

PAPER DRAGONFLY

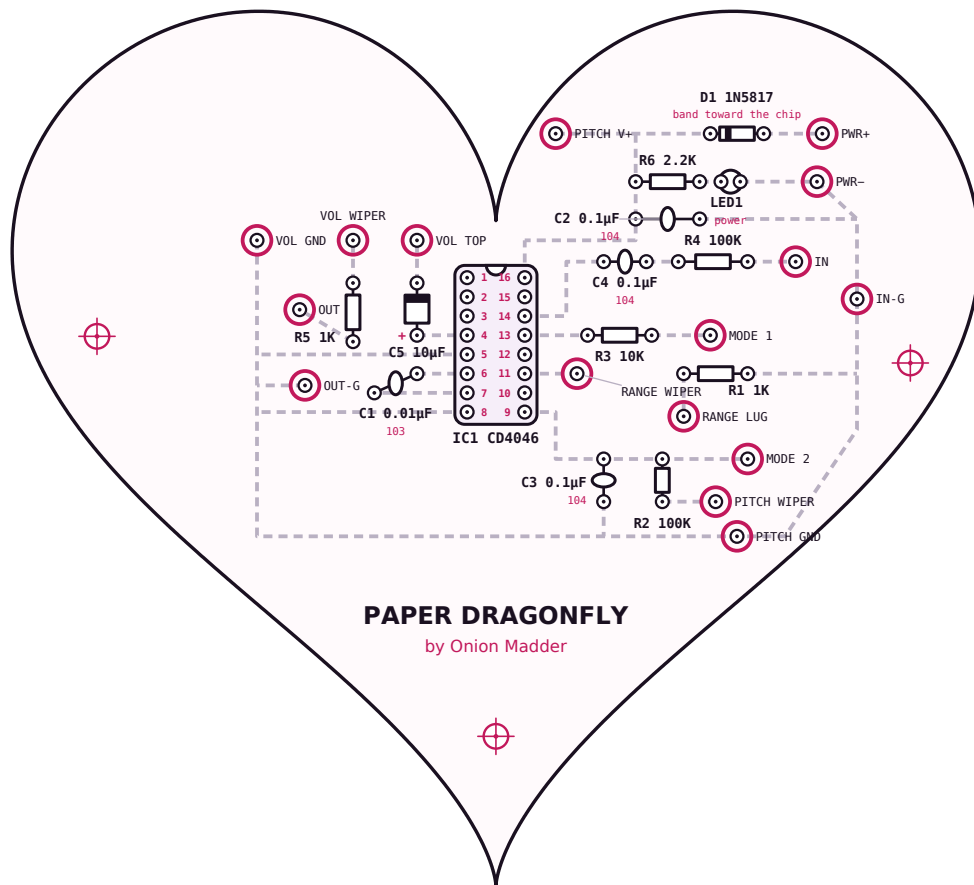
a CD4046 VCO as a paper circuit · two hearts, print at 100% / Actual size

