

# Joule Thief – Detailed Construction

North Fulton Amateur Radio League

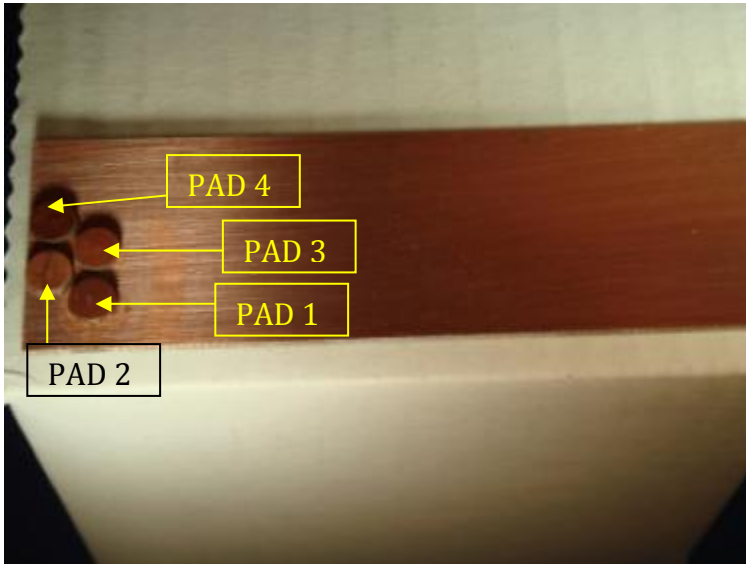
[www.nfarl.org](http://www.nfarl.org)

The Joule Thief makes a great little light for field day, night light, camping light, and even one missionary intends to use them in Africa. Get the last bit of life from those supposedly dead batteries. Learn Manhattan construction.

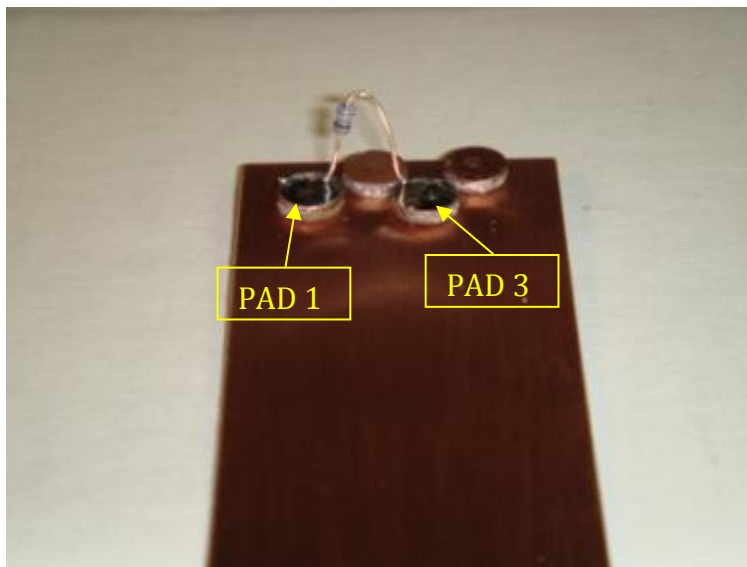


## Parts List

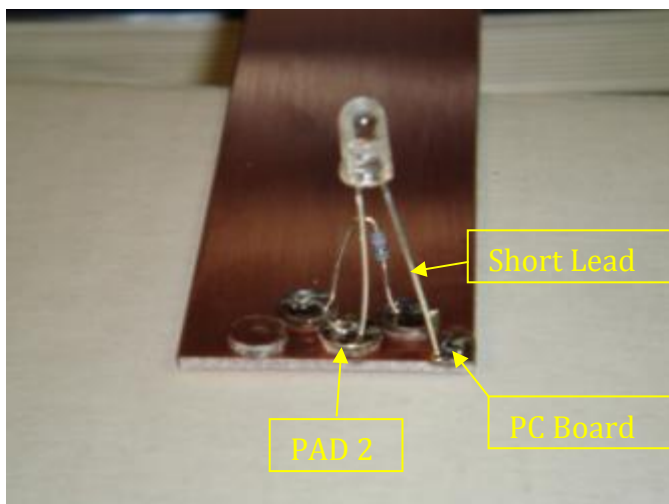
PC Board
4 ea - pads
Battery holder
LED
Toroid
2 ea-13 inches wire
Transistor
1,000 ohm resistor



