

Spot-welding with

A truly flashing lab aid

6.30V ⊕

Jeroen Domburg & Thijs Beckers

Repairing the connection between two cells in a battery pack actually requires specialised welding equipment. Alas, that kind of gear is expensive, and soldering is not an option either. So we cook up another solution, in this case using dead common electrolytic capacitors, conveniently abusing their ability to deliver brief, high current pulses for none other purpose than... welding!

Short circuiting a charged electrolytic capacitor results in nice sparks. Admit it — you, too have done or seen this on occasions, either accidentally or on purpose. The following is true: the higher the voltage and the larger the capacitance, the bigger the spark will be. Apart from a high entertainment value, this effect has other consequences. Every now and then the terminals of the poor capacitor will end up secured to the piece of metal that's used to short-circuit them. But hey, sometimes that's quite a robust connection! We can put this welding effect to very good use.

What are we going to do?

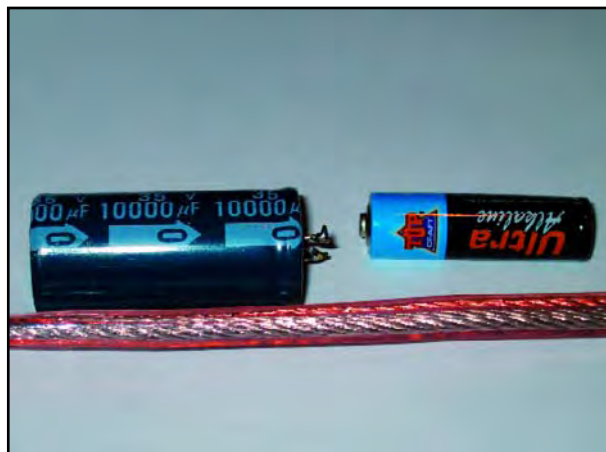
Battery packs are usually made by attaching metal strips with small spot-welds to the individual cells. The equipment that makes these kinds of spot-welds is unfortunately rather pricey, if not totally unavailable for personal use. In these types of situations the hobbyist with a broken battery pack is likely to reach (out of necessity) for the soldering iron. Soldering is actually a very bad and, what's more, dangerous method to interconnect batteries without solder tags. The worst-case scenario is that the

over-pressure valves will open and the battery explodes if it becomes too hot.

Welding is therefore a safer solution. Because only a very small area of metal is heated for a short time, not much happens to the rest of the battery. Electrolytic capacitors are perfect for the currents that are required for this type of welding operation. In order to make the welding more controlled than the brute and awkward short-circuiting of the capacitor terminals, we designed a circuit that (kind of) controls the welding process. By obtaining the energy for the welding from a set of capacitors instead of from the mains voltage, the whole arrangement is also reasonably safe.

How are we going to do it?

The circuit consists of four parts: the power supply, the array of capacitors, the power stage and the 'ignition'. The capacitors form the heart and are probably the largest physical part of the circuit. They deliver the current surge required to spot weld. Eight capacitors of 10,000 μF each is enough, in principle, but more or bigger capacitors may be better in some cases.

