These are the assembly instructions for a flashlight that runs continuously for one year, when powered by three rechargeable 2400mAh NiMH batteries.

Note that the batteries must be of the low-self-discharge type, or the batteries will go flat faster.

The PCB is designed to fit into a 4xAA battery holder, in place of one of the batteries.

The description of this circuit is published in Renew magazine, issue 166, available from January 2024. https://renew.org.au/renew-magazine/

Note that there is a typo in some editions of the above magazine article: in some places in the text, the capacitor has been described as “10mF”. This should say “10uF”, as it did in the pre-prints of the article that I received.

Tools needed for assembly:

- Soldering iron and solder.
- Wire cutter.
- Fine-point pliers, often called “needle nose” pliers.
- A coat hanger made from wire, and two wooden spring-type pegs.
- A file or some fine-grit sandpaper.

Optional tools that are not necessary, but will help with assembly:

- Solder Wick, in case you get a short while soldering.
- A step drill with handle (see picture in Step 3), if you want both ends of the flashlight to be flat.

Parts list:

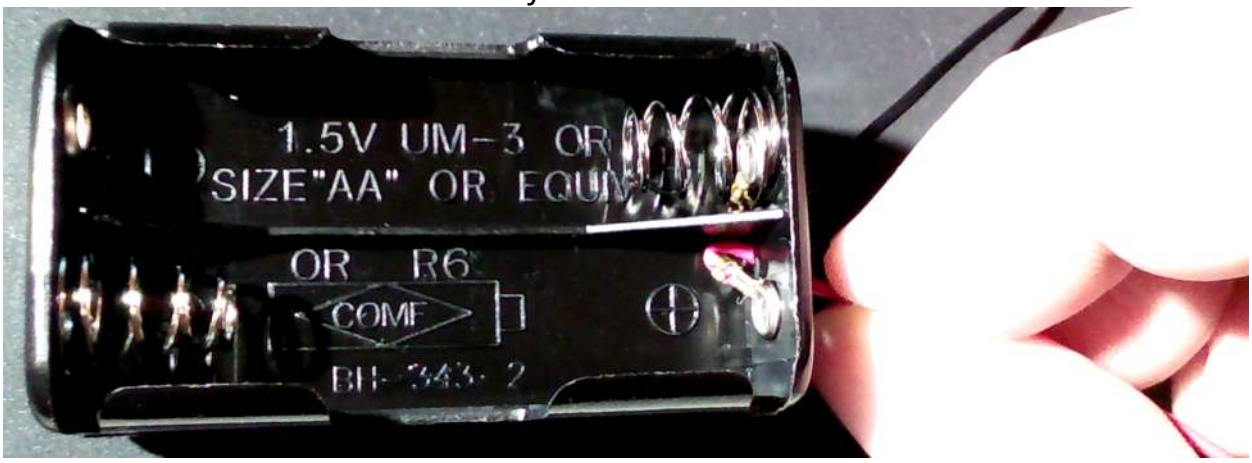
- the PCB, ordered from Osh Park: https://oshpark.com/profiles/Renew-Magazine-1-year-flashlight
- a paperclip made of wire, approximately 25mm (1-inch) long.
- one battery holder that takes four AA batteries. Jaycar PH9200 is suitable.
- one 100-ohm resistor, 1/4W rating.
- one 3.3k resistor, 1/4W rating.
- two 10k resistors, 1/4W rating.
- five 220k resistors, 1/4W rating.
- one BC546 transistor (BC547, BC548 and BC549 are suitable alternatives).
- three BC556 transistors (BC557, BC558 and BC559 are suitable alternatives).
- one 10uF electrolytic capacitor with 6.3mm diameter or smaller, and 6V or higher rating.
- one superbright 5mm LED. Jaycar’s ZD0196 is suitable, and it appears to be a Cree C512A-WNN.

A note about the resistors: you can use resistors with a higher power rating, if they'll fit on the board. The body of the resistors must not exceed 8mm long and 2.5mm diameter.

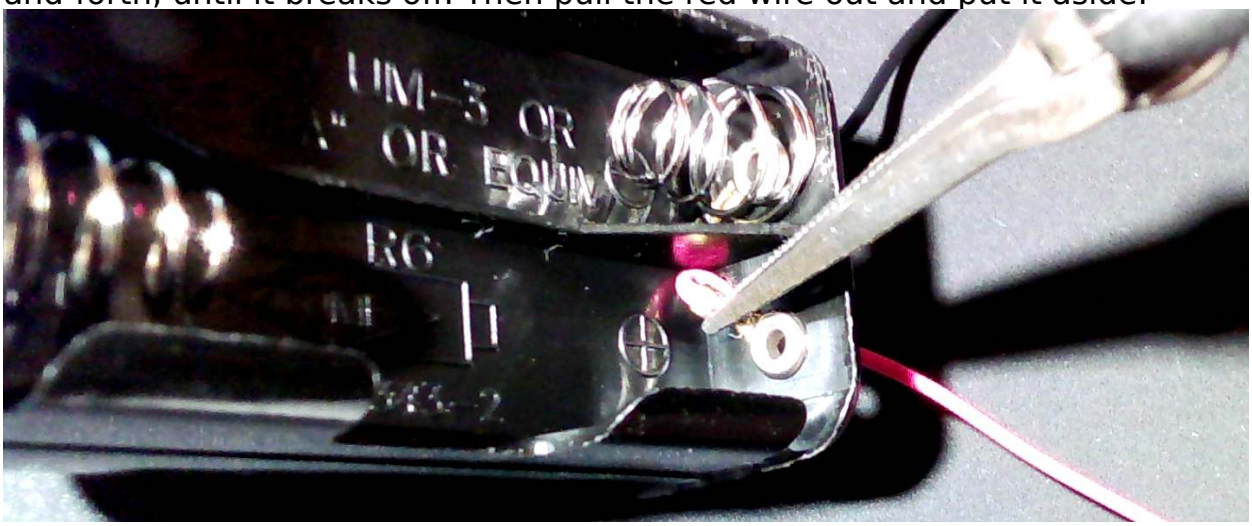
Assembly instructions:

