



"Joule Thief" LED Night Light

by [ledartist](#) on September 2, 2011

Table of Contents

"Joule Thief" LED Night Light	1
Intro: "Joule Thief" LED Night Light	2
Step 1: Features	2
Step 2: Technical Overview	3
File Downloads	4
Step 3: Assembly	4
Step 4: Performance	5
Step 5: PCB & Kit	6
Related Instructables	6
Comments	6



Author: [ledartist](#) [My Blog](#)

I work with LEDs and microcontrollers to create beautiful objects.

Intro: "Joule Thief" LED Night Light

I have many used batteries around. Remote controls, cameras, many electronic gadgets all use batteries, mostly AA size. I always felt guilty for throwing away the used batteries. I know there are rechargeable batteries, but many electronics don't work well with rechargeables.

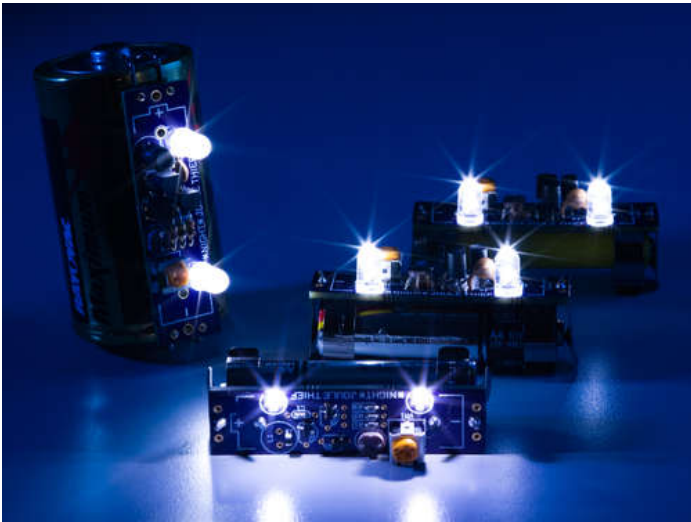
I also know that those "used" or "spent" batteries usually have some juice left in them. So to come up with a good use of used batteries, I've created a LED night light.

I like having a little night light on when I sleep. LEDs are perfect for this purpose, because they are energy efficient, and good at providing low intensity illumination.

This LED night light operates with just one battery. It utilizes a little circuit called Joule Thief to boost voltage out of an AA battery. I also added a light sensor to turn it on automatically when the surrounding is dark.

The circuit is energy efficient, and requires very low voltage to work. So it effectively sucks every bit of energy out of batteries. This type of circuit is often called "Joule Thief", because it works as though stealing every bit of energy (Joule is a unit for energy) out of battery.

I'm calling this project Night Joule Thief.



Step 1: Features

Here are the highlights of the Night Joule Thief.

- Compact & streamlined design
- Uses only one AA battery (or any 1.5V battery you can hook up to)
- Easily adaptable to different size batteries - hook up holes to attach home made clips
- Two white LEDs
- Automatic turn on via a light sensor (adjustable sensitivity level)
- Energy efficient - works even with a run-down battery, down to 0.6V
- Choice of through-hole only components or SMD - mix & match on the same PCB

