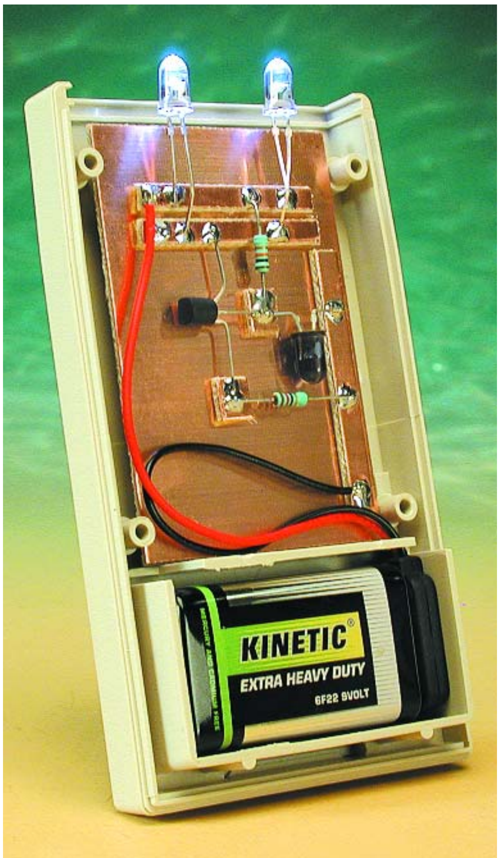
Two-Eyed LED Lamp

One lamp, three types of LED

Design by W. Zeiller



We have featured numerous torch circuits using white LEDs. This simple design adds a couple of other types of LED to extend light emissions either side of the visible spectrum.

LEDs are usually driven from a constant current source so that the LED brightness is not dependent on a varying supply voltage. The circuit here in **Figure 1** shows a constant-current source produced by transistor T1.

To explore its workings in a bit more detail assume that at switch on the voltage at the base of T1 (V_B) is greater than the base conduction voltage (V_{BE} = 0.65 V) of T1. Current flows into the base and T1 starts to conduct. This will make current flow through its collector-emitter junction and resistor R2, generating a voltage across R2. This raises the emitter of T1 above ground potential. The current through R2 can only reach a level where the voltage drop across R2 plus V_{BE} of the transistor is equal to the base voltage V_B. Current cannot get any larger because that would generate a bigger voltage across R2 which would turn off the transistor. The collector current therefore settles at a value so that the voltage drop across R2 plus V_{BE} equals the base voltage V_B.

We have produced a constant current through R2 defined by the constant voltage V_B.

In the circuit, R1 and D1 form the constant-voltage source. D1 is an infrared LED and has a forward conduction voltage of around 1.0 V. In contrast, red LEDs conduct at about 1.8 V while white ones conduct at about 3.5 V. An IR LED was chosen just for its forward conduction voltage and the actual type is not important, you could salvage one from a scrapped TV remote or you may have one in your junkbox. Alternatively if such an LED is not available it is possible to replace D1 with two diodes connected in series: a standard silicon diode (0.65 V) e.g., 1N4148 with a Schottky diode (0.35 V) e.g., BAT 85 or BAT 43.

Using a supply voltage of 9 V and a 10 kΩ resistor for R1 the current through D1 will be:

$$I_{LED} = (V_B - V_{D1}) / R1 = 800\ \mu A$$

ignoring current flowing into the base of T1. This level of current is too small to produce any IR output from D1 but prolongs battery life. To produce IR light (you still won't be able to see it though) the current through D1 needs to be about 20 mA, this gives a value for R1 of 510 Ω. D1 is not a perfect voltage source and the increased current will raise the voltage drop across the diode.

The constant current through the collector–emitter path of T1 is divided between two white LEDs, each requiring 20 mA so the value of R2 can be found:

$$R2 = (V_{D1} - V_{BE}) / I_{D2,D3} = (1.0\ V - 0.65\ V) / 40\ mA = 8.75\ \Omega$$

To be on the safe side R2 is increased to 12 Ω, the difference in brightness is hardly noticeable.

Series or parallel?

At first glance it seems pointless to connect both white LEDs in parallel. It would be better to connect them in series and they would then consume only half of the current. The problem is their relatively high forward conduction voltage. Each white LED conducts when the voltage across it exceeds 3.3 V so if we add the 0.35 V drop across R2 together with the collector-emitter voltage drop across T1 we need at least 4 V supply voltage before current will flow through the LED and T1. Connecting a second LED in series with the first will drop another 3.3 V

