PAPER WATER STRIDER

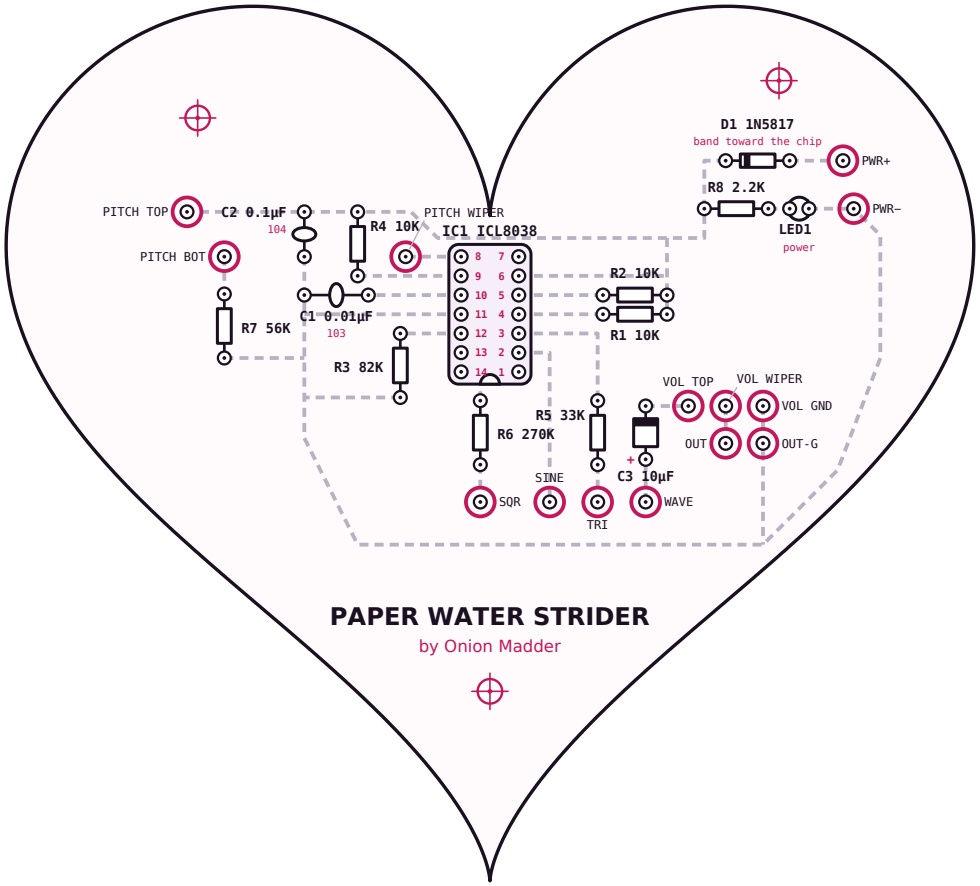
a one-chip sine, triangle and square generator as a paper circuit · two hearts, print at 100% / Actual size