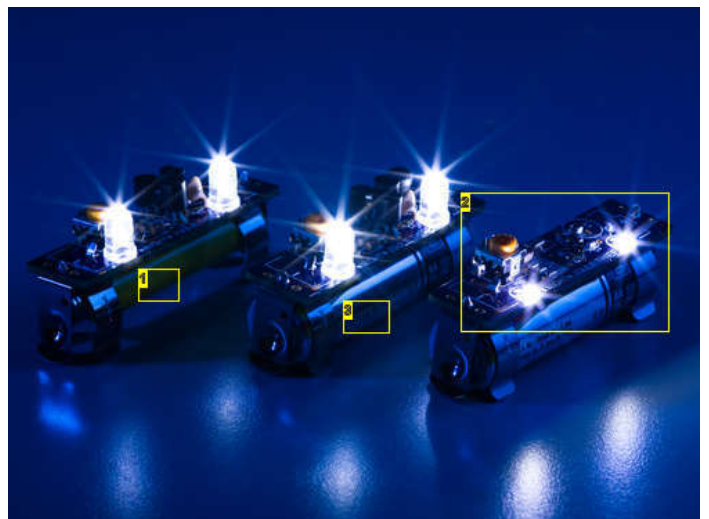
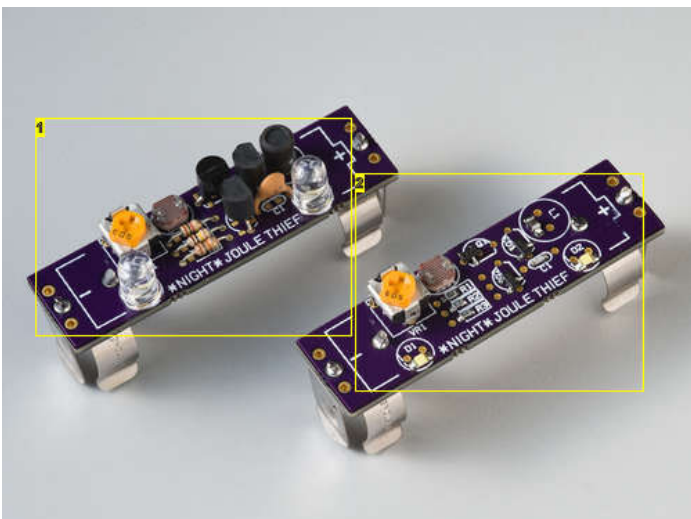


Image Notes

1. Through-hole version.
2. SMD (Surface Mount Device) version. Hard to believe this is the same circuit, but it works exactly the same as one on left. Ok, the LEDs are slightly less bright.

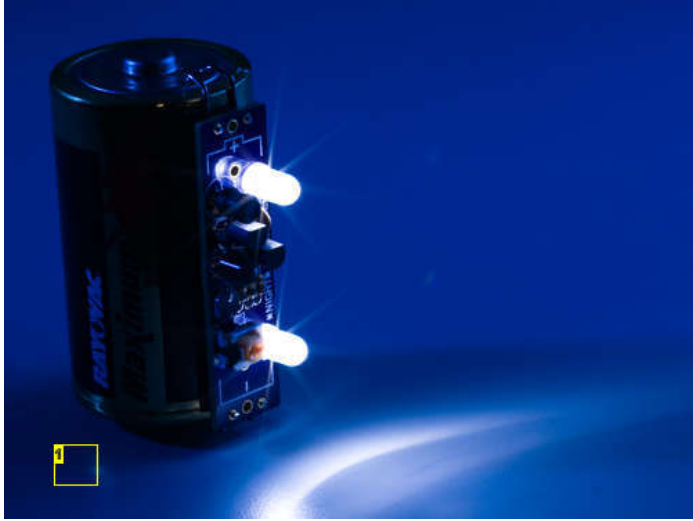


Image Notes

1. AAA battery inserted with a help of small magnets.
2. SMD version - very low profile.
3. Standard AA battery snugly fit in the clips.



Image Notes

1. Other sizes, such as D cell can be attached by making a pair of little metal clips. Just cut and bend paper clips.

Step 2: Technical Overview

"Joule Thief" circuit is an inductor based voltage booster circuit to light LEDs with low supply voltage. As most of you know LEDs need higher than 2V (3V for white LEDs), so usually at least two batteries are needed to light them. The "Joule Thief" circuit was published in 1999 and has been quite popular. You can see the principle of the circuit here. http://en.wikipedia.org/wiki/Joule_thief

My version is a variation that uses single coil inductor, to make the inductor easily obtainable. I design the circuit using readily available parts only, to make it an ideal DIY project.

Circuit

The L1, Q2, Q3, C1, R2, and LEDs D1 & D2 make the Joule Thief. And the Q1, and the rest of the parts form the light sensor. CdS is the device that actually senses the light and change its resistance accordingly. When the surrounding of CdS is bright, it has low resistance (anywhere around 1k to 3k ohm), and when the surrounding is dark, the resistance goes up to 100k to 3M ohm range. So in this circuit, the base voltage of Q1 is controlled by the ambient light level. When the base voltage of Q1 goes more than 0.6V below the power supply(battery) voltage, current goes through R1, turning the Joule Thief circuit on.

