Light Therapy Box

Blue LEDs combat the Winter Blues

By Ton Giesberts (Elektor Labs)

During the winter many people suffer from Seasonal Affective Disorder (SAD), which is commonly known as the winter blues. With the help of blue light these symptoms can be reduced. The blue-light generator described here has a built-in timer and is perfect for this task.

Specifications

Power line adapter (9 V / min. 0.5 A)

Current consumption:
0.03 A (minimum brightness)
0.46 A (maximum brightness)

Duty cycle: 8% (f = 1 kHz) to 92% (f = 750 Hz)

Programmable period:
from about 4 to 30 minutes

When the days become shorter after the summer months many people start to feel fatigued. This could manifest itself as anything from a slight tiredness to heavy depression. The most noticeable symptoms are lethargy and problems with eating and sleeping.
This condition is nowadays officially recognised and is called 'Seasonal Affective Disorder' although it is more commonly known as the winter blues.
When the days become shorter and the amount of daylight reduces, Nature tends to slow down and this is therefore perfectly normal. However, some people with the winter blues are affected so much that their normal way of life is severely disrupted.
Much research has been carried out into the causes of the winter blues and most conclusions show that the biological clock is affected by the reduction in the amount of light that is experienced. The sunlight that strikes the retina triggers chemical processes that affect the working of the pineal gland in the brain. This pineal gland is responsible for the production of melatonin, a hormone that plays a big role in the sleeping process and regulating the internal biological clock.
It is assumed that an excess of melatonin has a depressive influence. It is possible that the production of melatonin has been adversely affected in people who suffer from winter depression. To counteract this phenomenon people are given light therapy, where the retina is exposed to bright artificial light for a certain time every day. The result of this is that the production of melatonin is reduced.
Recent research has found that the light therapy doesn't necessarily have to be carried out using white light. It appears that it is predominantly blue light with a wavelength between 445 nm and 475 nm that is most effective at combating the winter blues. As a result of this, Philips developed a number of therapy lights (goLITE BLU) that uses a matrix with a large number of LEDs to produce a good amount of blue light.
These therapy lights are not exactly cheap and as electronics enthusiasts we have the tendency to see if we could make such a circuit ourselves (and cheaper). This resulted in the idea to make a blue-light lamp with a built-in timer in the Elektor lab, which was suitable for use by the whole family.