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

this bar must measure 100 mm

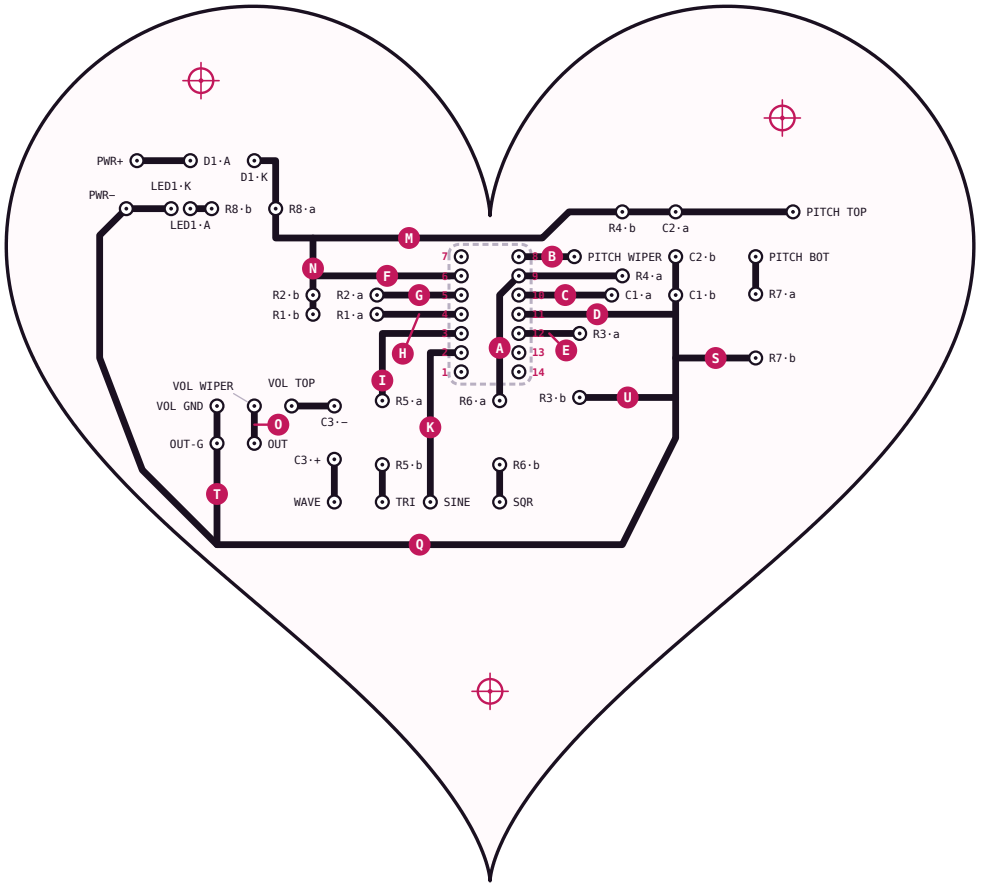
FRONT - parts side

parts go in from this face · the pots, the switch, the jack 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 Water Strider

a one-chip sine, triangle and square generator on an ICL8038, as a full heart-shaped paper circuit

This one is a **function generator**: one ICL8038 makes a sine, a triangle and a square wave at the same time, and a three-way switch picks which one you hear. The other paper builds are square waves, so this is the first one with a smooth sine on it.

The pitch knob sets a voltage on one pin, and the chip's pitch follows it in a straight line: from nothing at one end of the knob to about 2.3 kHz at the other. It runs on a 12 V supply, because the chip needs at least 10 V on a single supply.

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.

56 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; PITCH TOP, PITCH WIPER and PITCH BOT for the pitch pot; SINE, TRI, SQR and WAVE for the waveform switch; 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.

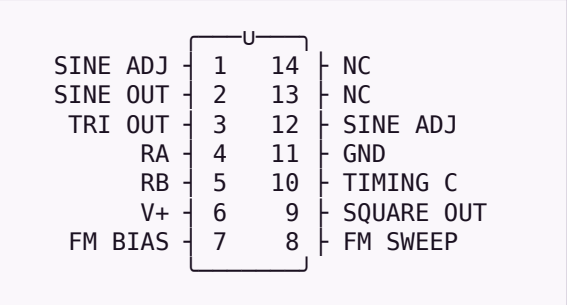
Back: every bold black line is bare wire or a bent part leg. The lines with a letter in a circle are bare wire, and the steps name them by that letter; the short unlettered ones are a part's own leg, bent along the line. Small pink numbers beside the chip holes are its pin numbers. One lettered wire runs between the chip's two rows of legs and out underneath it: that is on purpose, and the steps say which pins it passes.

The circuit follows the ICL8038's own datasheet: the timing resistors, the pitch on the sweep pin and the 82K for the cleaner sine are all from it. 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× ICL8038 function generator (IC1)** · *spot it:* 8038 printed on top, notch or dot at pin 1, 14 pins. It solders straight to the paper, no socket. It is an old part, out of production; clones are common.
- **Resistors: 3× 10K (R1, R2, R4), 82K (R3), 56K (R7), 33K (R5), 270K (R6)** · *spot it:* 10K brown-black-orange, 82K gray-red-orange, 56K green-blue-orange, 33K orange-orange-orange, 270K red-violet-yellow. R1 and R2 set the timing, R4 pulls the square up, R3 shapes the sine, R7 sits under the pitch pot, and R5 and R6 bring the triangle and square down to the sine's level.
- **Ceramic caps: 0.01 µF (C1), 0.1 µF (C2)** · *spot it:* printed 103 and 104. C1 is the timing cap; C2 sits across the supply.
- **1× 10 µF electrolytic (C3)** · *spot it:* a little can, stripe marks the − leg. The output's DC blocker.
- **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 (R8)** · *spot it:* the power light. The LED's long leg is +, the flat side of the rim −; 2.2K is red-red-red
- **1× B10K pot (pitch)** · *spot it:* marked B10K; B = linear. All three lugs are used. It hangs off the board on wires, so any style fits.
- **1× A100K pot (volume)** · *spot it:* marked A100K; A = log, the right taper for volume. On wires too.
- **1× three-way switch** · *spot it:* one pole, three positions: a small rotary switch, or an on-on-on toggle. 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 2.1 mm DC jack and a 12 V center-negative adapter** · *spot it:* 12 V, not 9 V: the chip wants at least 10 V on a single supply
- **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



This is the chip the usual way up. **On the sheet it sits notch DOWN**, toward the bottom of the heart, so its left row reads 8 to 14 from the top and its right row 7 down to 1. Match it to the drawn notch. Pins 1, 7, 13 and 14 stay empty on purpose.

