

# Ambience S.V.P! PC & TV Mood Lighting

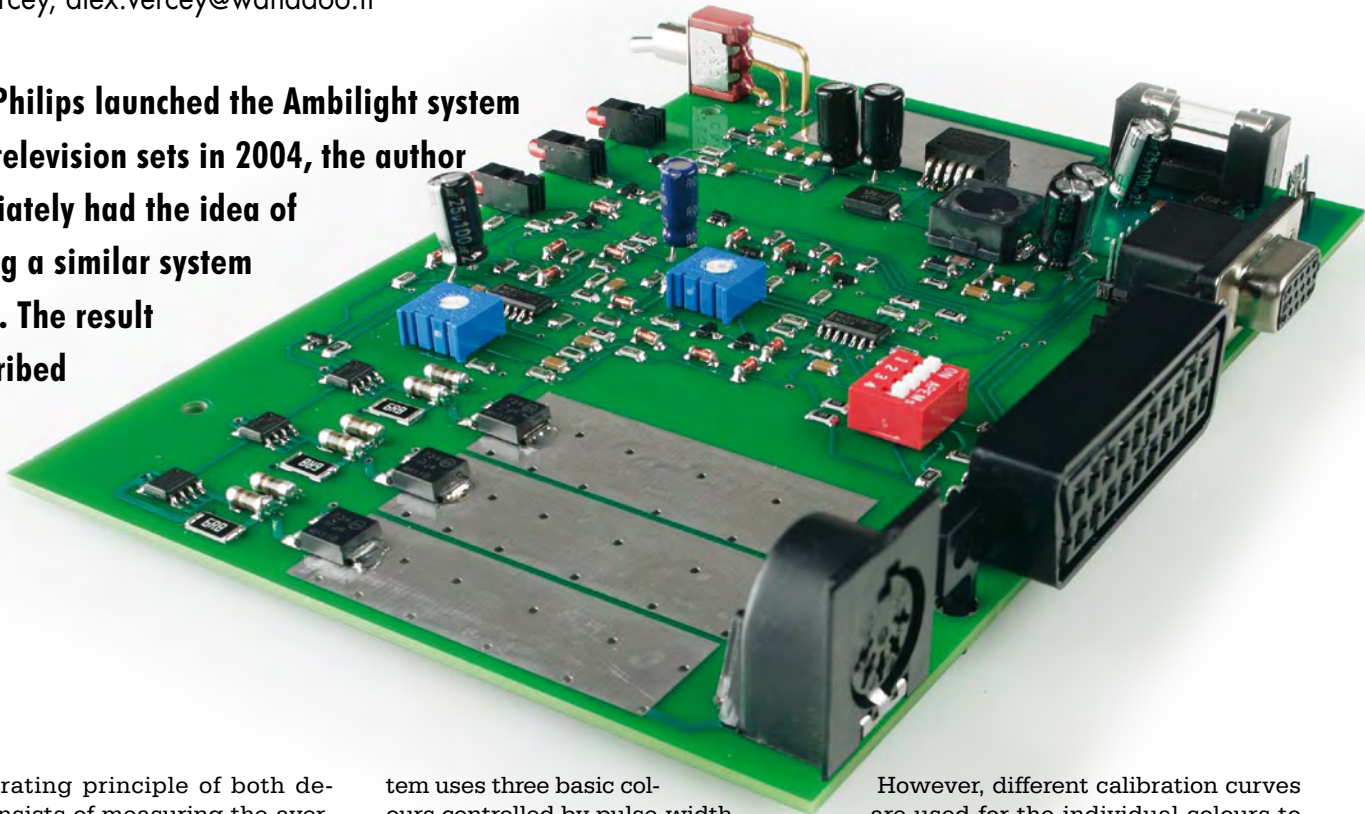


**Due to the fact that we received two circuit designs for television mood lighting and they both fit with the theme of this issue, we initiated a unique Elektor project: in this issue we present two completely different designs that produce nearly the same effect. Our French contributor Alex Vercey took the analogue approach, while Steffen Schütte from Germany went the 'microcontroller way'.**

# The analogue approach Surround Light

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When Philips launched the Ambilight system for its television sets in 2004, the author immediately had the idea of building a similar system for PCs. The result is described here.



The operating principle of both designs consists of measuring the average colour of an image and using colour LEDs to emit the same colour in order to 'paint' an impression of the image on the background behind the screen. This generates a more intense experience, creates a visual point of reference, and produces refined mood lighting.

The target audience for this product consists of dedicated film fans and voracious gamers.

## Technical considerations

In its product, Philips uses a spectrum analyser integrated in the video matrix processor. This method is only used with LCD and plasma displays. The control logic of non-scanned displays of this sort allows digital analysis of the signal based on the individual regions of the internal display driver matrix. Philips originally used a system with small neon tubes and an acrylic reflector to diffuse the light. However, LEDs are used in the latest models. The sys-

tem uses three basic colours controlled by pulse-width modulated (PWM) signals with a resolution of only four bits.

The design described here operates on a different principle, with the objective of achieving better reproducibility. In addition, the system described here can also be used with a PC or a raster-scan monitor (an 'old-fashioned' CRT monitor).

The system described in this article is the PC version of the Surround Light design. The television version is more complex, primarily due to safety considerations rather than technical issues.

The Surround Light system consists of a three-colour LED lamp driven by analogue signals, which allows all possible colour combinations (14 billion) to be generated from the three basic colours. For comparison, the software-controlled version uses an ADC and PWM signal with 16-bit resolution, which yields 65,536 possible colours.

Three identical circuits are used for the LED drivers (one for each colour).

However, different calibration curves are used for the individual colours to adapt the visually perceived colours to the spectrum of the LEDs used in the system.

As specified by the CCIR VGA standard, the maximum amplitude of a PC video signal (700 mV) corresponds to a full white image. This was confirmed by measurements made using a GeForce FX7300 card. There is also an option for isolation of the input signal.

As a minor detail, this system (unlike the Philips system) does not support generation of different colours on the left and right sides of the monitor, since this would require a much more complicated colour analyser.

LEDs are active semiconductor devices with a non-linear response to an electrical signal, and they are **current driven** instead of **voltage driven**. This means that the brightness of a LED cannot be controlled by adjusting the supply voltage.

In theory, it would be possible to vary the intensity of a LED by very accurately adjusting the voltage across the

LED, but this approach has a very small tolerance and essentially requires individual calibration of each type of LED in order to obtain good results. For this reason, current control is used here, which allows any desired type of LED to be used with an assured output control range of 0 to 100%.

**Protection**

The LEDs used in the prototype became hot when stationary white are-

circuit is triggered at the end of a defined time. This is a distinctly analogue approach.

This timeout is only necessary to avoid restrictions on the system when a stationary white image is displayed.

The timeout is approximately 20 seconds, which is long enough to ignore 'white' sequences in films.

The discharge time (after the screen is no longer white and the Surround Light can thus return to normal operation) is the same to keep things simple, and it

tor network to limit the rising edges of the signal with high-resolution video (1600 × 1200).

An RC network integrates the signal to obtain the average voltage (the colour signal resulting from this process), which is fed to an adjustable voltage divider.

The LEDs are driven by a voltage-to-current converter with a MOSFET power stage.

Finally, the protection circuit responds to detection of a stationary image and the output level of the voltage regulator. If the supply drops too low or the regulator malfunctions, the LED drive current is reduced to prevent damage due to an unstable supply voltage or an inappropriate image. The overall transfer function of the system can be described with the following formula:

$$(V_{input} \div 2 \times 18.49 - 1.2 \text{ V}) \div 9.33$$

**Schematic diagram**

The schematic diagram in **Figure 2** shows the functional elements of the block diagram in more detail. Let's examine the technical aspects of some of them more closely.

**Video input and clipping (A)**

The input impedance is 10 kΩ to 22 kΩ, depending on the fitted resistors. This value provides a good match to the amplifier input, avoids overloading the output of the graphic card, and avoids distortion of the video signals due to excessively low parallel impedance.

The input circuit attenuates the signal by 50% because the serial and parallel resistors have the same value.

Jumpers are fitted at the input. They can be replaced by serial capacitors if clamping is necessary. Clamping is optional because it is not compatible with the video signal, but it may be necessary in some cases.

The gain (k1) is determined by the colour threshold value, which is set to 1210 mV by two 1N4148 diodes connected in series (this approach was chosen because it provides a stable threshold value). This value must correspond to **15% of the nominal signal voltage**.

This is the key to the entire design, and maintaining a threshold level of 15% of the dynamic range of the signal is essential for good results. We can now calculate the gain as follows: 1210 mV across the series-connected diodes = 15% of (350 mV × k1)

This yields a value of 18.49 for k1.

