e LABS PROJECT

12-V LED Driver

lights up the dark nights

Supposing you'd want to bring some light into a boat or campervan during the evening you could connect a couple of 12-V incandescent lamps to the on-board battery. The disadvantage of this solution is that the battery can be drained quite quickly — incandescent lamps aren't exactly known for their energy efficiency. LED lamps fare much better in this respect, but the light fittings required for 12-volt operation are costly. So, the author set out to design a compact, but versatile driver that lets you use inexpensive 230 V LED lamps.

By **Louter van der Kolk**
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The Swedish discount home furnishing store Ikea sells a nice-looking LED wall/clamp spotlight (called the Jansjö) that costs about €/£10, which just begs to be used in a caravan, campervan or boat.

Features

- Powered from a 12-V battery
- Suitable for efficient LED lamps
- Configurable output current up to 350 mA
- Various dimming levels via the on/off switch

The disadvantage of this spotlight is that it's meant to be used on an AC power outlet (via an external adapter), rather than a 12-V battery. We therefore need to find a way round this problem.

The wrong way

In the not too distant past we used to have inverters that changed the 12-V DC battery voltage into 230 V_{AC} (US: 115 V_{AC}), allowing you to use 'normal' fluorescent tubes or incandescent lamps. This could obviously be used here as well. But wait a moment, that means we would first convert the battery voltage into an AC voltage, and then use an adapter to convert the 230 V_{AC} line voltage into a suitable DC voltage for the LED spotlight. A step-up converter followed by a step-down adapter? That seems to be a solution that belongs in the book *Electronics for Dummies* and not in a publication like *Elektor Magazine*...

The right way

The only correct solution is of course a dedicated LED driver that takes its power from the 12 V battery and which directly drives the LED in the spotlight. The Ikea spotlight is perfect for this, since there is a direct connection available to the LED without having to take anything apart. We first need to find out what the nominal current is through the LED during normal operation of the spotlight. This can be easily measured using a standard (DC) ammeter; this current was found to be about 165 mA.
We therefore need to design an LED driver (current source) that takes the

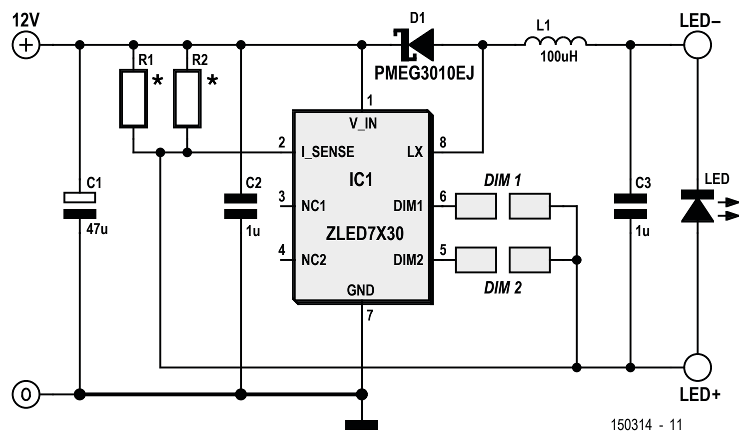


Figure 1. The circuits consists of a single IC and a handful of small components.

PROJECT INFORMATION

LED driver
battery powered
dimming modes

➡ entry level
intermediate level
expert level

1 hour approx.

Soldering iron suitable for SMD work

£22 / €25 / $28 approx.

