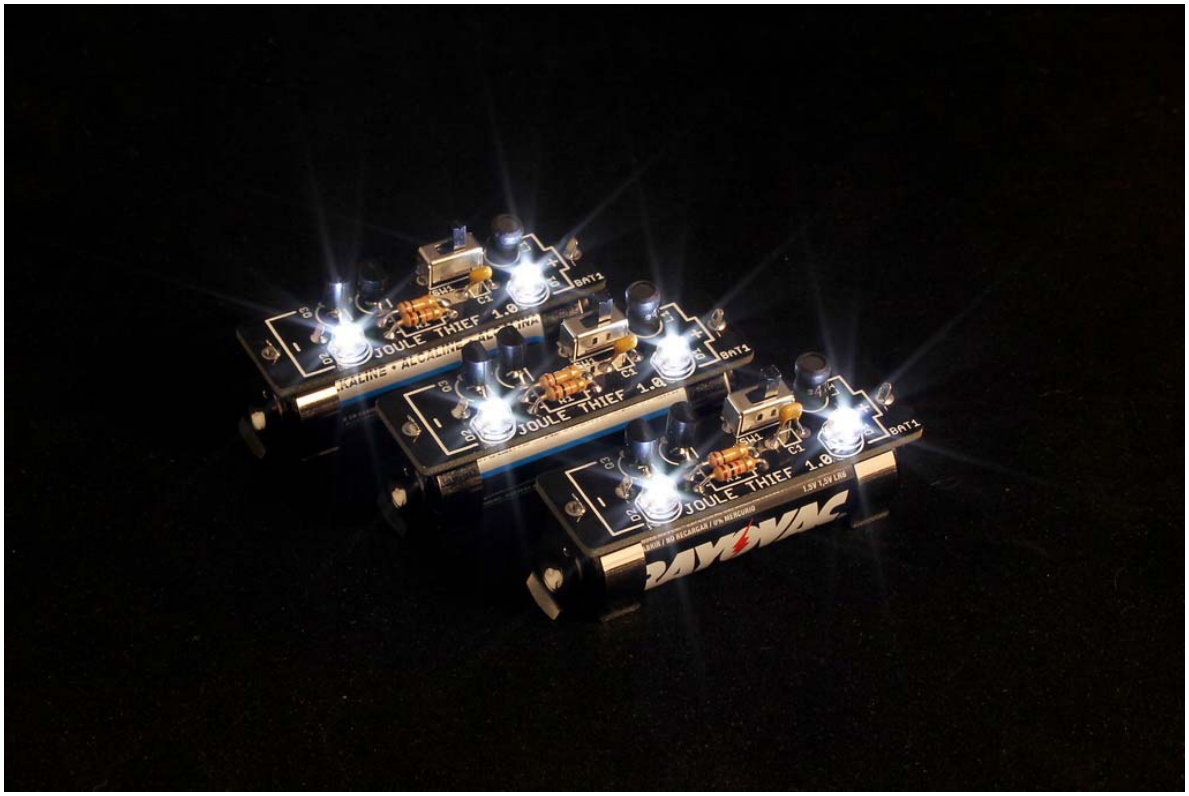
Joule Thief 1.0 Kit



(Please note that the image above represents our initial prototype devices. The device you will receive when ordering will look somewhat different.)

Instruction Manual

Eastern Voltage Research, LLC

Introduction to the Joule Thief 1.0 Kit

Thank you for purchasing the Joule Thief 1.0. Our Joule Thief 1.0 kit has been one of our most popular educational kits we originally offered only through the various outreach programs we conducted here at Eastern Voltage Research. We recently decided to offer this kit to the public and the feedback thus far has been extremely positive. So what is a Joule Thief? Well, simply put, a Joule Thief is simply a circuit that utilizes the remaining energy in an almost drained battery and uses that remaining energy to power some type of electrical load or as in this case, two (2) LEDs. Its a fun way to use up all those "dead" batteries you have lying around and put them to work in the form of a very bright LED light source. The LEDs we utilize in our Joule Thief 1.0 kit are ultrabright white LEDs which have a 110 degree viewing angle which is capable of illuminating an entire room if its dark. A few of these can be extremely handy when the power goes out in your house or on a camping trip. They are also very popular with the kids. Whenever I leave my Joule Thief kits left unattended, my 4 year old son always manages to sneak and take them away to play with them. They are so fun and the light they produce is spectacular!

