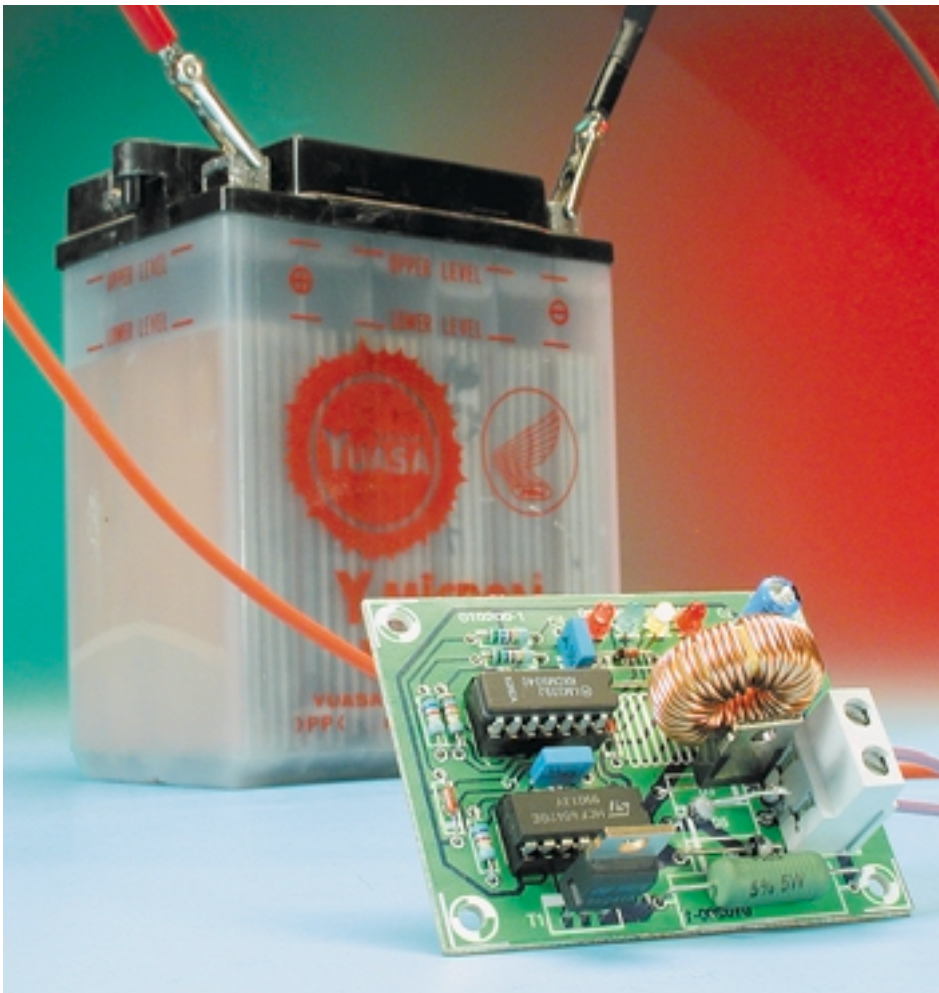


# Lead-Acid Battery Revitaliser

a de-sulphation device for worn out batteries

Design by K. Walraven

This circuit makes it possible to do something that was previously unthinkable: reversing the effects of sulphation in tired lead-acid batteries. The circuit is also recommended for use as a conditioner for new batteries.



In a recent scientific journal it was stated that 80% of lead-acid batteries eventually fail due to sulphation. This sulphation occurs due to general old age, non-ideal charge/discharge cycles or storage in a discharged state for too long. The last happens often with batteries in motorbikes and classic cars, since these have an enforced rest during the winter months. To counter this, *Elektor Electronics* has designed a special charger a couple of years ago, which keeps the batteries in good condition during their winter sleep.