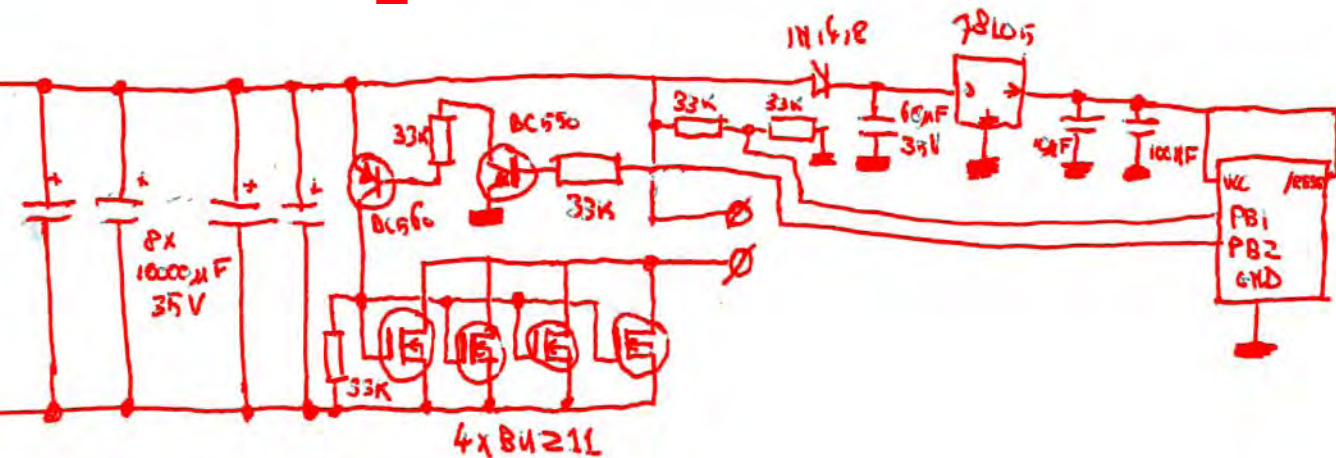


The main part: the capacitor. This is a 10,000 μF -version. Eight of these are tied together with thick loudspeaker cable (the battery is an AA penlite, for reference)



Like this. The loudspeaker cable has been stripped and well tinned at the places where the capacitors are soldered to it.

th Capacitors



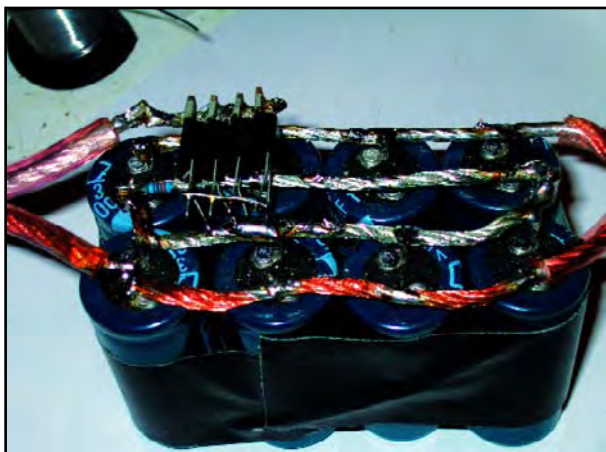
For the power supply, a benchtop power supply is best. This has as the advantage that the welding power can be adjusted to some extent by changing the voltage. The current that the power supply will deliver can also be limited. As an alternative, a short-circuit proof transformer followed by a rectifier will also work reasonably. The power stage consists of a number of BUZ11 MOSFETs connected in parallel. These MOSFETs can usually be bought for relatively little money, yet can cope with 30 A. Determining the number of FETs required for the job is a bit of a wild stab in the dark. After all, the amount of current that will flow depends on a number of factors that are not easily determined. Start with five or so MOSFETs. Should one burn out then you can come to the conclusion that you did not have enough of them. Because MOSFETs are voltage controlled components, adding more FETs does not require any other changes to the circuit.

The BUZ11 FETs need to be driven with a voltage on the gates. They will conduct harder as the gate-drain voltage increases. To make optimum use of this effect, the MOSFETs are not connected directly to the ignition circuit but via a transistor stage. In this way the MOSFETs are sup-

