LEBT Magnetic Lens Power Supply
Summary Tech Note
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Overview

This tech note combines three tech notes, adds some new information, and summarizes the evolution of this power supply.

We need to consider a capacitive discharge design for two current levels - a high current model, where only one is required, and a small current model, where six or more are required. Let's start with the large unit.

- Max current 3,000 A
- Min current = 30% of max current = 900A
- Max usable pulse width = 1 msec
- Max total pulse width = 15 msec
- Flatness during usable pulse width = 1%
- Inductance = 1.13 mHy
- Resistance = 30 mOhm

From this, we can determine we need a half sine wave with a base 15 msec wide. The maximum repetition rate is 5 Hz, and the pulse amplitude can vary between 10% and 100%. This last requirement means we can't recover energy to charge the capacitor for the next pulse. To do so would pre-charge the capacitor to a value higher than we want.

The Resonantly Charged Circuit

This circuit is shown in Figure 1. It turns out that it's really not practical, as the charging inductor is way too big. We'll have a fix for that a little further along in this note. But, this circuit shows the timing and the basic waveforms needed to get the job done.

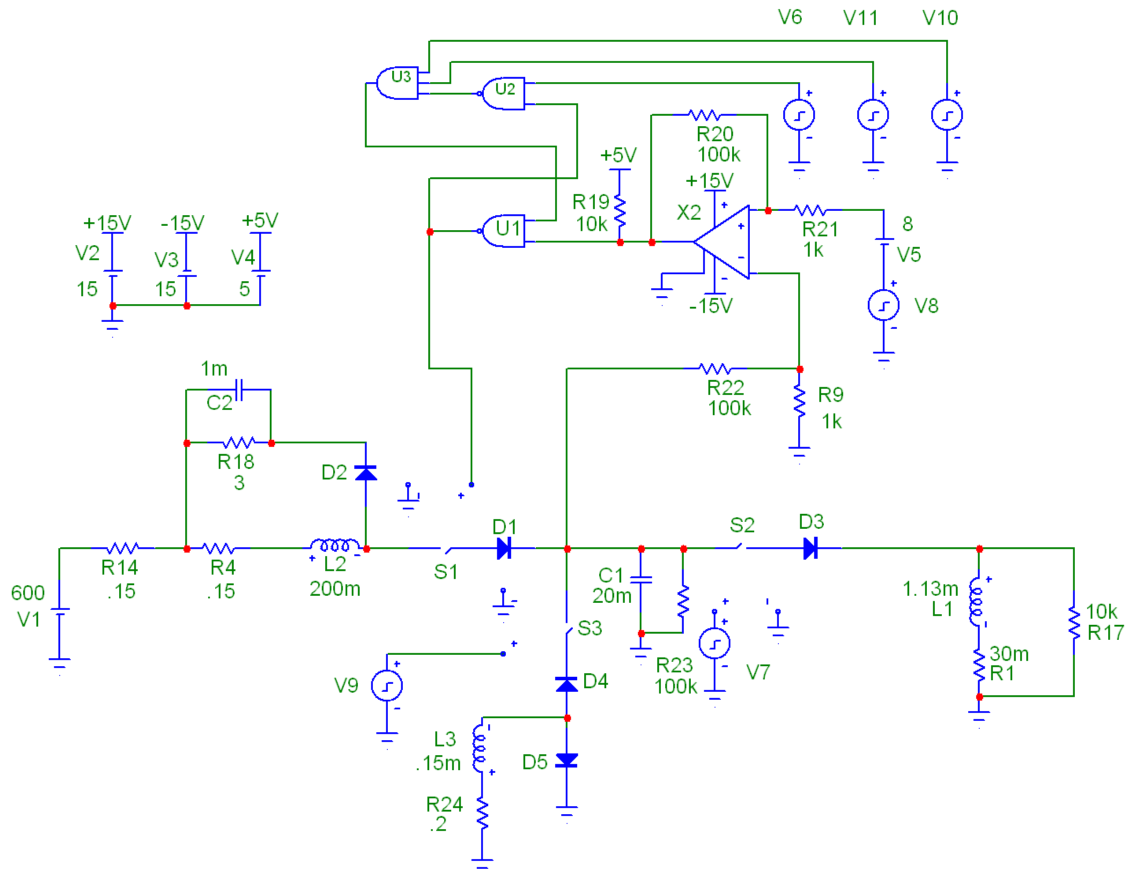


Figure 1. New Circuit

The recovery network consists of L3, R24, D5, and a simulated SCR formed by D4 and S3. L3 = 0.15mHy and R = 0.2 Ohms limit the current to about 2,000A, but discharge capacitor C1 in about 15 msec. D5 makes sure that C1 does not go positive.

Optimizing the circuit further, L2 is increased to 200 mHy and the charging supply V1 is decreased to 600V.

For this first example, four 3,000 Amp pulses will be shown in Figure 2.

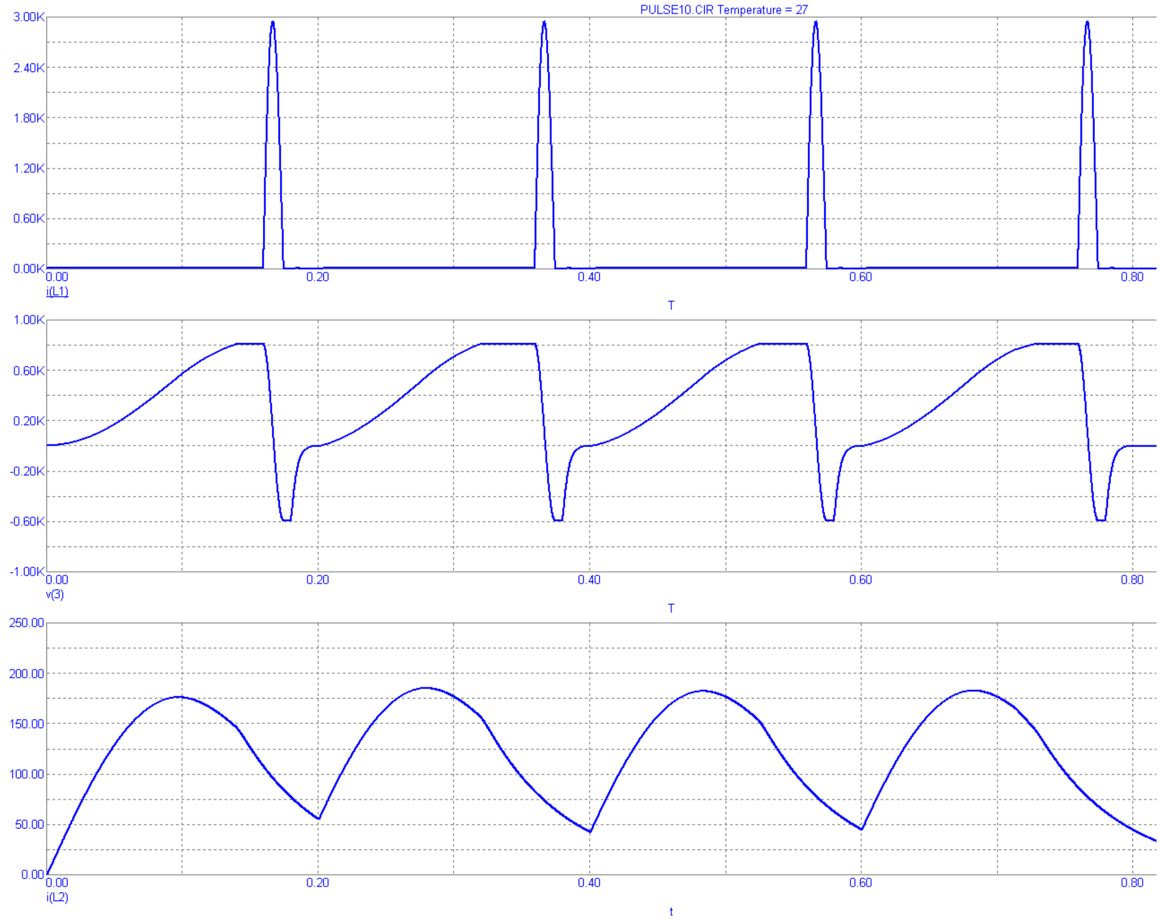


Figure 2. Optimized Waveforms

The top waveform in Figure 1 is the load current, the middle waveform is the voltage on C1, and the bottom waveform is the current in the charging choke.