The circuit

For this project we decided not to use a microprocessor for a change. We've used

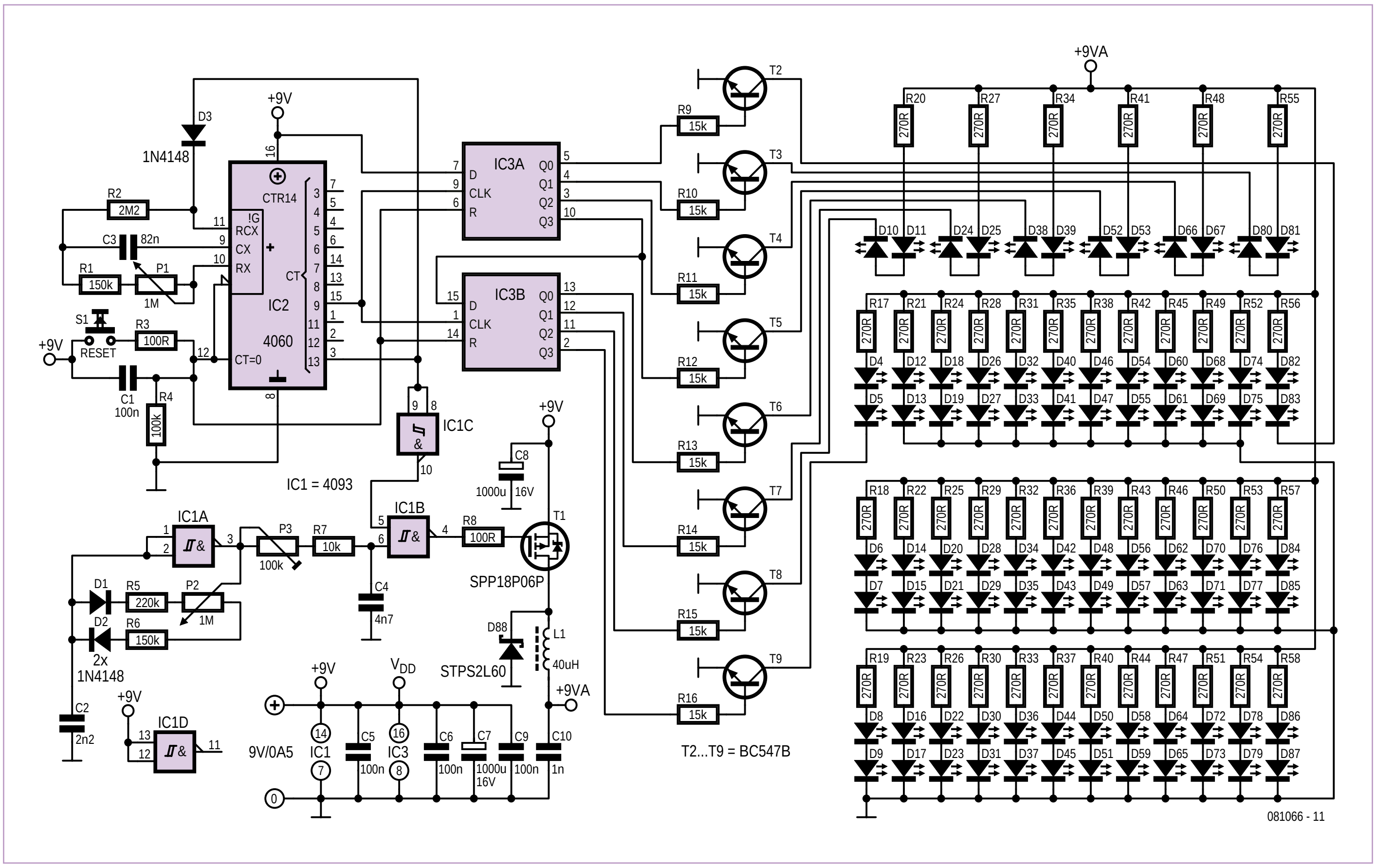

Figure 1. The most conspicuous part in this circuit is the matrix containing 84 blue LEDs.

ICs from the standard CMOS 4000 series in the trusted through-hole packaging.

The largest part of the circuit in **Figure 1** is obviously taken up by the numerous LEDs: there are 84 of them. In this case it makes sense to buy 100 pieces, since that usually works out cheaper due to quantity pricing. The LEDs have been positioned fairly close together on the board, so they present a uniform area of light. One row of LEDs is used as a simple display for the timer. The time that the LEDs are lit for can be adjusted with a potentiometer from about 4 minutes to 30 minutes. After this period has elapsed the LEDs are automatically turned off. A second potentiometer is used to adjust the brightness of the LEDs steplessly. Because we've used pulse-width modulation instead of normal voltage regulation the brightness range isn't affected by the value of the forward voltage drop of the LEDs.

As we wanted to make the turn-on time fairly accurate we've used a 4060 for the clock, which is an asynchronous counter with an oscillator. Due to the long period involved we had to use an RC oscillator (if we used a crystal oscillator we required a much larger frequency division). By taking the output from the last stage of the divider (pin 3) and choosing a value of 1 MΩ for the potentiometer, the value of the capacitor used in the oscillator section (C3) can be kept small. For the longest period the frequency is theoretically 4.61 Hz. The frequency of the RC oscillator is about

$$1 / (2.3 \cdot RC) \text{ [Hz]}$$

The time before the last (14th) divider output becomes high is then about 1776 seconds ($2^{13} \times 4.61^{-1}$), or 29.6 minutes. For the shortest period a frequency of about 35 Hz is needed, which results in a period of 3.86 minutes. In practice the period will be affected by various tolerances. Often the potentiometer, which can have a tolerance of 20%, will be the cause of a difference in the period.

The output of the last divider stage is connected via a diode to the oscillator section. When this output becomes high the oscillator stops and the 4060 will stay in this state until the reset input (pin 12) is pulled high. With S1 the 4060 can be reset at any time, after which the turn-on period starts again.