What exactly is 'sulphation'? This is a condition when the lead sulphate that is formed on the plates of a battery during its discharge changes in structure. Fairly large sulphate crystals are formed, which block the pores of the lead plates and hence reduce their active area. This causes the capacity of the battery to be reduced — it can no longer supply large currents and it can not be charged effectively in the usual way. When such a sulphated battery was charged, conducting bridges (short circuits) appeared between the plates, of which it was thought up to now that they could not be

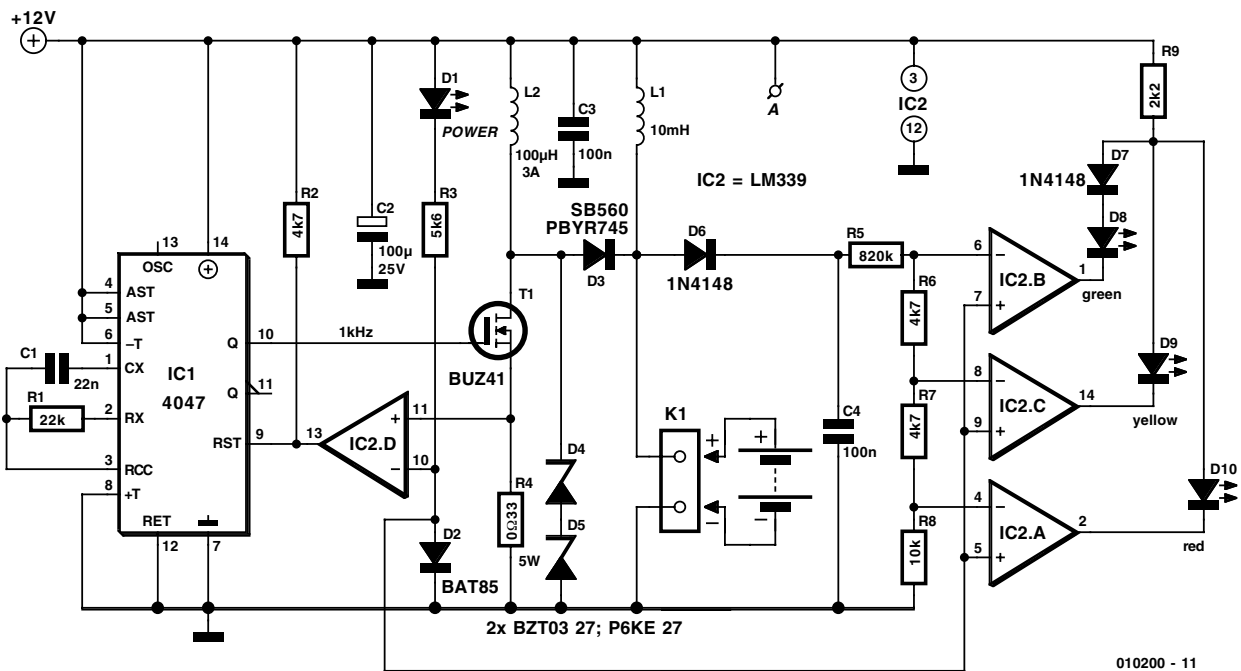


Figure 1. The circuit consists of a pulse generator and an indicator section.

removed. For the battery concerned it meant the end of its service life.

### Known tricks

In the true spirit of electronics enthusiasts, you will not immediately take a tired battery to the recycling depot. After all, they aren't cheap and it is worth it to check that it really is at the end of its tether.

Insiders will undoubtedly know a few tricks that pep up a tired battery. One of the best known is to charge and discharge the battery repeatedly. This method causes a large part of the lost capacity to be restored for some reason or other. In other cases, applying large current pulses periodically seems to have some effect.

But both these methods leave something to be desired in cases where badly sulphated batteries have to be brought back to life.

### Cure

In recent years several manufacturers have been developing methods for the reversal of sulphation in lead-acid batteries, with varying success. The working methods seem to rely

on some kind of pulsed charging. This is in contrast to normal charging procedures, which mostly use a constant voltage.

The design described here represents the latest techniques for revitalising lead-acid batteries. It is a device that periodically feeds short but fierce pulses to the battery, while discharging it slightly in between the pulses. This is, as far as known at the moment, the most effective way to break up unwanted deposits of sulphate crystals and to restore the battery plates to a reasonable condition.

Since the energy required for the charging pulses is derived from the battery itself (that may seem a bit weird at first, but the discharge of the battery is also part of this process), it is recommended to connect a charger in parallel with the battery and revitaliser when the battery has very little capacity left – but we'll go into detail of that later.