12 V_{DC} from the battery and supplies a fixed current of 165 mA to the LED.

The circuit

It is of course possible (and probably quite enjoyable and educational) to design an LED driver using only discrete transistors, capacitors, resistors and inductors — numerous designs can be found on the Internet. But let's be honest: this is no longer how things are done, and certainly not if we want to end up with a compact circuit. For this reason we have selected an integrated solution: the ZLED7x30 made by IDT (Integrated Device Technology). This small IC requires only a handful of external components and has a number of interesting features, such as a dimming function that operates via the on/off switch. It is also possible to accurately set the output current via a single external resistor. A small disadvantage of this IC is that it is only available as an SMD version, although it's still possible to solder it by hand. There are several versions available of this driver IC, with the only difference being the maximum supported output current; the functionality and pin-out are the same (see **Table 1**).
Since we only need a maximum current of 165 mA for our Ikea spotlight, we decided to use the ZLED7730. You can use the table to select the required version for other (greater) currents.
The circuit diagram is shown in **Figure 1**.

This is a standard continuous-mode inductive stepdown converter, built around IC1, D1, L1 en C3. With this type of stepdown converter (also known as a buck converter) the output voltage will always be lower than the (absolute value of the) input voltage. Inductor L1 and capacitor C3 function as an energy buffer and ensure that the load (in this case the LED) is supplied with a continuous, constant current.
The main function of capacitor C1 is to provide smoothing when the circuit is powered via a bridge rectifier. Since the circuit is powered by a battery, the capacitor value isn't critical in this instance. In the datasheet [1] for the IC you can read more about how to select a suitable value for this capacitor. C2 reduces the ground bounce effect [2], which exhibits itself when the output MOSFET in the IC is switched. This capacitor should be mounted as close as possible to the IC. Inductor L1 should have a value between 30 μH and 220 μH. When you start experimenting with different output currents, you may find that you will need to use a value different to the 100 μH mentioned in the circuit in order to obtain a stable operation. Under certain circumstances you may find that the chosen inductor won't fit on the PCB designed for this circuit.

Configuring the output current

One of the nice features of the ZLED7x30 is that the output current is determined

Table 1: ZLED7x30 types

Type	Maximum output current
ZLED7030	1.2 A
ZLED7330	1.0 A
ZLED7530	750 mA
ZLED7730	350 mA

by a single external resistor (R_{Sense}). In order to make the output current setting as accurate as possible, we've used resistors R1 and R2 in parallel for R_S in our circuit. The formula for the output current is:

$$I_{out} = \frac{0.1V}{R_S}$$

When we use a value of 1.2 Ω for both R1 and R2, the parallel circuit has a resistance of 0.6 Ω. The output current then becomes 166 mA — just what we need. Note that the internal thermal protection could come into play when you experiment with different values and you make the output current greater than the maximum value permitted for the particular ZLED type (Table 1).

Configuring the dimming mode

Another nice feature of the driver IC is that the dimming mode can be configured with two solder bridges (or two 0 Ω resistors if you prefer the look of those).

COMPONENT LIST

Resistors
R1,R2 = 1.2Ω * (SMD 0805, 0.25W, 1%)

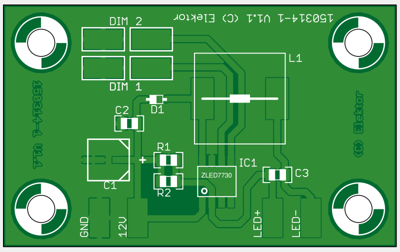
Capacitors
C1 = 47µF 25V, SMD 0805, aluminum electrolytic capacitor (Panasonic EEE-FT1E470AR)
C2,C3 = 1µF 50V, X7R, SMD 0805

Inductor
L1 = 100µH SMD, 3.1A / 0.11Ω (Würth Elektronik 7447709101)

Semiconductors
D1 = NXP PMEG3010EJ, Schottky diode 30V 1A, SMD SOD-323F
IC1 = ZLED7730, LED driver, SMD SOP-8 (IDT, ZMDI) *

Miscellaneous
PCB 150314-1

* see text



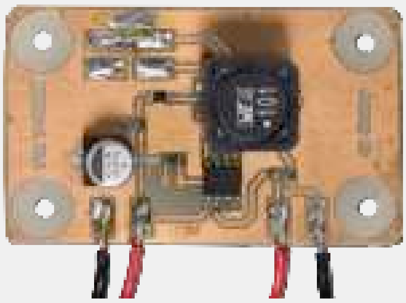


Figure 2. The small PCB for the LED driver. All components are SMD types.