The peak current is now less than 200 Amps. With half the current that the circuit would have without the recovery network, the stored energy is reduced by four. As we increased the inductance from 150 mHy to 200 mHy, we only improve by a factor of three.

It can be noted that the first charging cycle takes longer than the other three. This is because the snubber network of R18 and C2 do not discharge the charging inductor completely, and that current helps the charging cycle.

<u>Operational Timing</u>

The simulation also had U3, V10, and V11 added. This will give the operational cycle shown in Figure 3.

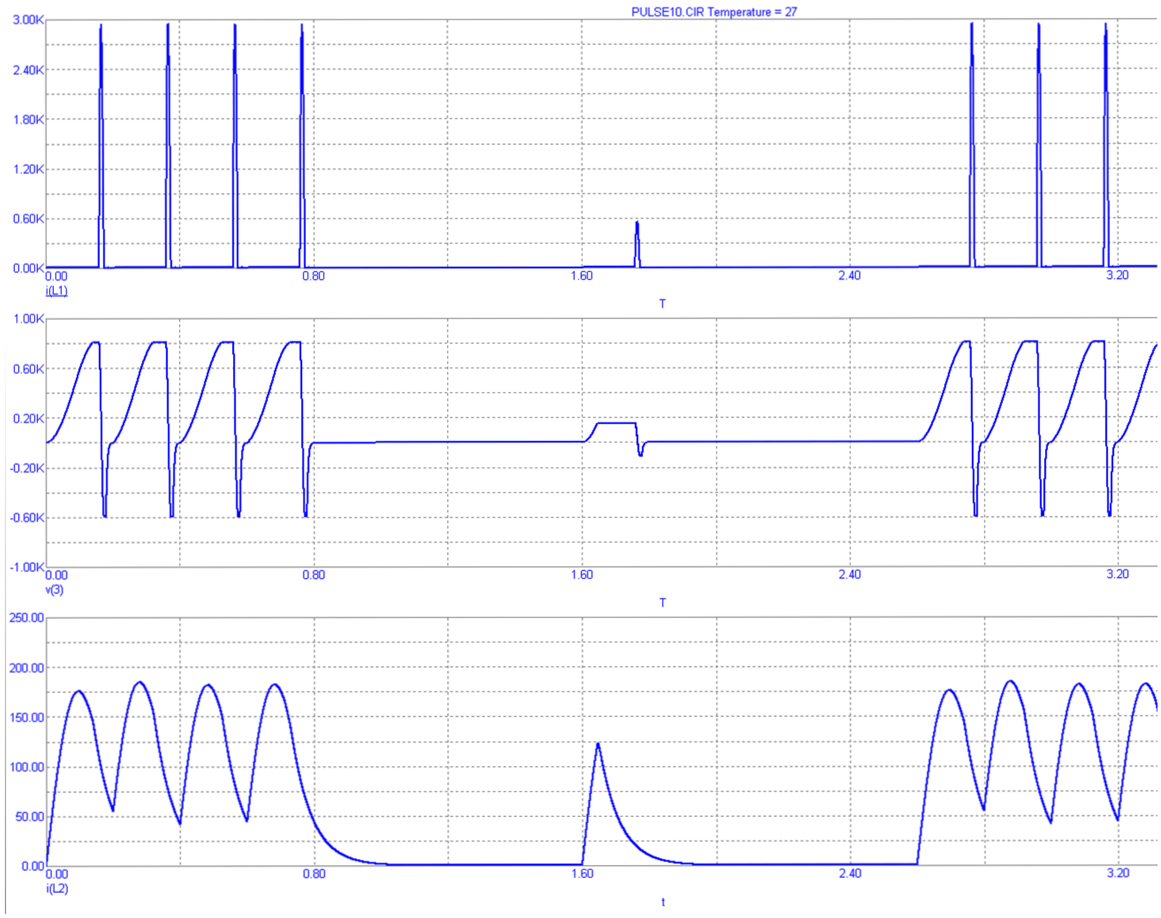


Figure 3. Operational Cycle

