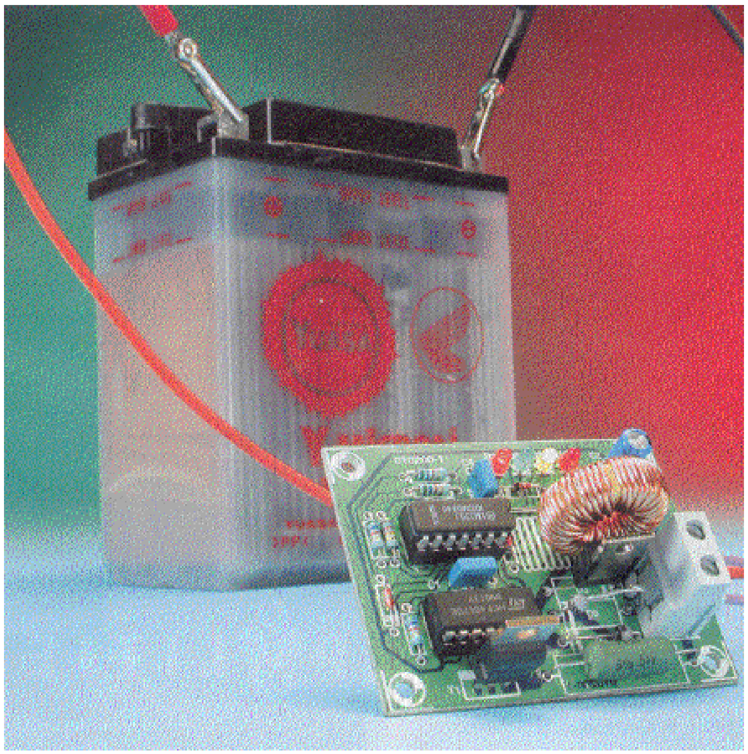
Pulsing Lead-Acid Batteries

(Reversing type III sulfation)



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(A. Shiekh)

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A. Shiekh

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Abstract

Various approaches to pulsing lead-acid batteries to drive type III sulfation back into solution are reviewed, and the promising resistive based design is considered for accelerated desulfation

1 Introduction

Lead acid batteries have been with us for over 100 years now, and despite their heavy weight, they remain viable options for rechargeable (secondary) storage devices.

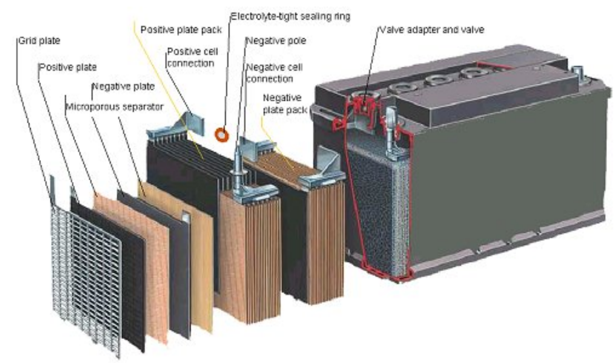

Fig 1: Cut-away of a multi-cell lead-acid battery

Their chemistry is simple, with just over 2 volts generated per cell, and reversible reaction given by:

POSITIVE PLATE (Lead Oxide):

$$\overbrace{\mathbf{PbSO_4} + 2\mathrm{H_2}0}^{charging\Rightarrow} \Longleftrightarrow \overbrace{\mathrm{PbO_2} + \mathrm{H_2SO_4} + 2\mathrm{e}^- + 2\mathrm{H}^+}^{\Leftarrow discharging} \quad (1)$$

NEGATIVE PLATE (Spongy lead):

$$\overbrace{\mathbf{PbSO_4} + 2\mathrm{e}^- + 2\mathrm{H}^+}^{charging\Rightarrow} \Longleftrightarrow \overbrace{\mathrm{Pb} + \mathrm{H_2SO_4}}^{\Leftarrow discharging} \quad (2)$$

Such technology has several failure modes, but the predominant one tends to be sulfation, where the lead sulfate crystallizes out into an insoluble, and so inaccessible, form. The sulfation actually progresses in stages, with the final level III bonds being insulators, and it is this form that is being targeted here.

Given the quantity of lead employed in a battery, and the toxicity of lead to the environment (not to mention the sulfuric acid), a system that can extend the operational life of such batteries is highly desirable.