These solder bridges are shown as DIM1 and DIM2 in the circuit diagram.
The presence or not of the two solder bridges results in four possible dimming modes, as shown in **Table 2**.
Switching between the dim settings in the selected dimming mode is simplicity itself: just switch the driver off and on quickly using the on/off switch, which incidentally isn't shown in the circuit diagram because it is present in the +12 V power cable from the battery.

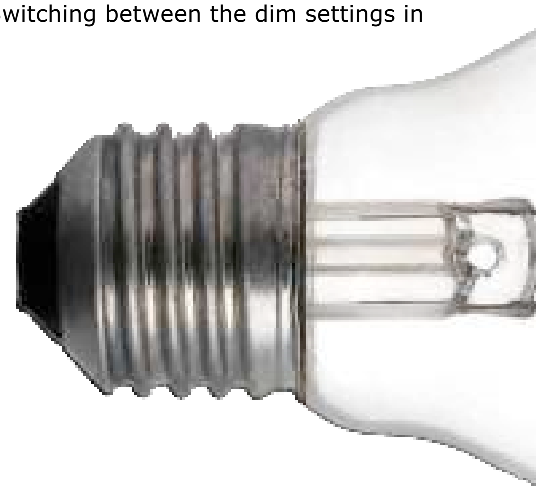


Table 2: Configuring the dimming mode

DIM1	DIM2	Dimming mode
open	open	don't dim: maximum on, completely off
open	solder bridge	3 settings: 100% → 50% → 20% → 100% → ...
solder bridge	open	3 settings: 100% → 60% → 30% → 100% → ...
solder bridge	solder bridge	2 settings: 100% → 30% → 100% → ...

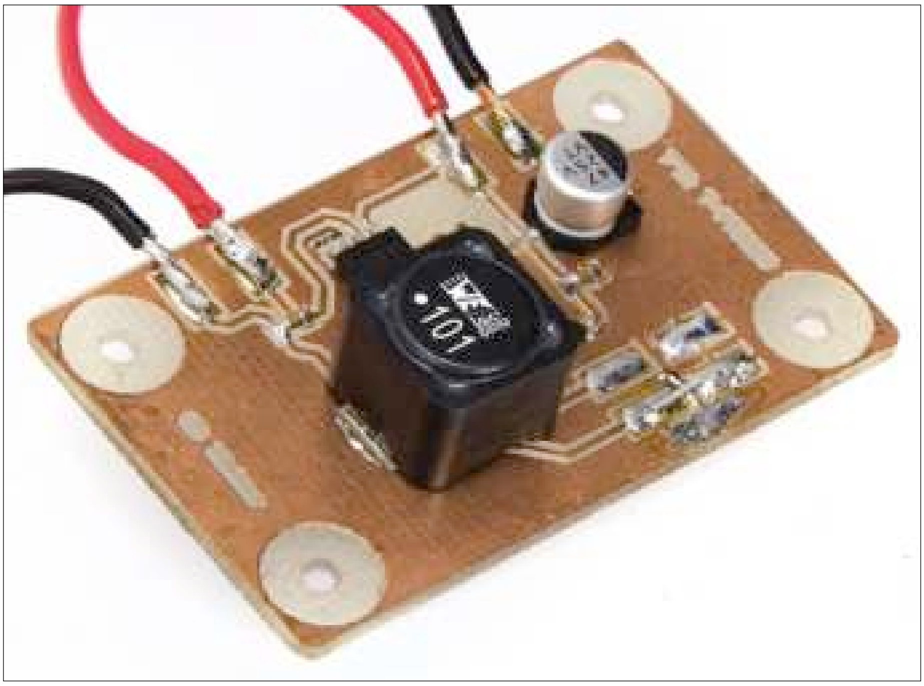
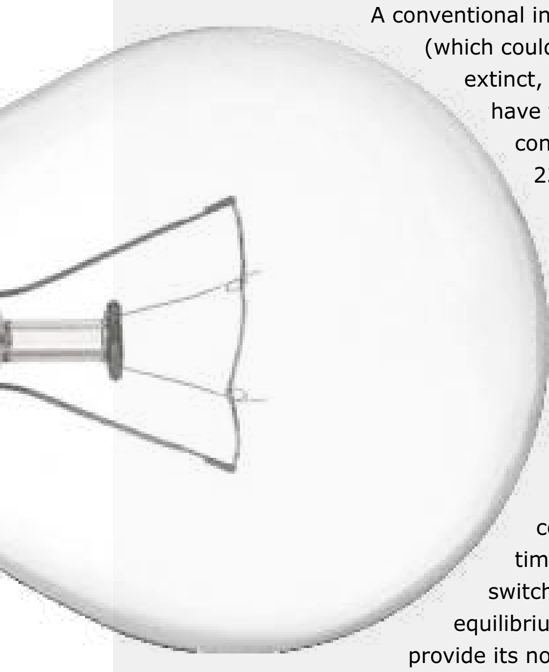