We have to be honest here and admit that our own experience of the circuit is not enough to give it an unconditional guarantee of successful operation. But since the circuit is not really expensive, its use deserves the benefit of the doubt.

### Pulse generator

It can be seen from the circuit diagram in **Figure 1** that the electronics required for the revitaliser are very modest. The circuit contains two parts: a generator built round IC1, IC2d and T1, which creates the charging pulses, and an indicator circuit consisting of little more than three opamps (IC2a, b, c) and three LEDs, which show what state the battery is in.

Let's look at the pulse generator first. Just as the rest of the circuit, its supply is taken from the battery via K1. While we're talking about the supply, it should have a fairly constant voltage and be free from spikes (apart from the ones generated by the circuit itself). Suppression inductor L1 has been added to remove unwanted spikes, with C2 and C3 acting as reservoir capacitors. LED D1 lights up when the supply voltage is present.

To continue with the pulse generator, IC1 (a 4047) creates a square wave with a frequency of 1 kHz and a duty cycle that normally is 50%. As soon as the Q output of IC1 becomes high, FET T1 will turn on. This causes a (discharge) current to flow from the battery through L2, which increases linearly until the voltage across R4 is about 0.35 V; the current is then about 1 A.

At that moment comparator IC2d will switch over, causing IC1 to be reset and T1 to be turned off. The stored magnetic energy in L2 is now converted into a voltage spike,

## COMPONENTS LIST

### Resistors:

R1 = 22k $\Omega$   
 R2,R6,R7 = 4k $\Omega$   
 R3 = 5k $\Omega$   
 R4 = 0 $\Omega$ 33 5W  
 R5 = 820k $\Omega$   
 R8 = 10k $\Omega$   
 R9 = 2k $\Omega$

### Capacitors:

C1 = 22nF  
 C2 = 100 $\mu$ F 25V radial  
 C3,C4 = 100nF

### Inductors:

L1 = 10mH  
 L2 = 100 $\mu$ H 3A suppressor coil

### Semiconductors:

D1 = LED  
 D2 = BAT85  
 D3 = SB560 or PBYR745  
 D4,D5 = BZT03 27 or P6KE 27  
 D6,D7 = 1N4148  
 D8 = LED, green (high efficiency)  
 D9 = LED, yellow (high efficiency)  
 D10 = LED, red (high efficiency)  
 T1 = BUZ41  
 IC1 = 4047  
 IC2 = LM339

### Miscellaneous:

K1 = 2-way PCB terminal block, lead pitch 7.5mm  
 PCB, order code **010200-1** (see Readers Services or Elektor Electronics website)

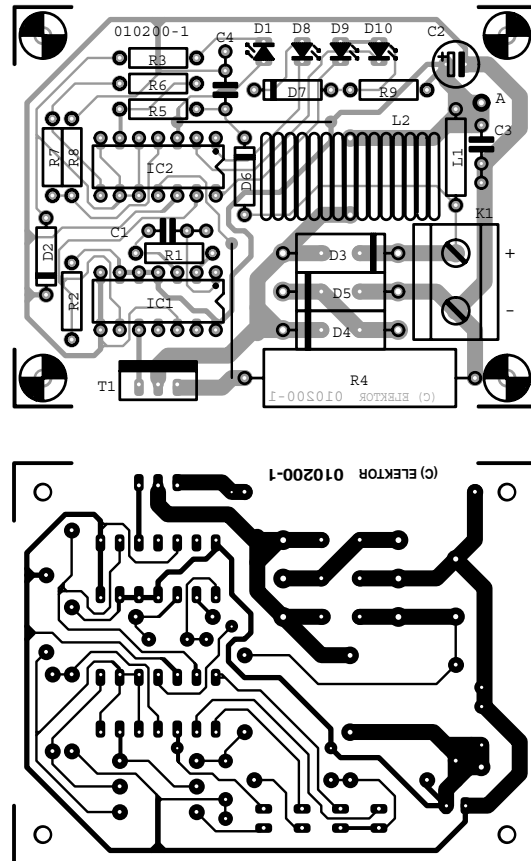


Figure 2. The use of this printed circuit board makes construction easy.

which is fed to the battery via D3.

