1 Background

Welding machines are useful tools for joining metal stock. Most welding machines use some subset of high voltage and high current to melt and join the materials being welded. TIG and MIG welding, for example use high voltages to ignite an arc between an electrode and the workpiece, and then deliver high current to heat the workpiece and join the materials. Spot welding does away with the high voltage arc, instead relying on the relatively high junction resistance between the parts in contact for heat generation. In addition, spot welders generally produce only a short spike of current, heating up and welding the two pieces at the spot where the electrodes touch (hence the name "spot welder"). One common way to make a spot welder for low power welding applications is to charge up a high-value capacitor or capacitor bank to a low voltage, and then short the capacitor[s] through the workpieces.

A Capacitor-Discharge (CD) spot welder has the potential to allow hobbyists to gain some of the advantages of welding without being exposed to most of the risks. The voltage at any point is well within a normal safe voltage range (typically between 1 V and 16 V), and the maximum energy delivered to the part or anything that gets in the way is limited by the capacitor bank. This makes long arcs impossible for any significant period of time, and removes much of the danger of damaging the parts or hurting anyone nearby. Peak currents are on the order of 150A, but pulse length is short\(^1\) and the current falls off exponentially after the initial turn-on.

CD spot welders are ideal for connecting thin sheets of sheet metal to each other or to thicker stock. Hobbyists have used DIY welders of a design similar to the one proposed in order to attach contacts to batteries or battery packs, or make low-to-moderate strength welded joints in thin sheet metal.\(^2\) \(^3\)

2 Hardware Description

The input power for this system comes from a wall outlet, and is converted from 120 VAC to a more appropriate voltage (on the order of 16 VAC). This AC waveform is converted to a smooth DC waveform by a bridge rectifier and a parallel capacitor, creating an approximately constant voltage for the buck converter and the associated control circuits for the later stages of the welder.

The buck converter acts as a current limiting charging circuit for the capacitor. Input from a current sense resistor in series between the buck output and the capacitor is used to determine the current being used to charge the capacitor. This information will be used to implement a voltage feedback controller that is also current limited to less than 1A. In addition, there is a power control knob that allows the user to indicate the maximum energy that they want to store in the capacitor, which affects the output voltage. The buck converter will regulate the duty cycle to remain at the appropriate voltage for that energy storage level. If the capacitor voltage is less than the desired voltage, the output pulse control will be disabled.

The capacitor is connected to a high current MOSFET, and this switch is connected to the output electrodes of the device. A foot switch will be used to trigger the pulse - the length of this pulse is variable and also controllable by the user. In addition, the buck converter is disabled slightly before the pulse begins.

\(^1\)Capacitor voltage falls to ten percent of initial voltage after less than 0.5 seconds, with estimated capacitor \(ESR = 100m\text{Ohms}, C = 2F, L = 50\text{uH}\). Modeled as series RLC circuit, and ignoring junction resistance at the weld point.

\(^2\)E.g. http://ledhacks.com/power/battery_tab_welder.htm

\(^3\)Also http://ultrakeet.com.au/index.php?id=article&amp;name=cdWelder
Figure 1: Block diagram of capacitor-discharge spot welder.
and turned back on slightly after the capacitor finishes discharging. This helps prevent the short circuit current from damaging the buck converter transistors.

The output connection consists of two segments of 8 gauge automotive copper wire, connected at the end to two copper electrodes ground to a point. Each electrode is mounted in an insulating delrin rod, and the top of these delrin rods are the only accessible parts of the project.

The workpieces and electrodes will be enclosed inside a wood and polycarbonate box to prevent any harm from arcs or metal splatter. The capacitor will also be enclosed within a separate box, in case of a catastrophic failure.

As a safety feature, there is also an additional capacitor discharge channel composed of a MOSFET and a power resistor. This channel has a toggle switch and allows a user to safely discharge any excess energy in the capacitor without having to use the welder.

3 Project Scope

3.1 Modest Risk

- Protective box for capacitor and welding area.
- Rectifier and filter circuit with less than 5\% voltage ripple.
- Buck converter with current limited operation.
- Controllable capacitor voltage.
- SCR as semiconductor switch for discharging capacitor (full discharge).
- Shutdown capacitor discharge channel.
- Controls on base station, electrodes are simple insulated copper rods.

3.2 More Risk

- MOSFET as semiconductor switch for discharging capacitor.
- Controllable pulse length for varying energy release to workpieces (enabled by MOSFET switch).
- Double pulse drive - smaller initial pulse “softens” the workpiece before full energy discharge.
- Automatic contact sensing - only trigger pulse if electrodes are actually electrically connected.

3.3 High Risk

- Power system completely off of a couple of AA batteries. This is in fact feasible for a small number of welds (40), as the capacitor stores only 256 J at full charge. It would make the rectifier and filter unnecessary, but would require a boost converter and corresponding self-start.
- Entire system integrated into a pack for the capacitors and control circuits, which - along with a hand-held electrode unit - would make it fully portable.
- Change controls to allow controlling voltage and total energy (pulse length would be a function of voltage and desired energy).
- Repetitive firing to allow for cutting thin sheet.
4 Specialized Components

4.1 Electrical Components

- High-capacity 20+ volt rated capacitor (spec. for 2 F “car audio capacitor”). Ideally has a low ESR, but with enough parasitic inductance to help limit the surge current spike.
- High current, low voltage MOSFET rated for 200A continuous operation.
- 120VAC to 16VAC transformer.
- High-value electrolytic capacitor for rectifier.

4.2 Physical Components

- 8-gauge insulated stranded copper wire.
- Copper rod for electrodes.
- Delrin insulating rods.
- Components for protective case for capacitor and work area.

5 Timetable

5.1 Week 1 (Nov 21st)
- Build protective box for capacitor and work area.
- Design buck converter and feedback.

5.2 Week 2 (Nov 28th)
- Build buck converter.
- Test buck control circuitry using lab power supply.
- Build AC to DC conversion segment.

5.3 Week 3 (Dec 5th)
- Test capacitor discharge at low voltages through resistor.
- Debug system integration problems.
- Use buck converter to charge capacitor.

5.4 Week 4 (Dec 12th)
- Test welding thin steel stock.
- Continue building and debugging.