This must be increased to compensate

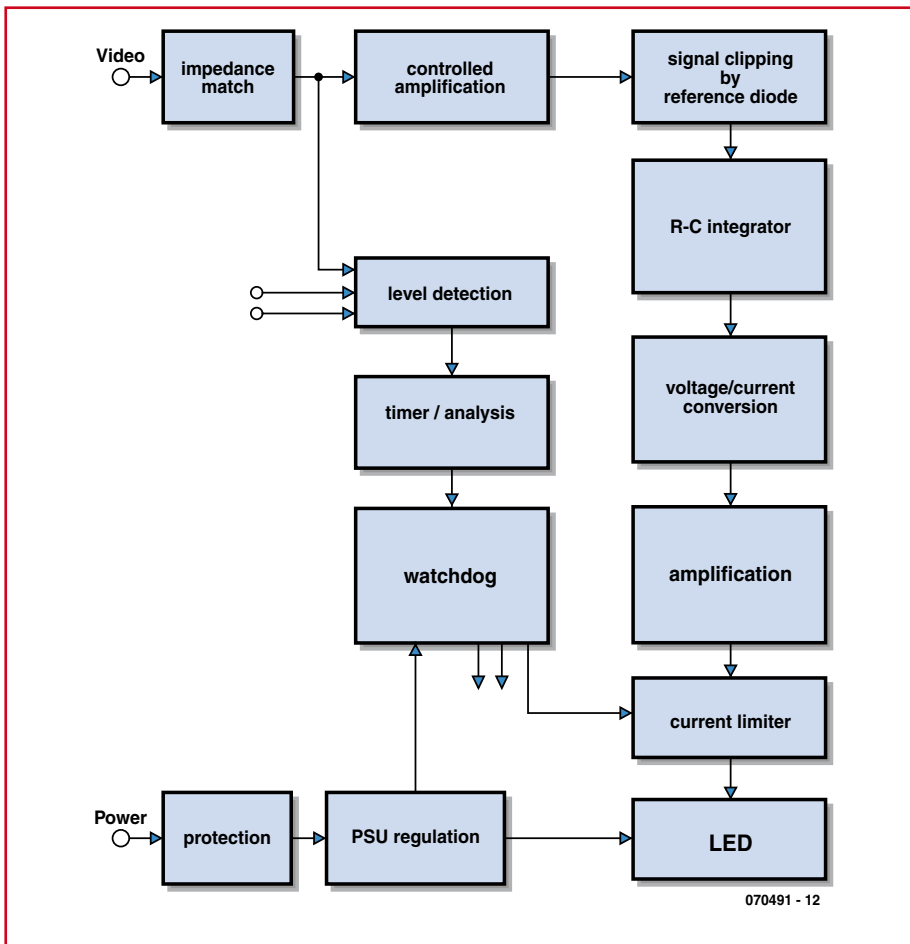


Figure 1. Block diagram of the Surround Light. Although the block diagram of the analogue version of this system looks much more complicated than its digital counterpart, the circuit is a lot smaller than you might expect.

as were present in the image (such as during word processing, working with text windows, or Web browsing), and in such situations mood lighting is anyhow not especially meaningful.

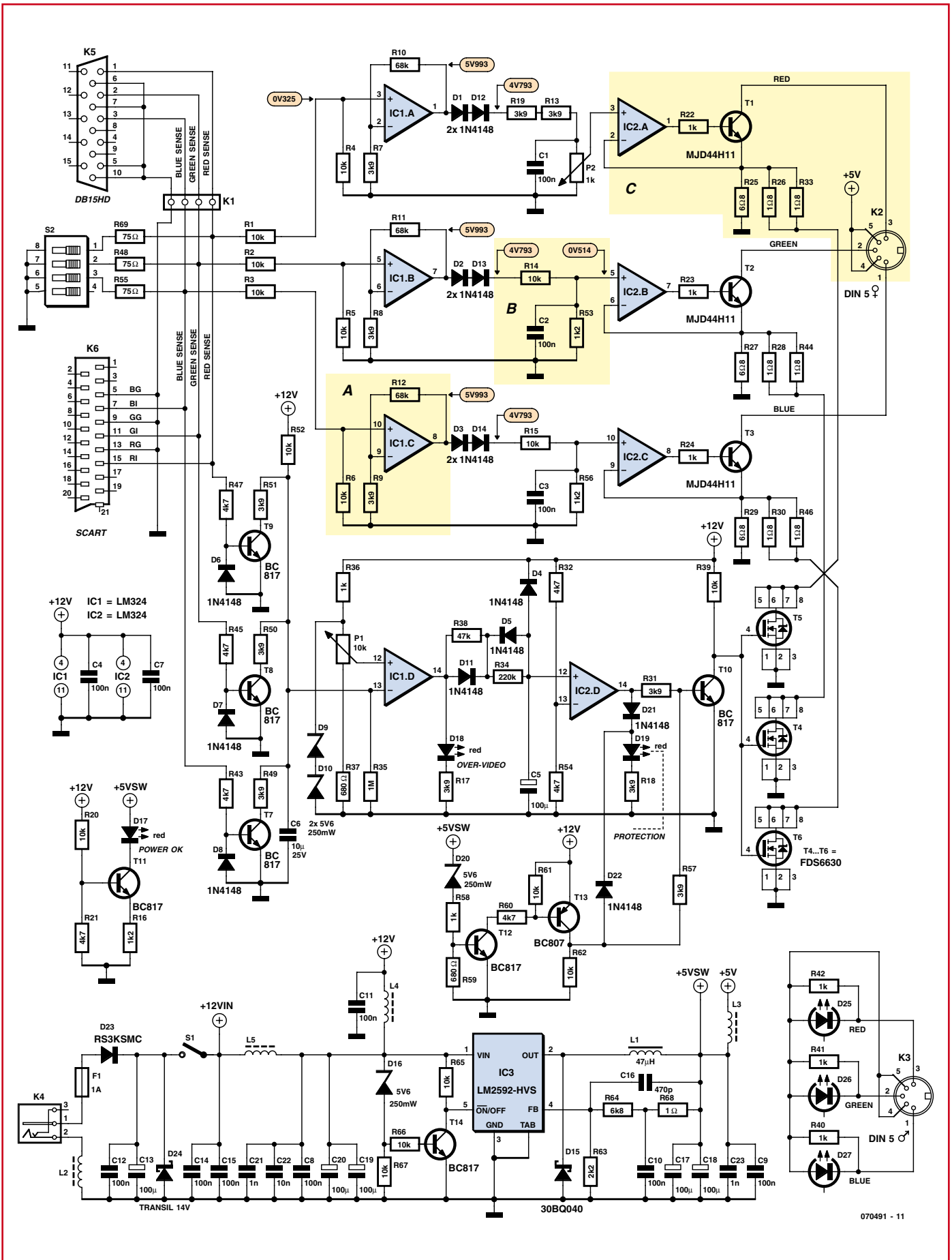
For this reason, the whiteness of the image is measured and after a suitable delay the brightness of the LEDs is reduced by decreasing the drive current supplied by the MOSFET.

Each colour is measured, and if white is detected a timeout is initiated using a capacitor charging circuit and a protection

avoids flickering when changing windows in an office application.

**Block diagram**

The block diagram in **Figure 1** is relatively complex. This arises from the processing of the video signal, which is received in VGA or X-XGA format. The signal first passes through a buffer. It is then amplified using a precisely defined gain. The resulting signal is clipped in a block that uses a diode. After this, the signal is fed to a resis-



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Figure 2. Schematic diagram of the Surround Light. You can easily see the various functions of the block diagram here.

**Table 1. Power dissipation of the driver transistors at various LED voltages.**

	Minimum		Average		Maximum	
	LED voltage	Power	LED voltage	Power	LED voltage	Power
Red LED	2.31 V	1.254 W	2.95 V	870 mW	3.51 V	534 mW
Green LED	2.79 V	966 mW	3.42 V	588 mW	4.23 V	102 mW
Blue LED	2.79 V	966 mW	3.42 V	588 mW	4.23 V	102 mW

for the loss over the diodes that provide the threshold value.

The SENSE lines are connected to the watchdog circuit, which monitors the average input voltage to see whether it rises above 600 mV. If it exceeds this value too long, the LEDs are placed in the protected mode.

**Signal integration and converter adjustment (B)**

The signal must be integrated before it is fed to the input of the voltage-to-current converter. The integration time constant is matched to the timing of the line pulses. The raster line pulses cause relatively weak modulation of the current, which is nevertheless sufficient to reduce the average power dissipation of the LEDs. (The LEDs used here are not suitable for pulse-mode operation.)

The time required to charge to 2/3 of the maximum level is 650 μs with component values of 10 kΩ and 100 nF, which is sufficient to eliminate the line sync pulses from the VGA signal.

The corresponding discharge time is 100 μs due to the presence of R53 in the voltage divider formed by R14 and R53. This value produces only a small delay in determining the colour (due to the total capacitance of the measuring chain), so the system has a sufficiently short response time.

**Drive circuits for the LUXEON K2 LEDs (C)**

As already mentioned, the LEDs are operated under current control. The LEDs are powered from the 5-V sup-

ply voltage with an average current of less than 700 mA (or 2.1 A peak if you ignore the breaks during the video signal flyback intervals).

The individual LEDs are driven by emitter followers (T1–T3) that form current sources in combination with the opamps in IC2.

The value of resistor R22 is small enough to supply sufficient current to T1 and large enough to limit the current from the opamp if no load (LED) is connected. The voltage rises to the maximum value when the output of the amplifier is open-circuited.

The LED current is sensed by resistors R25, R26 and R33 in the emitter circuit of the transistor, which also conduct the base current. The sensed value is  $i_{LED} = i_C + i_B$ , so  $i_B$  must be kept as small as possible to avoid adversely affecting current sensing: ( $i_{Bmax} = i_{Cmax} \div i_{min}$ ) = 700 ÷ 60 = 11 mA max, or 1.57%).