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.

Notch down. The ICL8038 goes in with its notch toward the bottom of the heart, the other way up from most of the paper builds. It solders straight to the paper with no socket, so check the notch before the first joint.

12 V. Power it from a 12 V center-negative adapter. A 9 V supply is under the chip’s 10 V minimum.

Mind the can. C3 is polarized: the stripe is the − leg, and the sheet marks the + 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 14 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.

Start in the middle: the chip and the square wave

Everything builds outward from the chip. The square wave leaves pin 9 two ways: out to the left for its pull-up resistor, and down between the chip's rows and out under it to the switch.

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

STEP	DO
13	Push the ICL8038 into the IC1 holes from the front, **notch DOWN**, toward the bottom of the heart (the drawn notch).
14	On the back, bend pins 7, 8, 14 and 1 (the four corners) outward slightly so the chip can't fall out.
15	Trace A: bare wire from the R4·a hole straight to pin 9, a little way in between the rows, down past pins 10 to 14 without touching them, out under the chip and down to the R6·a hole. Solder at pin 9; the two ends get soldered as R4 and R6 go in.
16	Check with a meter: trace A must not beep to pins 10, 11, 12, 13 or 14.

The left side: timing cap, sine trim and pitch

C1 is the timing cap, R3 shapes the sine, and pin 8 takes the pitch voltage from the pitch pot.

STEP	DO
17	C1, 0.01 µF (103): legs into C1·a and C1·b.
18	Trace C: bare wire from pin 10 out to the left to C1·a. Solder at both.
19	R3, 82K (gray-red-orange): legs into R3·a and R3·b, standing below C1.
20	Trace E: bare wire from pin 12 out to the left to R3·a. Solder at both.
21	Trace D: bare wire from pin 11 straight out to the left, between C1 and R3, to the ground line. Solder at pin 11.
22	Trace U: bare wire from R3·b straight out to the left to the ground line. Solder at R3·b.
23	R4, 10K (brown-black-orange): legs into R4·a and R4·b. Solder R4·a where trace A ends.
24	Trace B: bare wire from pin 8 out to the left to the PITCH WIPER pad. Solder at both.

The right side: the timing resistors

R1 and R2 set how fast C1 charges and discharges. Equal, they make the waves symmetrical.

STEP	DO
25	R2, 10K: legs into R2·a and R2·b. R1, 10K: legs into R1·a and R1·b, just below it.
26	Trace G: bare wire from pin 5 out to the right to R2·a. Solder at both.
27	Trace H: bare wire from pin 4 out to the right to R1·a. Solder at both.
28	Trace F: bare wire from pin 6 out to the right, above R2, to the +V branch. Solder at pin 6; the far end gets soldered with the branch.

Below the chip: the three waves

The sine comes straight off pin 2. The triangle and the square each go through a resistor that brings them down to about the sine's level, so the switch doesn't jump in volume.

> C3's stripe goes toward the top, the VOL TOP side.

STEP	DO
29	Trace K: bare wire from pin 2 out to the right a little, then straight down to the SINE pad. Solder at both.
30	R5, 33K (orange-orange-orange): legs into R5·a and R5·b. Bend R5·b's leg to the TRI pad and solder at both.
31	Trace I: bare wire from pin 3 out to the right, then down to R5·a. Solder at pin 3 and R5·a.
32	R6, 270K (red-violet-yellow): legs into R6·a and R6·b. Solder R6·a where trace A ends. Bend R6·b's leg to the SQR pad and solder at both.
33	C3, 10 µF: long + leg into C3·+, striped leg into C3·−. Bend C3·+'s leg to the WAVE pad and C3·−'s leg to the VOL TOP pad, and solder at all four.

Power corner and the +V line

Power comes in on two pads at the top right. D1 only lets current through one way, so power hooked up backwards does nothing; the LED says it's on, and C2 steadies the supply.