Joule Thief circuits have been around for a very long time. There are many different variations on the traditional Joule Thief theme, but they are all practically the same. The Joule Thief 1.0 circuit is based on a conventional switching boost converter design, in that it contains a single inductor and a switch, when operated, creates a higher voltage than the input battery voltage. The classical Joule Thief circuit utilizes a custom wound transformer with feedback winding, however, we have always felt this was a bit difficult and tedious to wind, so decided to use a conventional boost circuit that uses an off-the-shelf inductor instead of the transformer. In this particular case, the boost circuit converts takes the energy from an AA or similar battery which can have an output voltage of anywhere between 0.8V and 1.5V, and converts it to 6V to power two (2) white (or other color) LEDs.

Notice to Beginners: If you are a first time kit builder, you may find this instruction manual easier to understand than expected. Each component in this kit has an individual check box, while a detailed description of each component is provided as well. If you follow each step in the instruction manual in order, and practice good soldering and kit building skills, the kit is next to fail-safe.

Please read this manual in its entirety before building, testing, or operating your kit!

Circuit Description

The Joule Thief 1.0 kit is basically a simple boost converter power supply that converts the low voltage of an AA battery (typically 0.8 to 1.5V) to a higher voltage of 6V to power two (2) LEDs. Just as in classic boost converter, there is an inductor, L1, and a switch, Q2. Energy is stored in the inductor during the ON period of switch, Q2, and then the energy is released when the switch, Q1 is turned OFF. There are three (3) primary switching cycles of operation which are described in more detail below:

SWITCHING CYCLE 1

Power is first applied to the circuit when switch, SW1, is closed. Current from the battery, BAT1, flows through the 1k resistor into the base of Q2 turning Q2 ON. This causes current to begin flowing from the battery through inductor, L1.

SWITCHING CYCLE 2

As current begins flowing through inductor, L1, this causes a voltage to begin charging up across capacitor, C1, which eventually charges up sufficient enough at the base of Q1 to turn Q1 ON. C1 is charged directly from the battery through resistors R1 and R2. Thus, the time constant of the switching is determined by the combined resistance of R1+R2 and capacitance, C1. When Q1 turns ON, it pulls the base of Q2 to GND and turns Q2 OFF. Once Q2 switches OFF, current stops flowing through inductor, L1. Because the current in an inductor cannot stop instantaneously, the inductor induces a large voltage across itself in an attempt to maintain current flow. This voltage (6V) is created across the inductor to allow current to keep flowing through itself. The voltage, is developed across LEDs, D1 and D2, and cause them to illuminate.

The oscilloscope plot below shows the voltage output of the Joule Thief which is across the two (2) LEDs. The output voltage is 6.40V, which is the sum of the two (2) LEDs forward voltages. The output current through the two (2) LEDs is approximately 50mA peak at a duty cycle of 12%. The effective average output current being applied to the LEDs is approximately 6mA (50mA * 0.12%) for this particular battery being used.

LED Output Voltage and Current
(Yellow = Output Voltage 2V/div)
(Green = Output Current 20mA/div)

SWITCHING CYCLE 3

Once Q1 turns ON and Q2 turns OFF, C1 begins discharging its energy through current limiting resistor, R3, and through the base of Q1. R3 is used to prevent the peak discharge currents from C1 from overly stressing the base-emitter junction of Q1. Once C1 discharges to a voltage less than 0.6V, Q1 turns OFF again and Q2 turns ON. This switching process then repeats.

