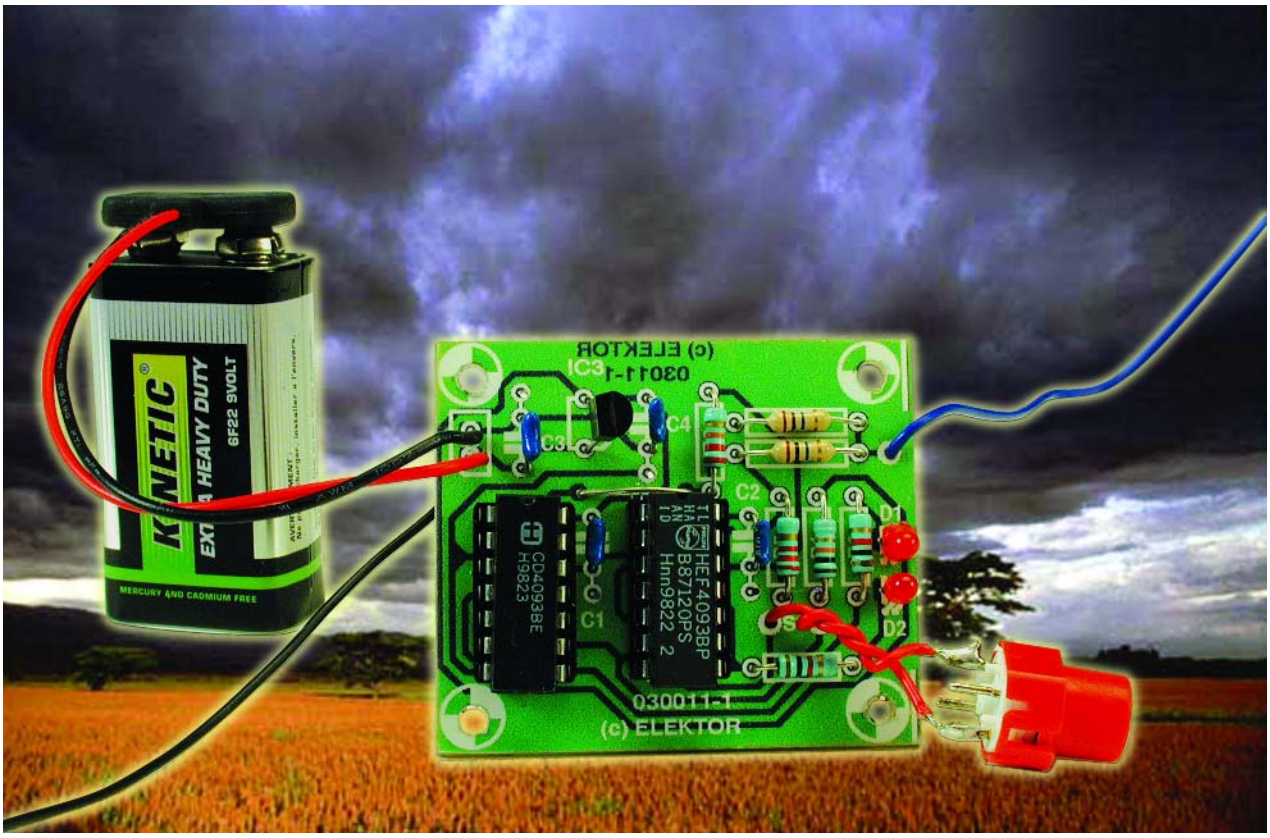
Lightning Intensity Detector

An indicator for extremely high voltages

From an idea by B. Oehlerking

It is generally known that the forces of nature can be destructive, as proved time and again by storms, tsunamis, tornados, tidal waves and earthquakes to mention but a few. Fortunately, the occurrence of these awe-inspiring natural forces is rare. The thunderstorm, a more frequently occurring phenomenon with less impact than any of the above (but by no means less dangerous), is caused by electricity (at an enormous scale), which makes it suitable for detection by electronic means.



The author got the idea to design this circuit during an outdoor sports event. Many among the audience were quick to deploy their umbrellas when it started to rain. This happened while a distant sound of thunder could be heard. All of a sudden, a large group of people appeared to throw their umbrella to the ground. A few seconds later, lightning struck. Apparently, the umbrellas had worked as a kind of antenna, drawing in at least a portion of the huge voltage field associated with lightning. Fortunately, there was no direct hit, so the amount of energy must have been small enough to prevent injuries or serious damage.
Once recovered from the 'attack' from above one of the umbrella owners started to explore the subject of thunderstorms and translated his findings in a practical circuit that would allow him to get a better insight into the 'workings' of this fascinating natural event. At this point we should hasten to add that the design discussed here is intended **for lightning detection only**. Unfortunately, this type of detection does not tell you the distance between the lightning and the detector, and neither does it provide an early warning of an imminent lightning bolt. On the other hand, the circuit does provide a useful indication of the electrical field strength that comes with a lightning discharge.