The Joule Thief circuit is boosting the battery voltage up to over 6V to light two LEDs in series. LEDs light up with the battery voltage as low as 0.6V! Amazing!

PCB layout can be downloaded as an editable PDF, so you can etch your own board if you like. Custom 2 layer PCB and kit are available for sale as well. The 2 layer PCBs have extra front pads for SMD where possible, so you can build the same circuit with SMD parts as you wish.

Parts List

- 1x CdS Photoresistor (rated 3k - 0.3M ohm) (CDS1)
- 1x 1k ohm (R1)
- 1x 100k ohm (R2)
- 1x 10k ohm (R3)
- 1x 50k ohm trim pot (VR1)
- 1x 22pF (C1)
- 1x 470uH (L1) (anywhere between 22 - 470uH would work - might have to reduce the C1 value however)
- 1x 2N5401 or equivalent (Q1) (or just about any general purpose PNP transistor, such as PN2907, 2N3906, etc...)
- 2x MPSA06 or equivalent (Q2, Q3) (or just about any general purpose NPN transistor, such as PN2222A, 2N3904, 2N4400, etc...)
- 2x LED (D1, D2) (Just about any LEDs can be used)
- 2x Battery Clips

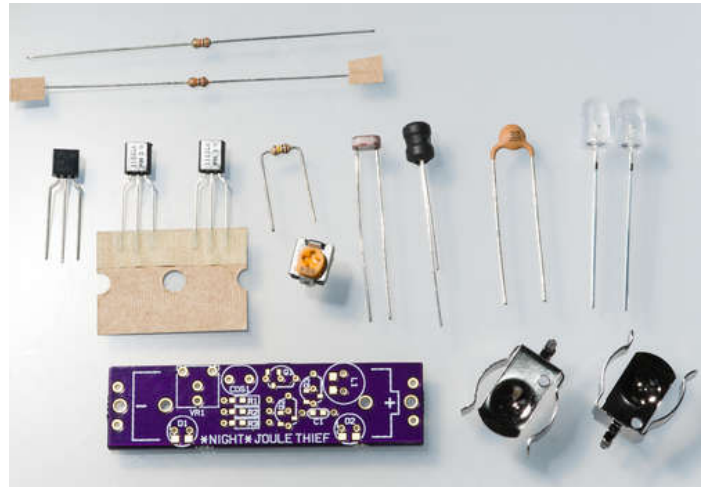
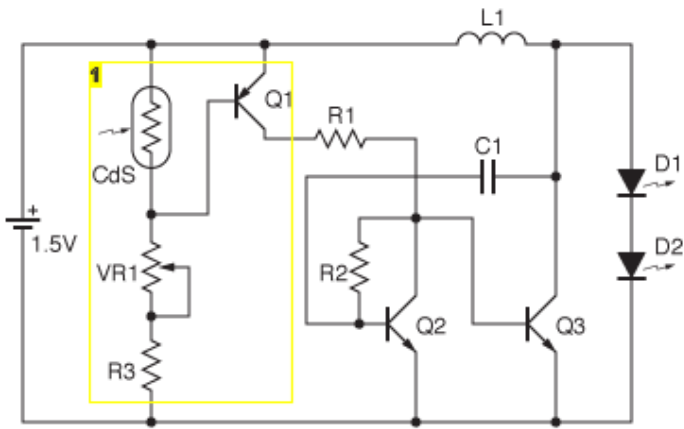
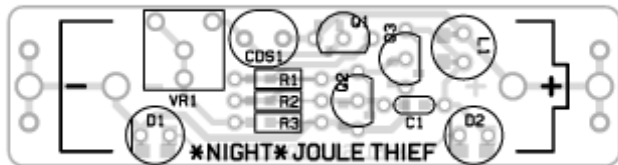


Image Notes

1. Light sensor circuit with sensitivity adjust.



File Downloads



NightJouleThief-PCB.pdf (54 KB)

[NOTE: When saving, if you see .tmp as the file ext, rename it to 'NightJouleThief-PCB.pdf']

Step 3: Assembly

The assembly is very straight forward. Insert the parts into the PCB, and solder them. Start with small components, follow the order below.

