PAPER FLEA

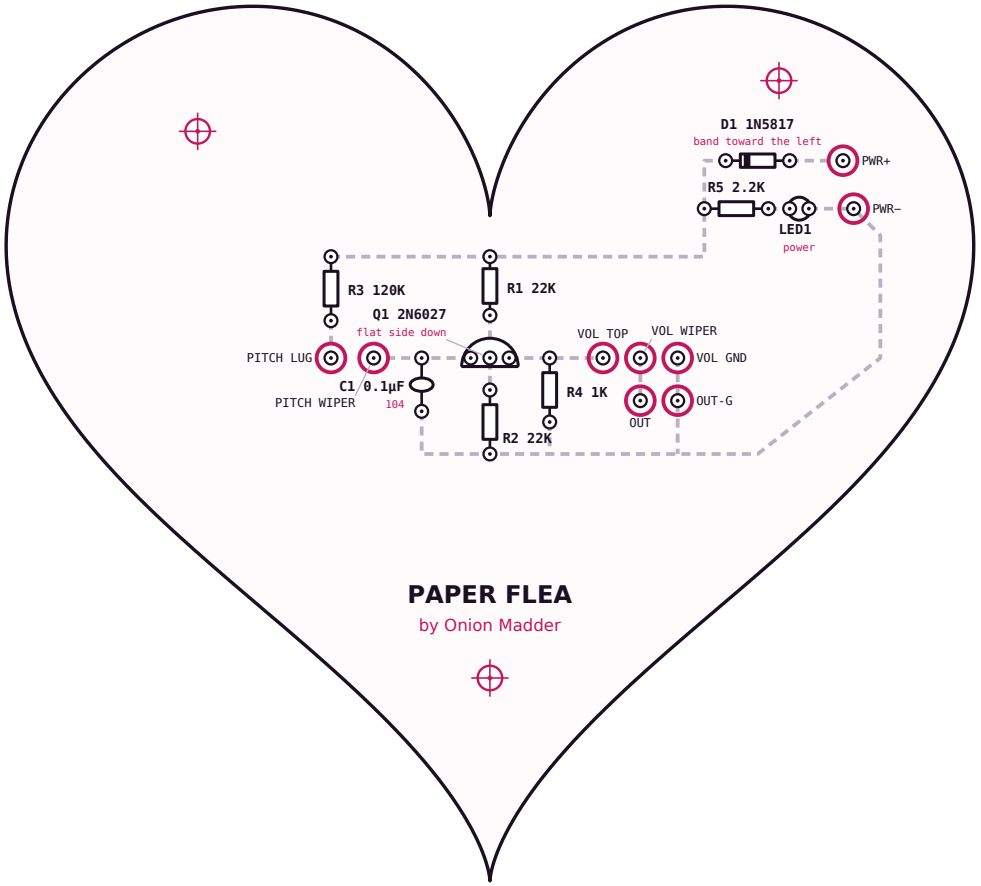
a one-transistor ticking oscillator as a paper circuit · two hearts, print at 100% / Actual size