Thunderstorms

While scientists hold different theories about the exact origins and effects of thunderstorms, they generally agree about the following.

A large voltage difference arises between a thundercloud and the earth's surface, resulting in an extremely strong electrical field. Eventually, the field strength between the cloud and the earth rises to a level where, as a result of ionisation, a region of gas (air) is turned into plasma. Plasma provides a conducting path for an arc discharge. Once the plasma path reaches the earth, a charge-cancelling current can start to flow between cloud and the earth. The resulting currents in the plasma path are immense.

Because the plasma path represents a certain resistance (albeit very small), heat is produced. Scientific measurements have indicated that temperatures inside lightning bolt may exceed those at the sun's surface! The sudden temperature rise causes surrounding air to expand and produce a propagating shockwave which we can hear as a thunderclap.

The shockwave, by the way, can be dangerous, and not only to your eardrums! The shorter the discharge, the more intense the shockwave. Cases have been recorded of houses being crumbled by shockwaves produced by lightning discharges.

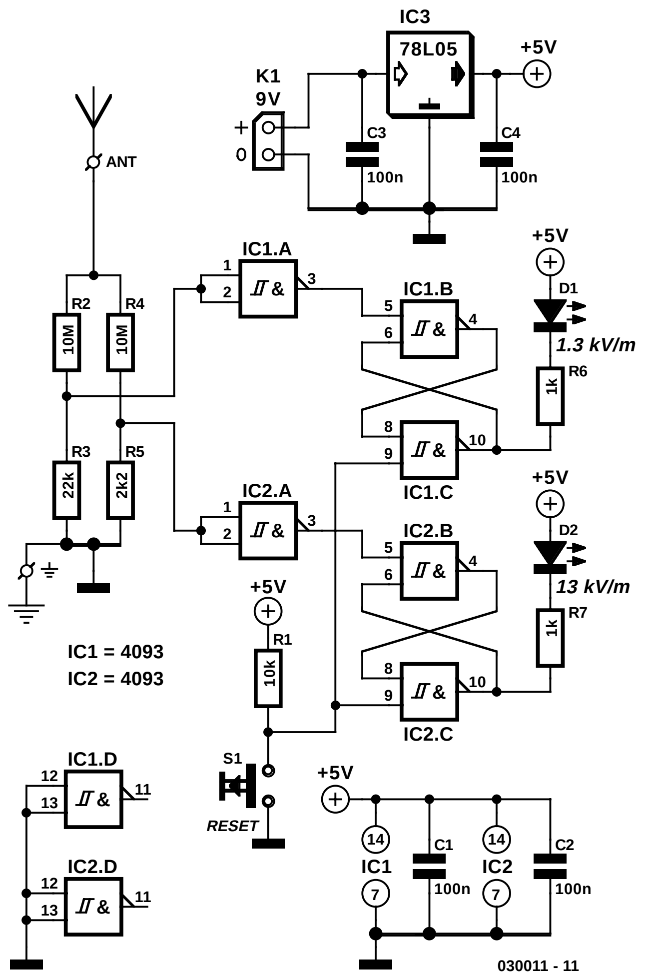


Figure 1. The core of the circuit are two potential dividers and associated flip-flops. LEDs are used to indicate and record the occurrence of two levels of electrical field strength, 1.3 kV/m and 13 kV/m.

Measuring

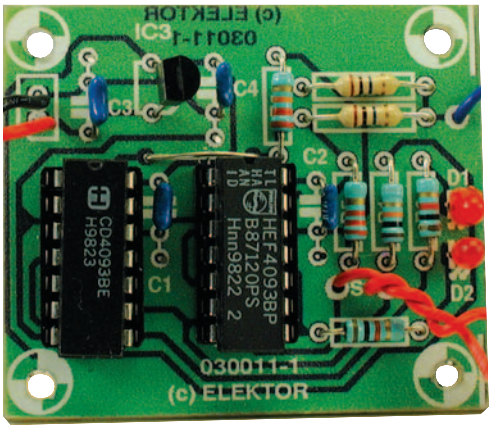
So how can we measure if a lightning discharge occurred in the neighbourhood? While the plasma path is being formed, the electrical potential of the plasma will be about equal to that of the thundercloud. An electrical field may be described in terms of potential difference per unit of distance (volt per metre). With the plasma path rapidly approaching the earth, the field density between it and the earth will increase.

This sudden increase in electrical field density can be detected using an antenna. Because the voltages we're talking about are massive, they need to be reduced to levels at which semiconductors are happy to work for us.

Circuit description

The practical circuit of the lightning intensity detector is show in **Figure 1**. The pickup device is a common or garden telescopic antenna with a length of about 1 m, connected to the input terminal marked 'ANT'. If the thunderstorm is still relatively far off, or if you want to have a go at recording 'summer lighting', the sensitivity of the detector may be increased by connecting the terminal identified with the earth symbol to the plumbing or central heating. The voltage picked p by the antenna is lowered by two potential dividers, R2-R3 and R4-R5.