The isolated pulse does not have to be the value of 600A that I made it. It could be the full 3,000A. But, it can go as low as 600A, which is 20% of the peak.

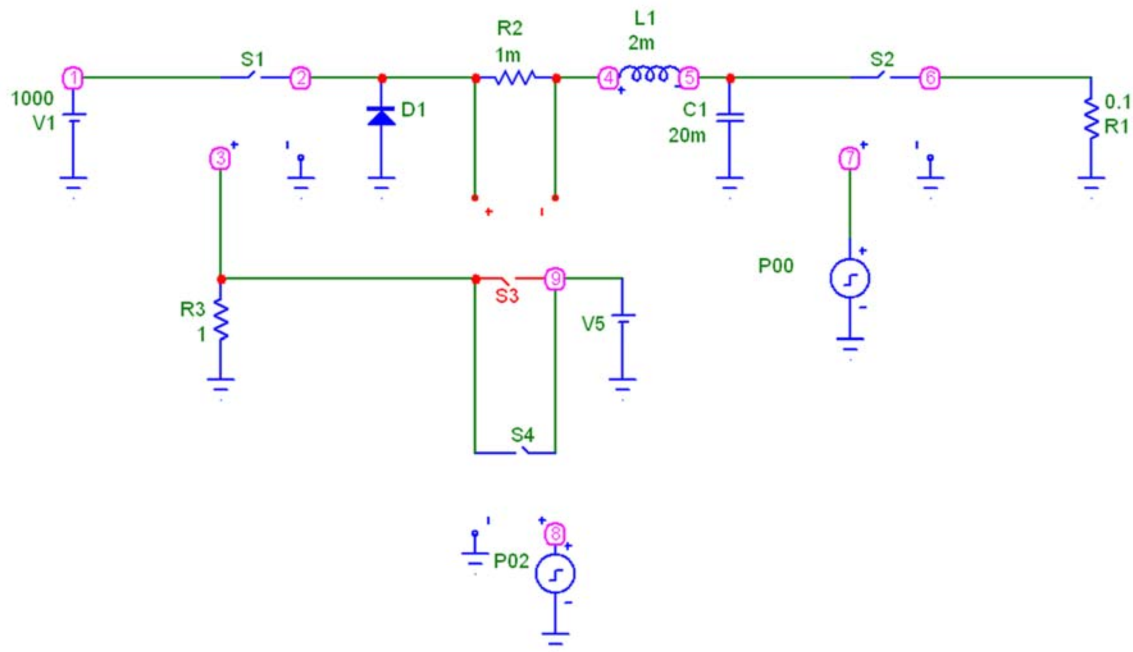
A Better Charging Circuit

The capacitive discharge circuit previously described uses a 150 mHy choke to smooth out the charging current to the discharge capacitor. This is much too big.

A buck front end will accomplish the same function, and it will reduce the peak line current as well. In this example the inductor is reduced from 150 mHy to 2 mHy, making it a bit more practical. Of course it means we'll need to add a power semiconductor (IGBT) and some electronics.