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

this bar must measure 100 mm

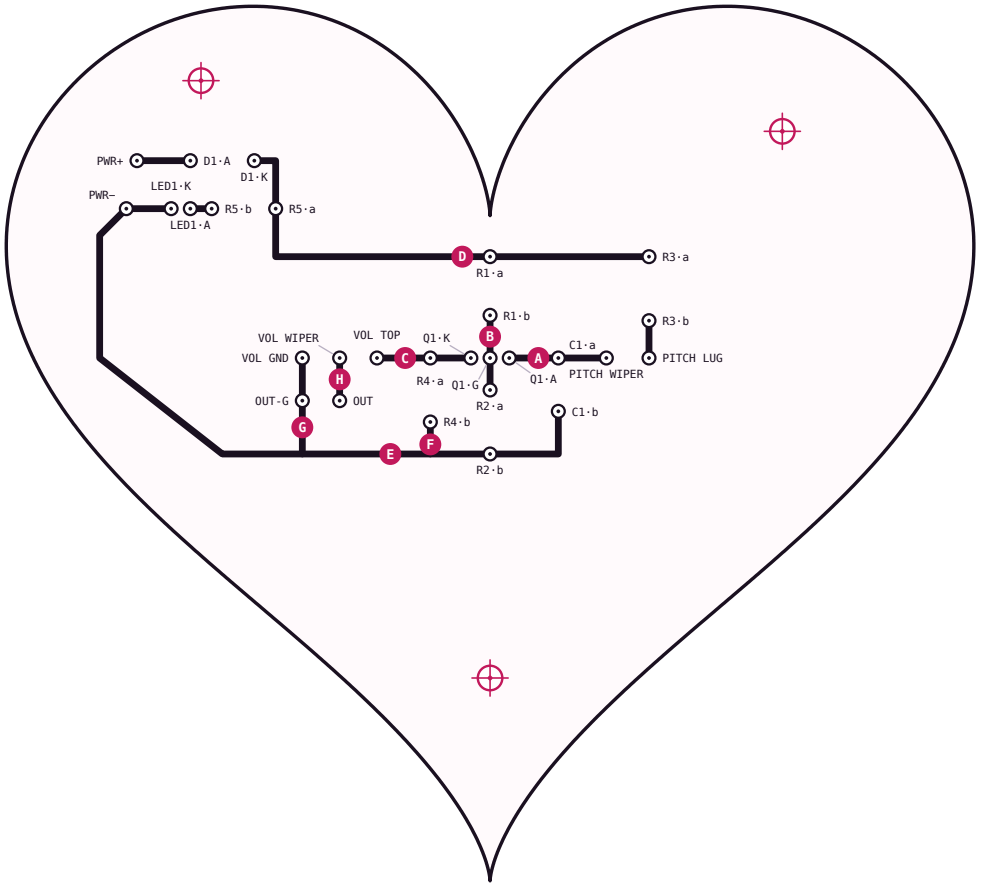
FRONT - parts side

parts go in from this face · the pitch and volume pots, 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 Flea

a one-transistor ticking oscillator, from a tick to a buzz, as a full heart-shaped paper circuit

This one is the smallest circuit on the site: **one transistor**, a 2N6027, and a handful of parts. A capacitor fills up slowly through the pitch knob, and when it gets to half the supply the 2N6027 snaps on, empties it in one go, and lets go again. Every snap is a click.

Turn the knob one way and the clicks come slowly enough to count, a dry ticking. Turn it the other way and they run together into a low, rough buzz. It is the oldest kind of oscillator there is, and the easiest one to see working.

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.

41 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 LUG and PITCH WIPER for the pitch 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.

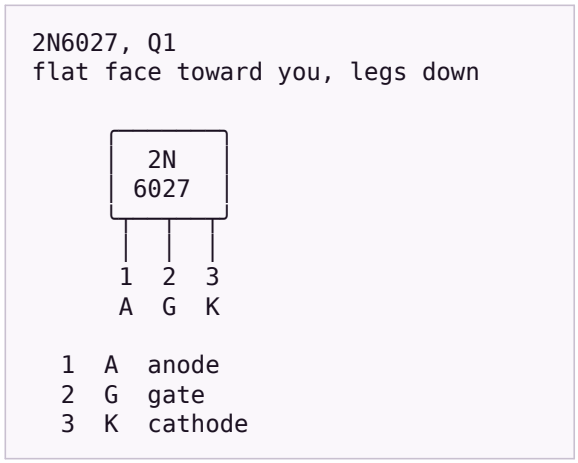
Back: every bold black line is bare wire or a bent part leg. The lines with a letter in a circle are bare wire, and the steps name them by that letter; the short unlettered ones are a part’s own leg, bent along the line. Q1’s three legs are only 2.5 mm apart: the wire up and down from its middle leg passes between the other two without touching them.

The programmable unijunction relaxation oscillator is the textbook circuit for the 2N6027, from its own datasheet onward. 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× 2N6027 programmable unijunction transistor (Q1)** · *spot it:* a little black D-shaped body with three legs, printed 2N6027 on the flat face. It looks like any small transistor: check the printing.
- **2× 22K resistors (R1, R2)** · *spot it:* red-red-orange. They hold Q1's middle leg at half the supply.
- **1× 120K resistor (R3)** · *spot it:* brown-red-yellow. It stays in series with the pitch pot, and it has to be at least about 110K or Q1 sticks on.
- **1× 1K resistor (R4)** · *spot it:* brown-black-red. The clicks come out across it.
- **1× 0.1 µF ceramic (C1)** · *spot it:* printed 104. It sets the speed.
- **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 (R5)** · *spot it:* the power light. The LED's long leg is +, the flat side of the rim −; 2.2K is red-red-red
- **1× B500K pot (pitch)** · *spot it:* marked B500K; B = linear. Only two of its 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× 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 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 transistor, flat face toward you



On the sheet Q1 lies with its flat face toward the bottom of the heart, so from the front its legs run A, G, K left to right, just like this. The drawn D shape shows which way the flat side goes.

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.

Three close legs. Q1's legs are 2.5 mm apart and a bare wire runs between them on the back. Keep each joint small, and check with a meter that no two legs beep.

Flat side down. Q1 goes in with its flat face toward the bottom of the heart. Backwards, the anode and cathode swap and it won’t tick.

120K, not 12K. R3 is brown-red-yellow. With too little resistance there Q1 switches on and stays on.

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 3 holes for Q1, the transistor, straight down through all four layers with pointed tweezers, held closed. The box takes the points.
11	Poke the other 25 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 Q1’s three legs into its holes until they come through on the back. If a leg won’t go, open that hole a little more.

Start in the middle: Q1 and its gate

Everything builds outward from Q1. R1 and R2 hold its middle leg, the gate, at half the supply; that is the level the capacitor has to reach before Q1 fires.