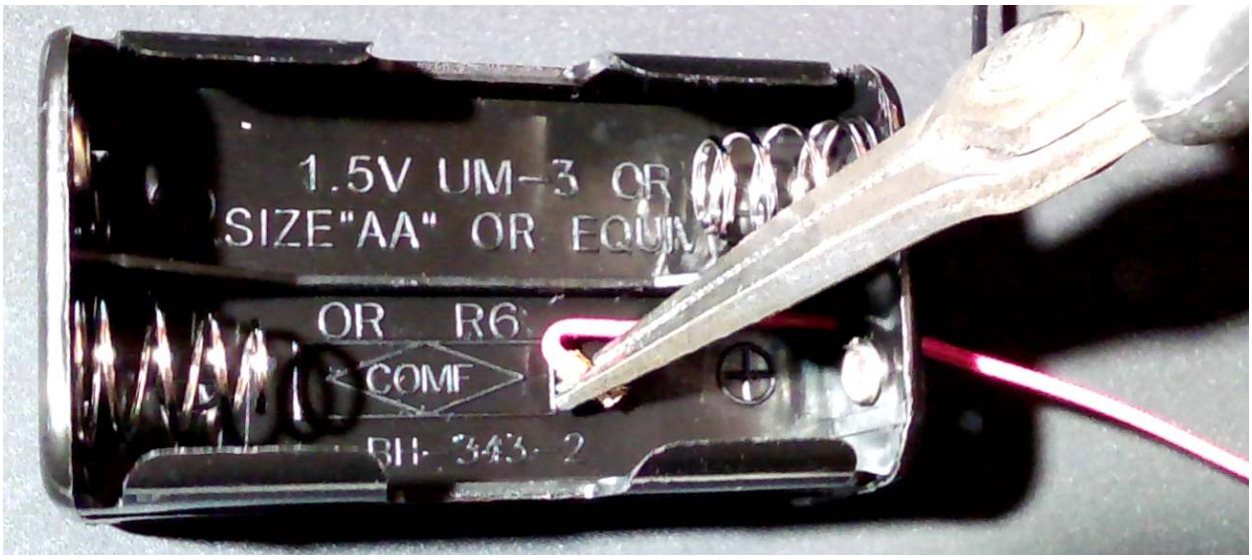
Step 1: Preparation of the battery holder.

Push the red lead into the battery holder:



(Step 1 continued) Now grab the metal part with the pliers and bend it back-and-forth, until it breaks off. Then pull the red wire out and put it aside:





Step 2: Decide whether you want to have both ends of the flashlight to be flat. It’s useful for both ends to be flat, as you can put it down on either end without it being “wobbly” on one end.

If you’re okay with only one flat end, feed the black wire through the hole that the red wire was in, and skip ahead to Step 4:

(Optional) Step 3: This is the process to make the black wire not “stick out” from the end. It requires you to enlarge the hole that the red wire went through, with a drill.

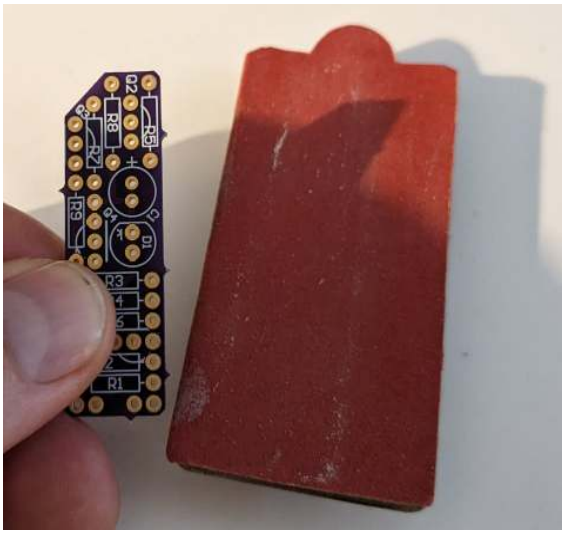
Note that you can use a conventional drill bit for this, but conventional drill bits are usually be held by electric drills, which can be quite dangerous when removing such a small amount of plastic. It’d be really easy to injure yourself this way.

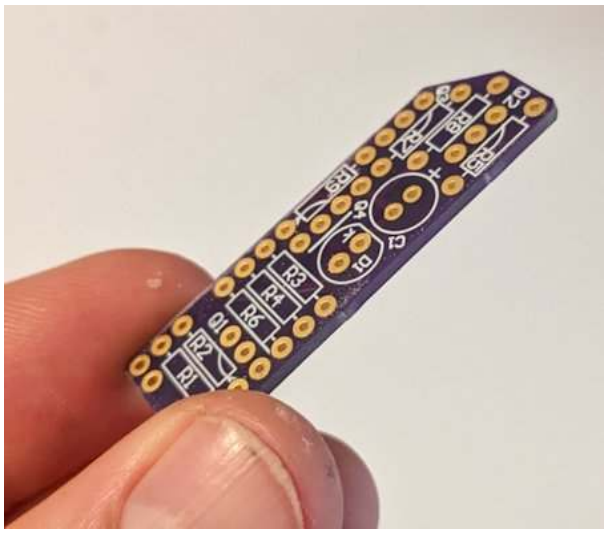
So I recommend using a “step drill” with a hex shank, and holding it in a screwdriver bit handle. This is a 3-13mm step drill and a bit handle:

(Step 3 continued): Use the step drill to enlarge the hole the red wire came out of, until the hole almost touches the hole the black wire is poking through:

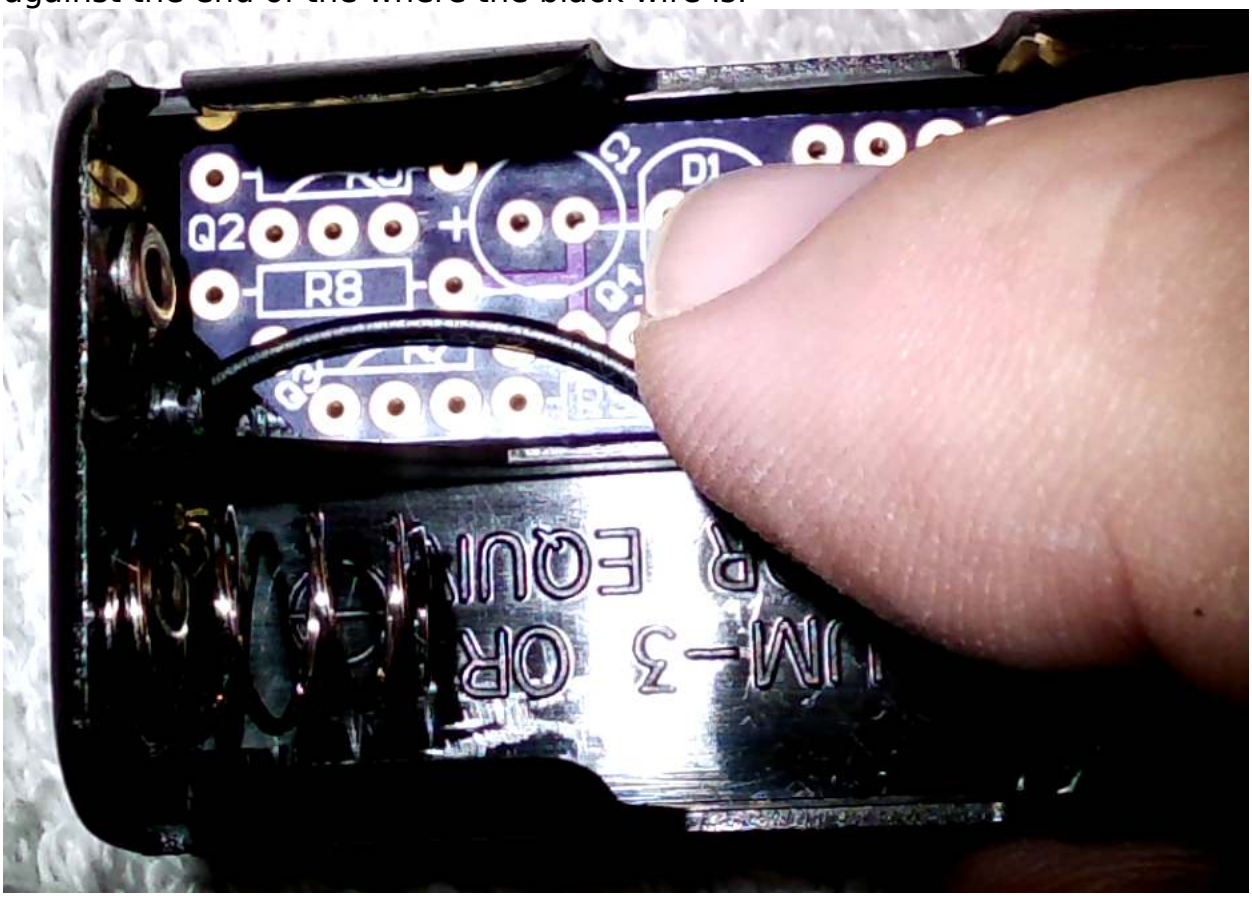
(Step 3 continued): Now use wire cutters to snip out the small piece of plastic between the two holes, and feed the black wire through the large hole:

Step 4: As supplied by Osh Park, the PCB will usually have “spikes” of PCB material sticking out on the sides, where the PCB was joined to other PCBs in the manufacturing process. Use a file or sandpaper to remove those spikes:

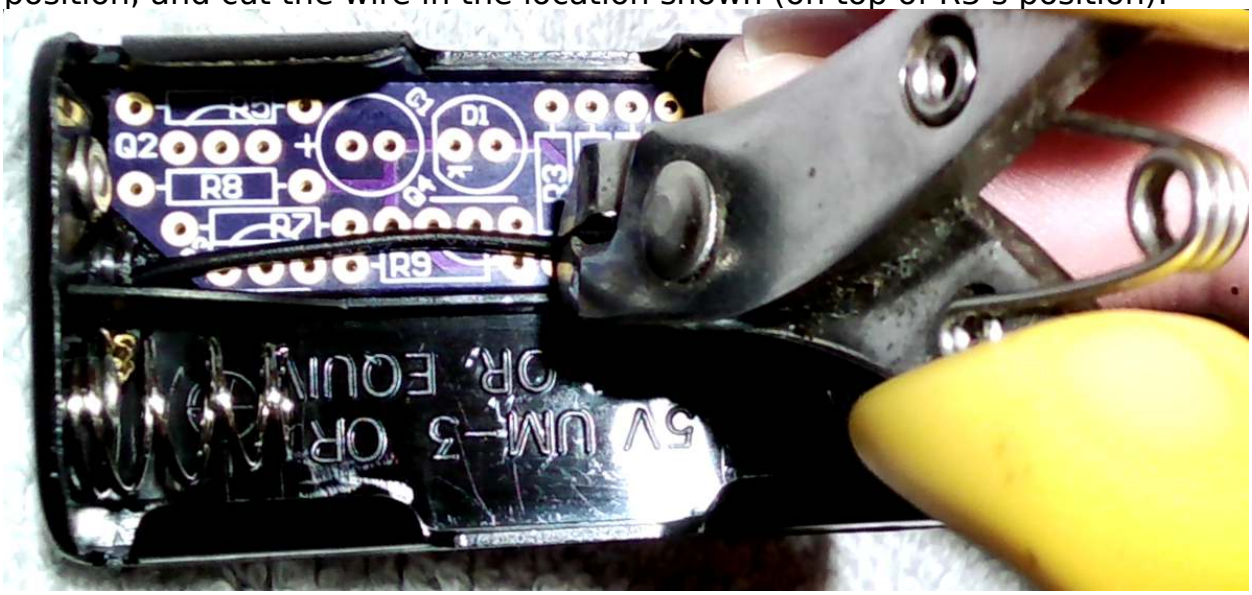




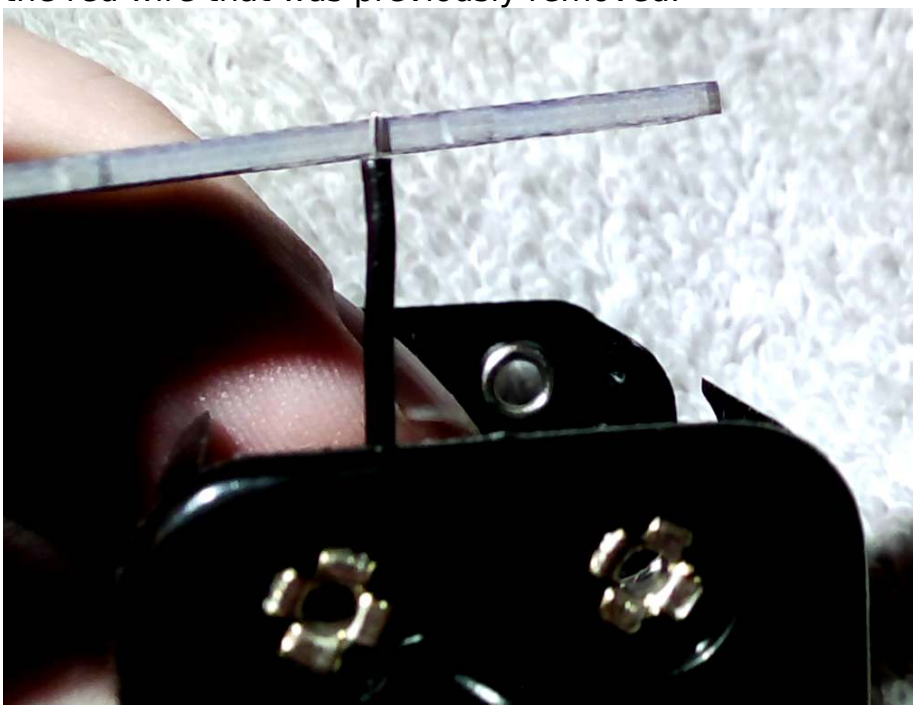
Step 5: Put the PCB into the battery holder to check it fits. Push the PCB up against the end of the where the black wire is:



Step 6: Now pull the black wire taut, while keeping the PCB in the same position, and cut the wire in the location shown (on top of R3‘s position):



Step 7: Now strip a bit of insulation off the wire, so the wire strands are exposed. The bit exposed should be about as long as the PCB is thick, or slightly more. If you’re not skilled at stripping wire this precisely, practice on the red wire that was previously removed.

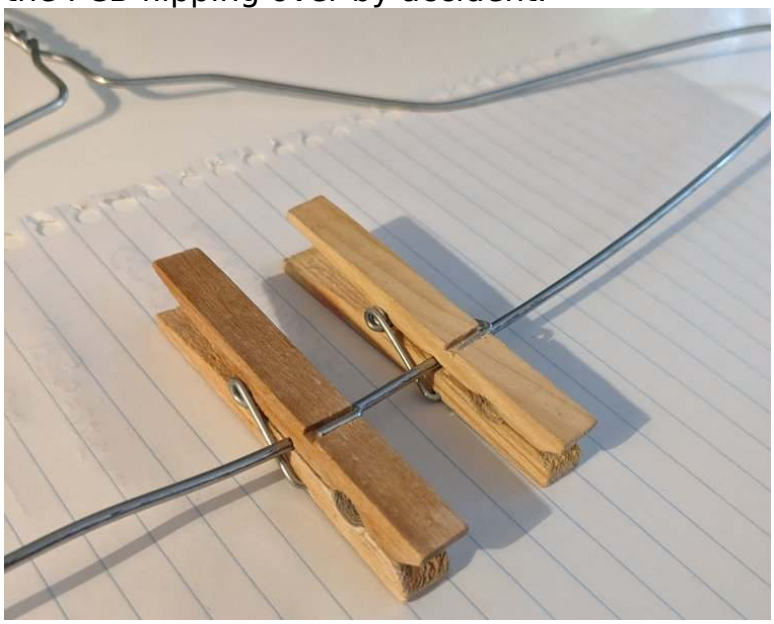


Step 8: Now use the solder and soldering iron to tin the exposed part of the black wire, and also to tin the spring that the PCB will be connecting to. You can see a glob of solder on the spring in the photo below.