The transistor type used here is designed for operation with a small  $V_{CE}$ , so it does not lose much of the 5 V even when in saturation. This ensures that there is sufficient voltage available for the LED.

The design value of the sense voltage is around 500 mV at the rated current, which yields a power dissipation of 350 mW in the resistors. A larger resistance would yield somewhat better accuracy, but it would also increase the power dissipation.

The transistors are thermally coupled to a copper plane on the PCB with an area of approximately 7 cm<sup>2</sup> to improve cooling.

The nominal dissipation depends on two parameters: the actual current through the LED and the voltage across the LED.

With regard to thermal dissipation at 25 °C, the manufacturer’s data sheet indicates that the power is approximately 500 mW per transistor at maximum brightness (with an average voltage of 3.75 V at 650 mA). The thermal coefficient of the transistor is 6.25 K/W, which would yield a temperature rise of 3.5 °C with an ideal heat sink.

The thermal resistance from the PCB to the air is not known, so the maximum temperature rise is not known precisely. An estimate based on the copper area on the PCB and the total volume of copper yields a value of 45 °C/W, which yields a maximum temperature rise of 24.5 °C (plus 3.5 °C due to the thermal resistance of the package), or  $\Theta_{amb} + 24.5$  °C.

Transistor derating and possible effects from the power dissipation of adjacent devices have been ignored here.

**Power dissipation**

Each transistor dissipates a power  $P$  proportional to the current level:

$$P = (5\text{ V} - V_{LED} - V_{SEN}) \times i$$

The power dissipation of the driver transistors at various LED voltages is shown in **Table 1** for a LED current of 600 mA, a supply voltage of exactly 5 V, and  $V_{SEN} = 500$  mV.

**Protection circuit**

The circuit is protected against stationary images on the monitor. There is not much point in mood lighting for office applications, so the current is reduced in such situations to minimise power dissipation and increase the useful life of the LEDs.

The protection circuit is triggered when a very bright image is present for longer than a defined time. When this occurs, the current through the

LED specifications					
	LUXEON K2				
Basic colour	Royal Blue	Green	Red	Blue	Red-Orange
Max. continuous current [mA]	1 500	1 500	700	1 500	700
Continuous voltage [V]	3.85	3.85	3.4	3.85	3.4
Effective continuous voltage [V]	3.2 V @350 mA	3.2 V @310 mA	2.56 V @230 mA	3.5 V @280 mA	2.7 V @190 mA
Wavelength [nm]	455	530	630	470	617
Luminous flux [lumen]	250 mW/rad.	130	75	46	100
Total included angle [°]	160	140	140	140	140

With the LUXEON configuration, Red-Orange is preferable to Red and Blue is preferable to Royal Blue.

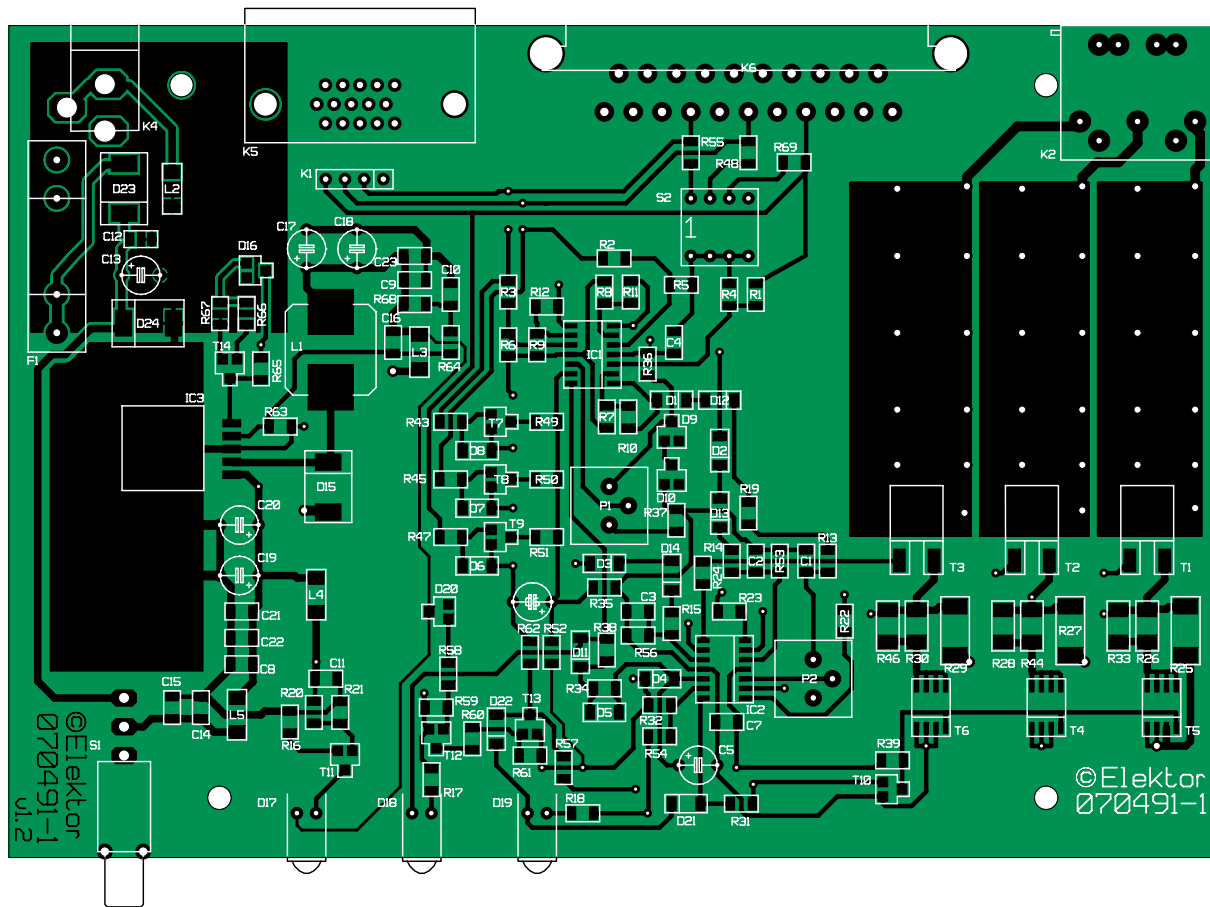


Figure 3. The component layout of the main circuit board...

LEDs is reduced by a factor of 10 and the power dissipation remains below 1 W (with a 5-V supply voltage).

### Detection

The image is considered to be very bright if all three colours have high

levels at the same time. A circuit with three transistors measures these high levels approximately, since the detec-

## COMPONENTS LIST

### Resistors

R1-R6, R14, R15, R20, R39, R52, R61, R62, R65, R66, R67 = 10k $\Omega$  (SMD 1206)  
 R7, R8, R9, R13, R17, R18, R19, R31, R49, R50, R51, R57 = 3k $\Omega$ 9 (SMD 1206)  
 R10, R11, R12 = 68k $\Omega$  (SMD 1206)  
 R16, R53, R56 = 1k $\Omega$  (SMD 1206)  
 R21, R32, R43, R45, R47, R54, R60 = 4k $\Omega$ 7 (SMD 1206)  
 R22, R23, R24, R36, R40, R41, R42, R58 = 1k $\Omega$  (SMD 1206)  
 R25, R27, R29 = 6 $\Omega$ 8 (SMD 2512)  
 R26, R28, R30, R33, R44, R46 = 1 $\Omega$ 8 (0207)  
 R34 = 220k $\Omega$  (SMD 1206)  
 R35 = 1M $\Omega$  (SMD 1206)  
 R37, R59 = 680 $\Omega$  (SMD 1206)  
 R38 = 47k $\Omega$  (SMD 1206)  
 R63 = 2k $\Omega$ 2 (SMD 1206)  
 R64 = 6k $\Omega$ 8 (SMD 1206)  
 R68 = 1 $\Omega$  (SMD 1206)  
 R48, R55, R69 = 75 $\Omega$  (SMD 1206)  
 P1 = 10k $\Omega$   
 P2 = 1k $\Omega$

### Capacitors

C1-C4, C7-C12, C14, C15 = 100nF (SMD 1206)  
 C22 = 10nF (SMD 1206)  
 C21, C23 = 1nF (SMD 1206)  
 C16 = 470pF (SMD 1206)  
 C5, C13, C17-C20 = 100 $\mu$ F 25V  
 C6 = 10 $\mu$ F 25 V

### Inductors

L1 = 47 $\mu$ H (W $\ddot{u}$ rth 12x12)  
 L2-L5 = choke, 91  $\Omega$  @ 100 MHz (SMD 1808)

### Semiconductors

D1-D8, D11-D14, D21, D22 = LL4148 (SMD SOD-80)  
 D9, D10, D16, D20 = BZX84C5V6 (SMD SOT-23)  
 D17, D18, D19 = LED, 3mm, red  
 D23 = RS3K (SMD SMC)  
 D15, D24 = 30BQ040 (SMD SMC)  
 T1, T2, T3 = MJD44H11 (SMD DPAK-N)  
 T4, T5, T6 = FDS6630 (SMD SO-8)  
 T7-T12, T14 = BC817 SMD SOT-23)  
 T13 = BC807 (SMD SOT-23)

IC1, IC2 = LM324 (SMD SO14)

IC3 = LM2592 (SMD SOT-263)