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



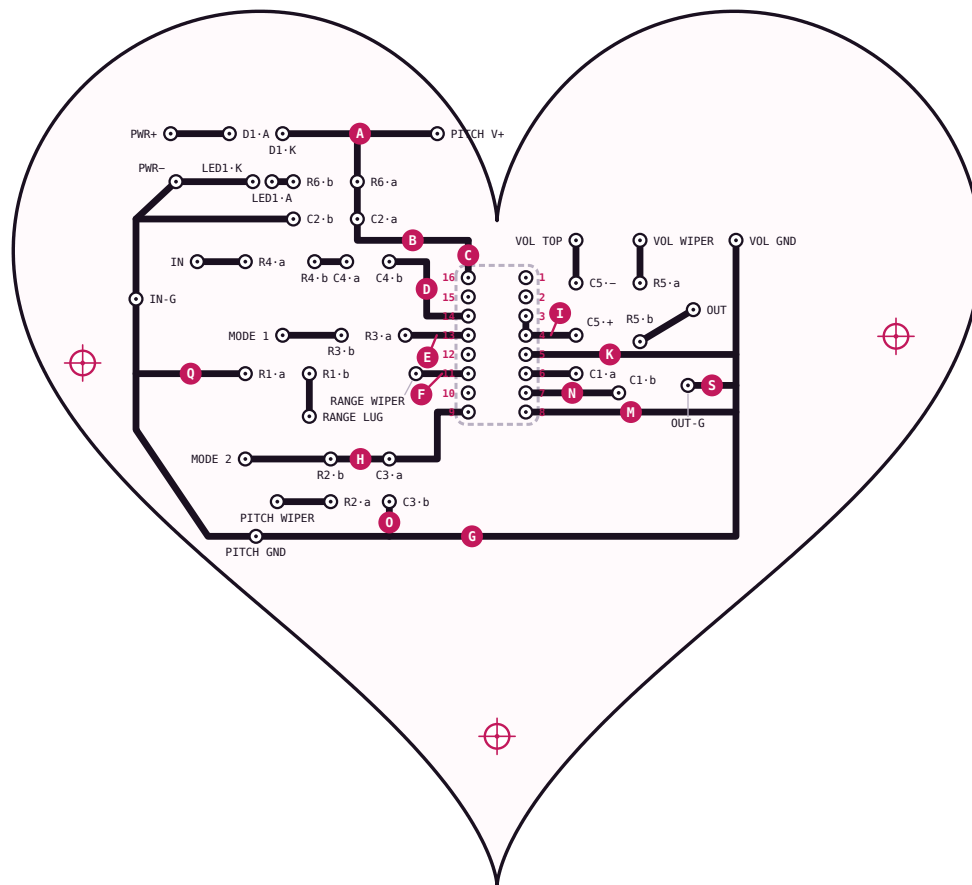
FRONT - parts side

parts go in from this face · three pots, the mode switch, 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 Dragonfly

the Dragonfly CD4046 VCO, rebuilt as a full heart-shaped paper circuit

A paper circuit is a circuit board you print: the drawing is the board, the holes are poked with tweezers, and the traces are bare wire laid along the lines on the back. This is the **Dragonfly** on paper. A CD4046 is a phase-locked loop, a chip built to make one signal follow another, and most synth builds use only its oscillator half. This one keeps both: a pitch knob for playing it, and an input and a mode switch for letting the loop chase whatever you feed it.

It is my built 9 by 14 Dragonfly, part for part. I built that one without the mode switch, so on that board the chase is untried; the first Dragonfly board had it, and with something on the input and the switch thrown it goes hunting.

54 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 V+, PITCH WIPER and PITCH GND, RANGE WIPER and RANGE LUG, and VOL TOP, VOL WIPER and VOL GND for the three pots; MODE 1 and MODE 2 for the mode switch; IN and IN-G, OUT and OUT-G for the jacks. The three target marks are an extra check for the very careful: on the finished heart they sit on top of each other.

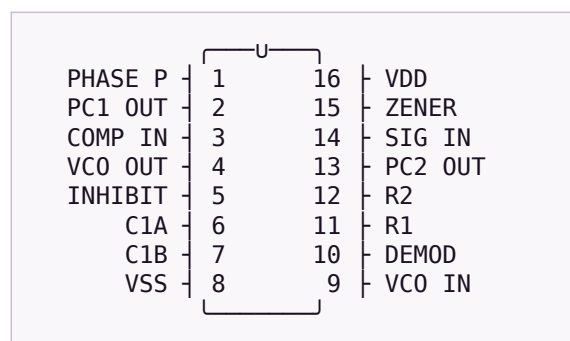
Back: every bold black line is bare wire or a bent part leg. The lines with a letter in a circle are bare wire, and the steps name them by that letter; the short unlettered ones are a part's own leg, bent along the line. Small pink numbers beside the chip holes are its pin numbers.

The CD4046 VCO is the datasheet's; this one is my Dragonfly. 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× CD4046 phase-locked loop (IC1)** · *spot it:* CD4046 printed on top, notch or dot at pin 1, 16 pins. It solders straight to the paper, no socket.
- **3× B100K pots (pitch, range, volume)** · *spot it:* marked B100K; B = linear. They hang off the board on wires, so any style of pot fits.
- **1× 0.01 µF ceramic (C1)** · *spot it:* printed 103. The timing cap: it sets the range, and bigger means lower.
- **3× 0.1 µF ceramic (C2, C3, C4)** · *spot it:* printed 104. One across the supply, two in the control path.
- **1× 10 µF electrolytic (C5)** · *spot it:* a little can, stripe marks the – leg. The output's DC blocker.
- **2× 1K resistors (R1, R5)** · *spot it:* brown-black-red. R1 is the range pot's floor: don't leave it out.
- **1× 10K resistor (R3)** · *spot it:* brown-black-orange
- **2× 100K resistors (R2, R4)** · *spot it:* brown-black-yellow
- **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 (R6)** · *spot it:* the power light. The LED's long leg is +, the flat side of the rim –; 2.2K is red-red-red
- **2× SPST toggles** · *spot it:* one for the mode switch, one for power; both hang off the board on wires
- **2× jacks** · *spot it:* input and 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 chip, from above