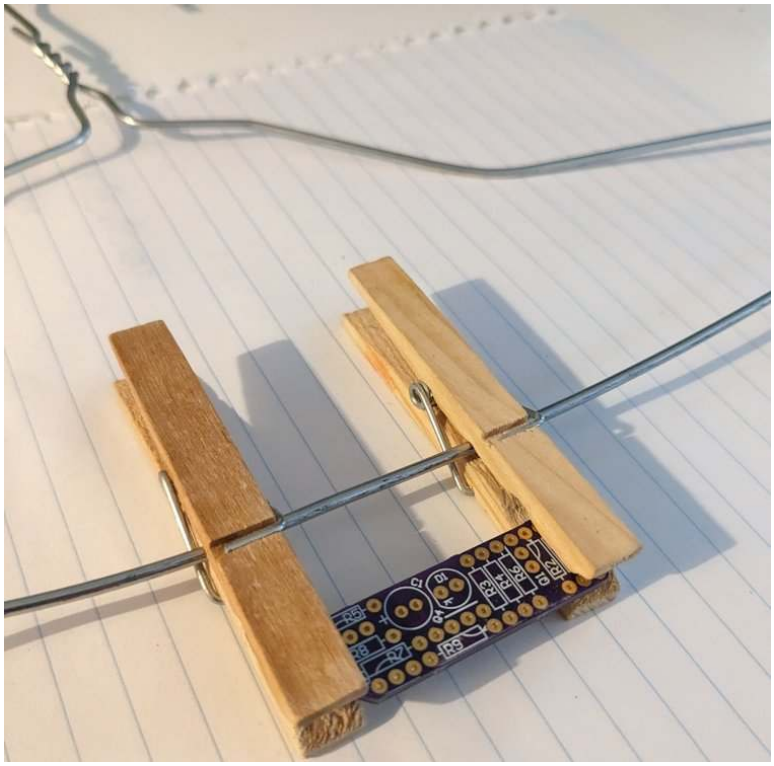
The reason for tinning both of these is to make them easier to solder to later, and to stop the strands of wire from “fraying” and making it difficult to insert the wire into the PCB.

You want to keep the soldering iron on the wire for as short a time as possible, no more than five seconds. You will notice that the wire’s insulation swells slightly, and starts to shrink back from the soldering iron. You want to minimize this, by being quick, but some swelling and shrinkage is normal.

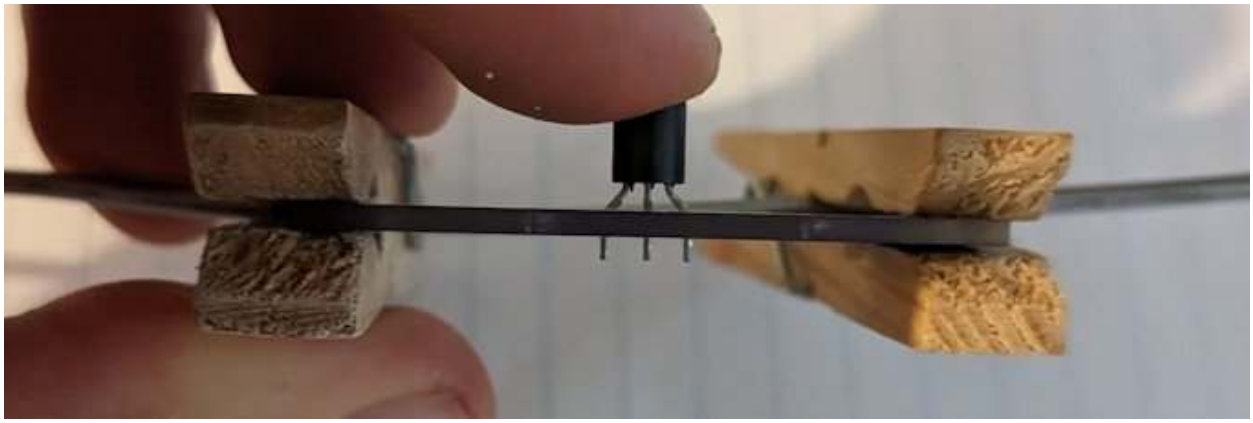
Step 9: Clip the two wooden pegs onto the longest straight part of the coat hanger, so the coat hanger passes through the smaller groove between the halves of the peg. This is to become your holder of the PCB while you're soldering the PCB. The coat hanger holds the pegs in alignment, and stops the PCB flipping over by accident.



Step 10: Clip the PCB between the pegs. Have one peg at each end of the PCB.



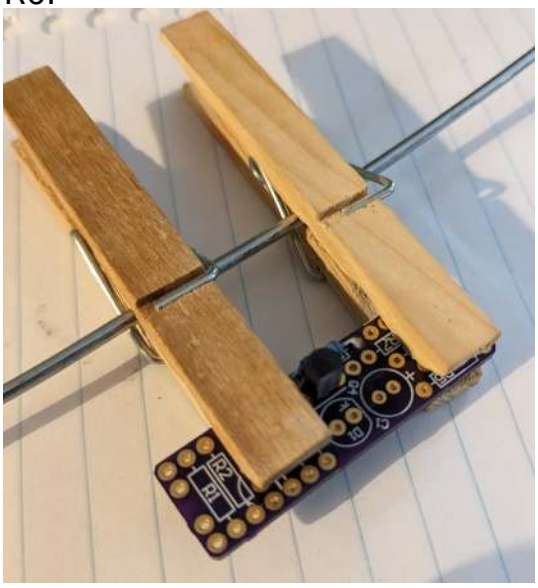
Step 11: Solder Q4 (BC546) into place. You may need to spread the legs of the transistor apart, if your transistor has the legs too close together. Make sure you have the transistor oriented the same as the curve and straight line drawn on the PCB, and the plastic body of the transistor should sit about 2mm to 3mm above the PCB. Solder the transistor from the top side of the PCB. Note that you don't have to solder all of the legs, the soldering at this stage is just to hold the parts in place. Once you've soldered the transistor into place, flip the PCB over, and cut the legs of the transistor so that about 2mm sticks below the bottom side of the PCB.