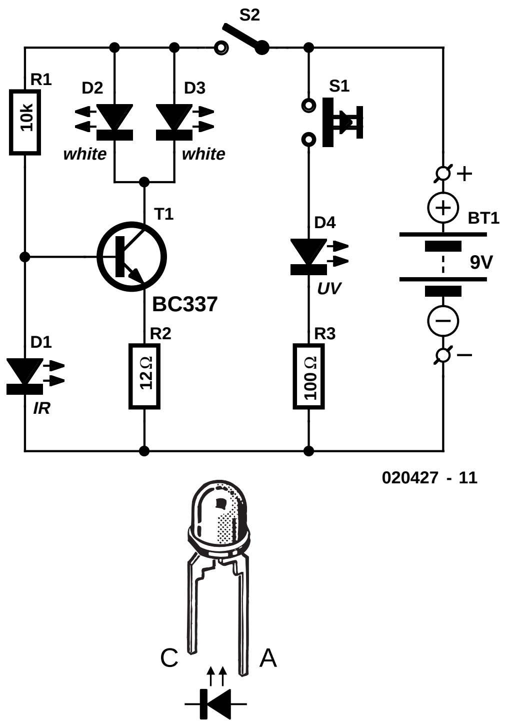


Figure 1. The circuit uses two super-bright white LEDs and a constant current source.

so the supply must now be 7.3 V.

This voltage level should not be a problem if we use a 9 V battery but a closer look at the discharge characteristics for a typical alkaline PP3 shown in **Figure 2** (developments in modern cell design show improvements to these figures but they remain broadly similar) reveals that with a load of 220 Ω (a combined LED current of 40 mA) the cell voltage falls below the conduction threshold (4 V) after 13 hrs use while the 470 Ω load (equivalent to the two LEDs connected in series) will cross the conduction threshold (this time 7.3 V) after only 11 hrs approximately. Some white LEDs have an even higher forward conduction voltage of 3.6 V. Connecting two in a series configuration would raise the conduction threshold for the circuit to 7.9 V and looking at the 470 Ω load curve we can see that the LEDs would extinguish after only 4 hrs use!

During tests the author found that with the LEDs connected in parallel the lamp could burn continuously for 17 hrs powered by a PP3 type battery and even when the voltage had fallen to 3 V (!) there was still enough light to help you pinpoint those elusive keyholes.

LEDs are usually not connected in parallel because the device with the lowest conduction voltage will always conduct before the other LED and take the majority of the current. The reason that this configuration works is that white LEDs have a typical series resistance of about 18 Ω. This produces an additional voltage drop when conduction begins and helps to share the current more evenly between the two.

A problem can occur if the characteristics are too dissimilar because one LED will take most of the current, increasing its dissipation and eventually leading to an early demise, at which point the second LED will become overloaded and also fail when it must take the full 40 mA.

Ultraviolet

A useful addition to the circuit is the UV LED (D4) connected via a 100 Ω series resistor and pushbutton S1. This light source is handy for detecting counterfeit banknotes.

D4 emits light with a wavelength of 405 nm so it is not a true UV source but rather ‘UV near’ (UV light has a wavelength less than 400 nm), UV light from D4 is relatively harmless to the eyes but it is not advisable to stare directly into the beam. This light source is only ever needed momentarily so a non-latching push button is used to switch it on.

The UV light intensity is very high and series resistor R3 limits current through D4.

Case notes

The finished circuit is fitted into a plastic enclosure with a separate battery compartment. The circuit is so simple that a purpose-made PCB is not necessary; a ‘custom’ board can easily be made up from off cuts of PCB sheet instead. First remove the dull oxide coating from the copper surface with very fine emery or sandpaper. Cut a rectangular piece of the PCB to fit into the enclosure and act as a base plate, next cut a few strips of the remaining PCB sheet to form the connecting tracks and pads for the circuit. Fix these tracks in the correct position on the base plate using either double-sided tape or super glue. The components can now be soldered onto these tracks to form the circuit. The title picture shows how this has been achieved.

The switch and push button are secured to the enclosure lid with hot-melt glue and then wired to the circuit board.

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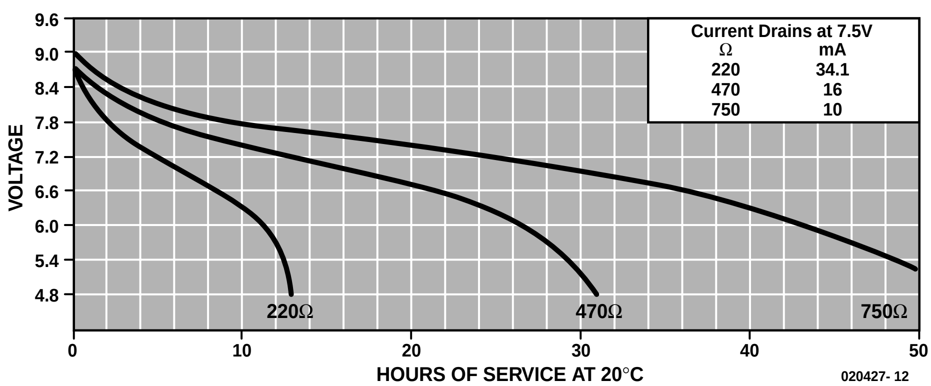

Figure 2. Typical alkaline battery discharge characteristics.