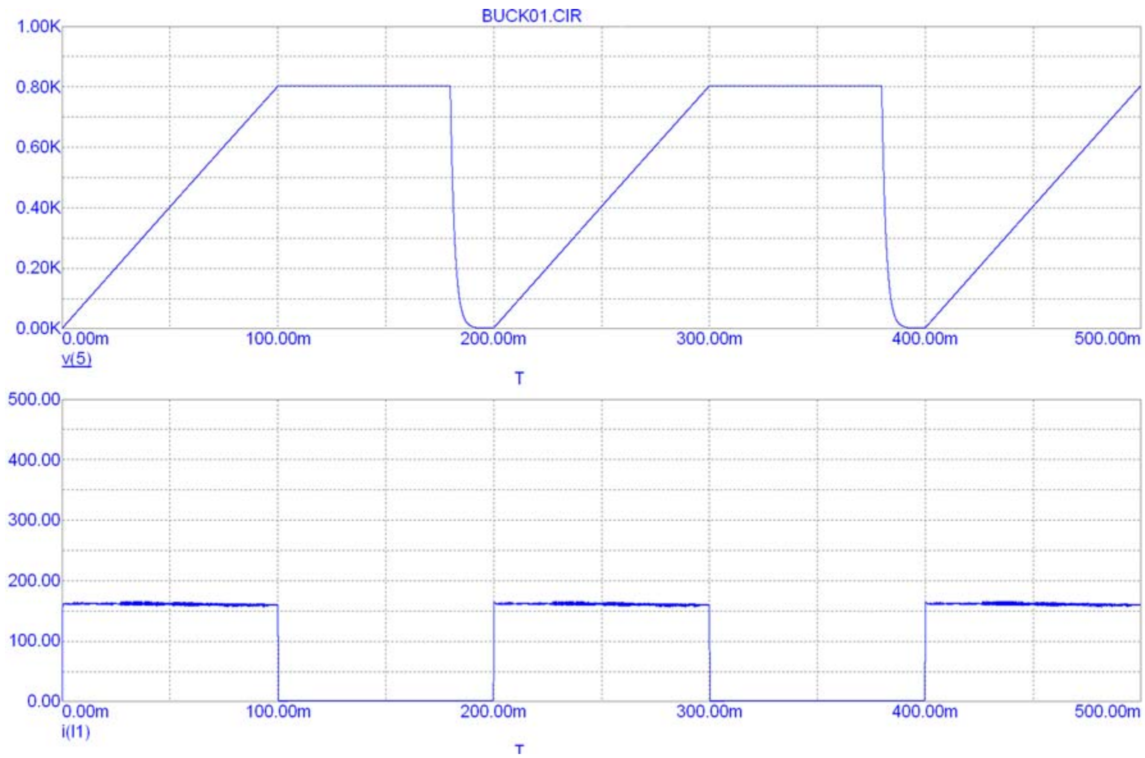
The Buck Front End

We need to charge a 20 mF capacitor to 800V. The last simulation told us that. The diagram below shows a MicroCap 6 simulation of the buck front end. For simplicity, I just discharge the capacitor at the end of the cycle with a resistor.



In this design we use a 2 mHy choke. The buck regulating switch, S1, limits the current to about 160 Amps. When the switch is closed, the current rises in L1 to some value, say Imax. With the switch open, current is supplied through the free wheeling diode, D1. When the current falls a lower value, say Imin, we close S1 again. This results in triangular current waveform in L1 with an average value of 160 Amps, and a peak to peak ripple of Imax - Imin. This ripple is smoothed by the capacitor. The maximum current supplied by the voltage source, V1, is Imax.

Simulation Waveforms



The top waveform shows the voltage on the capacitance, and the bottom waveform is the current through the 20 mHy inductor. The supply current is a chopped up version of the inductor current as the inductor current alternately comes from the source and the free wheeling diode.

Voltage Regulation

In this simple simulation, I regulate the voltage on the capacitor by shutting the switch off. With this method, the rest of the stored energy of the inductor continues into the capacitor. We might well need a stop charge circuit here, as we did with the previous design for regulation precision.

The Low Current Model

The requirements of the smaller model, four use on drift tube quadrupoles, is not as well defined. Until measurements are made, we're going with 450A peak, and the same 1.13 MHy inductance. We want the same wave shape (half sine, 15 msec on base) as before. The voltages will then scale. Vpk = 800 * (450/3000) = 120 V.