Many cures to restoring the sulfation to solution have been suggested, but of the many trials, treating the battery with short electrical spikes has been confirmed successful, although the exact mode of operation is still up for debate.

This project is intended to run at a low budget, hobby level, with stock circuits being available in kit form for around $50. Commercial units exist at a comparable cost (`http://www.pulsetech.com/`), and the military has been taking advantage of such technology for over a decade now to ensure the readiness of its equipment in storage.

2 Which theory?

Some manner of theory would be most enlightening, for operating without one is like wandering in the dark, with too many things to try, and matters soon become very opinionated and loyalties to certain approaches develop.

It would seem that the insulator type III crystals form the dielectric of a capacitor, each 'ringing' at a differing frequency; the ringing being the manner in which one induces over-voltage on the crystals. So one would see the function of the impulse as having the purpose of resonating the various crystal 'capacitors'. This would suggest a resistive produced pulse might be as good as an inductive one.

3 Variations on a theme

Having decided that pulsing is a good thing, still leaves the territory wide open to variations. Should the pulses be inductively or resistively produced Of what height, width and repetition rate?

Producing an inductive pulse is somewhat challenging, while a resistive pulse is simpler to implement. Two circuit kits exist for the inductor based, approach; the so called 'Couper' circuit (HomePower #77; June/July 2000), and the 'Dutch' variation (Elector #14; Sept. 2001). More recently a resistive pulse design has appeared (BA 80 and BLA 1000) in the form of a 'German' circuit from ELV (2003). Challenging is the fact that while the 'Couper' circuit is documented in English, the 'Dutch' circuit is in Dutch (though available in English) and the 'German' circuit is in German (translation available).

4 Standardization or Control

One dilemma is the inability to accurately gauge performance, as no form of standardization, or control, has been developed to compare against. This just fires the strength of opinions for various approaches.

One might anticipate the development of a standard cell in a beaker with the addition of lead sulfate crystals between the plates, to be driven into solution by the pulser circuit.

5 Inductive Pulsers

5.1 'Dutch' design

The 'Dutch' circuit may be taken as typical of the inductor approach. Both operate impulses around 1 kHz, and power themselves from the very battery itself, loading up current into a main inductor and then discharging this rapidly back across the battery.

How this achieves a high voltage pulse is seen directly from the equation for inductance:

$$V = -L\frac{dI}{dt} \quad (3)$$

where V is the voltage, I the current and L the inductance.

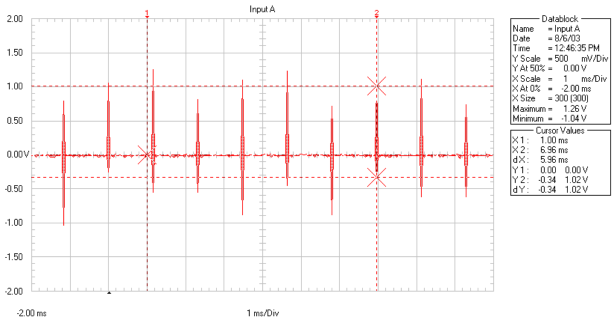

Fig 2: The main 'Dutch' 1 kHz impulse (with sampling artifacts)

When looked at more closely the impulse can be seen to actually have a dual nature.

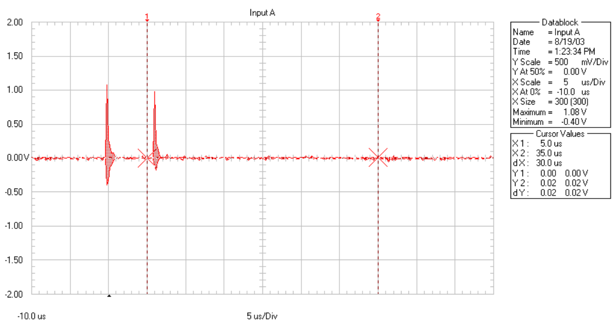

Fig 3: The dual nature of the impulse

The leading impulse is of very short duration and can be seen to have a ringing nature:

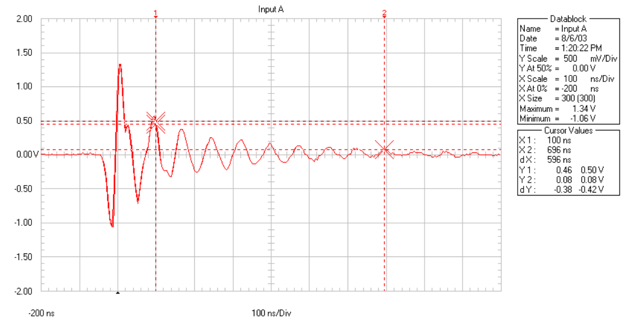

Fig 4: The leading impulse in detail (0.5 - 10 MHz content)

The ringing frequency is a function of the circuit and not the battery as can be seen by trying the same experiment across a dummy load. A low resistance shunt shows that a 40 amp peak accompanies the main voltage peak. These high currents and high frequencies suggest the use of Litz wire for the connecting leads. Enormous losses are noted in normal leads.