The indication of the time elapsed is achieved using a 4015 shift register. This twin 4-bit shift register is used as an 8-bit shift register by connecting the fourth output of the first register to the data input of the second register. This 8-bit shift register is clocked by output Q9 (pin 15) of the 4060. The data input of the first register is connected to the positive supply line, resulting in ones being shifted along every clock pulse. The clock input of the shift register acts on the rising edge of the pulse. After 8 clock pulses from Q9 the register has become 'full'. One clock pulse later output Q13 of the 4060 goes high and blocks the oscillator via diode D3. In this way the selected time period is visualised by the shift

COMPONENT LIST

Resistors
R1,R6 = 150kΩ
R2 = 2.2MΩ
R3,R8 = 100Ω
R4 = 100kΩ
R5 = 220kΩ
R7 = 10kΩ
R9–R16 = 15kΩ
R17–R58 = 270Ω
P1,P2 = 1MΩ potentiometer, linear
P3 = 100kΩ preset, horizontal

Capacitors
C1,C5,C6,C9 = 100nF MKT, lead pitch 5mm or 7.5mm (0.2” or 0.3”)
C2 = 2.2nF MKT, lead pitch 5mm or 7.5mm (0.2” or 0.3”)
C3 = 82nF MKT, lead pitch 5mm or 7.5mm (0.2” or 0.3”)
C4 = 4.7nF MKT, lead pitch 5mm or 7.5mm (0.2” or 0.3”)
C7,C8 = 1000µF 16V axial, lead pitch 28mm (1.1”)
C10 = 1nF ceramic, lead pitch 5mm (0.2”)

Inductor
L1 = 40µH 2A, axial (Epcos B82111EC23, Farnell # 9753354)

Semiconductors
D1,D2,D3 = 1N4148
D4.–D87 = blue LED, 5mm, 300mcd, wavelength 465nm, (e.g. Optek OVLLB8C7, Farnell # 1678692)
D88 = Schottky diode 60V 2A, (e.g. STPS2L60, Farnell # 9907637)
T1 = SPP18P06P (P-channel MOSFET 60V 0.13Ω, Farnell # 1056550)
T2–T9 = BC547B
IC1 = 4093
IC2 = 4060
IC3 = 4015

Miscellaneous
S1 = push button, panel mount
2-way pinheader, right-angled
2-way pinheader
2 3-way pinheader, right-angled
2 3-way socket
PCB # 081066, see www.elektor.com/081066

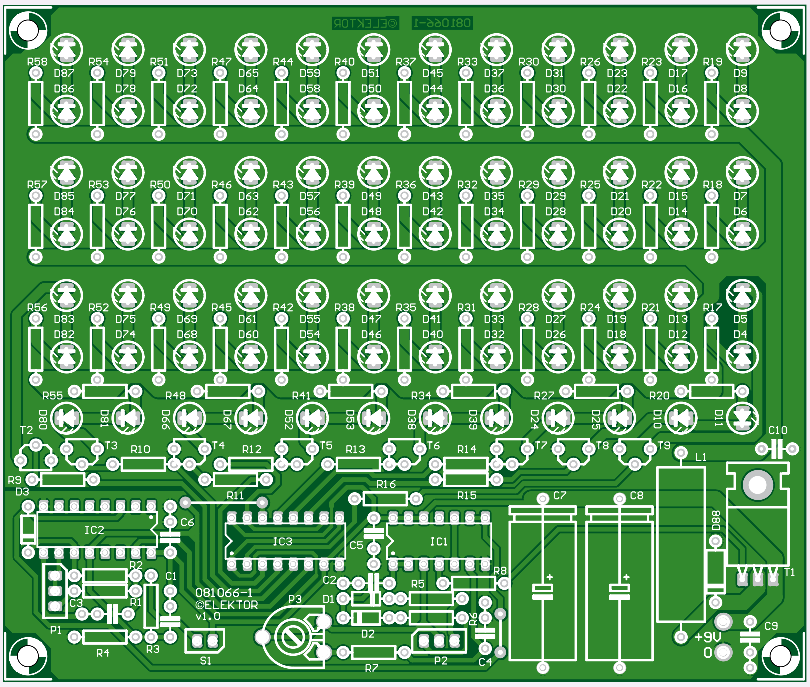

Figure 2. The size of the board is mainly determined by the LEDs.

