InSpiral Christmas Tree

With a flexible printed circuit board

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This distinctive variation of a Christmas tree is made from a thin printed circuit board, which is cut in the shape of a spiral. This is then stretched out to create the shape of a Christmas tree.
There are 25 white LEDs on the spiral, which are driven by a pseudo-random number generator.

Christmas trees come in various types and sizes, even electronic ones. Over the course of the years we have published a fair number of electronic variants in Elektor. Somebody in the Elektor Labs recently had the bright idea to design a spiral Christmas tree, made with a thin PCB. The PCB is stretched upwards, creating a shape similar to a Christmas tree. A set of (white) LEDs is mounted on the spiral. The onboard electronics ensures that the LEDs flash in a random pattern. To keep things as simple as possible, we haven't used a microcontroller. Instead, an 'old-fashioned' circuit using digital logic has been applied. This consists of a simple random number generator (built around a 4015 dual 4-bit static shift register and a 4070 quad XOR gate) and a number of FETs for driving the LEDs.

The flasher circuit

The circuit itself is very straightforward: there is a shift register with a feedback loop that produces a random pattern for driving the LEDs, an oscillator that provides the shift register with clock pulses, and a number of drivers, connected to the outputs of the shift register, that drive sets of three series-connected LEDs (**Figure 1**).
In the first prototype we used a random number generator with a 4-bit shift register, of which two outputs were fed back via an XOR gate. That resulted in a sequence of 15 different output combinations (0000 is not permitted, since it would always remain in this state). However, the result wasn't very satisfactory. Since there was a second shift register

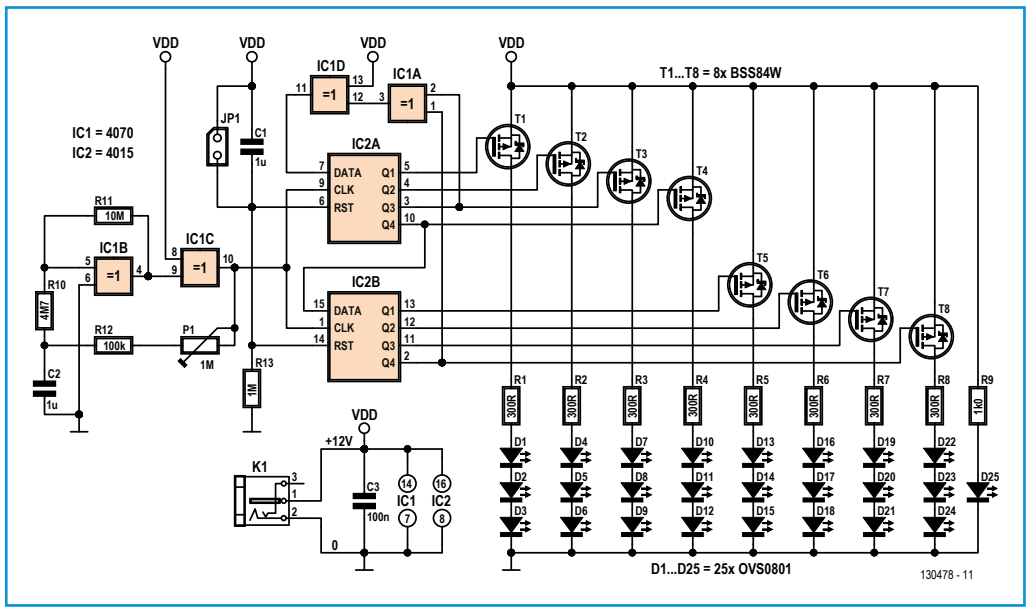


Figure 1.
The flashing lights on this Christmas tree are controlled by a pseudo-random number generator, which drives 8 sets of LEDs.

available in the 4015 anyway, we connected this in series with the first to create a better random sequence (IC2A and IC2B). As a bonus, there were now eight outputs available for driving the LEDs. After trying out many feedback combinations, we finally decided to feed back Q3 of IC2A and Q4 of IC2B.

Since the outputs of the 4015 can only provide several milliamps from its outputs, we've added a set of drivers (T1 to T8) for driving the LEDs. We selected some small BSS84W P-channel MOSFETs, which are available in a very small SOT323 package. Each MOSFET drives a set of three LEDs, connected in series, with a series-connected 300 Ω resistor limiting the current through the LEDs. There are therefore a total of 24 LEDs that are switched on and off, with three of them always lighting up at the same time. These have been spread out along the spiral in such a way that it's hardly noticeable that they turn on at the same time. At the top of the Christmas tree is a twenty-fifth LED (D25) that is permanently on.