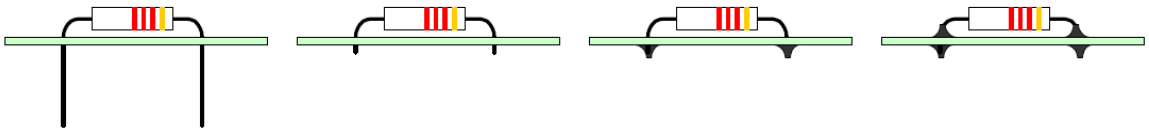
Finally, capacitor C2, resistor R4, and diode CR1 are utilized to provide soft turn-off / turn-on functionality with your device. When the switch is turned ON, it takes a brief amount of time to charge up capacitor C2 and this results in a pleasant looking soft turn-on. The same is true for turn-off.

Kit Building Tips

A good soldering technique is key! Let your soldering iron tip gently heat both the wires and pads simultaneously. Apply solder to the wire and the pad when the pad is hot enough to melt the solder. The finished joint should appear like a small shiny drop of water on paper, somewhat soaked in. If the pads have not heated up sufficiently, melted solder (heated only by the soldering iron itself) will form a cold solder joint and will not conduct properly. These cold joints appear as dull beads of solder, and can be easily fixed by applying additional heat to the pad and wire. All components, unless otherwise noted, should be mounted on the top side of the board. This is the side with the silkscreen printing.

When installing components, the component is placed flat to the board and the leads are bent on the backside of the board to prevent the part from falling out before soldering. The part is then soldered securely to the board, and the remaining lead length is clipped off. It is also extremely important to place the components as close to the board as possible. This is necessary for proper operation over the wide frequency range of the various kits we provide. Also be sure that component lead lengths are always as short as possible. This will avoid adding any stray capacitances or inductances that can be detrimental to circuit operation.

An alternative approach (which is actually the one I use) is to install the component into the board and then apply a piece of masking tape on the topside to the hold the component in place temporarily. The leads on the backside of the board are then trimmed leaving about 0.10” lead protruding through the backside of the board, and then soldered from the backside. You can then remove the masking tape, and finally apply a small amount of solder on the top to complete the joint on both sides. This is shown in the figure below.



Joule Thief 1.0 Kit Parts List

RESISTORS

- ❒ 1 1k Resistor (brown-black-red), R1
- ❒ 1 51k Resistor (green-brown-orange), R2
- ❒ 1 100 ohm Resistor (brown-black-brown), R3
- ❒ 1 330 ohm Resistor (orange-orange-black), R4

CAPACITORS

- ❒ 1 15pF Ceramic Capacitor (marked 15J), C1
- ❒ 1 22uF Electrolytic Capacitor, C2

DIODES

- ❒ 2 LED, White, T-1-3/4, D1,D2

SEMICONDUCTORS

- ❒ 2 2N3904 Transistor, Q1,Q2
- ❒ 1 1N4148 Resistor, R4

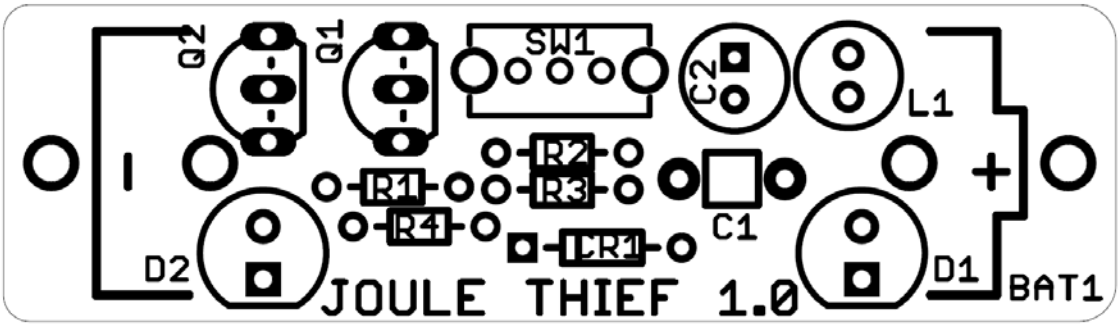
MISCELLANEOUS

- ❒ 1 Inductor, 330uH, L1
- ❒ 1 Switch, Slide, SW1
- ❒ 2 AA Battery Clips, BAT1
- ❒ 1 PCB Board, Joule Thief 1.0
- ❒ 1 Schematic, Joule Thief 1.0

REQUIRED, NOT SUPPLIED

- ❒ 1 AA Battery, BAT1

Joule Thief 1.0 - Component Layout Diagram



KIT Building Instructions

Now we will begin building the kit. There are just a few more important things to know before we install the first components.

