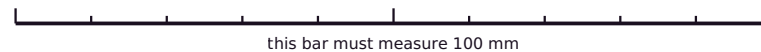


PAPER OPTO DUET

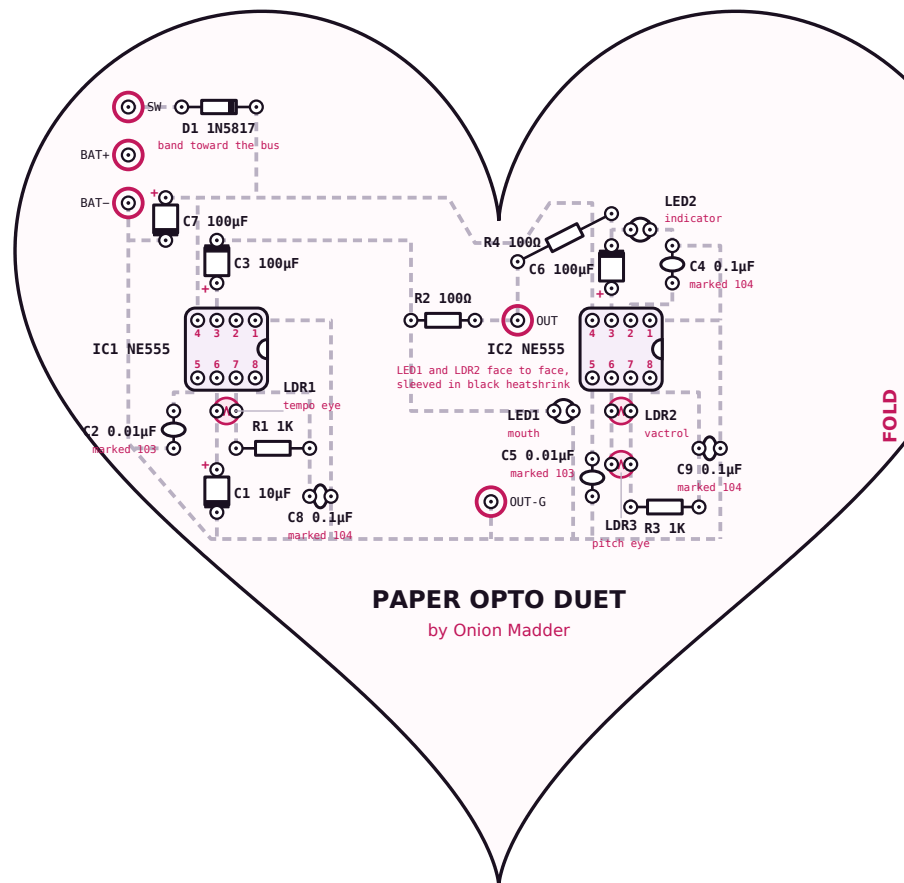
two 555s and a homemade vactrol as a paper circuit · fold sheet, print at 100% / Actual size