The size of the spike is dependent on the state of the battery. When the battery is in a reasonable condition and its internal resistance is fairly low, then the peak of the spike will also be low (less than 15 V). With a high internal resistance the peak can be as big as 50 V. Its maximum value is limited by the two series connected zener diodes, D4 and D5.

## Indicators

Since the condition of the battery can be determined by the size of the charging pulses, we've added a simple circuit that indicates the peak value of the pulses. The three comparators IC2a-c measure the peak value stored in C4 and switch over at voltages of 15, 20 and 30 V respectively. So when the battery is in a fairly good condition, the green LED (D8) lights up, with a mediocre battery the yellow LED (D9) and with a really poor battery the red LED (D10).

There is a detail that should be mentioned about the indicator circuit: to avoid all three LEDs from lighting up at the same time when the peak voltage is very high, they have been connected in parallel to one common series resistor (R9). Because the red LED has a lower voltage drop than the yellow LED, they will never light up at the same time. Since the yellow and green LEDs have a similar voltage drop, the same trick won't work here, which is why the green LED has an ordinary diode (D7) connected in series with it.

## Construction

A compact printed circuit board (Figure 2) has been designed for this circuit, making the construction of this clever revitaliser a simple task even for the less experienced hobbyists. It's just a matter following the component layout and parts list carefully before construction. The battery is connected to terminal block K1

(observe the polarity!). Don't forget the wire links though; there are only two in this case, but without them the circuit will not work at all!

Because the charging pulses can cause high frequency interference, the completed printed circuit board should be mounted in a metal case.

The choice of components is not very critical. Any small Schottky diode can be used for D2. For D3 any fast power Schottky diode rated for at least 60 V/3 A is suitable.

The choice of T1 is also fairly wide, because in practice any power FET is suitable which is rated for 3 A and 100 V. The well-known BUZ10 would even be suitable, but then the zener voltage would have to be reduced to 27 V by replacing one of the zeners (D4 or D5) with a wire link. One important thing about these zeners: they can't be normal ones, but should be fast types. The zener voltage isn't critical as such, but the basic assumption is that the total voltage of zeners D4/D5 should be in the region of 40 to 50 V. In any

case, don't leave out the zener diodes as that is a sure way to destroy MOSFET T1!

For L2 a standard suppression choke is used, which is rated for at least 3 A. The inductance of the choke is not critical; any value between 50  $\mu\text{H}$  and 200  $\mu\text{H}$  is fine. Special inductors for switch mode supplies are also suitable; often they function even better. The value of L1 also is not critical and can be anywhere between half and double the stated 10 mH.

## Usage

There are three different ways in which the revitaliser can be used.

The first is to use it in an existing system (in a car for example) to prevent sulphation from occurring in a battery with little or no sulphation. The circuit is integrated with the system by connecting it directly to the battery using as short as possible cables. Since the circuit can be left connected permanently, nothing else has to be done. The current consumption is about 20 mA, so the battery could discharge if it is not charged up occasionally.

Restoration of batteries that have already sulphated can be done in two ways. The first way is to charge the battery, remove the charger and then connect the revitaliser. Because the energy for the charging pulses is taken from the battery itself it will slowly discharge. This process has to be followed closely since a fully discharged battery has to be recharged immediately. It is likely that in practice many charge/discharge cycles will be required before a badly sulphated battery can be brought back to life.

Because the method mentioned above requires a lot of attention and carries a risk that the battery can be left in a discharged state unnecessarily (which is very bad for a lead-acid battery!), the next way is probably better.

The battery is connected to the revitaliser, with a trickle charger connected in parallel. So no chargers should be used which give a current of 7 A or more, but one which gives a maximum of 1 or 2 A. This can be left connected to the battery continuously without any problems.

As already mentioned, it is possible to connect the revitaliser in a car to the battery permanently. This does however carry the risk that pulses of around 50 V can be created in the car's wiring when the internal resistance of the battery is high, that is when the battery is known to suffer from sulphation already. The pulses are something which electronic equipment isn't very fond of. So, if there is reason assume the battery is in a poor state, it's better to be careful and not connect the revitaliser permanently. Instead, disconnect the battery from the car before connecting the revitaliser.