Parts List (in assembly order)

- 1x 1k ohm (R1)
- 1x 100k ohm (R2)
- 1x 10k ohm (R3)
- 1x Photoresistor (rated 3k - 0.3M ohm) (CDS1)
- 1x 50k ohm trim pot (VR1)
- 1x 22pF (C1)
- 1x 470uH (L1)
- 1x 2N5401 or equivalent (Q1)
- 2x MPSA06 or equivalent (Q2, Q3)
- 2x LED (D1, D2)
- 2x Battery Clips

Transistors, and LEDs have polarities, so make sure to insert them in the correct orientation. Battery holders need a bit of force to snap into the holes. They attach from the back side of PCB as you can see in the picture.

Once everything is soldered in place, double check the part placement, orientation and solder joints. Then insert a battery. The polarity is marked on the front side of PCB.

If you don't see the LEDs light up, don't worry. The room is probably too bright. Take a piece of black paper or tape and block the light from hitting CdS light sensor. (and/or darken the room) If the LEDs still don't come on, turn the trimmer (the little orange thing) with a screw driver, counter clockwise. This makes the sensor less sensitive to light, so the LEDs will come on by just placing the sensor under shade, or turning off the room light.

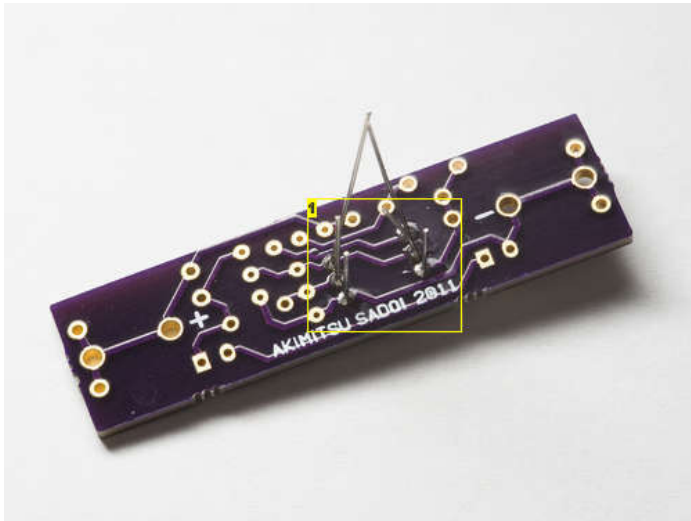
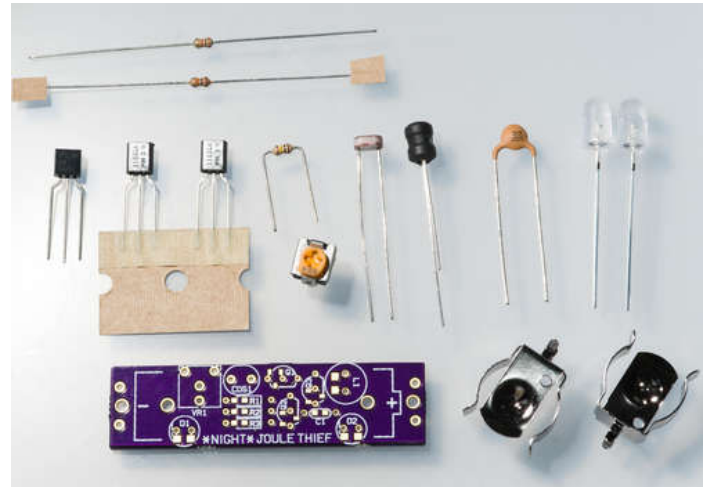
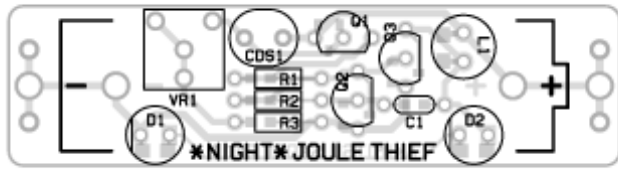