register on the LEDs in eight equal steps.
At the bottom of the matrix are eight groups of two LEDs that are driven by the register outputs via T2 to T9. In order to keep the intensity of these LEDs as similar as possible to the others in the matrix a ‘discrete’ circuit with normal transistors was chosen, instead of driver ICs (these often contain darlingtons, which results in too high a knee voltage; the knee voltage of T2 to T9 in the prototype turned out to be close to only 10 mV).
There are many ICs available for the pulse-width section that are specifically designed for this task. However, it can also be done simpler, using a modified Schmitt-trigger oscillator designed around the 4093 (quad NAND with Schmitt-trigger inputs). The standard resistor in the feedback loop is replaced by two resistors, each of which have a diode in series in opposite polarities, and a potentiometer in between. The ratio of the charge and discharge times of C2 is greater or smaller than 1, depending on the position of the potentiometer. At one extreme the charge time is determined by R6 and the discharge time by R5+P2. At the other extreme the charge time is determined by R6+P2 and the discharge time by R5. Since the hysteresis of the 4093 doesn’t occur around exactly half the supply voltage, the values for R5 and R6 had to be adapted to provide an almost symmetrical control range, for example from 10% to 90%. Due to this asymmetrical behaviour of the 4093 the frequency changes when the duty cycle is adjusted. In our prototype it was between 1 kHz and 750 Hz. This variation won’t be visible to the eye; it only reacts to the pulse width.

A simple integrator has been added after the oscillator in order to be able to turn the LEDs fully on or off. The time constant of R7+P3 and C4 can be adjusted using preset P3 such that the voltage across C4 won’t cross the threshold voltage of IC1B at the minimum pulse-width setting (for both positive and negative pulses) and the output of this gate stays low or high. The integrator has been made adjustable because the hysteresis window of the Schmitt-trigger is not the same for different manufacturers and can even deviate within the same series of a single manufacturer. The output of IC1B is the control signal for P-channel MOSFET T1, which in turn provides the driving voltage for the LEDs.
When the set time has expired, pin 3 of the 4060 goes high and is inverted by gate IC1C and the other input of IC1B is made Low. The output of IC1B stays High and T1 no longer conducts.
For the LEDs a type made by Optek was chosen (OVLLB8C7), which combines ample brightness (min. 170 mcd, typ. 300 mcd) with a large viewing angle of 85°. The wavelength of the generated light is 465 nm. The maximum DC current through the LEDs is 20 mA. The difference in brightness between an LED current of 10 mA and 20 mA was so small for this type that we decided to limit the current to 11 mA.

