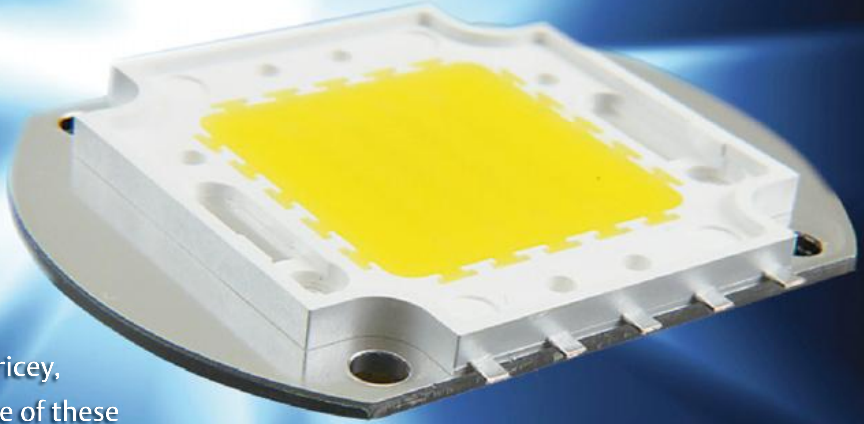
LED the Sun Shine

50-watt power LED with dimmer circuit

By Ton Giesberts (Elektor Labs) and
Thijs Beckers (Elektor Netherlands Editorial)



Power LEDs are getting more and more powerful. Although they are still a bit pricey, we wanted to see for ourselves what one of these modern 'heavyweights' can do. One of most powerful LEDs we found that is available to normal consumers is the H50WA CWS from Huey Jann Electronics, an LED module that weighs in at a strapping 50 watts.

LED technology is advancing in leaps and bounds. We had to rub our eyes recently when we saw a high power LED rated at no less than 50 watts in some mail order catalogues including that of Reichelt [1]. That's a lot of light, and we naturally wanted to see it with our own eyes. Reichelt was kind enough to provide two samples to us for our experiments. All we still needed was a power supply.

At first we had the idea of designing our own supply (preferably a switcher), but we quickly discovered that we would just be reinventing the wheel. When we found a Mean Well supply in the Reichelt catalogue that was virtually tailor-made for the power LED and with an almost unbelievable price, we realised that this was a better choice. However, we did develop a dimmer circuit to allow the LED brightness to be varied; it diverts some of the power from the supply to a shunt resistor.

Power to the LED

The ready-made LPC-60-1750 power supply from Mean Well (**Figure 1**) is very well suited to the 50-W high power LED from Huey Jann Electronics Industry Co. Ltd [2]. It could just about be made specifically for this purpose. The output current of the supply is exactly 1.75 A DC, which according to the data sheet of the power LED is the absolute maximum rated continuous current of the LED module. The supply can also handle an input voltage range of 90 to 264 V AC. The power supply is short-circuit proof and has protection against excessive constant output current and excessive output voltage.

As expected, the LED produces a beastly flood of light. The stream of visitors who came into the lab had to shield their eyes to protect them from the intense brightness. Even viewing the lit-up LED from the corner of your eye was extremely irritating. Of course, we had it lying fully exposed on the lab bench (mounted on a heat sink, of course), but after being carefully fitted in a suitable fixture it would be a good deal more tolerable.

Dimmer circuit

Up to this point, connecting the power LED to a power source was easy, but we also wanted to be able to adjust the brightness. Our first idea for this was to simply build a circuit with a load in parallel with the LED (using a power resistor with a MOSFET or a PWM controller) that could divert a variable amount of current from the LED, since our selected power supply acts as a current source. Not exactly a 'green' solution, since this would cause power consumption without generating light from the LED. However, it could be less than what the LED consumes at full power because the current source has a specified regulation range of 9 to 34 V. If the LED is fully dark, in principle only 16 W has to be dissipated (1.75 A × 9 V). Shorting the output or overloading it in order to consume even less power was not an option in our view, since we didn't know whether the supply could handle this over the long term.

The thought that power would still be dissipated even when the LED was dark stimulated us to come up with a more efficient solution. The component that (under ideal conditions) does not have any power dissipation with a DC current is an inductor. Our first idea was to connect a PWM load to the power supply and divert a variable amount

Power LED specs

Maximum continuous current: 1.75 A

Operating voltage: 27–28 V

Light flux: 2925–3735 lumen, depending on colour

Beam angle: 120 degrees

Colour temperature: 3300–8000 °K

LED junction temperature: 135 °C

Power supply specs

Output current: 1750 mA

Output voltage: 9–34 VDC

Input voltage: 90–264 VAC

Maximum power: 59.5 W

Efficiency: 87%

With overload protection and short-circuit protection

Figure 1. The output current (1.75 A) and current-source configuration make this Mean Well power supply ideal for use with the 50 W power LED.

of current from the LED in order to dim it (See **Figure 2**). The PWM frequency should be high enough to allow the inductor to be kept reasonably small (we chose approximately 100 Hz and a 40 µH inductor rated at 2 A).