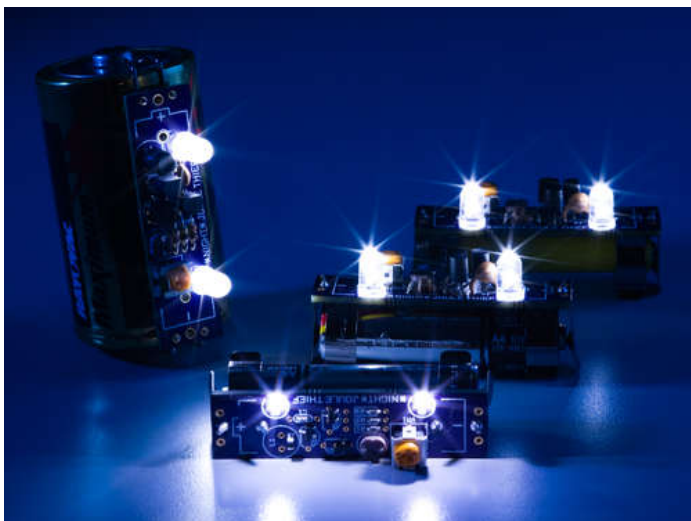
Image Notes
1. Resistors soldered in.

Step 4: Performance

This little night light performs very well. For starters, the brightness is not bad for using just one AA battery. I've been using these as flashlights as well.

The light sensor also works very well. Once adjusted, the light is steadily off during the day, even when you put the sensor under shade. Only when you block the sensor by a black object, the light would turn on. Yet after dusk, the light would come on when you turn off the room light.

A fresh battery lasts for weeks if only used as a night light. And the best use of this light is to "revive" used batteries. Those batteries from remote controls, cameras, etc. usually have quite a bit of juice left in them. Joule Thief sucks the juice out of those batteries till the last drop. It's like getting free energy when you can use something that were going to be thrown out.



Step 5: PCB & Kit

If you are handy, you can etch your own PCB, and build this night light entirely DIY.

However, to spread the goodness of Joule Thief and to contribute to the greener earth, I am putting together the PCB & kit available.

The details can be found here: <http://www.instructables.com/community/Joule-Thief-LED-Night-Light-Kit-PCB/>

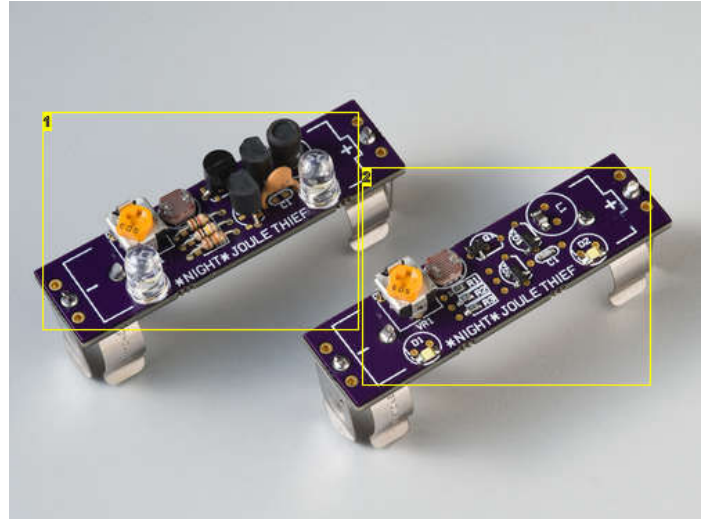
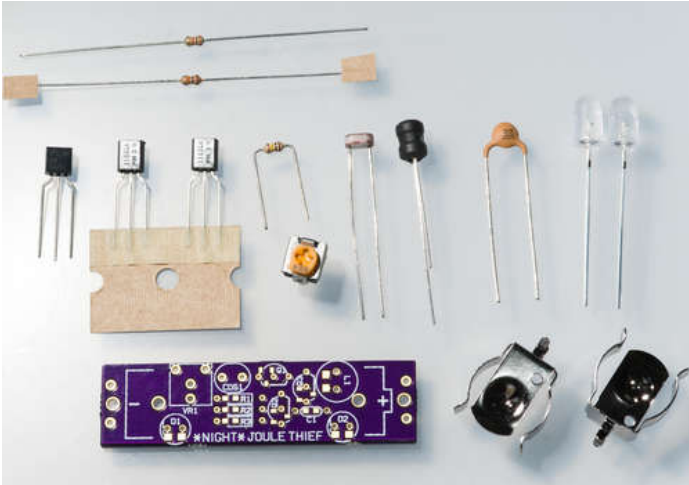


Image Notes

1. Through-hole version.
2. SMD (Surface Mount Device) version. Hard to believe this is the same circuit, but it works exactly the same as one on left. Ok, the LEDs are slightly less bright.