Note the negative nature of the leading edge.

5.2 'Couper' design

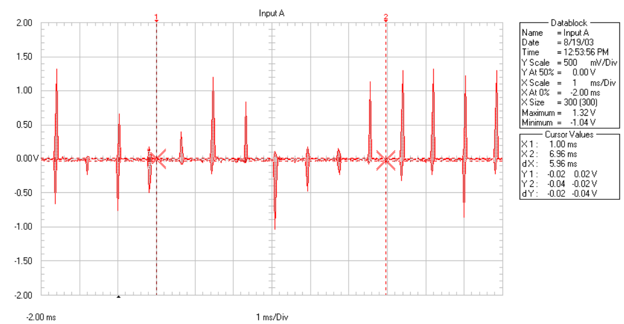

Fig 5: The main 'Couper' 1 kHz impulse (with sampling artifacts)

The impulse seems very variable, but this is believed to be a sampling artifact of the digital oscilloscope being used.

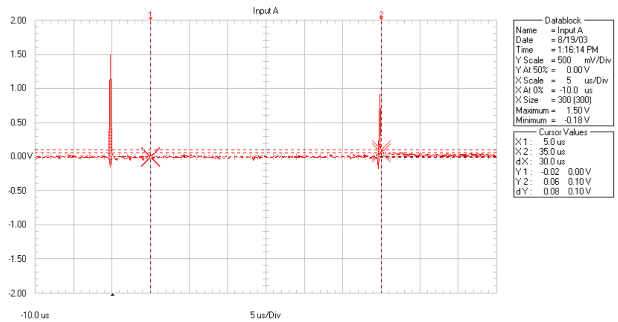

Fig 6: The dual nature of the impulse

On the same scale as for the 'Dutch' case, making it clear that the shadow impulse is considerably delayed relative to the 'Dutch' case (Figures 3 and 6).

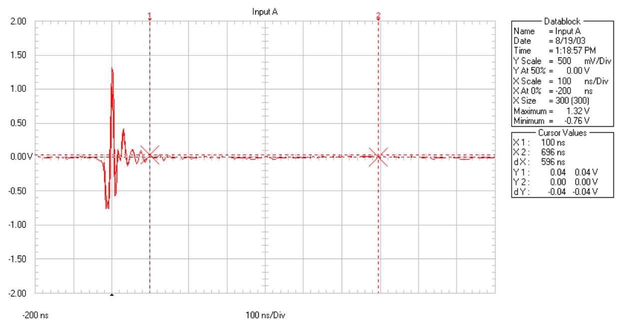

Fig 7: The leading impulse in detail
(3 - 50 MHz content)

Surprisingly the 'Dutch' and 'Couper' performance seem very similar (again note the negative leading edge), except that the 'Couper' has a further displaced shadow pulse and a warm (body temperature) running main diode.

The 'Couper' impulse is also much shorter and so possibly of too higher frequency content (Figures 4 and 7).

6 Circuit details

6.1 'Dutch'

To be able to develop a circuit beyond stock, one needs to be able to understand its operation.

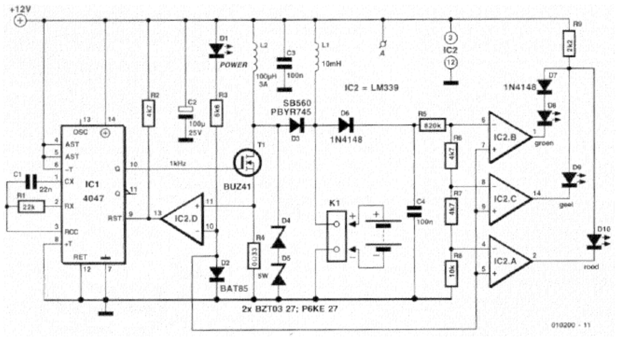

Fig 8: 'Dutch' schematics

Fortunately, the availability of stock kits avoids the labor of etching one's own circuit board.