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



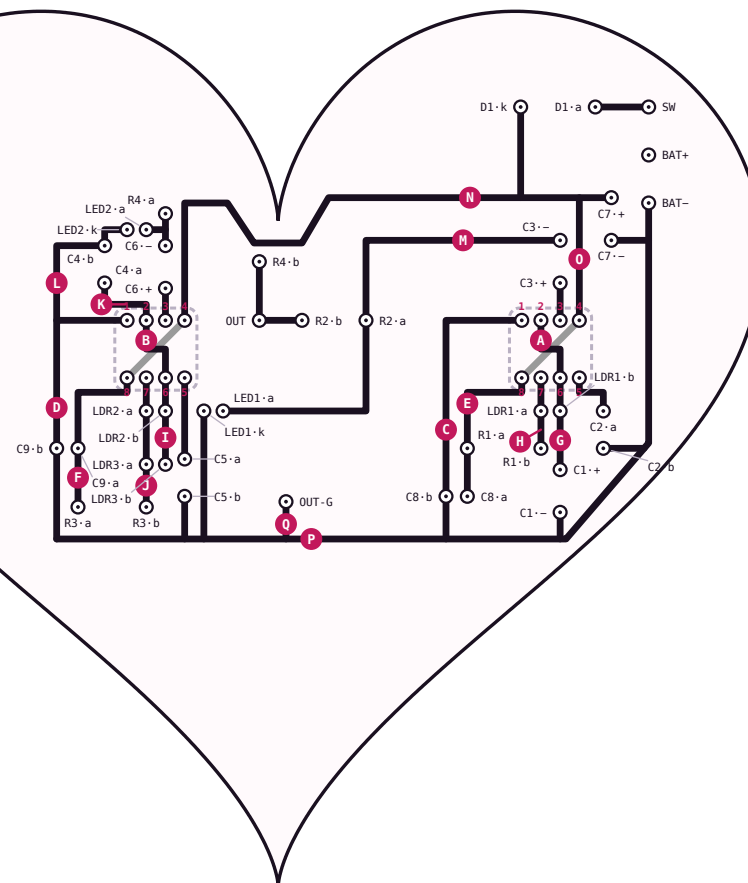
FRONT - parts side

parts go in from this face · the three light cells stand up on their legs



BACK - solder side

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



∞ glue up first, then cut along the heart outline through all four layers · don't cut the fold

build-up: blank sheet folded + glued as the core, then this sheet folded around it and glued = 4 sheets thick

Paper Opto Duet

two 555s and a homemade vactrol, rebuilt as a heart-shaped paper circuit

A paper circuit is a circuit board you print: the drawing is the board, the holes are poked with an awl, and the traces are bare wire laid along the lines on the back. This is the **Opto Duet** on paper: two 555 timers that talk to each other with light. IC1 ticks slowly, and every tick flashes LED1 into LDR2, a light cell in IC2's timing, so IC2 chirps on the beat. Shade the tempo eye and the ticks slow down; shade the pitch eye and the chirps drop. Same circuit and same values as the stripboard Opto Duet, so if you have built that one, every connection here will look familiar.

64 steps. Page 1 is the fold sheet; 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 five ringed holes are for wires going off the board: BAT+ and BAT− for the battery, SW for the toggle's return, OUT and OUT-G for the jack. Both chips lie on their side with the **notch to the right**, so pin 1 is the top right hole of each chip and pin 4 the top left.

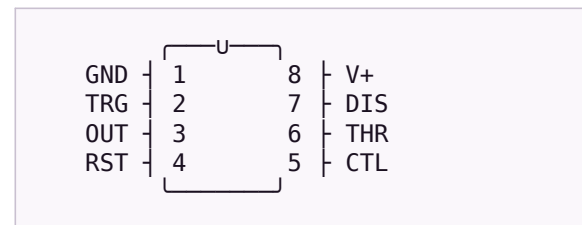
Back: every bold black line is bare wire or a bent part leg. The lines with a pink letter are bare wire, and the steps name them by that letter; the short unlettered ones are a part's own leg, bent along the line. The two gray diagonals are the insulated wires J1 and J2. Small pink numbers beside the chip holes are the pin numbers.

The Opto Duet is Onion Madder's circuit: two 555 theremins coupled by light. The paper-circuit method is Peter Blasser's / Ciat-Lonbarde's. This layout and the words are Onion Madder's.

What you'll need

- **2× NE555 timers** · *spot it:* NE555 printed on top, notch or dot at pin 1. They solder straight to the paper, no sockets.
- **3× LDR photocells (LDR1, LDR2, LDR3)** · *spot it:* a little disc with a wavy track across its face; either way around. LDR1 is the tempo eye, LDR3 the pitch eye, and LDR2 goes inside the vactrol.
- **2× LEDs (LED1, LED2)** · *spot it:* long leg +, flat side of the rim –. LED1 is the mouth that flashes into LDR2; LED2 is the indicator.
- **1× 1N5817 Schottky diode (D1)** · *spot it:* small black body, gray or silver band marks the cathode
- **2× 1K resistors (R1, R3)** · *spot it:* brown-black-red
- **2× 100Ω resistors (R2, R4)** · *spot it:* brown-black-brown
- **1× 10 μF electrolytic (C1)** · *spot it:* little can, stripe marks the – leg. This is what makes IC1 tick slowly.
- **3× 100 μF electrolytic (C3, C6, C7)** · *spot it:* bigger cans, same stripe
- **2× 0.01 μF ceramic (C2, C5)** · *spot it:* tiny disc printed 103
- **3× 0.1 μF ceramic (C4, C8, C9)** · *spot it:* disc printed 104
- **Bare tinned wire, and insulated white wire** · *spot it:* the bare wire makes the traces; the white wire is J1 and J2
- **A short piece of black heatshrink** · *spot it:* it sleeves LED1 and LDR2 together into the vactrol
- **SPST toggle, 9V battery and snap, jack or small speaker** · *spot it:* the toggle and jack hang off the board on wires
- **A second sheet of plain printer paper, glue stick, an awl** · *spot it:* the blank sheet becomes the core; any sharp point works in place of an awl