D25 = Luxeon LED, red (LXK2-PD12-R00)

D26 = Luxeon LED, green (LXK2-PM14-U00)

D27 = Luxeon LED, blue (LXK2-PB14-N00)

### Miscellaneous

S1 = single-pole on/off switch (Farnell # 9575502)

S2 = 4-way DIP switch

K1 = 4-way SIL pinheader

K2, K3 = 5-way DIN socket

K4 = DC supply socket, PCB mount

K5 = VGA socket, PCB mount

K6 = SCART socket, PCB mount

F1 = fuse, 1A slow, with PCB mount holder

Enclosure, e.g. Vero # 16-3638089

PCBs # **070491-1** and **070491-2**, see Elektor Shop section or [www.elektor.com](http://www.elektor.com)

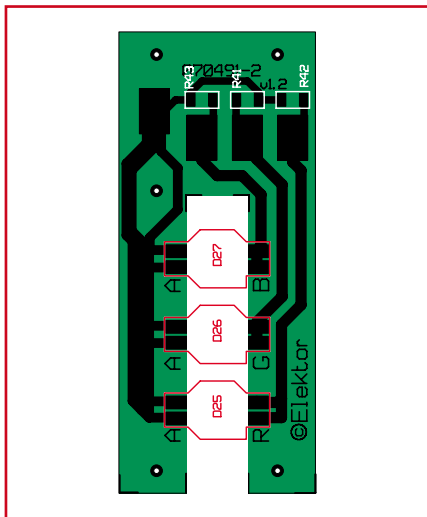


Figure 4. ...and the LED circuit board.

tion circuit is not thermally stabilised in order to keep the circuit simple. A digital signal indicates whether a bright image has been detected. A diode connected across the base-emitter junction of each detection transistor protects the transistor if there are problems with the video signal (such as a negative signal level due to poor clamping).

**Timeout delay**

The timeout delay is implemented very simply using an RC network with a binary comparator. The threshold level of

the delay circuit can be adjusted using trimpot RV1, but the actual time delay is not adjustable. The switch-on delay is much shorter than the switch-off delay. In other words, if moving imagery appears on the screen again, the LEDs will start operating again relatively quickly. This rapid return to normal operation is only necessary to prevent flickering when switching between windows on the PC. Diode D4 prevents C5 from discharging via IC2d if the IC is not powered, in order to avoid damage to the IC.

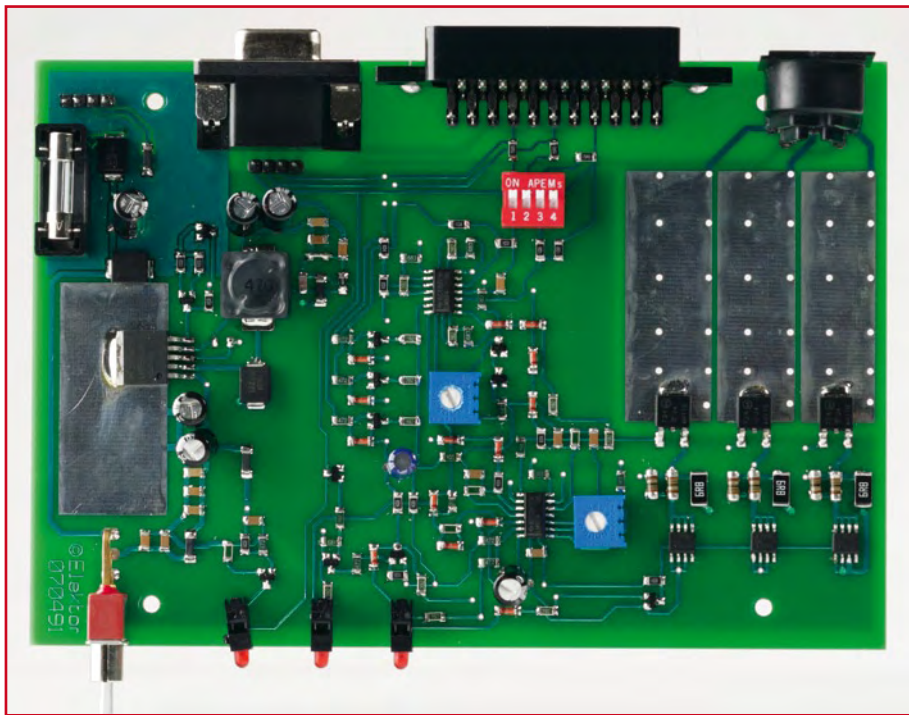
**Current limiting**

The current flowing through the LEDs is limited by modifying the operation of the drive circuits. During normal operation the current limiter is not active, and it holds the MOSFETs in the fully conducting state with low source-drain resistance ( $R_{DS(ON)}$ ). This increases the current level due to the relatively low resistances connected in parallel across the current-sense resistors. When current limit protection is activated, the MOSFETs are switched off and the full LED current flows through a larger resistance (R29), so the nominal voltage across the sense resistor is obtained at a lower current level. When current limiting is active, the current level is set by R29 alone, while in normal operation it is set by R29 and the parallel combination of R30 and R46 via the MOSFET (to use a simpli-

fied analysis). If desired, the two parallel resistors can be replaced by a single resistor rated at  $0.82 \Omega / 1 \text{ W}$ . For the sake of convenience, the author used two  $1.8\text{-}\Omega$  resistors in parallel to obtain an equivalent resistance of  $0.9 \Omega$ , but a single resistor rated at  $0.82 \Omega / 1 \text{ W}$  would work just as well. The current is 600 mA at 500 mV, which is not especially worrisome. A Tyco RL733A R82 would be perfect for this application.

**Supply voltage protection**

If the supply voltage for the LEDs rises too high, protection is triggered by a circuit that detects an overvoltage condition on the 5-V supply line. This would cause excessive dissipation in the supply circuitry, which is not good for the circuit. The temperature must also be kept below  $60 \text{ }^\circ\text{C}$  everywhere in the circuit to avoid the risk of burns. The detection threshold voltage is  $V_{Dz20} + 1.2 \text{ V} = 6.8 \text{ V}$ . The supply voltage protection circuit (built around T12 and T13) generates a signal that causes the MOSFETs to be switched off using the same arrangement as for current limiting with a stationary image. Resistors R58 and R58 provide a path for the leakage current of the Zener diode next to the voltage sense transistor.



Our first prototype. All connections are at the rear.

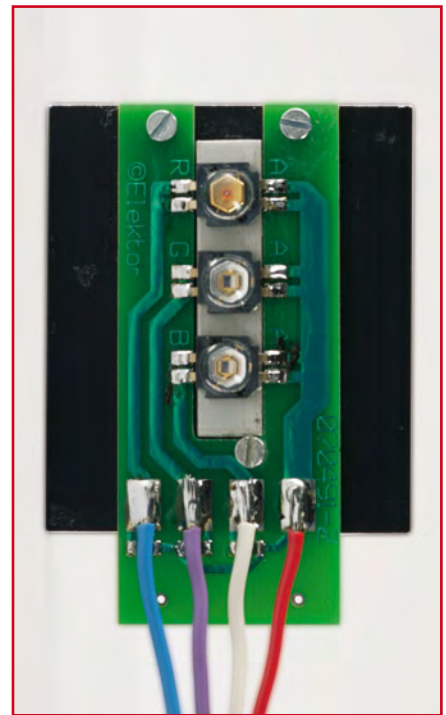


Photo of the printed circuit board with three LEDs. This requires a bit of mechanical assembly skill.

## Supply voltages

The circuit has three types of on-board supply voltages, all derived from the main supply voltage obtained via power connector K4:

- Stabilised reference voltages
- A filtered supply voltage for the opamps
- A high-power supply voltage for the LEDs

The stabilised voltages are generated locally using Zener diodes. Most of them are reference voltages for the comparators. The main +12 V supply voltage comes from an AC mains adapter, or it can be taken directly from the PC. This voltage is stabilised externally, and the circuit includes a fuse (FU3) and a diode (D23) for reverse-polarity protection.

The LEDs are powered from a much lower voltage in order to minimise the power dissipation in the control transistors, which operate in their linear region in this design. A switch-mode regulator is used to provide this voltage in the circuit described here, and it generates an accurately stabilised voltage from the +12-V supply voltage. This reduces the amount of current that has to be transported by the supply cable and makes it easier to handle. If the circuit is built into the PC, a convenient alternative is to use the 5-V supply voltage from the PC power supply.

The switch-mode regulator is built around a National Semiconductor LM2592 using a standard design. According to the manufacturer's data, the efficiency is nearly 80%.

A standby mode is implemented by monitoring the voltage on T14 and D26. The regulator shuts down if the voltage on the +12 V line is less than 6 V. The 5-V supply voltage is thus not present if the 12-V supply voltage is absent or is too low to ensure correct operation.

## Indicator LEDs

The circuit has three indicator LEDs:

- The 'Power OK' LED (D17) indicates that both supply voltages (12 V and 5 V) are present.
- The 'Over-Video' LED (D18) indicates that the video level is too high and the timeout has been actuated.
- The 'Protection' LED (D19) indicates that current limiting is in effect. It is lit when the MOSFETs are conducting. There are two possible causes for this: either temporary protection due to an excessive bright image or a power supply problem.

## Use of the LUXEON K2 LED

The principal model employs a system with three discrete LEDs type LUXEON K2 Power.