The chip sits on the sheet exactly like this, notch toward the top edge. Pins 1, 2, 10, 12 and 15 stay empty on purpose: pin 15 is the chip's internal zener, and pin 12 left open sets no floor on the lowest pitch.

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 CD4046 is soldered straight to the paper with no socket, and most parts end at one of its pins. Keep each joint quick: touch, flow, lift.

Mind the can. C5 is polarized: the stripe is the – leg, and the sheet marks its + hole, on the chip side.

Keep R1. The 1K under the range pot is its floor. Without it, the range pot at zero leaves pin 11 with no resistance at all.

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 16 chip holes straight down through all four layers with pointed tweezers, held closed. The box takes the points.
11	Poke the other 42 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 its pin lines

Everything builds outward from the chip. One bare wire runs out from each pin that is used; solder each at its pin now, and the holes along it as their parts go in.

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

STEP	DO
13	Push the CD4046 into the IC1 holes from the front, notch toward the top edge (the drawn notch).
14	On the back, bend pins 1, 8, 9 and 16 outward slightly so the chip can't fall out.
15	Trace I: bare wire from pin 3 down to pin 4, then out to the C5·+ hole. Solder at pin 3 and pin 4.
16	Trace K: bare wire from pin 5 out to the left ground line. Solder at pin 5 only; the far end gets soldered with the line.
17	Trace N: bare wire from pin 7 out to the C1·b hole. Solder at pin 7.
18	Trace M: bare wire from pin 8 out to the left ground line. Solder at pin 8 only.
19	Trace C: bare wire from pin 16 straight up to the +V line. Solder at pin 16.
20	Trace D: bare wire from pin 14 out, up, and across to the C4·b hole. Solder at pin 14.
21	Trace E: bare wire from pin 13 out to the R3·a hole. Solder at pin 13.
22	Trace F: bare wire from pin 11 out to the RANGE WIPER pad. Solder at pin 11 and at the pad.
23	Trace H: bare wire from pin 9 out, down, and across to the MODE 2 pad. Solder at pin 9 and at the pad.

The left side: timing and output

C1 sets the range. Pin 4 is the oscillator's output; it goes through C5 to the volume pot and comes back through R5 to OUT.

STEP	DO
24	C1, 0.01 μ F (103): legs into C1·a and C1·b. Bend C1·a's leg to pin 6 and solder at both; solder C1·b on trace N.
25	C5, 10 μ F: long + leg into C5·+, striped leg into C5·—. Solder C5·+ where trace I ends. Bend C5·—'s leg up to the VOL TOP pad and solder at both.
26	R5, 1K (brown-black-red): legs into R5·a and R5·b. Bend R5·a's leg up to the VOL WIPER pad and solder at both. Bend R5·b's leg to the OUT pad and solder at both.
27	Trace S: bare wire from the OUT-G pad across to the left ground line. Solder at OUT-G.

The right side: input, mode, range and pitch

The input reaches pin 14 through R4 and C4. Pin 13 is the phase comparator, and R3 takes it to the mode switch. Pin 9 is the pitch: R2 brings the pitch pot's wiper in, and C3 steadies it.

STEP	DO
28	C4, 0.1 μ F (104): legs into C4·a and C4·b. Solder C4·b where trace D ends.
29	R4, 100K (brown-black-yellow): legs into R4·a and R4·b. Bend C4·a's leg to R4·b and solder at both. Bend R4·a's leg to the IN pad and solder at both.
30	R3, 10K (brown-black-orange): legs into R3·a and R3·b. Solder R3·a where trace E ends. Bend R3·b's leg to the MODE 1 pad and solder at both.
31	R1, 1K: legs into R1·a and R1·b. Bend R1·b's leg down to the RANGE LUG pad and solder at both.
32	Trace Q: bare wire from R1·a across to the right ground line. Solder at R1·a.
33	C3, 0.1 μ F (104): legs into C3·a and C3·b. Solder C3·a on trace H.
34	Trace O: bare wire from C3·b down to the ground line. Solder at C3·b.
35	R2, 100K: legs into R2·a and R2·b. Solder R2·b on trace H. Bend R2·a's leg to the PITCH WIPER pad and solder at both.