The chip, from above



This is the 555 the usual way up, notch at the top. On the sheet both chips are turned so the notch points **right**: pins 4, 3, 2, 1 run along the top row from left to right and pins 5, 6, 7, 8 along the bottom. The sheet prints the number beside every chip hole on both faces.

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 straight in. Both 555s are soldered straight to the paper with no sockets, and most parts end at one of their pins. Keep each joint quick: touch, flow, lift.

Bare traces on the back can short. The tightest spots are traces A and B, which cross under each chip from pin 2 to pin 6. Keep them centered between the two rows of pins.

Mind the cans. C1, C3, C6 and C7 are polarized: the stripe is the – leg, and the sheet marks the + hole of each.

Print, fold, glue, poke

The sheet is the circuit board, and it's four sheets of paper thick. A plain sheet folded in half and glued to itself makes the core, then the printed hearts fold around the core and glue on, one heart on each face. The back heart is a mirror image of the front, so once it's folded the holes line up on both faces.

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	Fold a second, blank sheet of printer paper in half.
4	Glue-stick the whole inside of the blank sheet, close it, and press it flat. That's the core: two sheets thick.
5	Fold the printed sheet along the FOLD line, printing on the outside, so the two hearts sit back to back.
6	Unfold it again and glue-stick the back of the FRONT heart.
7	Press the core onto the glued back of the FRONT heart.
8	Glue-stick the back of the BACK heart, fold it over onto the other face of the core, and press it flat. Now it's four sheets thick.
9	Let the glue set for a few minutes, then cut along the heart outline through all four layers. Don't cut across the FOLD hinge.
10	Poke the 16 chip holes from the front with an awl or other sharp point, straight down through all four layers.
11	Poke the other 43 dots the same way. Check the back and open any hole that didn't come all the way through.

Start in the middle: the chips

Everything builds outward from the two chips. Each part goes in from the printed front, then on the back its legs bend along their lines and get soldered there. Every part you add is anchored to the middle, so the board gets stiffer as you go instead of floppier.

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

STEP	DO
12	Push an NE555 into the IC1 holes from the front, notch to the right (the drawn notch).
13	Push the other NE555 into the IC2 holes the same way, notch to the right.

14	On the back, bend each chip's four corner pins outward slightly so the chips can't fall out.
15	Insulated white wire J1 from IC1 pin 4 to IC1 pin 8, corner to corner across the chip. Solder at both pins.
16	Insulated white wire J2 from IC2 pin 4 to IC2 pin 8 the same way. Solder at both pins.
17	Trace A: bare wire from IC1 pin 2 down the middle, under the chip, to pin 6, centered between the rows. Solder at pin 2 and pin 6.
18	Trace B: the same under IC2, pin 2 to pin 6. Solder at both pins.
19	Trace C: bare wire from IC1 pin 1 right, then straight down to the ground-bus line. Solder at pin 1 only; the far end gets soldered with the bus.
20	Trace D: bare wire from IC2 pin 1 right, then straight down to the ground-bus line. Solder at pin 1 only.
21	Trace E: bare wire from IC1 pin 8 down, right, then down through the R1·a and C8·a holes. Solder at pin 8; R1 and C8 join it later.
22	Trace F: bare wire from IC2 pin 8 down, right, then down through the C9·a and R3·a holes. Solder at pin 8; C9 and R3 join it later.