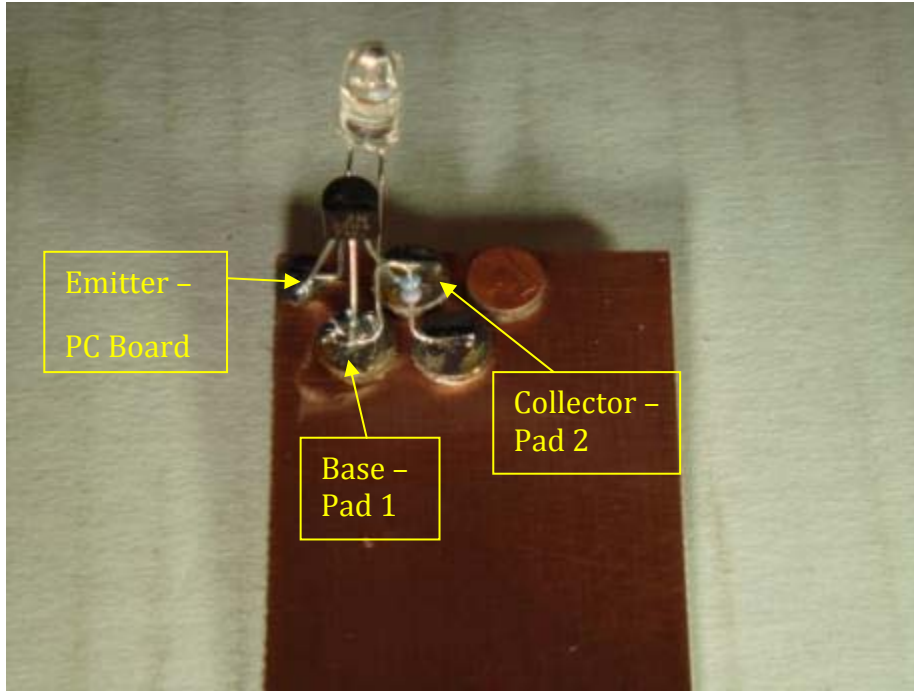
Superglue four pads to the PC board. Make sure they are not touching each other. You should have roughly 1/8 inch between the pads. Apply a small drop of superglue on the board and press the pad onto the board with the small dimple up. Use a small screwdriver to hold pressure on the pad until the glue dries (about 10 seconds).



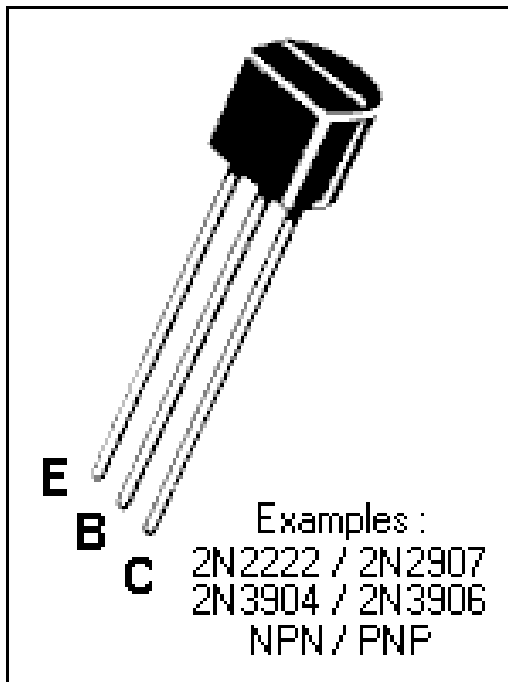
Solder the 1,000 ohm resistor onto pads 1 and 3. When soldering all components, place a 90-degree bend on the ends of the component where they touch the pad to allow better soldering. There is no polarity on a resistor.