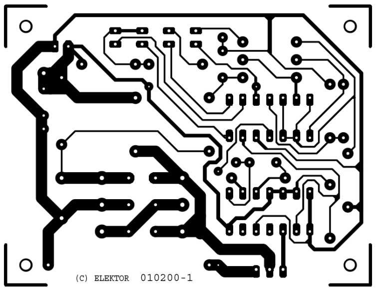

Fig 9: 'Dutch' circuit board

which gives rise to a tidy looking end product:

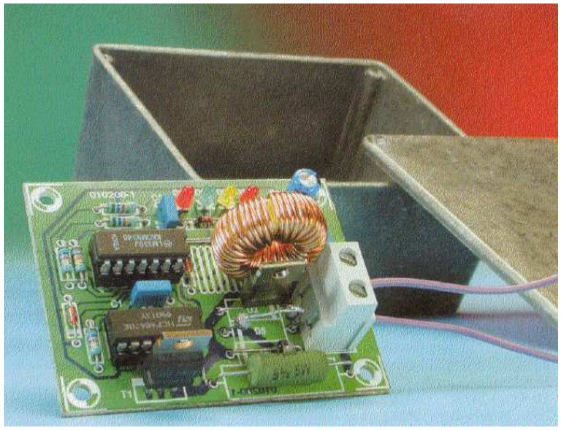

Fig 10: 'Dutch' board assembled

6.2 'Couper'

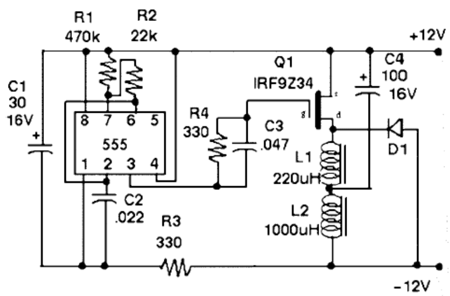

Fig 11: 'Couper' schematics

6.3 'German'

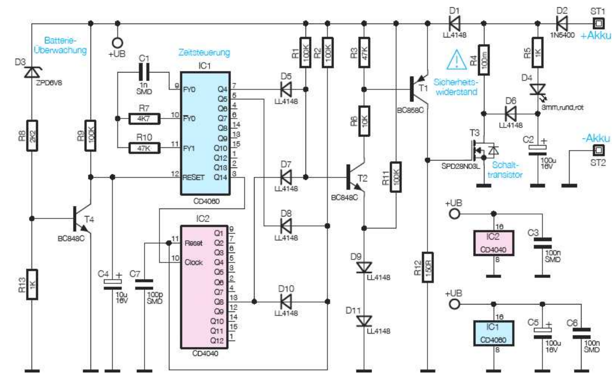

Fig 12: 'German' schematics

7 The Need for Speed

With present units, desulfation can take on the order of weeks, so there is a definite need for a highly accelerated version, if at all possible.

Attempting to increase the pulse rate limits the time available to get the inductor up to current for inductive pulse designs, and so is counterproductive in the case of the inductor based design.

Given all the resultant problems associated with inductive pulse circuits, it is anticipated that accelerated designs will be based upon the simpler resistive pulse approach, in which it is also easy to accommodate protection against accidental reverse connection.

7.1 Resistive based designs

How a resistive based design achieves desulfation should become clear when looking at the inductive based plots (figures 4 and 7), for they actually hit the battery with a negative pulse that initiates ringing.

One suspects that inductors or capacitors will still play a role in the final resistive design to ensure the circuit rings at the optimal frequency (probably around 3 MHz). The fast decay will ensure that the frequency is spread, as the crystal capacitors will have varied frequency responses.

The shadow impulse is possibly a result of reflection due to an impedance mismatch of the leads, and can probably be eliminated if desired.

Reference Material

Lead Acid Desulfation discussion board

`http://pub36.ezboard.com/bleadacidbatterydesulfation`

Couper circuit

`http://www.homepower.com/files/desulfator.pdf`

Dutch circuit

`http://www.elektor-electronics.co.uk/`

German circuit

`http://www.elv.de/`

DC converter basics

`http://www.powerdesigners.com/InfoWeb/design_center/articles/DC-DC/converter.shtm`