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

STEP	DO
34	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.
35	Trace M, the +V line: bare wire from D1·K down, along over the top of the chip, and out to the left to the PITCH TOP pad. Solder at D1·K, R4·b and PITCH TOP.
36	Trace N: bare wire from trace M straight down through R2·b to R1·b. Solder at both, where trace F meets it, and where it meets M.
37	C2, 0.1 µF (104): legs into C2·a and C2·b. Solder C2·a on trace M.
38	R8, 2.2K (red-red-red): legs into R8·a and R8·b. Solder R8·a on trace M.
39	LED1: long leg into LED1·A, short leg into LED1·K. Bend R8·b's leg to LED1·A and solder at both. Bend LED1·K's leg to the PWR− pad and solder at both.

The pitch pot’s bottom and the ground line

R7 sits under the pitch pot so its wiper only swings over the range the chip can use. One ground wire runs from C2 down the left side, along the bottom and up the right side to PWR−.

STEP	DO
40	R7, 56K (green-blue-orange): legs into R7·a and R7·b. Bend R7·a’s leg to the PITCH BOT pad and solder at both.
41	Trace Q, ground: bare wire from C2·b down the left side through C1·b, along the bottom under the switch pads, and up the right side to PWR−. Solder at C2·b, C1·b, PWR−, and where traces D and U meet it.
42	Trace S: bare wire from R7·b across to the ground line. Solder at R7·b and where it meets Q.
43	Trace T: bare wire from the VOL GND pad down through the OUT-G pad to the ground line. Solder at VOL GND, OUT-G and where it meets Q.
44	Trace O: bare wire from the VOL WIPER pad down to the OUT pad. Solder at both.
45	Snip every leg tail that sticks past its joint.

Off the board

The pitch pot, the switch, 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
46	Pitch pot: one outer lug to PITCH TOP, the middle lug (the wiper) to PITCH WIPER, the other outer lug to PITCH BOT. If the knob runs backwards, swap the two outer wires.
47	Waveform switch: its common (the middle lug of a toggle, or the center of a rotary) to WAVE, and its three positions to SINE, TRI and SQR.
48	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.
49	Output jack tip to OUT, sleeve to OUT-G.
50	A wire from one lug of the power toggle to the PWR+ pad.
51	A 2.1 mm DC jack for a center-negative 12 V adapter: 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 datasheet and the arithmetic, not off my board.

STEP	DO
52	Turn the volume all the way down. Plug in the 12 V adapter and toggle on. LED1 should light.
53	Meter pin 6 to pin 11: about 11.7 V.
54	Meter pin 8 to pin 11 while you turn the pitch knob: it moves between about 11.7 V and about 9.9 V.
55	Meter pin 2 and pin 3 to pin 11 with the pitch up: each about half the supply.
56	Bring the volume up slowly, switch between the three waves, and sweep the pitch.

Voltage check

METER BETWEEN	EXPECT (12 V adapter, toggle on)
PWR+ pad → PWR− pad	about 12 V
pin 6 → pin 11	about 11.7 V
pin 8 → pin 11	between about 11.7 V and 9.9 V, following the pitch knob
pin 2 → pin 11, and pin 3 → pin 11	about half of pin 6, with the pitch up
pin 9 → pin 11	about half of pin 6 on a meter: the square running

If it won’t sing

SYMPTOM	CHECK
Dead, LED dark	D1 in backwards (the band goes in D1·K), the adapter’s center not negative, or the toggle not between the jack’s + and PWR+.
LED lit, silent on every wave	Turn the pitch knob: at one end there is no tone at all. Then pin 8: it should move as the knob turns, so check trace B and the pitch pot’s three wires. Then C1 on trace C and the timing resistors.
One wave missing	Its own path: SINE is trace K; TRI is trace I and R5; SQR is trace A, R6 and R4. Then that wire on the switch.
Square only, at full supply level	R6 is the 270K (red-violet-yellow), not a 270 ohm.
Most of the knob is high notes	That is the chip: pitch follows the voltage in a straight line, so the low octaves are crowded at one end. A C (reverse log) pot for pitch spreads them out (untested).
Lopsided waves	R1 and R2 should both be 10K: unequal, the triangle leans and the square stops being square.
Paper scorched or a hole tore	Glue a scrap of paper over the back, re-poke, carry on. It is paper.

Things to try

- **Lower:** C1 at 0.1 µF (104) moves the whole range down by ten, into slow wobbles for the other boards. Untried.
- **Into the Paper Ring Mod.** The sine on one input of a ring mod gives a different smash from two squares. Untried.
- **A photocell under the pitch pot.** An LDR in place of R7 makes the pitch range follow the light. Untried.