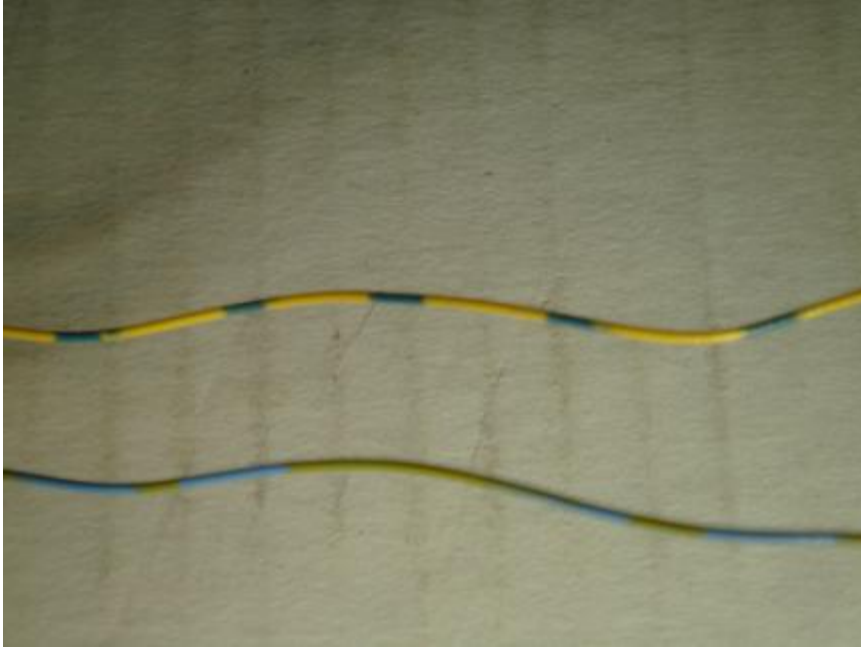
Solder the LED to the board. **VERY IMPORTANT:** Solder the **long lead** to pad 2 and the **short lead** directly to the PC board. The LED will not illuminate if you put it in backwards. If you look into the LED, the anvil shaped part is the lead that gets soldered to the PC board.



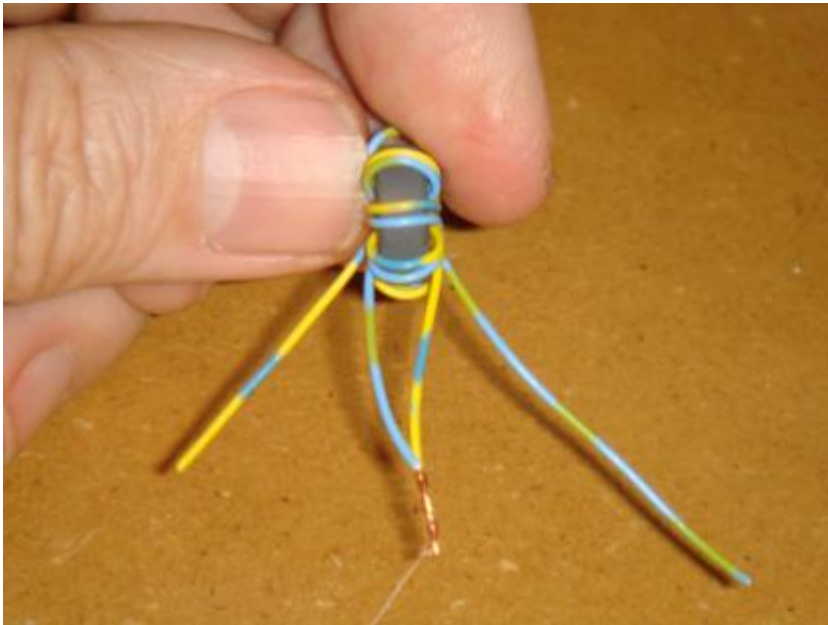
Solder the transistor to the board. With the flat part facing you the left lead (emitter) is soldered directly to the PC board. The center lead (base) is soldered to pad 1. The right lead (collector) is soldered to pad 2. Failure to install this part correctly will prevent the Joule Thief from working.