The voltage reduction is considerable.



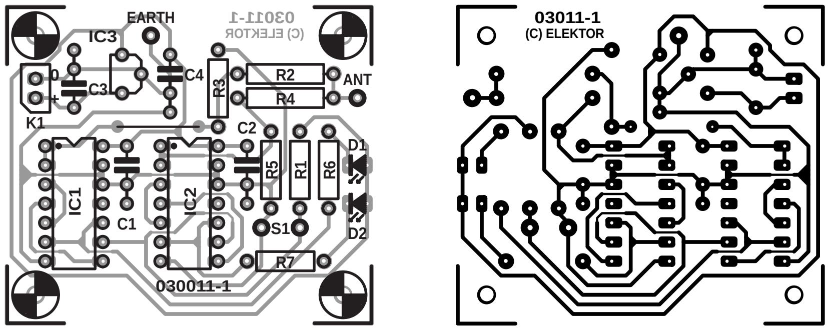


Figure 2. Copper track layout and component mounting plan of the PCB designed for the Lightning Intensity Detector (PCB available from The PCBShop).

Potential divider R2-R3 reduces the voltage by a factor of

(R2+R3) / R3 = 214

while R4-R5 is dimensioned for a factor of

(R4+R5) / R5 = 4,546.

Each of the reduced voltages is applied to the 'set' input of a set/reset (S/R) flip-flop. Here, the flip-flops are built from NAND gates with a Schmitt trigger input. Two ICs type 4093 (IC1 and IC2) are applied in this circuit. They were chosen because Schmitt trigger gates do not allow their output to change state (i.e., High to Low or Low to High) until the voltage at the input exceeds or drops below an accurately defined upper or lower level, respectively. The hysteresis created in this way ensures the absence of an 'undefined' range between logic Low and High levels.

As soon as the antenna voltage exceeds 1.3 kilovolts (1,300 volts!), R3 will drop about 2.9 volts. That is the typical switching threshold for a 4093 operated at a supply voltage of 5 volts. Consequently, inverter gate IC1a will drop its output to logic Low and so cause the flip-flop built around IC1b and IC1c to be set, as well as LED D1 to light. Because of the latching effect of the flip-flop (a rudimentary memory device), the LED will remain on even if the antenna voltage disappears again. The LED can only be switched off by resetting the flip-flop and that is done by pressing push-button S1.

The same principle of operation applies to IC2 and LED D2, albeit that the antenna voltage has to exceed 13 kV before a voltage of 2.9 V can occur at the input of IC2a. In other words, this second detector requires a stronger electrical field to make the LED light, so it is less 'sensitive' than the other detector.

The values of R3 and R5 are, of course, subject to experimenting to see what sort of electrical fields occur around your home during an average thunderstorm.

After a lightning discharge, the circuit can be prepared for the next measurement by pressing reset button S1.

COMPONENTS LIST

Resistors:
R1 = 10kΩ
R2,R4 = 10MΩ
R3 = 22kΩ
R5 = 2kΩ2
R6,R7 = 1kΩ

Capacitors:
C1-C4 = 100nF

Semiconductors:
D1,D2 = LED, red, low-current
IC1,IC2 = 4093
IC3 = 78L05 (see text)

Miscellaneous:
ANT = antenna, telescopic whip or 1 metre wire
K1 = 9V battery with clip-on leads
S1 = pushbutton, 1 make contact
PCB, available from The PCBShop

Power supply

The power supply for the circuit could not be simpler. A 9-V (PP3 or 6F22) battery supplies a 78L05 regulator (IC3), which in turn provides a stable 5-V supply rail for the rest of the circuit. If desired, the circuit can be made to work from a 6-volt battery pack by using a low-drop regulator in position IC3. For example, the 2951 requires just 5.5 V at its input to supply a stable 5-V output voltage.

The current consumption of the circuit is modest at just a few milliamps. Because the circuit does not have to be on all the time, a PP3 battery will probably last for a number of years.

Construction

A printed circuit board has been designed for the detector (**Figure 2**). You can either etch it yourself or order one ready-made from The PCBShop (accessible via the *Elektor Electronics* website). The PCB has the size of a matchbox and is unlikely to take more than half a hour or so to populate.

Small enclosures to hold the stuffed PCB and the battery should be widely available in various shapes and sizes. The antenna may be a genuine telescopic whip, but if you need to cut costs then a piece of wire with a length of 1 m will also suffice.

Warning

Direct lightning and some secondary discharges represent lethal voltages and current levels. Never use this instrument at a position above the highest point of a lighting arrestor system, in the direct vicinity of such a system, or in any other way with a view to attracting lightning.

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