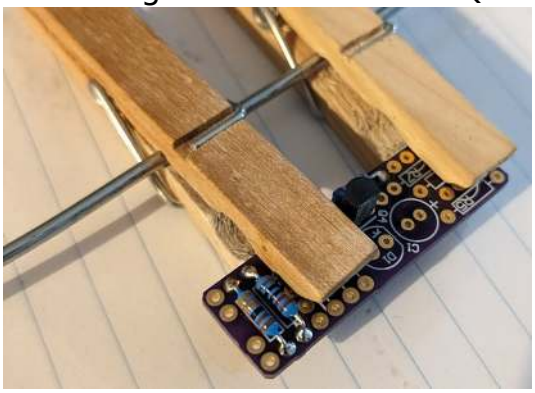
Step 12: Solder R9 (220k) into place. You'll need to make right-angle bends in the resistor leads. To make the bends in the resistor leads, hold the resistor lead with your needle-nose pliers, and bend the lead. The pliers must always be between the resistor's body and the bend, so you don't stress the resistor. Take care to squeeze gently with the pliers, you don't want to crush the lead. Here is a photo using special round-nose pliers, but ordinary needle nose pliers will do.

Now insert the resistor into the PCB, flip the PCB over, and cut the resistor legs so about 2mm sticks below the bottom side of the PCB. Now flip the PCB back, and solder R9 from the top side. Note that resistors can be soldered in either way around.

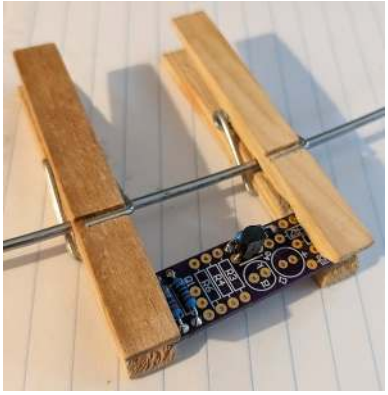
Step 13: Move the peg covering R1’s position, so now it covers R3, R4 and R6.



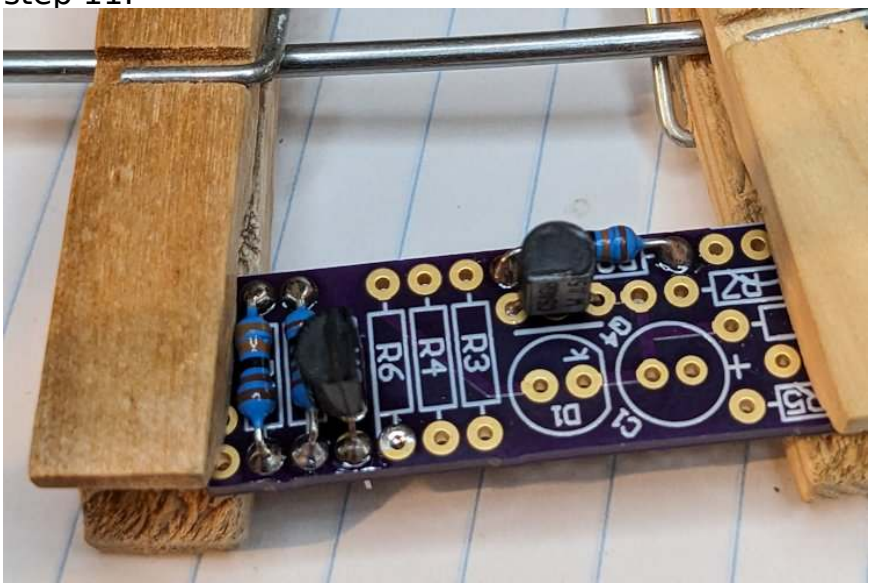
Step 14: In order, solder R2 (10k) and R1 (3k3) into place. Use the same process as you did in step 12. Before soldering R2, note the curve on the PCB indicating the orientation of Q1.



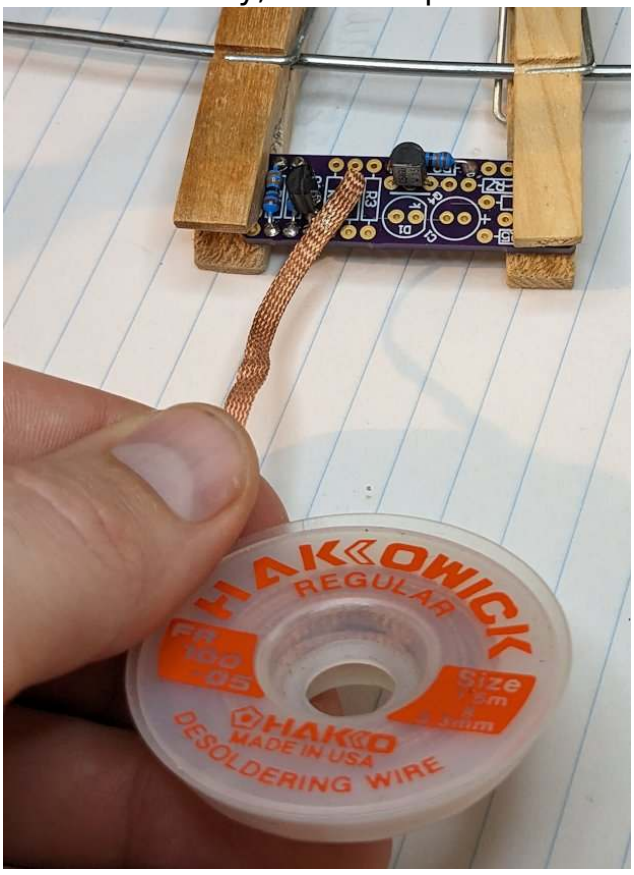
Step 15: Move the peg covering the R3, R4 and R6 positions, so now it clips to the end of the PCB beside R1.



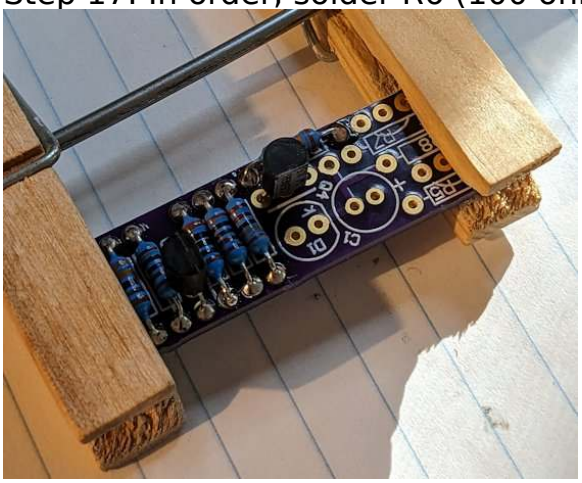
Step 16: Solder Q1 (BC556) into place, using the same process you used in step 11.



Oops, solder has filled one of the holes for R6. Here’s where solder wick comes in handy, to soak up that solder:



Step 17: In order, solder R6 (100 ohms), R4 (10k) and R3 (220k) into place.