Unfortunately, this idea didn't work. The problem with this approach is that a certain amount of power must always be drawn from the supply, and it has to go somewhere. This 'excess' power is normally converted into heat. Here we attempted to avoid this by converting the excess energy into a magnetic field. Our simulation showed that the magnetic field strength rose higher and higher and never returned to zero. Of course, a magnetic field that increases indefinitely is impossible in practice. Unfortunately, a flyback diode was not enough to dissipate the energy in the time when the inductor was not acting as a load. Even with a low duty cycle, after a few switching cycles the current would rise so high that it would cause the MOSFET to fail, and perhaps the inductor as well if the power supply could deliver enough current. In the case of our current source, which has a maximum output of 1.75 A, the LED would go dark even with a low duty cycle. All in all, not an especially practical circuit.

Another idea ...

One way to prevent the inductor from becoming saturated is to reverse the polarity of the magnetic field with each switching cycle. For example, this could be done by using two MOSFETs in a circuit configured as a push-pull converter with a centre-tapped transformer. In our case, we could take a standard interference suppression choke and add a second winding with the same number of turns as the existing one. However, we would still have the problem that the inductor constantly absorbs energy and must give it back somehow. We didn't see any sense in pursuing the idea of using an inductor for controlling the LED brightness any further. However, we still secretly wonder what would happen if we drove the

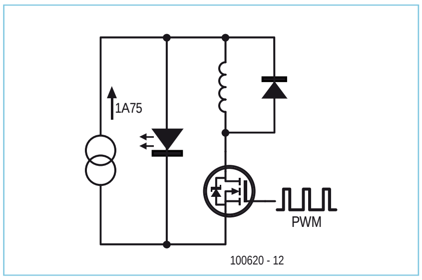


Figure 2. The basic design of our first idea for a dimmer circuit has a few pitfalls.

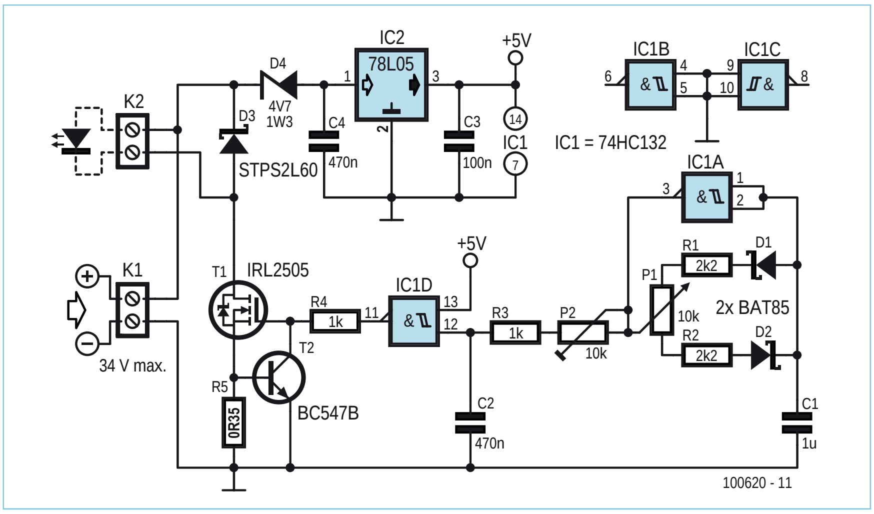


Figure 3. The schematic of the dimmer control circuit we ultimately came up with shows the simplicity of the design.

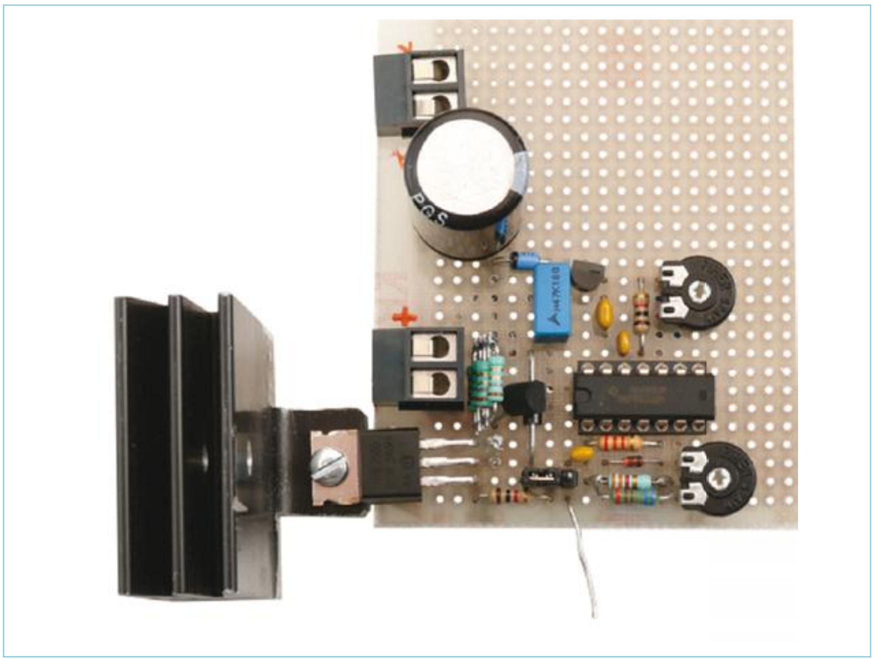


Figure 4. We didn't design a PCB layout for the dimmer circuit. Our experimental version was built on a prototyping board.

inductor with a symmetric current (pure square wave) at a variable frequency.