The mounting of the LEDs on aluminium pads is identical to the previous model because the metal part on the board has been designed for compatibility with both systems.

Only the LED current is changed to fall within a range of 300 to 700 mA (per LED), with the Philips LUXEON chip capable of carrying this current and outputting very bright light at no less than 3 x 75 lumens.

Chromatic rebalancing may be viable by trial and error. The initial values are those resulting from tests with the triple LED (PROLIGHT).

### Characteristics of PROLIGHT power LEDs

Total included angle:	140°		
Power:	red = 2.2 V	blue = 3.55 V	green = 3.55 V
Current :	350 mA max. for each colour		
Wavelength:	red = 625 nm	green = 530 nm	blue = 470 nm
Luminosity:	red = 30 lumen	green = 30 lumen	blue = 10 lumen

## Mechanical assembly

After all this discussion of theory, it's time to turn our attention to something more interesting.

We designed two PCBs for this project: the main circuit board (**Figure 3**) and the LED circuit board (**Figure 4**). The figures show only the component layouts; the copper track layouts can be downloaded from the Elektor website. You can also order the two PCBs from the Elektor Shop (order numbers **070491-1** and **070491-2**).

Start by assembling the main circuit board. Solder the components in the following order: resistors, inductors, capacitors, diodes, transistors, ICs, and finally the MOSFETs.

Using a multimeter, check to ensure that the supply voltage lines are not shorted anywhere, and check for continuity between the supply sources and the positive supply voltage pins of IC1 and IC2.

After fitting all the components, check everything again for short circuits and incorrect or incorrectly fitted components. Ensure that the MOSFETs make good thermal contact with the associated copper surfaces. This also applies to the LM2592.

Now it's time to assemble the LED board as shown in the photo in **Figure 5**. To provide proper cooling of the LEDs, the LED board is secured to a heat sink using a DIY clamp fixture.

- Cut a piece of aluminium with the same thickness as the PCB (1.2 mm) to dimensions of 20 x 7 mm such that it fits in the slot in the LED circuit board (see photo).
- Prepare the heat sink by drilling and

tapping holes for securing the LED circuit board with the aluminium strip in between.

- Pre-assemble the board without applying any pressure to the heatsink surfaces of the LEDs and solder the LEDs to their solder pads.

- Loosely fit the assembly to the heat sink using screws of the right size. You can optionally place mica insulators under the LEDs. The mating surfaces of the components and the heat sink can be coated with thermal paste (this is recommended) to improve the thermal contact. Apply only a thin coating, as otherwise it will be ineffective.

After the LEDs with their mica insulators are properly fitted, carefully tighten the screws until they are moderately tight (to avoid damaging the LEDs). Take care to avoid applying any force to the LEDs during this operation. Also be careful with the diffuser lenses, which are very fragile.

– Solder four wires (three for the colours and one for +5 V) to the four solder pads, and then solder the other ends to a DIN 5 plug according to the schematic diagram shown in **Figure 2**.

## Set-up and adjustment

- Fit the Surround Light board in an open plastic box to avoid electrical contact between the circuit board and any conductive surfaces.
- Set trimpots RV1 and RV2 to their midrange points.
- Connect the LED board via the connector.
- Place the LED board behind the PC monitor.



- Switch on the Surround Light supply voltage.
- Connect a cable from the monitor (VGA) to the Surround Light. You will need a VGA splitter for connection to the PC. Now you have to adjust trimpots RV1 and RV2.
- Configure the PC to display a bright white image on the screen, measure the currents through the sense resistors (maximum 700 mA), and ensure that the protection circuit is not activated (12 V on pin 14 of IC1 – if necessary, turn RV1 back until protection is

no longer active).

- Again display a white image on the monitor (a picture or Word document) to adjust the protection circuit for office applications.
- Using a hair dryer, heat the Surround Light circuit board to around 35–40 °C and turn RV1 while measuring the voltage on pin 13 of IC1.
- Adjust until you reach the switching point of the comparator (from 0 V to 12 V, or until the 'Protection' LED lights up). Verify that the comparator output switches when the screen display

changes from a picture to the window of a word-processing program. Now you're all set to go. We wish you many pleasant hours with the Surround Light in your free time (or at work!).

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## Web Links

### LM2592 data sheet:

<http://cache.national.com/ds/LM/LM2592HV.pdf>

# The digital approach TV Surround Light

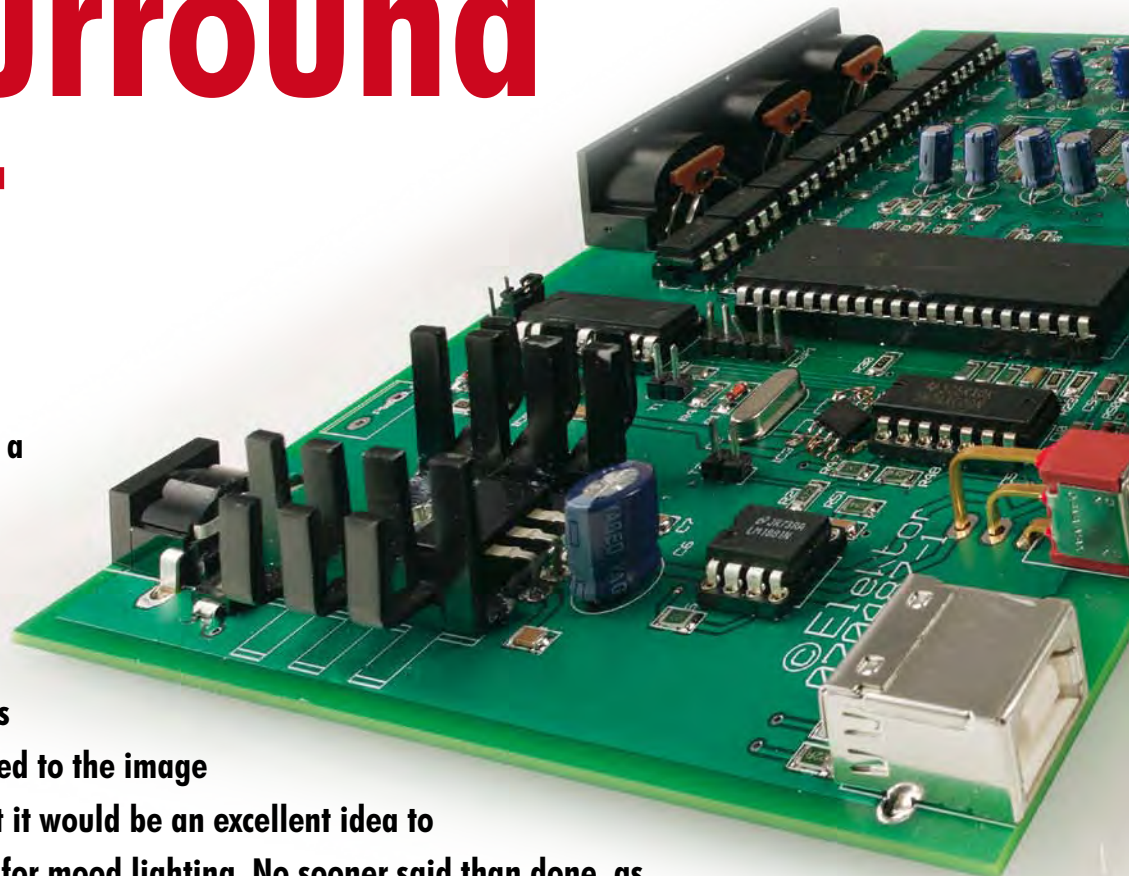
Steffen Schütte

**A while ago the author saw a demonstration of a Philips television system equipped with the Ambilight system. This lights up the background with colours that are dynamically matched to the image content. The author thought it would be an excellent idea to create a similar DIY system for mood lighting. No sooner said than done, as can be seen from the TV Light project described here – a system that is very similar to the now legendary Ambilight system.**

Before starting on this project, the author ploughed through a whole stack of specifications for different video signals. It shouldn't be all that difficult, he

thought – after all, there are only a few types of connections: the well-known Cinch (RCA) sockets and the SCART connector. All you have to do is to find

out which type of signal is being used in order to decide how to design a circuit for TV background lighting as quickly, simply and inexpensively as



possible.

He gradually realised that the SCART standard is only a point of reference for all sorts of signals that are necessary for connecting various kinds of video equipment to a television set. To avoid any misunderstanding, note that the circuit described here can only be used with equipment that supplies RGB signals, in combination with a fully wired SCART cable.

Due to the complexity of the composite video signal, it is not possible to use a direct connection to the yellow Cinch socket that provides this signal, which is also present on pin 19 of the SCART connector. For someone in the author's situation (i.e. not an expert in the complicated theory of signal processing), working with RGB signals is a lot easier – and it makes explaining the ins and outs of the circuit easier. See reference [1] for a summary description of video standards.

### First considerations

Before delving in to the details of the design, we need to consider what types of LEDs to use for this project.

A bit of searching on the Internet turns up two usable types of LEDs:

1. SuperFlux LEDs [2] at approximately 70 p (euro 1.20) each;
2. LED arrays (light bars with nine SMD LEDs) at around £ 15 (euro 24) per bar.

The SuperFlux LEDs have a luminous intensity of 10,000 mcd and thus produce sufficient light (a maximum of six per section is needed), but they have the disadvantage that the colour mixing is not homogeneous.