Related Instructables



Joule Thief - use LEDs with only one AA battery! by RazorConcepts



Ferrite, the joule thief (Photos) by botronics



Electronic Night Light by TinkerJim



Ultraviolet Light Pen by junits15



Mini 'Joule Thief' (Photos) by Mudbud



Altoids Joule Thief Flashlight (Photos) by cynical_chemical

Comments

33 comments [Add Comment](#)



tosacj says:

Great idea. Let me know when the kit becomes available.

Sep 4, 2011. 10:47 AM [REPLY](#)



ledartist says:

I will post the information on "Kits" section of the forum and on my blog (theLEDart.com). The kit & PCB are scheduled to be ready in mid September. Thanks, Aki

Sep 4, 2011. 12:38 PM [REPLY](#)



haxcess says:

This is a very neat application of the joule thief. I am wondering if it would be possible to replace the light-sensor circuit with a small battery charging circuit (solar). I suppose that would ruin the beautiful form factor you have here.

Sep 5, 2011. 8:16 AM [REPLY](#)



apalacios2 says:

Excellent circuit. May I remove the CdS circuit and use a button switch instead (thru the resistor connected to the transistor)? I find great that it uses a coil instead of a toroid transformer. Kudos!

Sep 5, 2011. 7:07 AM [REPLY](#)



ledartist says:

Sep 5, 2011. 7:28 AM [REPLY](#)

Yes, you can. In fact I made sure that you can fit a 6mm tactile switch in place of trimmer pot. You can omit the CdS, and solder a switch in place of trimmer pot.

You can also remove Q1 and put a switch there as well, but my PCB won't accommodate that.

Yeah I found having to wind my own inductor a hassle, so I designed this circuit to use off-the-shelf inductors.

Aki



bhvm says:

Sep 4, 2011. 9:17 PM [REPLY](#)

Excellent build!

How many mA does this circuit give? Can we use a single 150mA power LED in place of 2x 5mm LEDs?



ledartist says:

Sep 5, 2011. 7:20 AM [REPLY](#)

The current through the LEDs is about 20mA or less peak (it's pulsed current in about 50kHz)

So you won't get any more light by using a high power LED. By using only one LED, you do get a bit more brightness per LED though. However just a regular LED will give you the same brightness as a high power LED because you are not driving the LED with high current anyway...

It's not that you can't drive high current LED, but this circuit is designed to run with as little power as possible.

Aki



abbtech says:

Sep 4, 2011. 7:10 PM [REPLY](#)

Great looking project.



ledartist says:

Sep 4, 2011. 7:18 PM [REPLY](#)

Thanks!



vruiz3 says:

Sep 4, 2011. 1:56 PM [REPLY](#)

afraid of the night??? :D



timotet says:

Sep 4, 2011. 1:21 PM [REPLY](#)

great job!



gnafpliotis says:

Sep 3, 2011. 3:06 PM [REPLY](#)

Can't we hack laptop's batteries that way to perform more? Is it only letting through a small amount of amps?



ledartist says:

Sep 4, 2011. 1:17 PM [REPLY](#)

Laptops and many other "high-tech" gadget has many of inductor based boost/buck (to reduce voltage) voltage converter circuit in them. Especially LED back light screens use voltage converter to efficiently drive LEDs.

So in a way the battery life is already enhanced. (Some gadgets are better than others, of course...)

Aki



jolshefsky says:

Sep 4, 2011. 6:19 AM [REPLY](#)

Yes, but only if you wanted to use your batteries once. Once a lithium rechargeable (like in laptops) is discharged past a certain point, it can no longer be recharged. So there is always some energy left in a laptop battery even when it says it's dead — albeit energy you can't use without ruining the battery.



stoobers says:

Sep 4, 2011. 7:29 PM [REPLY](#)

I've heard this theory. Have you done any experiments that might validate this theory?



jamwaffles says:

Sep 4, 2011. 6:14 AM [REPLY](#)

This might not be 100% accurate but yes, that's why we can't use the same technique for laptops. Joule thieves ramp the voltage up, but the current goes down due to $V = IR$, assuming the load is constant which it is if it's the same laptop ;-)



jamwaffles says:

Sep 4, 2011. 6:15 AM [REPLY](#)

A very professional looking product. This is a great idea; the amount of power saved using old batteries instead of a herd of plug-in night lights, as well as the amount of batteries re-used is incredible.