When a single XOR gate is used in the feedback loop, there can be a state where all outputs are high, resulting in all LEDs being turned off. This is because the MOSFETs are inverting, so the LEDs light up when the outputs of the shift register are low. To make sure that there is always at least one active (low) output, we've added an extra gate (IC1D) after IC1A, which now functions as an XNOR, since one input is connected to the positive supply.

A clock generator is required to drive the shift register. This is built around the two remaining XOR gates in the 4070. This is a commonly used circuit, which uses an inverter with a Schmitt-trigger input. Gate IC1B has been configured as a non-inverting buffer by connecting one of its inputs to ground. R10 and R11 determine the Schmitt-trigger-levels. A second EXOR gate follows this, which functions as an inverter since one input is connected to the positive supply. R12, P1 and C2 in the feedback loop determine the frequency at which the oscillator operates. The preset can be used to vary the frequency over a wide range.

When the supply voltage is first applied, the shift register is reset via R13/C1, which causes all LEDs to light up momentarily. In order to check if all of the LEDs are working you can put a jumper on JP1. You can leave JP1 off the board if you don't intend to use this feature.

To keep the electronics on the Christmas tree as unobtrusive as possible, all of the components have been selected in SMD packaging, with the exception of the power supply connector. The shift register and the EXOR gates are in an SOIC package. Even the preset for the flash frequency comes in a very small SMD version. The other components are 0603 versions. The white LEDs used here are 0805 types with a with a beam angle of 140°, which

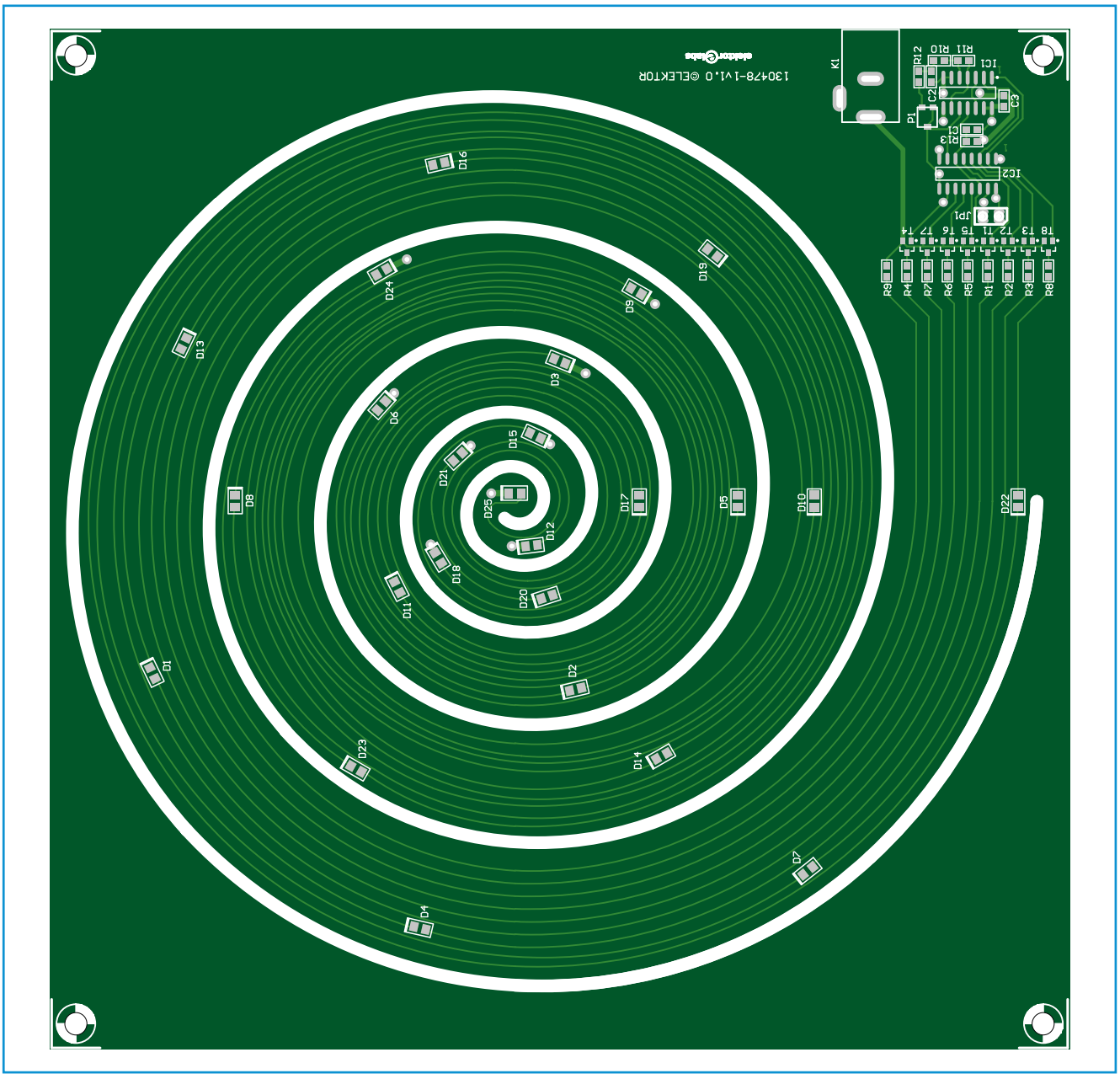
emit their light upwards, but which can still be clearly seen from the side due to their wide viewing angle (they emit about 400 mcd at 20 mA, although we drive a current of about 10 mA through each LED).

