to pin 6. Solder at R5·b and pin 6.
35	Trace H: bare wire from R3·b down, along the bottom and up to meet trace G. Solder at R3·b and where it meets G.
36	R4, 47K: legs into R4·a and R4·b.
37	Trace I: bare wire from R4·b down to trace G. Solder at R4·b and where it meets G.
38	C2, 10 µF: long + leg into C2·+, striped leg into C2·−. Bend C2·−'s leg to the VOL TOP pad and solder at both.
39	Trace K: bare wire from pin 7 out to the right through R4·a and up to C2·+. Solder at all three.

Power corner and the +V line

Power comes in on two pads at the top left. D1 only lets current through one way, so power hooked up backwards does nothing, and LED1 says it’s on.

> D1’s band goes in D1·K, toward the chip.

STEP	DO
40	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.
41	Trace M: bare wire from D1·K across and down to R7·a. Solder at D1·K and R7·a.
42	Trace N, +V: bare wire from trace M along over the top of the chip to pin 8. Solder at pin 8 and where it meets M.
43	R9, 2.2K (red-red-red): legs into R9·a and R9·b. Solder R9·a on trace M.
44	LED1: long leg into LED1·A, short leg into LED1·K. Bend R9·b’s leg to LED1·A and solder at both. Bend LED1·K’s leg to the PWR− pad and solder at both.

The ground line

One ground wire runs from PWR− down the left side, through the IN-G pad, along the bottom and up the right side to the volume pads.

STEP	DO
45	Trace S, ground: bare wire from the IN-G pad up the left side to PWR−. Solder at IN-G and PWR−.
46	Trace T: bare wire from R8·b out to the left to trace S. Solder where it meets S.
47	Trace U: bare wire from the OUT-G pad down through the VOL GND pad, down the right side, along the bottom to the IN-G pad. Solder at OUT-G, VOL GND and IN-G.
48	Trace Q: bare wire from the VOL WIPER pad up to the OUT pad. Solder at both.
49	Snip every leg tail that sticks past its joint.

Off the board

The FOLD pot, the volume pot, the two jacks, 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
50	FOLD pot: the middle lug (the wiper) to FOLD WIPER and one outer lug to FOLD LUG. The other outer lug stays empty. If it folds more as you turn it down, move the FOLD LUG wire to the other outer lug.
51	Volume pot: one outer lug to VOL TOP, the middle lug 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	Input jack tip to IN, sleeve to IN-G. Output jack tip to OUT, sleeve to OUT-G.

53	A wire from one lug of the power toggle to the PWR+ pad.
54	Battery: the snap’s red (+) wire to the toggle’s other lug, its black (−) wire to PWR−. Or a 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−.

Check, then play

Meter it before you play it. These readings come from the design and a simulation, not off my board.

STEP	DO
55	Turn the volume down and FOLD all the way down. Toggle on: LED1 should light.
56	Meter pin 8 to pin 4: the supply voltage minus about 0.3 V. Meter pins 1, 3, 5, 6 and 7 to pin 4: each about half of that.
57	Plug a sine or triangle into IN: the Paper Water Strider is ideal. Bring the volume up: you hear it clean.
58	Turn FOLD up slowly. From about a fifth of its turn the peaks fold back, the fold moves earlier in the wave as you go, and the sound gets brighter. LED2 and LED3 glow faintly while it folds, brighter with a louder input.

Voltage check

METER BETWEEN	EXPECT (toggle on, nothing plugged in)
PWR+ pad → PWR− pad	supply voltage
pin 8 → pin 4	supply voltage minus about 0.3 V
pin 3 and pin 5 → pin 4	half of pin 8, about 4.3 V on a fresh 9 V
pin 1 and pin 7 → pin 4	the same half, within a few tenths

If it won’t sing

SYMPTOM	CHECK
Dead, LED1 dark	D1 in backwards (the band goes in D1·K), the power wires reversed, or the toggle not between the supply’s + and PWR+.
LED1 lit, silent	Pin 7 should read half the supply: if not, check trace G into pin 6 and R4. Then C2 to VOL TOP, the volume pot, and the input: trace D and C1.
Clean, but FOLD does nothing	The source must be smooth and loud enough: a sine or triangle of about a volt. Then J2, trace R and the LEDs, and the FOLD pot wires, trace B and trace C, and trace A to R5.
Folds on the top but not the bottom	One LED is in the same way as the other: LED2 and LED3 must point opposite ways.
A square wave comes out unchanged	That is right: a square has no slope to fold. Use a sine or a triangle.

SYMPTOM	CHECK
Paper scorched or a hole tore	Glue a scrap of paper over the back, re-poke, carry on. It is paper.

Things to try

- **Different LEDs.** Green or blue turn on later than red, so the fold starts higher. Untried.
- **The Water Strider’s triangle** folds into sharper shapes than its sine. Untried.
- **An LFO on FOLD.** A photocell across the FOLD pads, under a blinking LED, sweeps the folding. Untried.