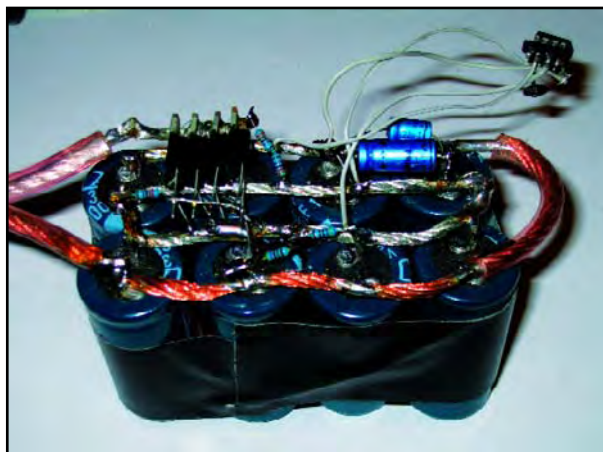
plied with a higher voltage and are turned on harder. A microcontroller controls the 'ignition'. It measures the voltage at the welding electrode which is connected to the MOSFETs (via a voltage divider, because 30 V is a little too high for its input). When this voltage goes high (that is, when the two electrodes are touching each other), the microcontroller will wait one second and then turn the MOSFETs on. This way there is enough time to put the electrodes in the right position and perhaps brace yourself for the 'bang'.

Although the logic in the microcontroller doesn't amount to much (a comparator and a couple of monostables could do the same job), we still chose an ATtiny13. Should a future application require it, a specific trigger or ignition pattern could then be programmed in the microcontroller.

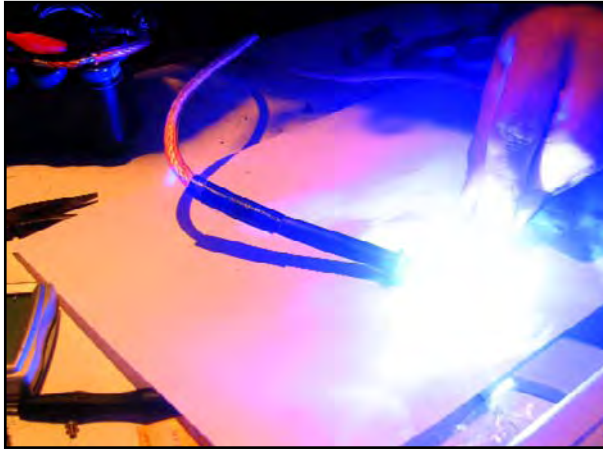
There is also a 5-volt power supply included in the circuit, for the sole benefit of the microcontroller. The output voltage is quite well filtered and has some buffer capacitors to rely on, because the other parts of the circuit generate quite a few current and voltage surges. The biggest is a peak of more than one hundred amps while welding.



The MOSFETs. We had no need for blown up PCBs, so we built the prototype on top of the capacitors 'in the air'.



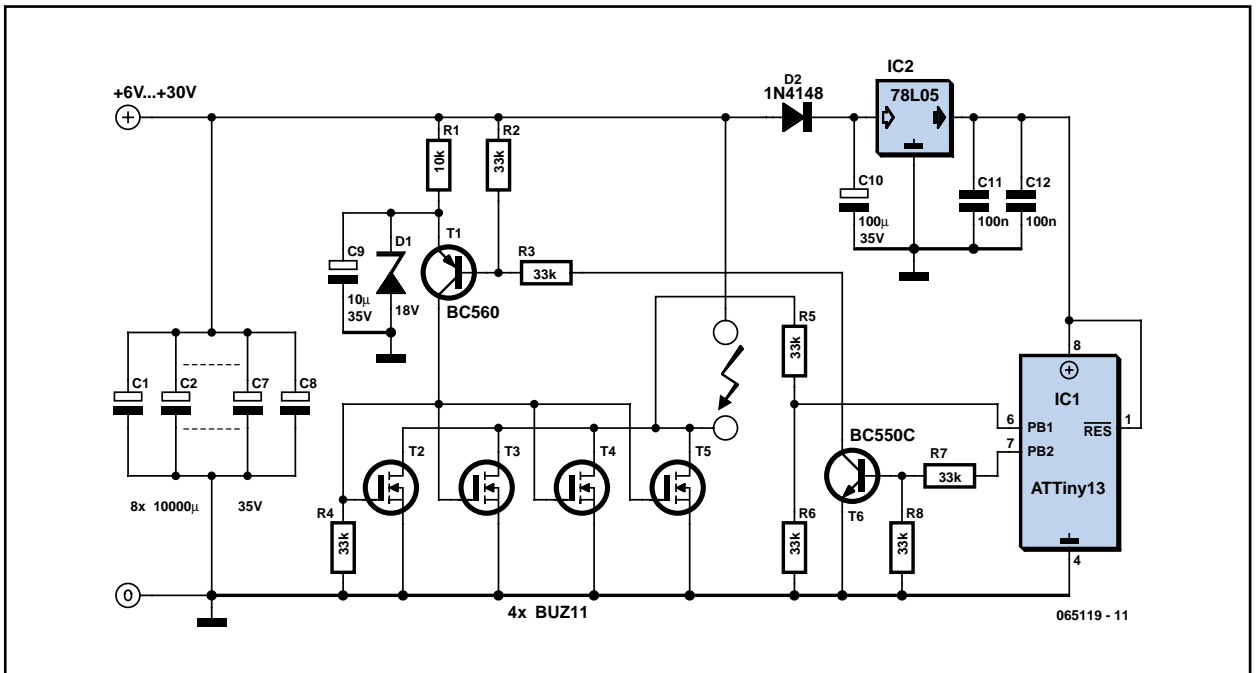
Here is the transistor driving stage (bottom left), the 5-V power supply (top right) and the microcontroller (on wires) mounted with it.