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; C2 steadies the supply and the LED says it's on.

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

STEP	DO
36	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.
37	Trace A: bare wire from the PITCH V+ pad across to D1·K. Solder at the pad and at D1·K.
38	Trace B, the +V line: bare wire from trace A down and along above the chip to where trace C comes up. Solder where it meets A and C.
39	R6, 2.2K (red-red-red): legs into R6·a and R6·b. Solder R6·a on trace B.
40	LED1: long leg into LED1·A, short leg into LED1·K. Bend R6·b's leg to LED1·A and solder at both. Bend LED1·K's leg to the PWR– pad and solder at both.
41	C2, 0.1 μ F (104): legs into C2·a and C2·b. Solder C2·a on trace B. Bend C2·b's leg across to the right ground line and solder where it meets it.

The ground line

One ground wire runs from VOL GND down the left side, along the bottom and up the right side to PWR–, and everything that goes to ground drops onto it.

STEP	DO
42	Trace G, ground: bare wire from the VOL GND pad down the left side, along the bottom through the PITCH GND pad, up the right side through the IN-G pad, to PWR–. Solder at every pad on it, and where traces K, M, S, O and Q and C2-b's leg meet it.
43	Snip every leg tail that sticks past its joint.

Off the board

The three pots, the mode switch, the jacks, the toggle and the power hang off the pads on insulated wire.

If a knob feels backwards, swap that pot's two outer wires.

STEP	DO
44	PITCH pot: one outer lug to PITCH V+, the other outer lug to PITCH GND, the middle lug to PITCH WIPER. It is a divider, all three lugs, because pin 9 wants a voltage. This is the playing knob.
45	RANGE pot: the middle lug to RANGE WIPER, one outer lug to RANGE LUG. The third lug stays empty.
46	VOLUME pot: one outer lug to VOL TOP, the middle lug to VOL WIPER, the other outer lug to VOL GND.
47	Mode switch, an SPST toggle: one lug to MODE 1, the other to MODE 2. Open, it is a plain VCO on the pitch knob; closed, the loop chases whatever is on the input.
48	Input jack tip to IN, sleeve to IN-G. Output jack tip to OUT, sleeve to OUT-G.
49	A wire from one lug of the power toggle to the PWR+ pad.
50	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 are with the chip in.

STEP	DO
51	Clip the battery on or plug the supply in, and toggle on. LED1 should light.
52	Meter pin 16 to pin 8: the supply voltage minus about 0.3 V. Pin 5 to pin 8 should read zero: that pin has to be low or the oscillator stops.
53	Mode switch open, into an amp turned down: bring the volume up, sweep PITCH, then RANGE.
54	Something on the input, mode switch closed: the pitch knob gives way and the loop goes hunting for the input.

Voltage check

METER BETWEEN	EXPECT (toggle on)
PWR+ pad → PWR– pad	supply voltage
pin 16 → pin 8	supply voltage minus about 0.3 V
pin 5 → pin 8	zero (the inhibit pin, held low)
PITCH WIPER → pin 8	sweeps from zero to the supply as you turn PITCH

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	Pin 5 has to read zero (trace K to ground). Then the volume pot: VOL TOP from C5, the wiper to VOL WIPER. Then C1 across pins 6 and 7.
Sound, but PITCH does nothing	The pitch pot needs all three lugs: PITCH V+, PITCH WIPER and PITCH GND. Meter PITCH WIPER while you turn it.
Stuck very high or very low	C1 the wrong value (103 is 0.01 μ F), or the range pot's wires: its wiper on RANGE WIPER, one outer lug on RANGE LUG.
The mode switch does nothing	There has to be something on the input for the loop to chase. Then R3 to MODE 1, and pin 9's line to MODE 2.
Paper scorched or a hole tore	Glue a scrap of paper over the back, re-poke, carry on. It is paper.

Things to try

- **The DROP toggle:** on my boxed Dragonfly, a toggle between the range pot's unused lug and pin 16 drops the tone about an octave, and how far depends on where the range knob sits. Here that is the empty range lug and the PITCH V+ pad.
- **A starve pot:** my boxed one has a 100K starve pot in the supply leg.