Since we're using CMOS ICs from the 4000 series, we can use a supply voltage of up to 15 V, which can be provided by a mains adapter with an output of 12 V DC. There is no need for any extra voltage stabilization. The power adapter should be able to supply at least 250 mA.

Practical implementation

We used Altium Designer to create the printed circuit board layout, which is shown in **Figure 2**. The usual thickness of a normal board is about 1.6 mm. This type of board is very inflexible, and it wouldn't be possible to transform it into the shape of a Christmas tree (cone). For the prototype we therefore use a board with a thickness of only 0.2 mm, which is much more flexible. To compensate for the reduced bending of the spiral nearer the top, we've made it narrower towards the center

Figure 2.
The board is made from PCB material with a thickness of just 0.2 mm, which makes it easy for it to be transformed into the shape of a Christmas tree.



Component List

Resistors

R1–R8 = 300Ω, 0.1W, 5%, SMD 0603
R9 = 1kΩ, 0.2W, 5%, SMD 0603
R10 = 4.7MΩ, 0.1W, 5%, SMD 0603
R11 = 10MΩ, 0.1W, 5%, SMD 0603
R12 = 100kΩ, 0.1W, 5%, SMD 0603
R13 = 1MΩ, 0.1W, 5%, SMD 0603
P1 = 1MΩ SMD preset, 0.1W, 30% (e.g. Murata PVZ3G105C01R00)

Capacitors

C1,C2 = 1µF 25V, 10%, X5R, SMD 0603
C3 = 100nF 25V, 10%, X7R, SMD 0603

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D1–D25 = LED, white, SMD 0805 (e.g. Multicomp OVS-0801)
T1–T8 = BSS84W, P-channel MOSFET, SMD SOT323
IC1 = 4070, SMD SOIC14
IC2 = 4015, SMD SOIC16

Miscellaneous

JP1 = 2-pin pinheader, 0.1” pitch, with jumper
K1 = DC adapter, PCB mount, center pin 1.95mm, 12V, 3A (e.g. Lumberg NEB 21 R)
PCB artwork file # 130478-1, from [1]

with a logarithmic progression. This makes the vertical separation between the spiral segments almost the same along its height (see photos). An advantage of this design is that more space is available for the tracks at the beginning of the spiral. The closer we get to the center/top, the fewer tracks that are required to drive the LEDs.
Because of the high production costs of such an unusual board, we have decided not to make it available for sale through the Elektor Store. However, the board layout is available as a free download [1] for those of you who would like to experiment with this circuit.
The majority of this circuit, with the exception of the LEDs, is on the base of the board, near the power connector. Almost all components are SMD devices, to keep everything as small and unobtrusive as possible. If you already have some experience of SMD soldering, you should be able to manually solder all the parts on the board. It is recommended to mount the populated board on a sturdy base (a piece of Perspex, for example) and to use a transparent plastic rod for the ‘trunk’ of the Christmas tree, turning it into an appealing project.

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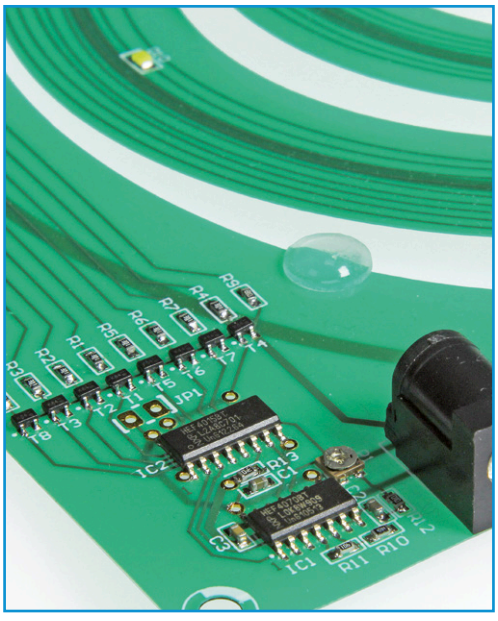

Figure 3.
Apart from the LEDs, all of the electronics are mounted on the base of the Christmas tree.

Web Link

[1] www.elektor-magazine.com/post