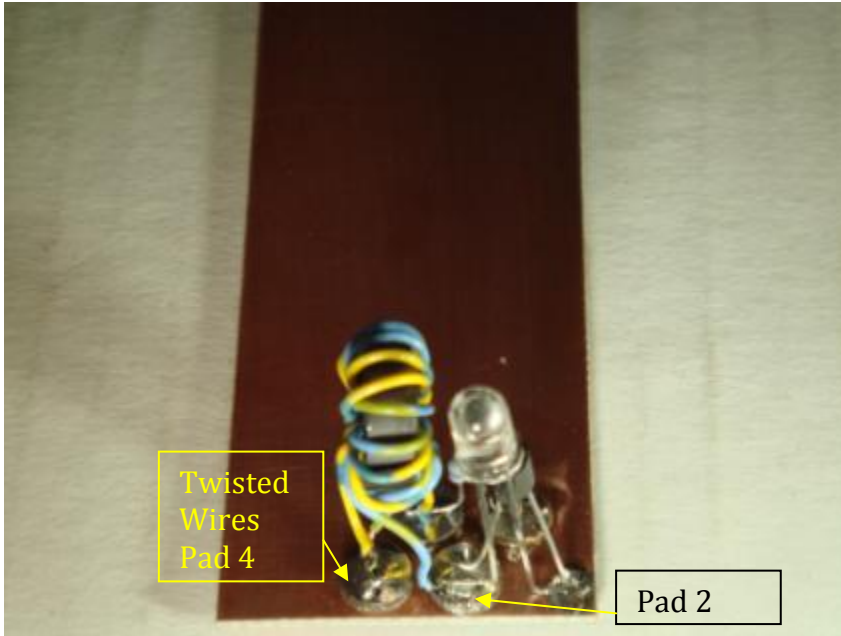
This is a diagram of the transistor showing the emitter, base and collector. Flat side forward, left to right.



Take the two pieces of wire and **untwist** them if they are twisted. The toroid requires 12 inches of wire. You will wind the toroid with this pair of wires side by side.



Wind the toroid with **9 turns** of the wire. Each turn through the hole in the center counts as one turn. **VERY IMPORTANT:** You must take one wire **from each side of the winding** and twist them together. This makes the transformer windings out of phase. This is critical to operation. Connect one wire of each color.



Solder the twisted wires on the toroid to pad 4. Solder one of the other toroid wires (doesn't matter which one) to pad 2.



Solder the other wire on the toroid to pad 3.



Solder the battery holder. Connect a short piece of wire from the positive terminal (the one without the spring) to pad 4. Solder the negative terminal (the one with the spring) directly to the PC board using a short piece of wire. Use hot glue or some other glue to secure the battery holder to the PC

board.

#### **Suggested tools for construction:**

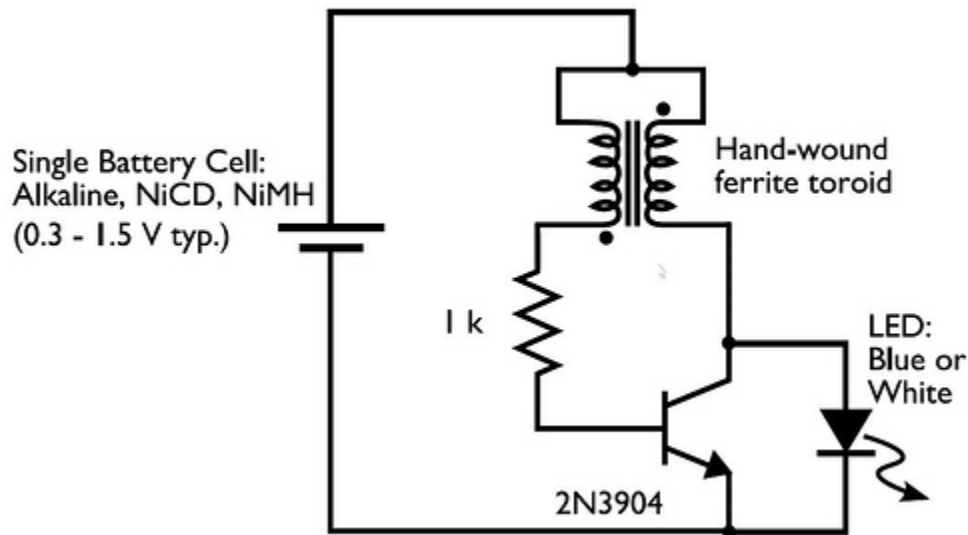
- Soldering iron (low wattage)
- Rosin core solder 60/40 (**do not use acid core solder**)
- Small pair of wire cutters
- Needle nose pliers may be helpful but not required
- Super glue
- Hot glue or other glue for the battery holder