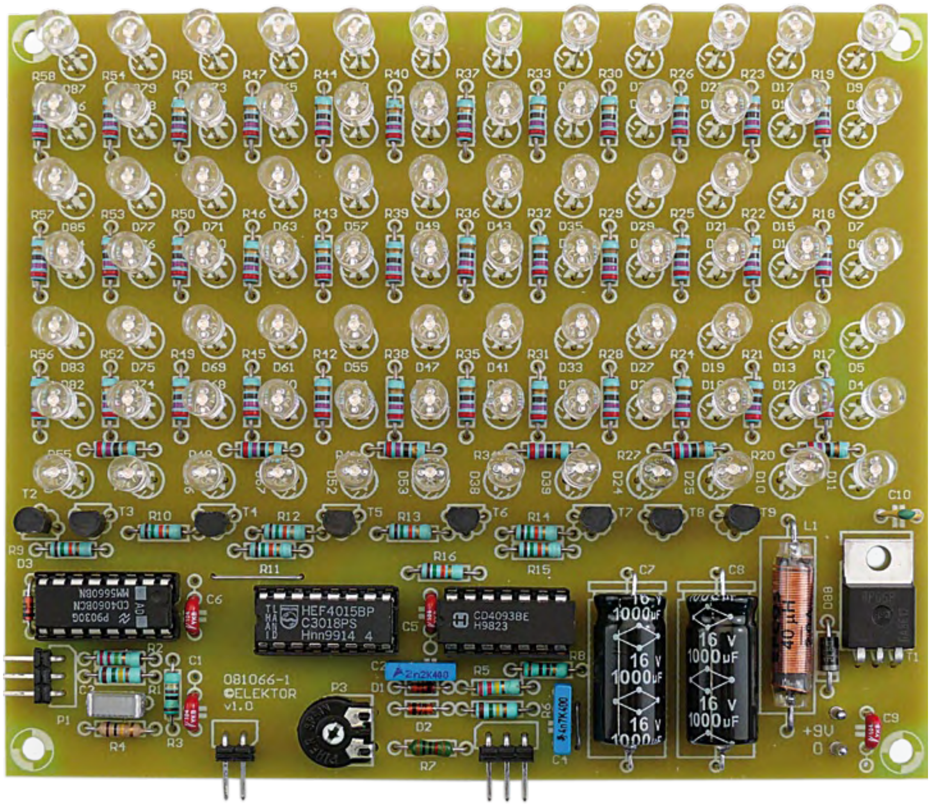

Figure 3. The completed prototype in all its glory.

Instructions for use

- The recommended daily usage period is between 10 and 30 minutes. The exact period has to be found by trial and error, along with the optimum brightness setting. Start with a short period and see if it has any effect. If it doesn't work, try it for a longer period.
- Start with a fairly low setting for the brightness and increase this in step with the duration until you notice a result.
- The blue-light generator has to be positioned next to you at an angle, so you won't be looking directly into the light. The intention is that the blue light shines onto your eyes from the side. Place the circuit at a distance of about 50 to 80 cm, for example next to your monitor on the desk if you're working with the computer.
- This therapy works best if you start at the beginning of the winter (before any of the winter blues symptoms are noticed) and have a blue light session daily, preferably in the morning.

Warning: Don't look directly into to burning LEDs for long periods since they produce a significant amount of light at higher brightness settings!

A somewhat higher voltage drop across the series resistors was chosen in order to reduce the effect of any differences in the forward voltage drop of the LEDs. Using a 9 V mains adapter as a power source, we can connect two LEDs in series. The LEDs in the prototype were found to have a forward voltage drop of just over 3 V, which resulted in a value of 270 Ω for R17 to R58. The total current consumption of the LEDs adds up to almost 0.5 A (42 x 11 mA).

Inductor L1 has been connected in series with the positive supply to the LEDs for interference suppression. It is therefore not meant to smooth out the current through the LEDs. The same applies to C10. Schottky diode D88 is a freewheel diode that prevents negative spikes from damaging the LEDs.

Two electrolytic capacitors of 1000 µF have been placed close to L1 and T1 to provide decoupling of the supply voltage. A side effect of these relatively large decoupling capacitors is that when the supply voltage drops below the forward voltage drop of the LEDs (temporarily unplug the mains adapter) the supply will drop very slowly and the circuit continues running for a considerable time.

Construction

The population of the board (**Figure 2**) is fairly standard. The LEDs are best mounted last. Start with the two wire links, followed by the resistors, IC sockets, preset, capacitors, transistors T2 to T9, L1, T1 and finally the two electrolytic capacitors (C7 and C8).

For connecting the potentiometers and S1 you can use pin-headers (right-angled versions due to the height restriction) with sockets, but you can also solder the wires directly onto the board. To keep the height of all components to a minimum, we've used axial versions for electrolytic capacitors C7 and C8 and indictor L1, and T1 has been mounted flat on the board.

The LEDs can be mounted in different ways. The easiest method is to solder all of them as closely as possible to the board. That way they will automatically be in position and may at worst have to be bent slightly into line. If you prefer to mount the LEDs through a front panel, and hence have to mount them about 2 cm above the board to stick out above the other components, things become more difficult. In this case it helps if you first make a template. Take a piece of experimenter's board and drill 5 mm holes in the right places (the LEDs are mounted at every fifth hole of the experimenter's board).

For the case it should be easy to find something to your liking. You can place a piece of Plexiglass in front of the LEDs. Remember to add a riser at the back of the case, so it will be angled when you place it on the table.

And finally here is a little tip: if you're not interested in the time progress bar, you can replace transistors T2 to T9 with wire links (from emitter to collector). In this case there is also no need to mount IC3 and R9 to R16.

(081066-I)