Just out of interest, how long do these night lights last on one "averagely discharged" battery?



ledartist says:

The battery lasts very long, most likely much longer than you might think. It's hard to define "averagely discharged", but I had one cell that was already at 0.7V (to low to be used with anything), and the although the LEDs were dim, they lighted for over 48 hours. With my "dead" batteries coming out of a wireless mouse still have over 1V, I have plenty of light.

Aki

Sep 4, 2011. 1:10 PM [REPLY](#)



YakAttack says:

I concur!
@ledartist: Any tests on battery life so far?

Sep 4, 2011. 8:24 AM [REPLY](#)



nymgeek says:

Are those PCBs made by Laen at dorkbot pdx?

Sep 4, 2011. 7:42 AM [REPLY](#)



ledartist says:

Yup. They are very good!

Sep 4, 2011. 1:04 PM [REPLY](#)



acmefixer says:

I should have said in my previous comment that this does not mean there is anything wrong with your circuit. I think I would change Q2 and Q3 to an easier to obtain transistor such as a 2N4401 or PN2222A. Q1 could be a 2N3906 or just about any PNP transistor. If these changes are made, the resistors, especially R2, might need to be reduced. Thanks.

Sep 4, 2011. 10:06 AM [REPLY](#)



ledartist says:

Yes, you can use just about any general purpose transistors. R2 should be fine with most transistors, but 47k ohm might work better with some of them.

Aki

Sep 4, 2011. 1:03 PM [REPLY](#)



acmefixer says:

Unfortunately the link you gave to Joule Thief in Wikipedia is for a poorly written and totally inadequate definition. The authors (apparently several over time) do not have a firm understanding of how a JT works, and furthermore, they have made a mess of it. I have added comments in the discussion and some errors have been deleted, but it is still unworthy of use for a reference.

Also, by definition, the original blocking oscillator circuit later given the Joule Thief name used only a single transistor. Your circuit is not a one transistor blocking oscillator and bears little resemblance to the original JT, so I don't believe it should use the same name.

Sep 4, 2011. 10:00 AM [REPLY](#)



ledartist says:

I know the original circuit only uses one transistor, but the two conductor inductor is harder/expensive to purchase, and winding own inductors is a bit of work. I think using one extra transistor is a good trade off for not having to wind an inductor by hand. It also makes economical sense. (transistors are very cheap, so are single coil inductors.)

I did mention that my version is a variation of original, which I find very often on the net. I also think that showing different ways to achieve the same result can be inspirational.

I also contacted the person who named the circuit "Joule Thief" (Big Clive) and he did not have a problem with me using the name.

Aki

Sep 4, 2011. 12:59 PM [REPLY](#)



StoryAddict says:

"Joule Thief" - I love a clever pun!

Sep 4, 2011. 12:54 PM [REPLY](#)



MikeDel says:

Looks good. I'm interested!

Sep 4, 2011. 10:21 AM [REPLY](#)



Admiral Aaron Ravensdale says:

I like your "green" thinking.
I also use a joule thief in my expedition light.

I am very glad that you will provide the parts as a kit because many kits are able to solder a circuit but etching a little bit too dangerous for them.

Thanks for your endeavour to make this instructables buyable for many people...

Sep 4, 2011. 7:30 AM [REPLY](#)



kevinhannan says:
fantasic project and incredibly well explained.

Sep 4, 2011. 6:35 AM [REPLY](#)



UOS says:
Great instructable! Waiting the kit version to buy one but also I'm gonna make mine from scratch :D

Sep 3, 2011. 2:59 PM [REPLY](#)



tphillips2 says:
You are so inventive! Cool idea and great looking light!

Sep 3, 2011. 8:07 AM [REPLY](#)



ledartist says:
Thanks!

Sep 3, 2011. 8:18 AM [REPLY](#)



gweeds says:
What a great idea! must build one and see how long it gets out of a "used'ish" battery

Sep 3, 2011. 4:41 AM [REPLY](#)