#### **General Description**

The Joule Thief kit allows you to take your mostly drained batteries and squeeze the last Joule of energy from them. This gadget will run on a battery as low as 0.3v to power a 3.3v LED.

The Joule Thief teaches you how to build using *Manhattan Construction*. This construction technique uses punched out pieces of circuit boards as insulators to isolate components from the ground plane. Visit <http://www.k7qo.net/manart.pdf> for more information.

## Theory of Operation



The way the circuit works is somewhat complex. It starts when the transistor is off. Current flows through the left-hand side of the transformer and through the 1k resistor, into the base of the transistor. The transistor turns on slightly and produces a current in the collector-emitter circuit. This allows current to flow in the right-hand winding of the transformer and produce magnetic flux. This flux cuts the turns of the left-hand winding and produces a voltage that adds to the voltage produced by the battery. This increases the current into the base of the transistor and the transistor turns on more. This continues and the transistor turns on more and more until it cannot turn on any harder. At this point the magnetic flux in the right-hand winding is a maximum but is not expanding flux and thus the left-hand winding does not produce any additional voltage. The current into the base of the transistor reduces and the transistor turns off slightly. The current through the right-hand side of the winding reduces and the magnetic energy in the core of the ferrite ring starts to collapse and produce a voltage (in both windings) of opposite polarity. In the left-winding, it starts to turn the transistor off completely and in the right-winding, it delivers this energy to the LED.

Now here's the clever part.

When the current is abruptly switched off, as is the case with this circuit, a voltage is produced in both windings that has opposite polarity to the original voltage and will be higher amplitude than the original voltage. This voltage can be 10 or even 100 times higher than the original voltage and this is called the "Q" of the circuit.

We are not creating something-for-nothing as the voltage will be higher but the current will be lower than the current drawn from the battery. The voltage produced by this circuit will be over 10v but a white LED has a characteristic voltage

of about 3.2v to 3.6v and all the energy in the 10v spike, and the accompanying current, will be delivered to the LED to produce illumination. The LED starts to absorb energy at 3.2v and that's why the voltage across it never gets any higher than 3.6v. The waveform across the LED is somewhat square at 2.48V amplitude but with overshoot it was 4.2V, 50% duty cycle @ 65.6kHz

### **Possible Circuit Improvements. Feel free to experiment!**

Here's an improvement that will not only increase the brightness but consume 50% less current.

Connect the 1k resistor between the feedback winding and positive of the supply. This means the end of the feedback winding that was originally connected to the 1k resistor will now be connected to the base of the transistor and the feedback winding will now be connected between base and 1k.

Connect one lead of a 22nf capacitor to the point where the 1k meets the feedback winding and the other lead to the negative rail.

The current will drop to less than 50% and the brightness will increase. This makes the circuit much more efficient by forcing the energy produced by the feedback winding into the base of the transistor. This turns the transistor on more and faster than before as it acts as a "barrier" or "stopper" to the energy produced by the feedback winding and prevents it from flowing into the 1k resistor. The energy now gets sent almost entirely into the base of the transistor.