The three eyes and the timing lines

The light cells stand up on their legs on the front, where they can see the room. On the back, one bare wire runs down each column of holes under the chips and picks up every leg it passes.

STEP	DO
23	LDR1, the tempo eye: legs into LDR1·a and LDR1·b from the front, standing up on its legs.
24	Trace G: bare wire from IC1 pin 6 straight down through LDR1·b to the C1·+ hole. Solder at pin 6 and at LDR1·b.
25	Trace H: bare wire from IC1 pin 7 straight down through LDR1·a to the R1·b hole. Solder at pin 7 and at LDR1·a.
26	LDR2, the vactrol cell, into LDR2·a and LDR2·b, and LDR3, the pitch eye, into LDR3·a and LDR3·b, both standing up.
27	Trace I: bare wire from IC2 pin 6 straight down through LDR2·b to LDR3·b. Solder at pin 6, at LDR2·b and at LDR3·b.
28	Trace J: bare wire from IC2 pin 7 straight down through LDR2·a and LDR3·a to the R3·b hole. Solder at pin 7, at LDR2·a and at LDR3·a.

Next ring out: the caps and resistors

Each part goes in from the front. Where a part's hole is already on a bare wire, solder it there; where it isn't, bend the leg along its line on the back.

Leave the legs long until each one is soldered, then snip the tail.

STEP	D0
29	C2, 0.01 μ F (marked 103): legs into C2·a and C2·b. On the back, bend C2·a's leg up, right and up to IC1 pin 5. Solder at C2·a and at pin 5.
30	Solder C2·b's leg in its hole and bend the tail left onto the ground-bus line. The bus lands on it later.
31	C1, 10 μ F: long + leg into C1·+, striped leg into C1·-. Solder C1·+ where trace G arrives. Bend C1·-'s leg down to the ground-bus line and solder it in its hole.
32	R1, 1K (brown-black-red): legs into R1·a and R1·b. Solder R1·a on trace E and R1·b where trace H arrives.
33	C8, 0.1 μ F (marked 104): legs into C8·a and C8·b. Solder C8·a where trace E ends and C8·b where trace C passes.
34	C5, 0.01 μ F (marked 103): legs into C5·a and C5·b. Bend C5·a's leg up to IC2 pin 5 and solder at both. Bend C5·b's leg down to the ground-bus line and solder it in its hole.
35	R3, 1K: legs into R3·a and R3·b. Solder R3·a where trace F ends and R3·b where trace J ends.
36	C9, 0.1 μ F (marked 104): legs into C9·a and C9·b. Solder C9·a on trace F and C9·b where trace D passes.
37	C4, 0.1 μ F (marked 104): legs into C4·a and C4·b.
38	Trace K: bare wire from IC2 pin 2 up, right, then up to C4·a. Solder at pin 2 and at C4·a.
39	Trace L: bare wire from C4·b right, then down to trace D. Solder at C4·b and where it meets D.

The outputs and the vactrol

Each chip's output goes through a big cap to its LED and a 100 Ω resistor, and both resistors meet at the OUT pad. LED1 is the one that matters: it flashes on every tick, and LDR2 is what sees it.

STEP	D0
40	C3, 100 μ F: long + leg into C3·+, striped leg into C3·-. Bend C3·+'s leg down to IC1 pin 3 and solder at both.
41	Trace M: bare wire from C3·- right along the line, down through the R2·a hole to the corner, then right to the LED1·A hole. Solder at C3·-.
42	R2, 100 Ω (brown-black-brown): legs into R2·a and R2·b. Solder R2·a on trace M. Bend R2·b's leg right to the OUT pad and solder at both.
43	LED1: long leg into LED1·A, short leg into LED1·K. Solder LED1·A where trace M ends. Bend LED1·K's leg straight down to the ground-bus line and solder it in its hole.