A bit of browsing on the Internet to find a solution to this problem yielded a few tips and tricks, such as using baking paper and hot-melt glue, but they reduce the brightness too much. The LED light bars with SMD LEDs provide a better approach, but they are more expensive. They operate from a 12-V supply voltage (with a common anode) and provide a fully homogeneous colour palette, and they produce even more light than the SuperFlux LEDs.

### Block diagram

The block diagram in **Figure 1** shows that the circuit uses four input signals taken from the SCART connector of a DVD player or the VGA connector of a graphics card in a PC. These four signals – red (R), green (G), blue (B), and composite video (C) – are fed to the circuit via two connectors. All of the signals received via these two connectors are processed the same way.

The first three signals contain the colour information for each scan line, while the fourth signal (C) is only used for horizontal and vertical synchronisation. This means we can use an IC that is very often used for this purpose: the LM1881 [3].

As the three colour signals are analogue signals, we have to start by converting them to the digital domain. This requires a set of A/D converters, and here we used the Analog Devices type ADC1175 [4]. This IC is designed specifically for digitising video signals

to drive the nine LED sections of the system, consisting of one section for each colour (R, G and B) for each of the three parts of the image. That's all there is to be said about the block diagram, so it's time to turn our attention to the next topic: the detailed design.

### Schematic diagram

The schematic diagram in **Figure 2** is actually just a more detailed version of the block diagram in Figure 1. If you glance at the author's first prototype shown in the **photo**, you can recognise the main features of the block diagram in Figure 1. From left to right and top to bottom, you can see the three analogue to digital conversion modules using the ADC1175 (IC7–IC9). This A/D converter operates at 20 MHz and has a resolution of 8 bits.

After building the initial prototype using several circuit boards interconnected by a rat's nest of cables, we could

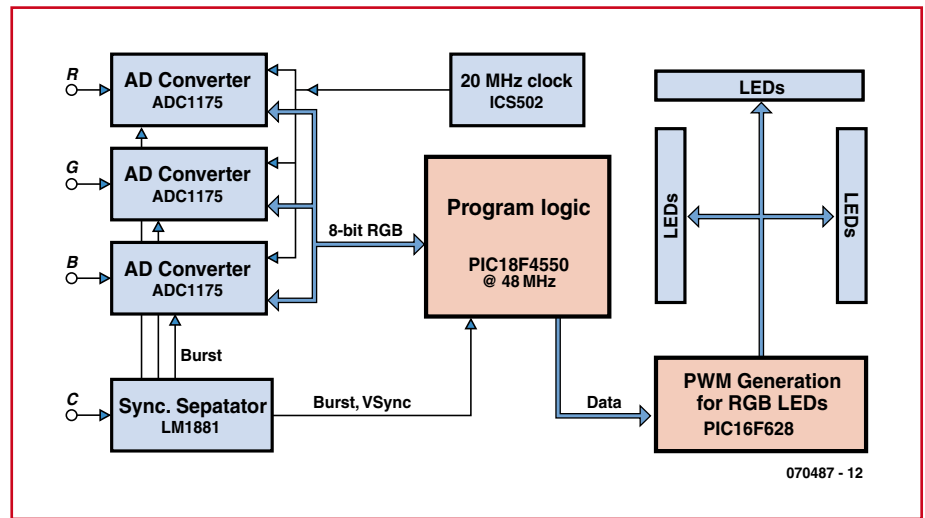


Figure 1. Block diagram of the TV Light. The digital approach to this ambient lighting system boasts two microcontrollers.

and can operate at clock rates up to 20 MHz. As the duration of a television scan line is 56 µs, this would in theory make a resolution of more than 1000 pixels per line possible (or more precisely, 1120 pixels).

A Microchip PIC18F4550 microcontroller clocked by the sync signal from the LM1881 processes the digital data and uses integration to compute the average values of the colours in the left, upper, and right parts of the image on the screen. These values are passed directly to a second microcontroller, in this case a Microchip PIC16F628, which in turn generates the PWM signals used

test the circuit to determine whether it worked the way the author intended. When everything proved to work properly, we designed a 'clean' circuit board layout that held most of the circuitry. The A/D converters were placed on three separate modules, which were connected to the PIC18F4550 by lengths of 10-way flat cable.

To make the final version of the circuit more suitable for DIY construction, we put everything on a single printed circuit board for the Elektor version to eliminate the need for complicated interconnections. The input signals are received via a SCART connector (K2)

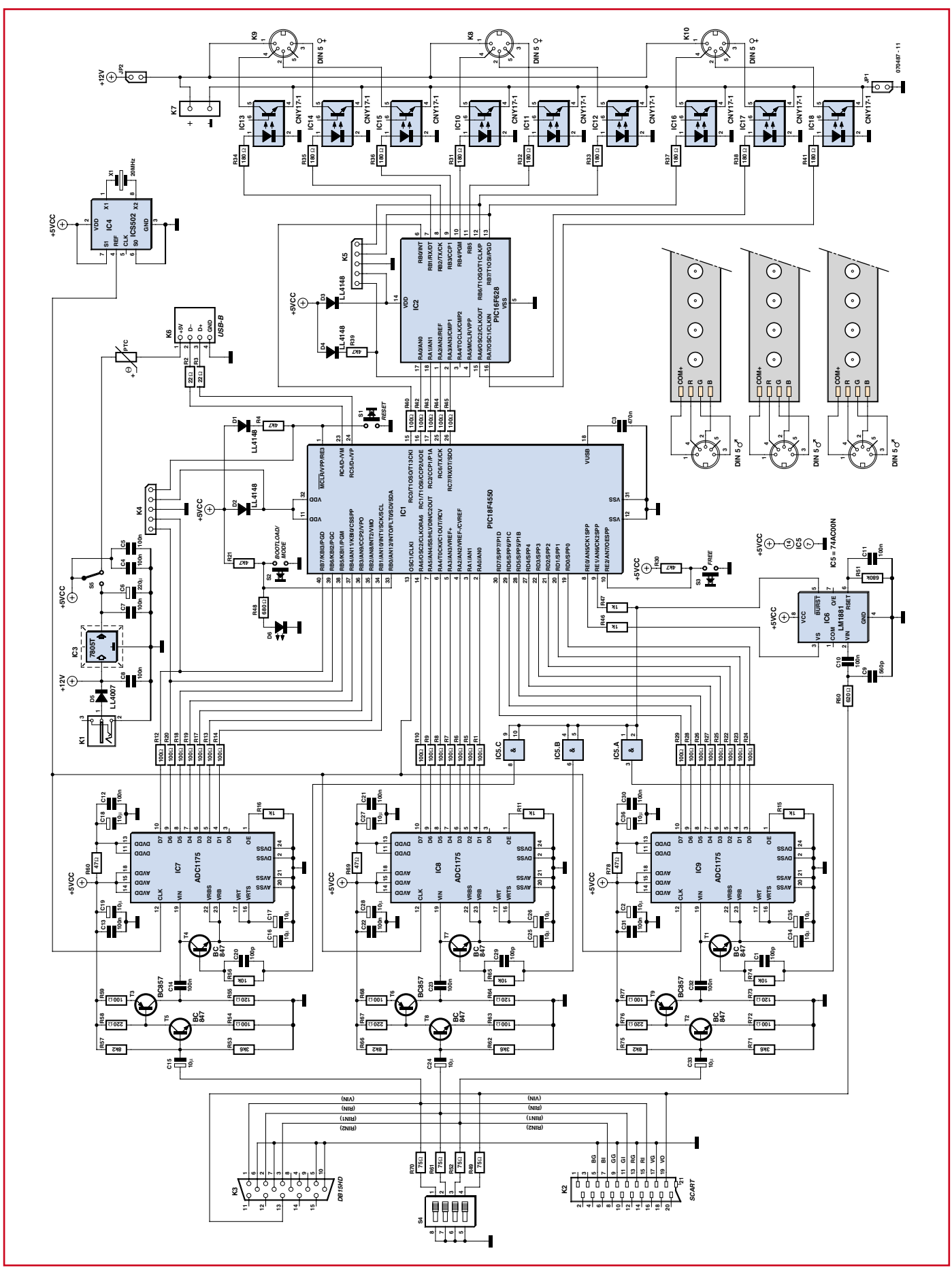


Figure 2. Schematic diagram of the TV Light. You can easily see the various functions of the block diagram here.