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

STEP	DO
13	Push Q1, the 2N6027, into the Q1 holes from the front, flat face toward the bottom of the heart (the drawn D shape). Its legs run A, G, K left to right.
14	On the back, bend the A and K legs outward slightly so it can’t fall out.
15	R1, 22K (red-red-orange): legs into R1·a and R1·b, above Q1.
16	R2, 22K: legs into R2·a and R2·b, below Q1.
17	Trace B: bare wire from R1·b straight down through Q1·G to R2·a. Solder at all three. It passes between Q1·A and Q1·K without touching them.
18	Check with a meter: Q1·A must not beep to Q1·G, and Q1·K must not beep to Q1·G.

The left side: the timing

C1 fills through R3 and the pitch pot, and Q1’s anode watches it.

STEP	DO
19	C1, 0.1 µF (104): legs into C1·a and C1·b.
20	R3, 120K (brown-red-yellow): legs into R3·a and R3·b. Bend R3·b’s leg to the PITCH LUG pad and solder at both.
21	Trace A: bare wire from Q1·A out to the left, through C1·a, to the PITCH WIPER pad. Solder at Q1·A, C1·a and PITCH WIPER.

The right side: the output

Every time Q1 fires, C1 empties through R4, and the spike across R4 is the sound.

STEP	DO
22	R4, 1K (brown-black-red): legs into R4·a and R4·b.
23	Trace C: bare wire from Q1·K out to the right, through R4·a, to the VOL TOP pad. Solder at Q1·K, R4·a and VOL TOP.

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, and the LED says it’s on.

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

STEP	DO
24	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.
25	Trace D, the +V line: bare wire from R3·a straight across over the top of Q1, through R1·a, then up to D1·K. Solder at R3·a, R1·a and D1·K.
26	R5, 2.2K (red-red-red): legs into R5·a and R5·b. Solder R5·a on trace D.
27	LED1: long leg into LED1·A, short leg into LED1·K. Bend R5·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 C1 along the bottom and up the right side to PWR−, and everything that goes to ground drops onto it.

STEP	DO
28	Trace E, ground: bare wire from C1·b down to the bottom, along it through R2·b, and up the right side to PWR−. Solder at C1·b, R2·b and PWR−.
29	Trace F: bare wire from R4·b straight down to the ground line. Solder at R4·b and where it meets E.
30	Trace G: bare wire from the VOL GND pad straight down through the OUT-G pad to the ground line. Solder at VOL GND, OUT-G and where it meets E.
31	Trace H: bare wire from the VOL WIPER pad down to the OUT pad. Solder at both.
32	Snip every leg tail that sticks past its joint.

Off the board

The pitch pot, 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
33	Pitch pot: the middle lug (the wiper) to PITCH WIPER, and one outer lug to PITCH LUG. The other outer lug stays empty. If the knob runs backwards, move the PITCH LUG wire to the other outer lug.
34	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.
35	Output jack tip to OUT, sleeve to OUT-G.
36	A wire from one lug of the power toggle to the PWR+ pad.

37	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 datasheet and the arithmetic, not off my board.

STEP	DO
38	Turn the volume all the way down. Clip the battery on or plug the supply in, and toggle on. LED1 should light.
39	Meter R1·a to the ground line: the supply minus about 0.3 V. Meter Q1·G to ground: about half that.
40	Meter Q1·A to ground with the pitch knob at its slow end: the reading climbs and drops back every time it ticks, somewhere between about 1 V and 5 V.
41	Bring the volume up slowly and sweep the pitch knob: slow ticks at one end, a low buzz at the other.

Voltage check

METER BETWEEN	EXPECT (toggle on)
PWR+ pad → PWR− pad	supply voltage
R1·a → ground	supply voltage minus about 0.3 V
Q1·G → ground	about half of R1·a, about 4.3 V on a fresh 9 V
Q1·A → ground	moving, between about 1 V and 5 V, with each tick
Q1·K → ground	near zero: the clicks are too short for a meter to see

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, silent, Q1·A sits at 5 V or more	Q1 never fires. Check it is flat side down, trace B through Q1·G, and that R2 is in. Then the pitch pot: wiper on PITCH WIPER, an outer lug on PITCH LUG.
LED lit, silent, Q1·A sits near 1 V	Q1 fired once and stuck on. R3 must be 120K (brown-red-yellow): with much less, too much current keeps it on.
Ticking at the meter, nothing in the speaker	The output side: trace C to VOL TOP, R4, and the volume pot (or the wire from VOL TOP to VOL WIPER), then the jack.
The knob does nothing over half its turn	The pitch pot is on the wrong two lugs. Use the wiper and one outer lug.

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

- **A photocell for the pitch pot.** An LDR across PITCH LUG and PITCH WIPER, the way I ran the Hive Drone, and the ticking follows your hand. A photocell can go very low in bright light, and R3 still keeps Q1 from sticking. Untried.
- **Higher:** C1 at 0.01 µF (103) moves the whole range up by ten, from a buzz to a whine. Untried.
- **Into the Paper Termite or the Paper Ring Mod.** Ticks make a good second input. Untried.