The first test: drawing sparks! It appears that the capacitor array can get rid of its power fast. Be aware of small pieces of metal shooting away.



How do we use this to join two batteries to each other? First the items we need for this: the batteries and a little strip of metal for the 'solder tag' (a piece from a tin can or such works well).



It helps to tin the metal well where it will be joined to the battery. Solder melts easier than the strip of metal or the metal end of the battery.



Attach the tag to one welding electrode and gently push it against the battery. Then push the other electrode firmly against the metal next to the tag and brace yourself for the flash.

Notes

The current that will flow through the weld depends on four things: the power supply voltage, the total capacitance of the capacitor array, the internal resistance of the capacitors and the resistance lurking in other parts of the circuit. The voltage is easily controlled. By using a transformer with a different turns ratio, or in the case of a lab PSU, by twirling the voltage knob, the welding current can be adjusted in a simple manner.

The resistance in the current path needs to be as low as is possible. That is why it is important to make the connections in the path electrode-capacitors-MOSFETs-electrode with as thick a wire as is practicable. To keep the total internal resistance of the capacitor array low, it is better to connect multiple capacitors in parallel instead of just one single large one. Low-ESR electrolytics are ideal for this application, but ordinary capacitors are much cheaper and also work well.

For the welding electrodes we used a pair of old, sturdy multimeter probes, but a thick piece of wire will do as well.



If all is well, the strip of metal is now firmly attached to the battery.

About the author:

Jeroen Domburg is a student at the Saxion Technical University in Enschede, the Netherlands. Jeroen is an enthusiastic hobbyist, with interests in microcontrollers, electronics and computers.

In this column he displays his personal handiwork, modifications and other interesting circuits, which do not necessarily have to be useful. In most cases they are not likely to win a beauty contest and safety is generally taken with a grain of salt. But that doesn't concern the author at all. As long as the circuit does what it was intended for then all is well. You have been warned!

The source code for the microcontroller can be downloaded free of charge from the publisher's or the author's website.

Warning

Although the relatively low power of the capacitor welder makes it safer than a 'normal' welder, it is still very wise to take note of a few safety rules:

- Make sure that while building the circuit the capacitors are connected up with the correct polarity.
- Wear eye protection when welding. Even though it may not happen very often that small pieces of metal fly around, it will be very painful if debris gets into your eye.
- Discharge the circuit after use. This will at least avoid a sudden fright if the electrodes touch each other while you're putting the circuit away.

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Web links

[1] www.elektor.com

[2] sprite.student.utwente.nl/~jeroen/projects/capwelder/



The second weld is done the same way.



And in the end, the two batteries are firmly connected to each other.