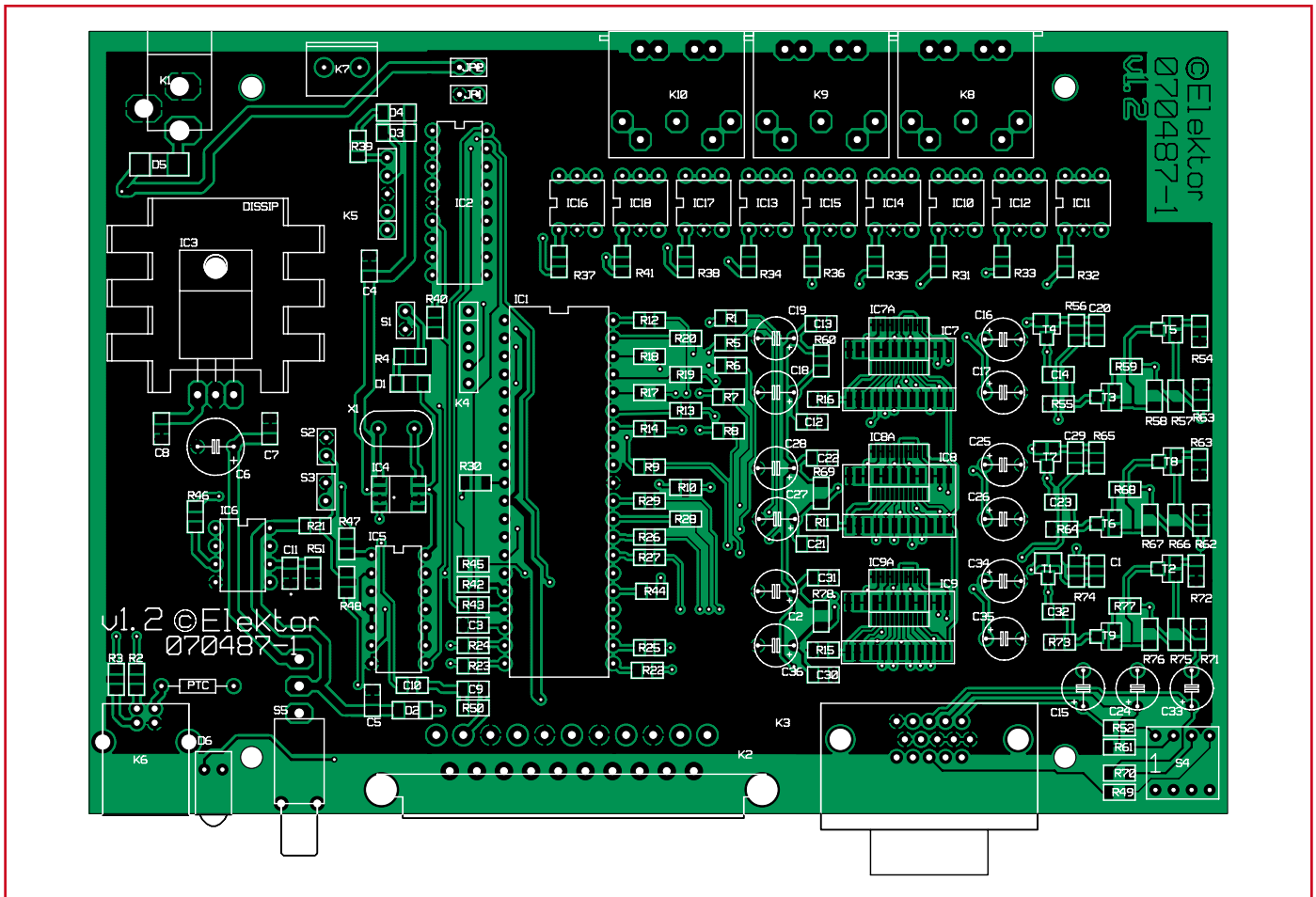


Figure 3. PCB layout for the TV Light circuit (reduced scale). Note that two positions are provided for components IC7 to IC9.

or VGA connector (K3). Now let's work through the schematic diagram from left to right and top to bottom. The system clock is provided by IC4, a type ICS502 [5]. This IC con-

tains a PLL circuit that oscillates at 20 MHz thanks to crystal X1. The 'inter-PIC' traffic is handled by five signal lines comprising a clock line and a line for each of the four data bits. There are

also 18 clock signals for the nine LEDs. The final clock pulse is held at a high level for a slightly longer interval to ensure proper synchronisation. The LM1881 (IC6) does exactly what

## COMPONENTS LIST

### Resistors

R1, R5-R20, R22-R29, R40, R42-R47, R54, R59, R63, R68, R72, R77 = 100Ω  
 R2, R3 = 22Ω  
 R4, R21, R30, R39, = 4kΩ  
 R31-R38, R41 = 180Ω  
 R48 = 680Ω  
 R49, R52, R61, R70 = 75Ω  
 R50 = 620Ω  
 R51 = 680kΩ  
 R53, R62, R71 = 3kΩ  
 R55, R64, R73 = 120Ω  
 R56, R65, R74 = 10kΩ  
 R57, R66, R75 = 8kΩ  
 R58, R67, R76 = 220Ω  
 R60, R69, R78 = 47Ω

### Capacitors

C3 = 470nF  
 C4, C5, C7, C8, C10-C14, C21, C22, C23, C30, C31, C32 = 100nF

C9 = 560pF  
 C1, C20, C29 = 100pF  
 C2, C15-C19, C24-C28, C33-C36 = 10μF  
 25V  
 C6 = 220μF 25V

### Semiconductors

D1-D4 = LL4148  
 D5 = LL4007 (SOD-106)  
 D6 = LED, 5mm, red  
 T3, T6, T9 = BC857  
 T1, T2, T4, T5, T7, T8 = BC847  
 IC1 = PIC18F4550-1P, programmed, Elektor Shop # **070487-41**  
 IC2 = PIC16F628-20I/P, programmed, Elektor Shop # **070487-42**  
 IC3 = ICS502 (SO8)  
 IC4 = 7805  
 IC5 = 74AC00N (DIP14)  
 IC6 = LM1881 (DIP8)  
 IC7, IC8, IC9 = ADC1175  
 IC10-IC18 = CNY17-1  
 X1 = 20 MHz

### Miscellaneous

S1, S2, S3 = 2-way SIL pinheader (pushbutton)  
 S4 = 4-way DIP switch  
 S5 = single-pole on/off switch (Farnell # 9575502)  
 K1 = DC supply socket, PCB mount  
 K2 = SCART socket  
 K3 = VGA socket  
 JP1, JP2 = 2-way SIL pinheader with jumper  
 K4, K5 = 5-way SIL pinheader  
 K6 = USB-B socket  
 K7 = connector (optional)  
 K8, K9, K10 = 5-way DIN socket  
 PTC = Current protection (PTC660 or wire link)  
 Enclosure, e.g. Vero # 16-3638089  
 PCB # 070487-1, see Elektor Shop section or [www.elektor.com](http://www.elektor.com)  
 Project software; PIC source and hex files in archive # 070487-11.zip, free download from [www.elektor.com](http://www.elektor.com)

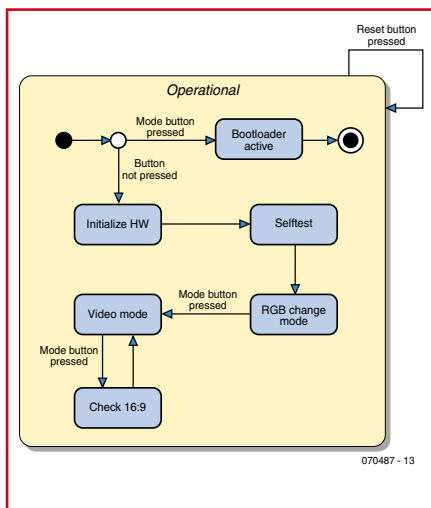


Figure 4. Summary of the functional modes of the TV Light.

it is designed to do: extract the sync signal from the composite video signal. The signal provided by this IC goes straight to the first PIC (IC1), which is the 'brain' of this complex design.

The four-way DIP switch (S4) can be used to connect termination resistors to the signal lines of the input connectors (SCART and VGA). They have the same effect here as in the Surround Light circuit described elsewhere in this issue. When the switches are open, the inputs have a relatively high impedance. When they are closed, the input impedance is 75 Ω.

The supply voltage for the circuit is provided by a 7805T (IC3) using a conventional circuit design that hardly needs any comment. LED D6 on the front side indicates that the supply voltage is present. Switch S5 can be used to select one of two supply voltage sources. This allows the supply voltage to be taken from a USB port if the TV Light is used in combination with a PC. The supply current is drawn via a thermistor that interrupts the supply voltage if the current becomes too large.

The red, green and blue LED light bars are connected to the system via 5-way DIN connectors (K8–K10). This method ensures reliable connections. Optocouplers IC10–IC18 provide galvanic isolation between the circuit and the LED light bars.

## PCB

If you look at the PCB layout in **Figure 3** (designed using Layo 1 PCB), you can see right away that it uses quite a few SMD components. Due to

possible availability problems with the ADC1175, the board is designed to accommodate two different SMD versions: JM and TC. The locations on the PCB for the smaller version (TC) are marked with an 'A'.

As this circuit operates using high-frequency signals, a large ground plane extending over the entire board is provided on the component side. Ground plane areas are also placed beneath the connectors on the other side.

## Assembly

Successful completion of this project requires a certain amount of experience in handling SMD devices. For readers with relatively little experience, we offer a PCB with all of these components pre-assembled (order number **070487-91**), so all you have to do is solder the connectors and operator control components. Preprogrammed PIC microcontrollers are also available from the Elektor Shop (**070487-41** and **-42**).

With the exception of a few ICs and connectors, all of the components are SMD types. It is thus important to always check everything that has to be done at each stage of assembly. Pay particular attention to correct orientation of the SMD ICs, since unsoldering incorrectly fitted IC can cause damage to the tracks on the PCB. Soldering the smaller version of the A/D converter requires special care to avoid producing shorts that will subsequently have to be eliminated.

A pair of pushbutton switches must be connected to the points marked 'S1' and 'S2'. They should be fitted to the rear panel of the enclosure between the 12-V power supply connector (J1) and the DIN connector for the red, green and blue LED light bars. These two buttons, which are labelled 'Reset' (S1) and 'Mode/Bootload' (S2), are used to select the operating mode of the unit. This is described in more detail below under the 'Operating modes' heading.