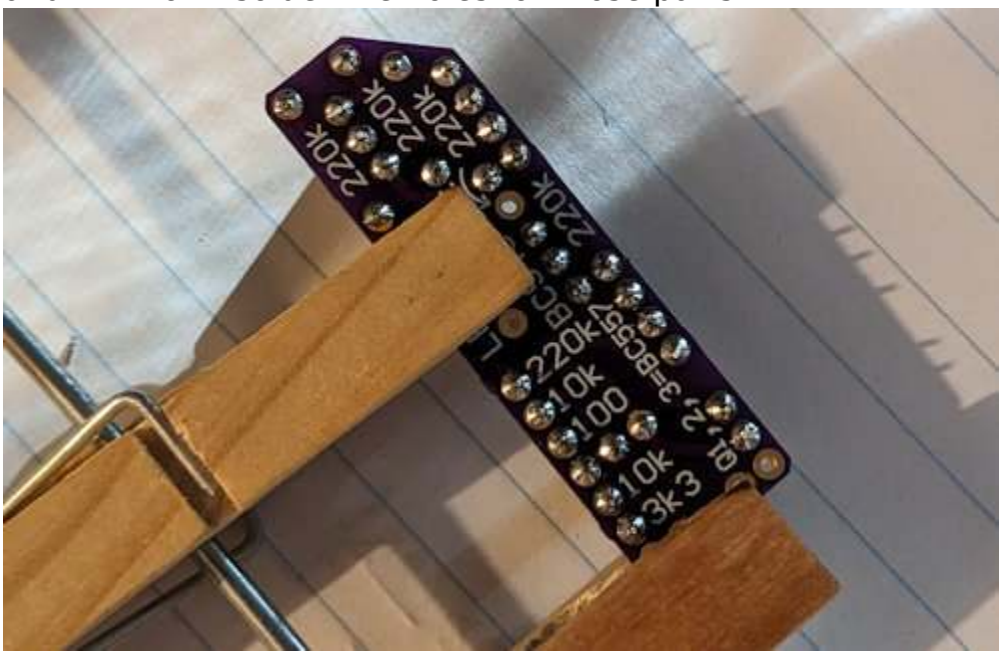


Step 18: Move the peg covering R8’s position, so now it clips onto the PCB on top of R3, R4 and R6.

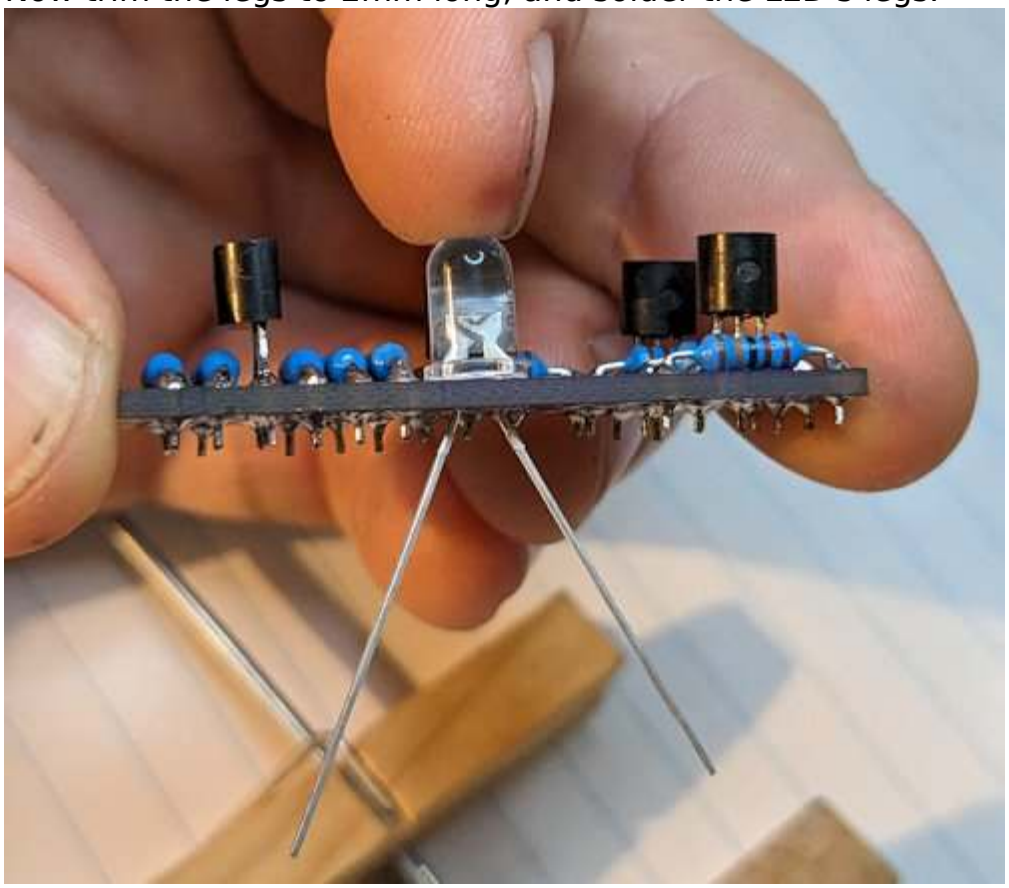
Step 19: Solder R5 (220k) into position, noting first the orientation of Q2.

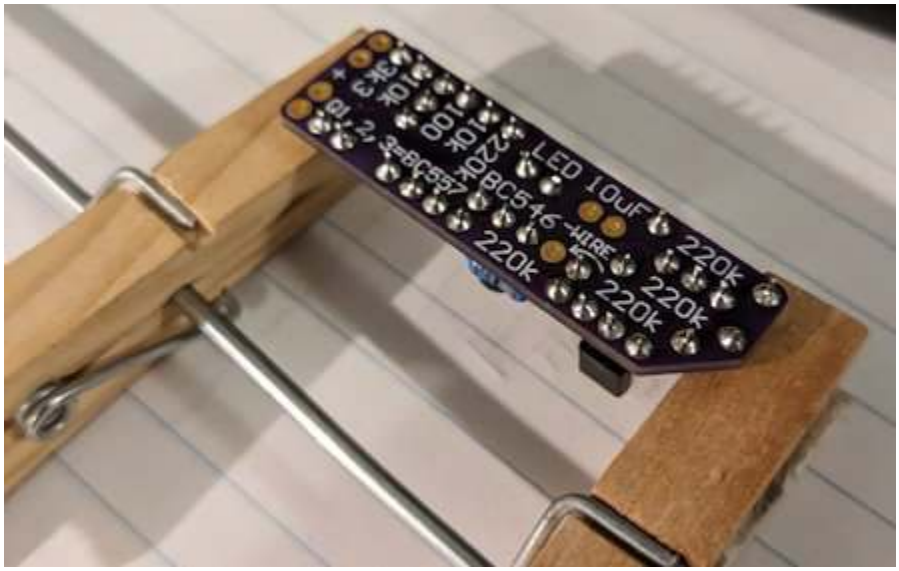
Step 20: In order, solder Q2 (BC556), R8 (220k), R7 (220k) and Q3 (BC556) into position. Q3 has the same orientation as Q2.

Step 21: Flip the PCB over, and solder all component legs protruding from the bottom side of the PCB to their pads. Note the LED and the 10uF capacitor haven’t been soldered in yet, nor the paperclip that solders into the holes beside R1, nor the negative wire connection that solders between Q4 and R7. Don’t solder the holes for those parts!