## Effect?

With the three LEDs it is very easy to see what effect the pulse charging has. If the sulphation does reduce, the active area of the plates increases and the internal resistance of the battery becomes less. The charge peaks supplied by the revitaliser then become smaller. This can be seen by the colour of the lit LED.

With a very poor battery the red LED will be lit initially. When the pulse charging has had some effect, the red LED will go out at some stage and the yellow LED will light up. And when the green LED finally takes over from the yellow one, it is a sign that the battery can be considered to be in a fairly good state again. A final check with a voltmeter should establish that the battery voltage (without the charger of course) is in the region of its nominal value of 12 V.

This check can be extended with a discharge test. A known load is connected to the battery and you simply time how long the battery can supply the load current. The useable capacity is calculated simply by multiplying the current by the time. When a 12 V battery is loaded by a 50 W lamp, a current of about 4 A will flow. If the battery lasts for five hours then its useable capacity is 20 Ah.

When the capacity is still a long way below the nominal value given by the manufacturer, the revitalising can be continued without any objection. Any further improvement should not be expected too quickly, since the restoration can easily take from several days to several weeks, depending on the state of the battery.

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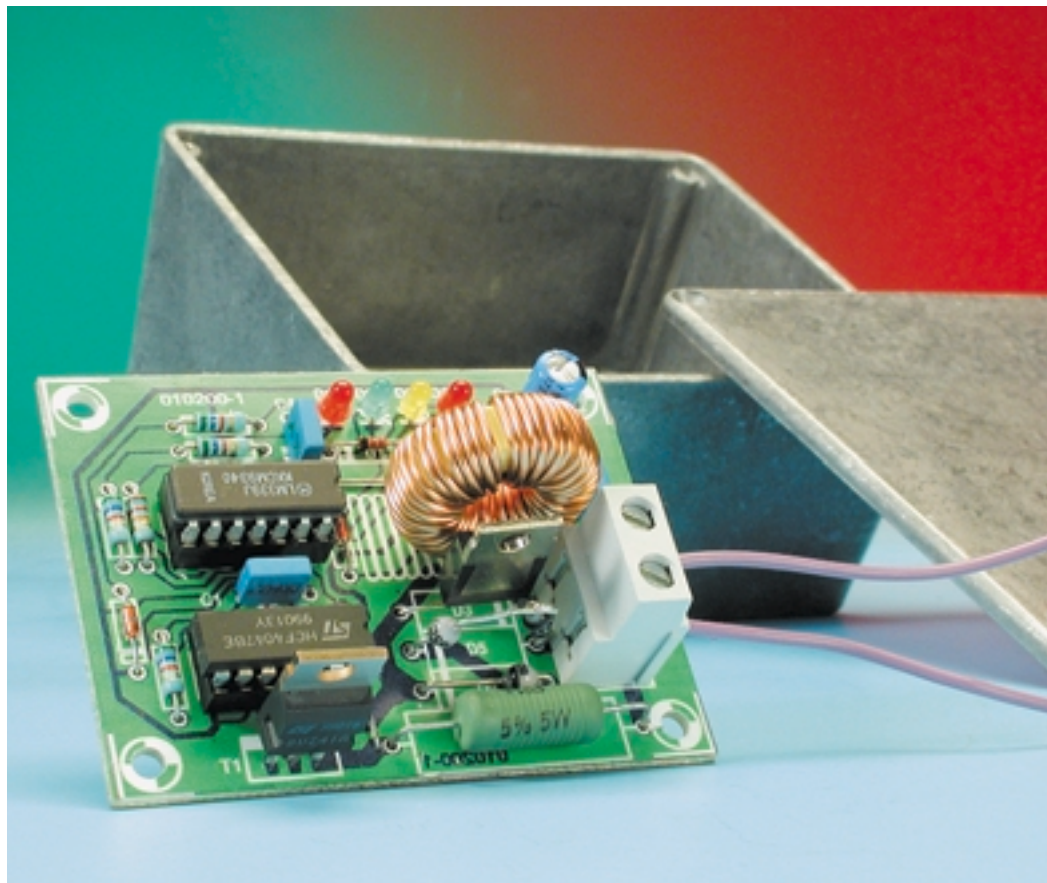


Figure 3. Keeping the possibility of interference in mind, the circuit is best mounted in a metal case.