**Note:** jumpers JP1 and JP2 must be fitted (closed) if the LEDs are powered via supply voltage connector K1.

## Operating modes

The PIC that generates the PWM signals (IC2) can be programmed using an ordinary programmer. The second PIC (the 18F4550) can be programmed using a USB cable, which is very practical if you want to develop your own software for the TV Light. The circuit can

remain switched on during programming, and you can program the PIC using a laptop computer next to the television set. Naturally, a boot loader has to be installed first. This is explained further on in this article.

The first button (S1, Reset) is used to restart the unit, while the second button (S2, Mode/Bootload) is used to select the operating mode after a restart. You can press the second button during a restart to activate the USB boot loader so you can reprogram the TV Light circuit, or press it in normal operating mode to switch between 4:3 and 16:9 image aspect ratios.

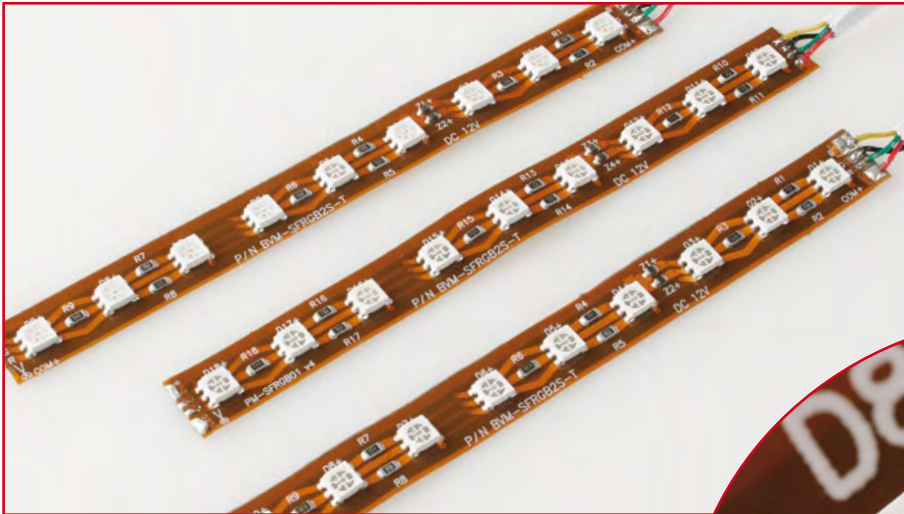
The various operating modes are summarised in **Figure 4** with associated comments.

To enter boot loader mode, hold the Mode button pressed while you switch on power or press the Reset button.

When you have finished programming the TV Light via the USB port, press the Reset button again (this time without pressing the Mode button). In response, the TV Light will initialise various parts of the circuit and then execute a test program that switches all the LEDs on and then switches off the nine outputs in sequence. This gives you an opportunity to check that the LEDs are positioned properly around the television set. This test is also very convenient for initial testing of the circuit after you have assembled the PCB, especially because it does not require any A/D conversion or input signals.

After the first test is completed, the TV Light switches to Light Show mode with RGB colours. In this mode it runs through a rainbow cycle with all nine LED light bars, which is repeated every 45 seconds. This low speed lets you get a good idea of the various colours. To exit this RGB mode, simply press the Mode button briefly. This causes the TV Light to switch immediately to the normal operating mode, in which the input signals are sampled and processed.

With films displayed in wide-screen format (16:9), it is not advisable to analyse the upper 10 percent of the image. To avoid this, simply press the Mode button once again. In response, the program will search for the first non-black line (note that here 'black' is not exactly zero, but instead a very low value from the A/D converter). The first non-black line is the uppermost line that is used for colour analysis (corresponding to the variable start-Line in the code segment detectTop of the source code).



An example of the LED light bars used in this project.

## Development tips and tricks

We are often asked to shed a bit more light on the design and development processes of our authors. Some of the interesting aspects are described here.

### RGB generator (PIC16F628A-I/P)

It is recommended to disable the brown-out reset while you are programming the PIC16F628.

After a bit of experimenting, it proved to be better to take the supply power for the LED light bars from a separate power supply.

It is advisable to use the I/P version of the PIC16F628A in this circuit because the PWM signals generated by a standard 16F628A produce flicker-

ing effects. The author does not know the exact reason for this, but the I/P version is intended for industrial applications and is probably less sensitive to electrical noise – and this circuit generates lots of noise.

### TV Light control logic (PIC18F4550)

Almost all pins of the PIC are used here. As the Microchip loader routine normally uses RB4, the author recompiled the code to use RB0 instead. This means that one of the colours has a resolution of only 7 bits, but this is

not noticeable to the naked eye. If you want to recompile the loader routine, you need the full version of the C18 compiler (or an educational version for a trial period) due to the optimisation performed by the compiler.

The configuration bits [6] are used to program the loader.

We hope you have a lot of fun with your TV Light!

(070487-1)

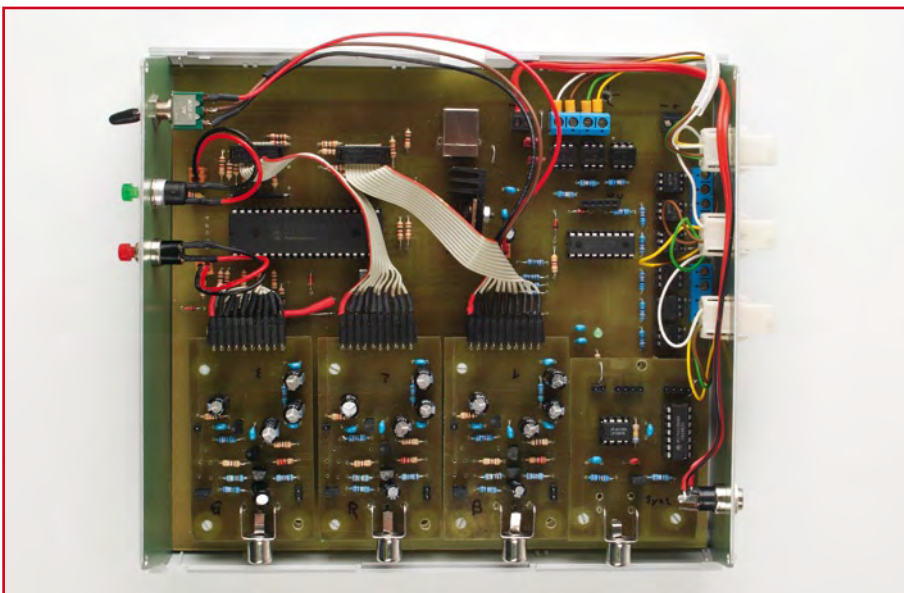
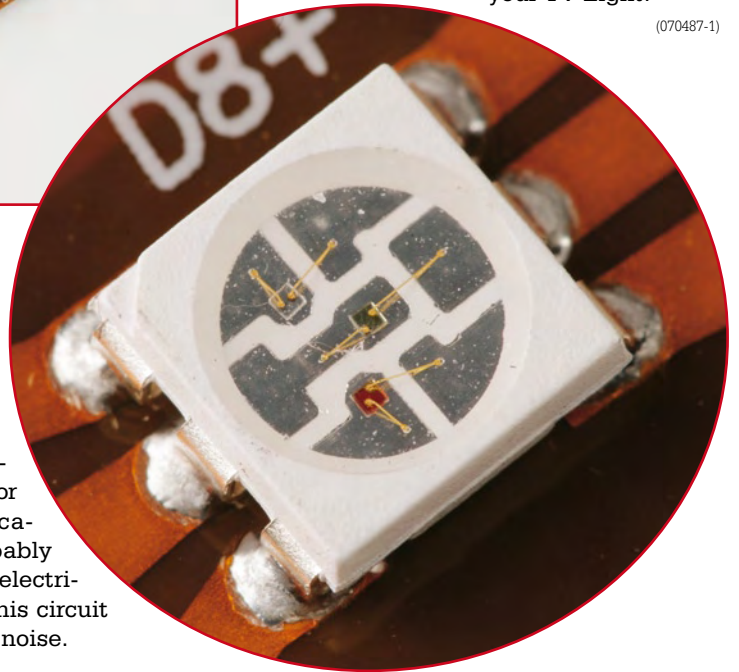


Photo of the author's initial prototype. It is somewhat larger than the final version described in this article.

## Web Links

[1] [www.mediaprofis.net](http://www.mediaprofis.net)

[2] SuperFlux LEDs datasheet:  
[www.lumileds.com/pdfs/DS05.pdf](http://www.lumileds.com/pdfs/DS05.pdf)

[3] LM1881 datasheet:  
<http://cache.national.com/ds/LM/LM1881.pdf>

[4] ADC1175 datasheet:  
<http://cache.national.com/ds/DC/DC1175.pdf>

[5] ICS502 datasheet:  
[www.idt.com/products/getDoc.cfm?docID=16325487](http://www.idt.com/products/getDoc.cfm?docID=16325487)

[6] [www.burger-web.com/Projects/PIC-18F4550USB/en\\_PIC18UsbBoard.htm.en](http://www.burger-web.com/Projects/PIC-18F4550USB/en_PIC18UsbBoard.htm.en)