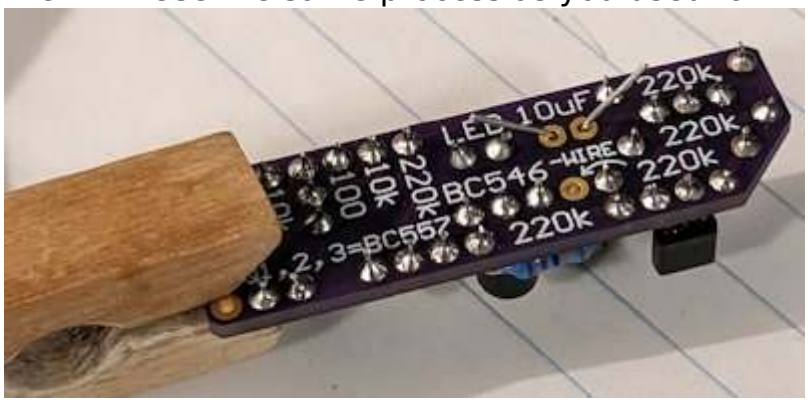


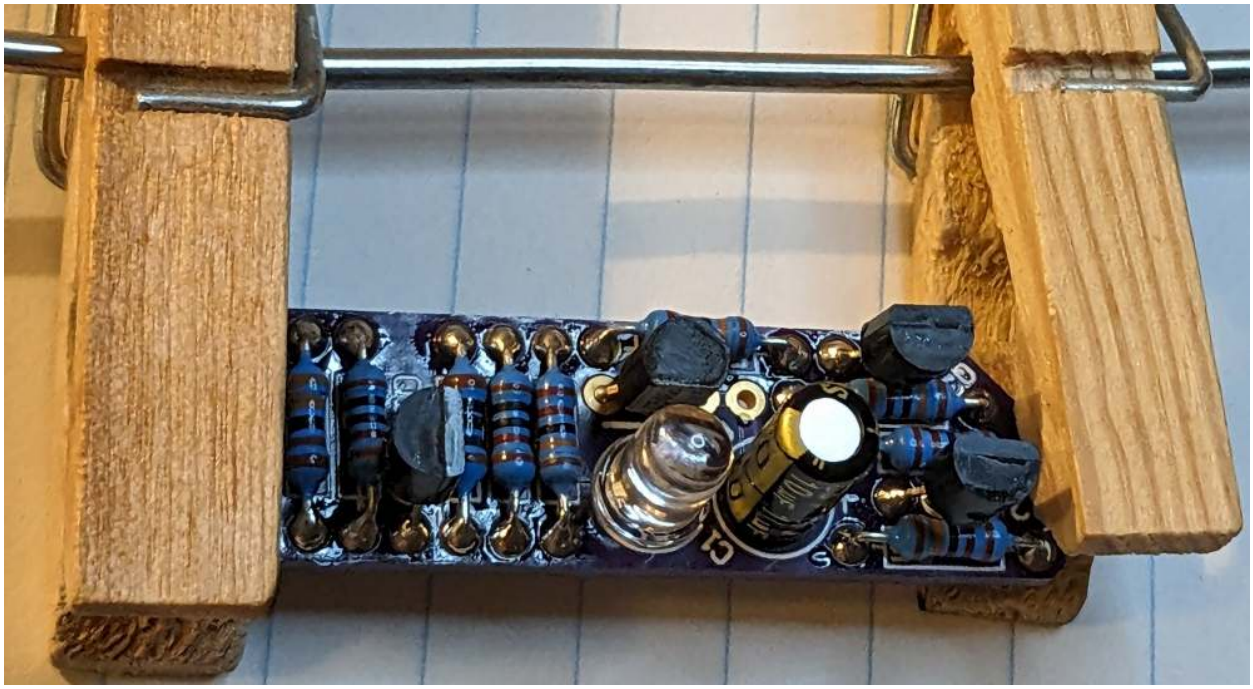
Step 22: Unclip the PCB from the pegs, and solder the LED into the D1 position, taking care that the flat on the plastic of the LED aligns with the flat drawn on the PCB. The LED should be held flush to the PCB, then bend the LED’s legs outwards at about 45 degrees, so it holds in position on the PCB. Now trim the legs to 2mm long, and solder the LED’s legs.





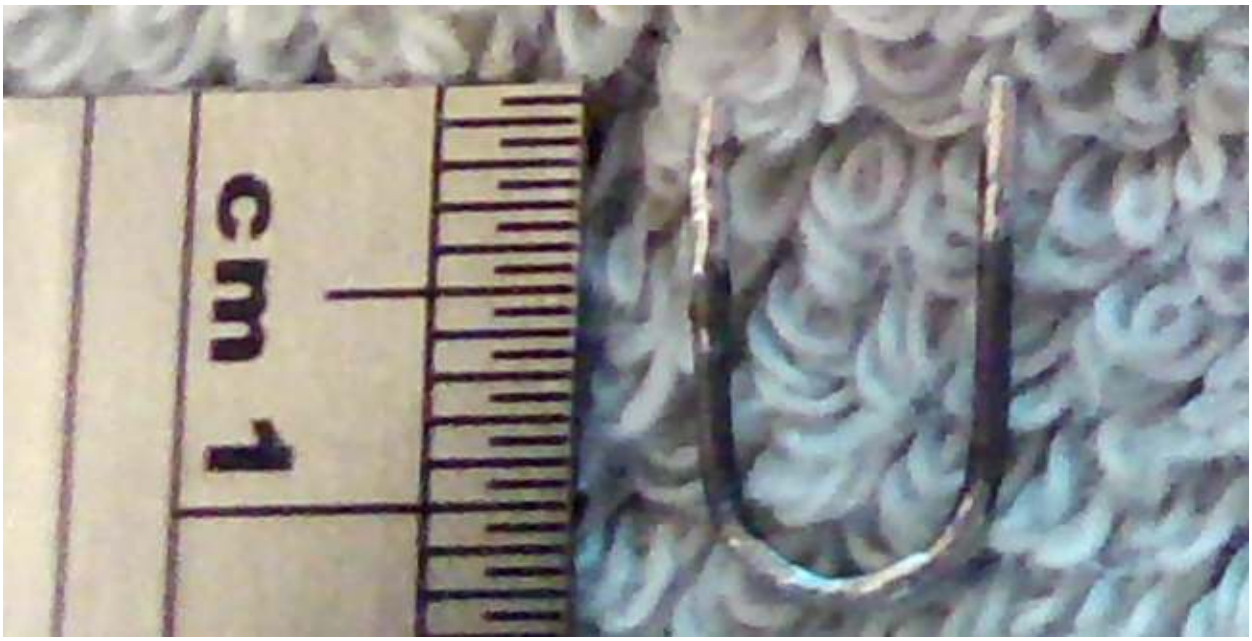
Step 23: Solder the 10uF electrolytic capacitor into the C1 position. Make sure the stripe on the capacitor’s body, indicating the negative side, faces the LED. Use the same process as you used for the LED.