- 44** C6, 100 μ F: long + leg into C6+, striped leg into C6-. Bend C6+'s leg down to IC2 pin 3 and solder at both.
- 45** R4, 100 Ω : legs into R4a and R4b; it lies at an angle across the V+ line. Bend R4a's leg down to C6- and solder at both. Bend R4b's leg down to the OUT pad and solder at both.
- 46** LED2: long leg into LED2A, short leg into LED2K. Bend LED2A's leg left onto R4's leg and solder. Bend LED2K's leg right and down to C4b and solder.
- 47** On the front, lean LED1 and LDR2 toward each other until LED1's top faces LDR2's face, and slide the black heatshrink over both heads so LDR2 sees only LED1.

Power corner and the two buses

Power comes in at the top left. D1 only lets current through one way, so a battery clipped on backwards does nothing instead of cooking the chips. The V+ bus runs along the top and dips under the heart's notch; the ground bus runs down the left curve and along the bottom.

D1's band is the side current leaves from. It goes in the D1k hole, the end whose leg bends down to the V+ bus, away from the SW pad.

STEP	DO
48	D1, 1N5817: band end into D1k, plain end into D1a. Bend D1a's leg left to the SW pad and solder at both. Bend D1k's leg straight down to the V+ bus line.
49	C7, 100 μ F: long + leg into C7+, striped leg into C7-. Bend C7-'s leg left to the ground-bus line and solder it in its hole.
50	Trace N, V+ bus: bare wire from C7+ right along the top, past D1k's leg, down under the heart's notch and across, then down to IC2 pin 4. Solder at C7+, where D1k's leg meets it, and at IC2 pin 4.
51	Trace O: bare wire from IC1 pin 4 straight up to the V+ bus. Solder at pin 4 and at the bus.
52	Trace P, ground bus: bare wire from the BAT- pad down the left side, around the curve and along the bottom to the end of trace D. Solder at BAT-, at every leg and trace that meets it, and at both ends.
53	Trace Q: bare wire from the OUT-G pad straight down to the ground bus. Solder at OUT-G and at the bus.
54	Snip every leg tail that sticks past its joint.

Off the board

The battery clips onto the board, and the toggle and jack hang off pads on flying leads so they can go wherever your enclosure wants them. Solder each wire on the back.

Leave the battery unclipped until the meter checks.

STEP	DO
55	Battery snap red (+) to the BAT+ pad.
56	Battery snap black (-) to the BAT- pad.

- 57 A wire from the BAT+ pad to one lug of the SPST toggle.
- 58 A wire from the other toggle lug to the SW pad.
- 59 Jack tip (or speaker +) to the OUT pad.
- 60 Jack sleeve (or speaker –) to the OUT-G pad.

Check, then play

Meter it before you listen. These readings are with the chips in.

STEP	DO
61	Turn your amp down. Clip the battery on, toggle on, and meter BAT+ to BAT–: battery voltage.
62	Meter IC1 pin 8 to IC1 pin 1: battery voltage minus about 0.3 V (the diode's drop). Then IC1 pin 4 to pin 1: the same.
63	Meter IC2 pin 8 to IC2 pin 1, then IC2 pin 4 to pin 1: the same reading both times.
64	Bring your amp up. Shade LDR1 and the ticks slow down; shade LDR3 and the chirps drop.

Voltage check

METER BETWEEN	EXPECT (toggle on)
BAT+ pad → BAT– pad	battery voltage
IC1 pin 8 → pin 1, and pin 4 → pin 1	battery voltage minus about 0.3 V
IC2 pin 8 → pin 1, and pin 4 → pin 1	battery voltage minus about 0.3 V

If it won't sing

SYMPTOM	CHECK
Dead, nothing at all	D1 in backwards (the band goes in D1·k), the battery snap reversed (D1 blocks it, nothing gets hurt), or the toggle wires not on BAT+ and SW.
One chip works, the other doesn't	That chip's insulated wire (J1 or J2) and its pin 8 and pin 4 readings. Then its tie under the chip (A or B).
It ticks but never chirps	LED1 and LDR2 not facing each other, or room light getting in around the heatshrink.
Silent, chips warm	Two bare traces touching on the back, most likely A or B brushing a pin. Hold the heart up to a light and look under the chips.
Works for a minute, then fades	A tired 9V does exactly this. Fresh battery.
Paper scorched or a hole tore	Glue a scrap of paper over the back, re-poke, carry on. It is paper.