... and yet another

Another fairly obvious solution is to switch the LED itself at a relatively low frequency, such as 150 Hz. To be on the safe side, we first tried operating the power supply with a switched resistor as a load. It's a good thing we did this first, because the power supply turned out to operate as a constant current source only with a constant load. Our test showed that the internal control circuit of the power supply has a very long response time. With a pulse-shaped load, the output voltage rises to the maximum level of 34 V.

Figure 5. This LED module obviously requires cooling. Following the motto 'better safe than sorry', we drew a somewhat oversized heat sink from stock for our circuit.

The supply delivers distinctly more than 3 A during the pulses (we didn't pursue this experiment any further), which would be far too much for the LED.

A workable solution

The right solution for switching the LED is simple. Instead of using the MOSFET only as a switch, we have it act as a current source as well. This only requires a sense resistor to measure the current and an additional transistor (T2 in **Figure 3**). The sense resistor is wired in series with the source of T1 and provides the base–emitter voltage for T2. The collector of T2 is connected to the gate of T1. If the voltage across the sense resistor rises to level where T2 starts to conduct, the gate voltage of T1 is pulled to ground.

This is a very simple constant-current source. One disadvantage of this circuit is the temperature dependence of T2. This causes the current to decrease as the temperature increases, which can be regarded as a form of protection. If you build this circuit yourself, it's a good idea to put T2 further away from the sense resistor than we did (see **Figure 4**), since the resistor can dissipate more than 1 W. When the controlled current through T1 is lower than the current delivered by the power supply and the duty cycle of the PWM signal generated by IC1a is 100%, the maximum dissipation of T1 can be more than 11 W. This means that T1 must be cooled by mounting it on a heat sink with a thermal resistance R_{th} of 3 K/W.

The MOSFET drive circuit is based on the 'Light Therapy Box' (a.k.a. Bluesbraker) design published in the November 2009 issue. In this case we used a 74HC132 for the Schmitt-input NAND gate. A 5-V signal is more than enough to properly drive the logic-level MOSFET T1. A simple oscillator is built around IC1a. Its duty cycle can be adjusted with P1 over a range of approximately 16% to 84% (nearly symmetrical around 50%). IC1d causes the PWM signal to the MOSFET to be always low or always high at the minimum or maximum duty cycle setting (respectively) of the signal from IC1a. This allows the LED to be adjusted to full on or full off, despite the limited range of the control circuit. It might be possible to extend the adjustment range of P1 by modifying the time constants of the two gates. With the component values shown in the schematic diagram, the minimum current before the LED goes dark is approximately 150 mA.

Power for IC1 is supplied by an 78L05. The maximum input voltage of the control circuit is 30 V; Zener diode D4 ensures that it stays in bounds. The current consumption of the control circuit built around IC1 is so low that the power dissipation of IC2 does not increase significantly at high input voltages. Diode D3 limits any inductive voltages generated by parasitic inductances in the wiring.

Toasty

If you want to build the LED and power supply into a lighting fixture, you'll have to devise something that allows sufficient cooling. The data sheet warns that the surface temperature of the LED can be as high as 150 °C, and that the aluminium mounting plate to which the LED is attached is far from adequate for dissipating the heat from the LED.

The heat sink shown in **Figure 5** is a bit exaggerated. The data sheet is not entirely clear on the amount of cooling required. It states for example that for use with horizontal orientation a surface area of 550 cm^2 is necessary for adequate cooling of the LED, but we wanted to be on the safe side during our experiments. The light output of the high-power 50 W LED is around twice that of a standard 100 W incandescent lamp (no longer available to consumers in most of Europe), with only half of the power consumption. When the LED is highly dimmed, you can see the individual points of light. It appears that Huey Jann Electronics constructs the modules by placing four strings of LEDs side by side, with eight LEDs in each string. This is consistent with the voltage obtained by multiplying the average voltage over a white LED (3.3 V) by 8. The resulting value (26.4 V) is very close to the rated forward voltage of the power LED module (27 V).

These LED modules are available from Reichelt in several colours, including warm, cool, natural and pure white. On the manufacturer's website and the data sheets you can see that the modules are also available in other colours, but at the time of writing they still haven't found their way to the electronics retail market. Fingers crossed — eyes wide open.

We wish to express our thanks to Reichelt Elektronik, Germany, for providing the power LEDs and the Mean Well power supply.

Internet Links

[1] www.reichelt.de

[2] www.hueyjann.com.tw