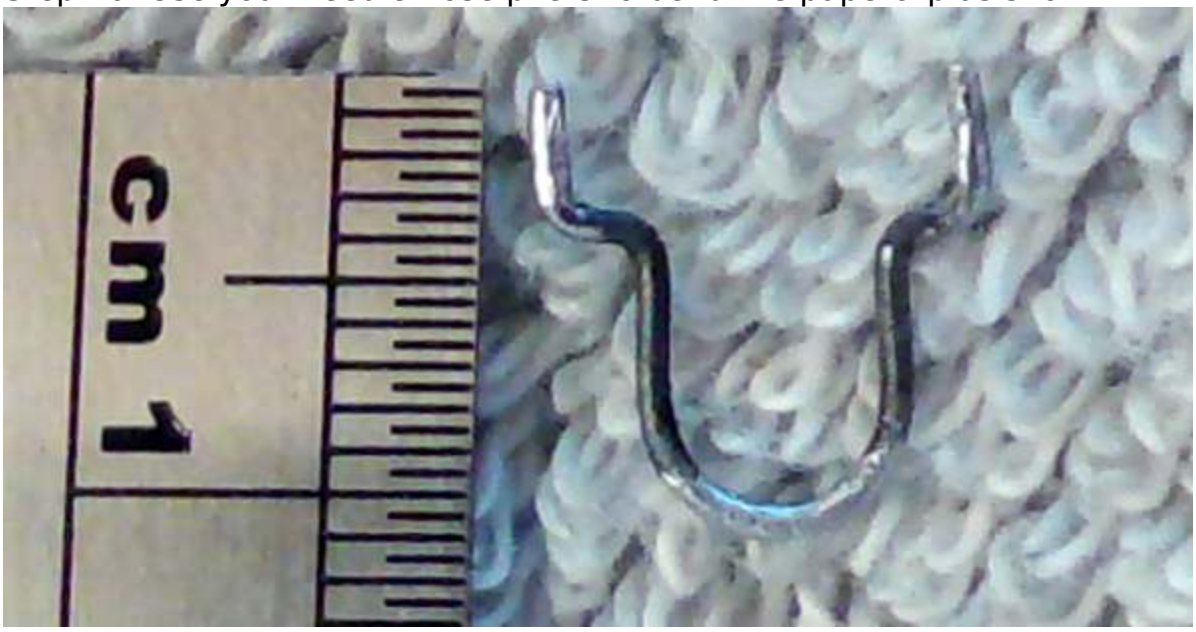


Step 24: Cut the paperclip in half, but be careful. Paperclips are quite stiff wire, and can damage the cutting edges of your wire cutter, so cut using the part of the wire cutter’s blade that is closest to the pivot of the wire cutter. Also be careful the cut pieces don’t fly off and injure someone. You’ll only use one of the paperclip bits, the rest can be saved for making more flashlights.

Step 25: Tinning the paperclip. I used an old paperclip which had gone quite grey to illustrate this. Hold the paperclip wth your pliers and use the solder and soldering iron to tin the shiny areas in the picture. Do this even if your paperclip already looks shiny, as many paperclips are nickel plated, and nickel is sometimes difficult to solder:

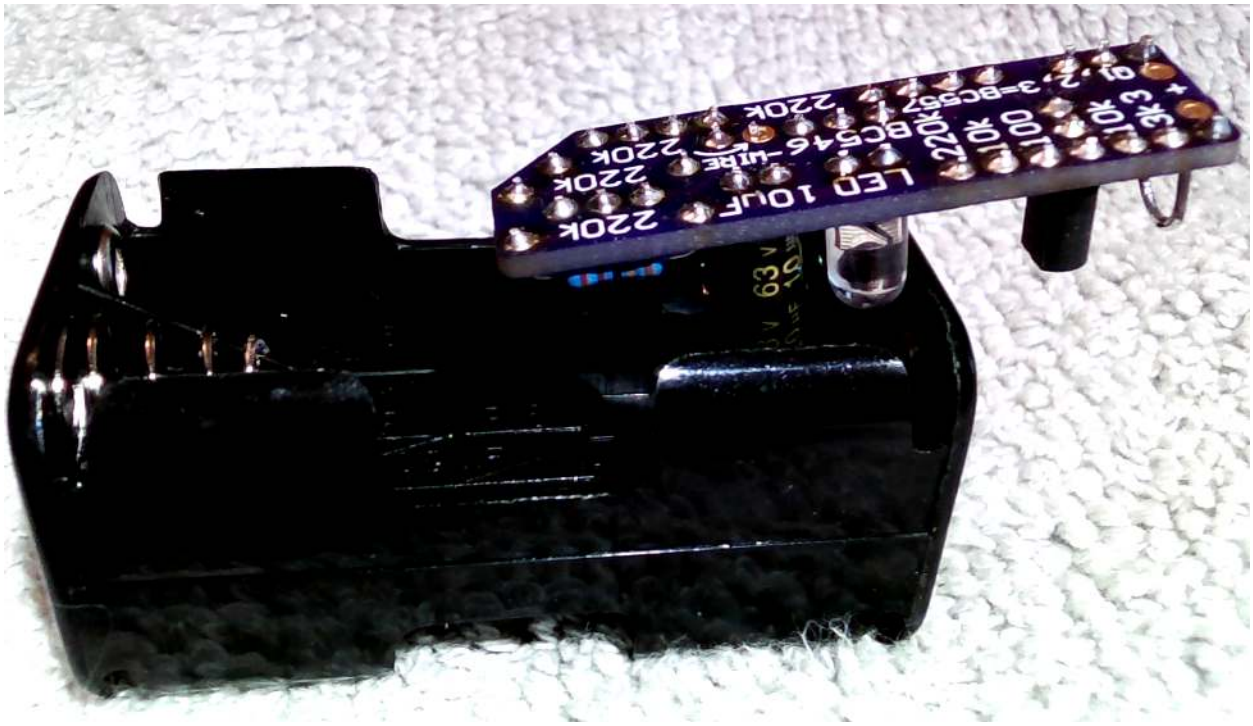


Step 26: Use your needle-nose pliers to bend the paperclip as shown:



Step 27: Put the paperclip into the holes beside R1, and solder it into place.

Step 28: Position the PCB so it is above that battery bay, with the components facing into the battery bay. Thread the tinned part of the black wire into its hole on the PCB, with the label “-WIRE”, and solder it.



Step 29: Now rotate the PCB 180 degrees in an end-over-end fashion, so it can sit inside the battery bay, with the paperclip pressing against the spring battery contact that you tinned back in Step 8. Solder the paperclip to the spring battery contact.

Step 30: You’ll probably find that the battery holder’s plastic is pressing against the electrolytic capacitor (as circled in the picture). If it is, use your wire cutters to trim that piece of plastic:

Step 31: Assembly is complete! Install three AA batteries in the empty battery bays, and the LED should light up immediately. If it doesn't, sometimes the battery holder's contacts have an invisible thin coating that prevents them from conducting. In each battery bay, try rolling the battery to wear through that coating. Also check that each battery's positive end is actually touching the battery holder's contact, as sometimes the batteries are a tight fit and spring doesn't provide enough pressure to push the batteries against the positive contact.

Here is a picture of the finished flashlight, taken at noon on an overcast day. Note that this is an older version of the PCB that didn't have as much writing on it, and that this PCB has been cleaned in alcohol to remove the flux that is left after soldering.

Russell Gurrin
January 2024.