Figure 3. It can be clearly seen that all the components used are still large enough to be soldered by hand.

Construction

We have designed a single-sided PCB for this circuit, which is shown in **Figure 2**. You may well have noticed that the our prototype board has been milled, rather than etched. All of the parts are SMD components; the passive components should be mounted first, and the IC last. If you haven't had any experience yet with SMD components, all we can say is: there's no need to panic! As a hobbyist you should give it a try one day, and this circuit is perfect as a first project to gain some experience. The components aren't that small that you need specialist equipment such as a reflow oven; all that's required is thin solder, a soldering iron with a narrow, tapering tip, and a supply of solder wick (desoldering braid). A magnifying reading lamp is a great help, and a steady hand would come in useful as well! When you have finished you should double-check the board for any shorts using a magnifying glass. The result should be like that shown in **Figure 3**.
The author has built his prototype into small enclosure made by Hammond (type 1551MBK); this can then be attached to the clamp of the spotlight using some hook & loop tape or a bolt (**Figure 4**).
Note that the prototype board made by the author is different to the one we

More about incandescent lamps and LEDs



A conventional incandescent lamp (which could soon become extinct, if the EU politicians have their way) can be connected directly to the 230 V AC line, since the resistance of the filament limits the current flow through the lamp. Furthermore, this resistance increases as the filament becomes warmer (positive temperature coefficient). A short time after it has been switched on it will reach an equilibrium and the lamp will provide its nominal light output.

For LEDs it's almost the opposite. An LED is a semiconducting diode, which has a certain voltage across it (its forward voltage drop) during normal operation. However, the current through the LED is not automatically limited. In the simplest case, this requires the addition of an in-line resistor (series resistor). There will be a voltage drop across this resistor (which needs to have its value recalculated if it's used with a different supply voltage) that is just the right amount for the correct current to flow through the LED so that it burns at its nominal intensity. If you were to connect the Ikea spotlight from our circuit directly to a 12-V battery, the current wouldn't be limited and the LED would output a very large amount of light for a very short time. It would then remain extinguished forever.
Depending on the supply voltage, a greater or lesser amount of current is needlessly converted into heat, which isn't very efficient. It's much better to use a dedicated LED driver, which acts as a current source to supply the correct current to the LED. This results in the correct voltage being maintained automatically across the LED.

An LED requires a current source, not a voltage source

made and which is available from the Elektor store. You can use the original in-line switch in the power cord, although it wouldn't be too difficult to add a small (slide) switch to the enclosure. ⏮

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Web Links

[1] www.idt.com/document/dst/zled7x30-datasheet

[2] https://en.wikipedia.org/wiki/Ground_bounce

Figure 4. The author has put his prototype in a small Hammond enclosure, which was then fixed onto the clamp of the spotlight.