For each component, the word "install" always means the following:

1. Pick the correct value to start with.
2. Insert the component into the correct printed circuit board (PCB) location.
3. Orient the component correctly – especially when there is a right and a wrong way to solder it in. (i.e. Electrolytic capacitors, diodes, ICs, transistors, etc…)
4. Solder all connections unless directed otherwise. Ensure enough heat is used to allow solder to flow for clean, shiny, and completed connections.

Also, please be sure to take us seriously when we say that good soldering is the key to the proper operation of your circuit!

- Use a 25W soldering pencil with a clean, sharp tip. DO NOT USE a high power soldering gun such as those trigger activated units.
- Use only rosin core solder intended for electronics use
- Ensure your work area is clean, and has plenty of bright lighting
- Build your kit in stages, taking breaks to check your work. Be sure to clean the board periodically with a brush or compressed air to remove any excess wire cuttings, etc…

Okay, so lets begin!

❒ 1. Install R1, 1k resistor (brown-black-red)

❒ 2. Install R2, 51k resistor (green-brown-orange)

❒ 3. Install R3, 100 ohm resistor (brown-black-brown)

❒ 4. Install R4, 330 ohm resistor (orange-orange-brown)

❒ 5. Install CR1, 1N4148 diode (marking 1N4148)

❒ 6. Install C1, 15pF capacitor (marking 15J)

❒ 7. Install C2, 22uF electrolytic capacitor

❒ 8. Install L1, 330uH inductor (marking 331)

❒ 9. Install D1, LED. The short lead of the diode is the cathode and will install into the square pad on the PCB board.

❒ 10. Install D2, LED. The short lead of the diode is the cathode and will install into the square pad on the PCB board.

❒ 11. Install Q1, 2N3904 transistor. This transistor needs to be orientated properly. Please insert Q1 into the board with the flat edge of the transistor orientated according to the silkscreen layout drawing.

❒ 12. Install Q2, 2N3904 transistor. This transistor needs to be orientated properly. Please insert Q2 into the board with the flat edge of the transistor orientated according to the silkscreen layout drawing.

❒ 13. Install SW1, switch. Note that there is no incorrect way to install this switch. The switch may be inserted in any orientation.

❒ 14. Install the (2) AA battery clips to the **underside** of the board.

Congratulations! You have just completed your Joule Thief 1.0 kit. Please take a few moments to look over the board and ensure that all the components are installed properly with the correct orientation. Since some of the parts may be unfamiliar to you, you may want to be extra sure that they have been inserted correctly. After you are sure that everything seems to be properly installed, move on to the set-up and testing section.

Set-up and Testing

Okay, so lets begin!

❒ 1. Install an AA battery into the battery clips. Make sure the battery is installed with the correct polarity.

❒ 2. Turn the switch to the ON position if the LEDs are not already illuminated.

Congratulations! Your Joule Thief 1.0 is now completed and operational.

Troubleshooting

PROBLEM: The LEDs do not illuminate when I turn the switch ON.
SOLUTION: Verify that the LEDs are installed correctly, the battery is installed correctly, and that the battery is not completely drained.

PROBLEM: The LEDs illuminate very dimly.
SOLUTION: The battery may be discharged below the 0.8V required for this circuit to operate correctly.

Conclusion

We sincerely hope that you have enjoyed the construction of this Eastern Voltage Research Kit. As always, we have tried to write this instruction manual in the easiest, most "user friendly" format that is possible. As our customers, we value your opinions, comments, and additions that you would like to see in future publications. Please submit comments or ideas to:

Eastern Voltage Research, LLC

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Thanks again from the people here at Eastern Voltage Research.

Terms and Conditions of Sale

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http://www.easternvoltageresearch.com/terms.html