

This series/parallel charge pump is a kind of DC-DC-converter that does not depend on inefficient inductors.

Basic idea

Capacitor cluster 1 is configured in a parallel configuration with an energy source. Then capacitor cluster 1 is configured in a series configuration with the energy source and both elements are configured in a parallel configuration with capacitor cluster 2. Then the roles of capacitor clusters 1 and 2 are swapped.

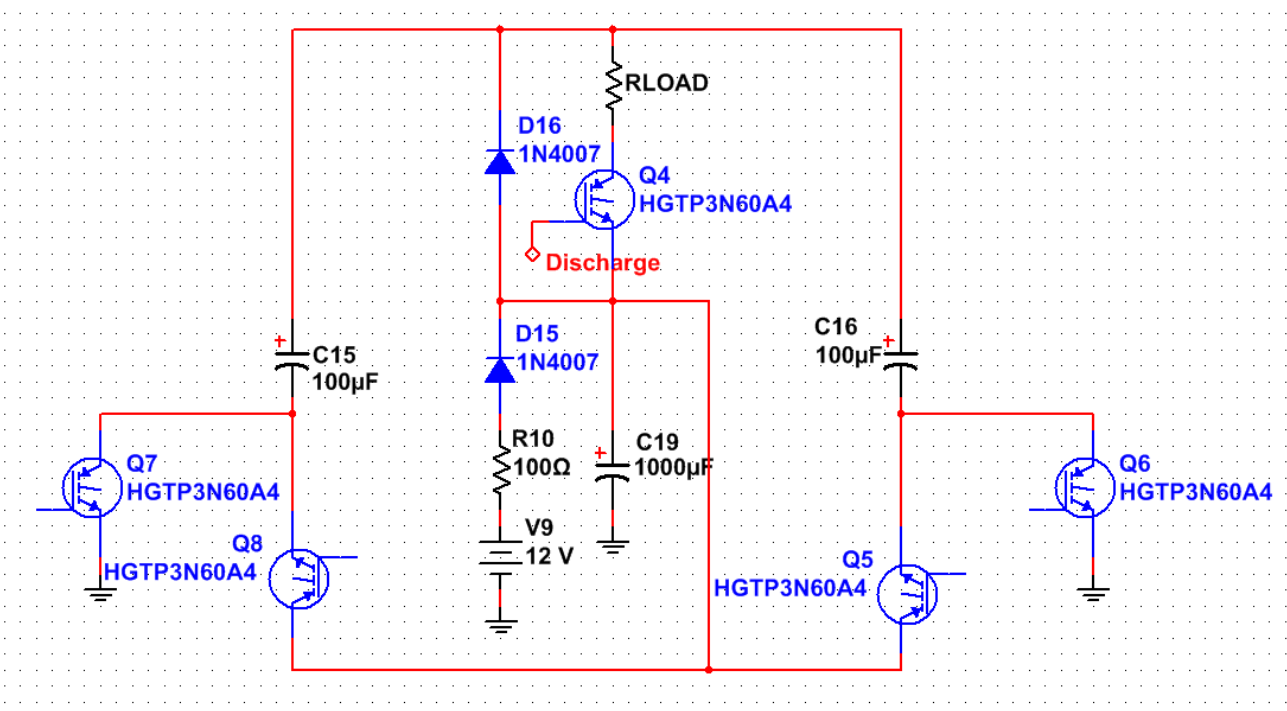
During each iteration, the voltage across the receiving capacitor cluster increases. After a number of iterations both capacitor clusters are discharged to a recovery capacitor with significantly larger capacitance than the sum of the capacitance of the two capacitor clusters. This will reduce the voltage in the circuit. The circuit states are:

- Parallel – Serial, No discharge
- Serial – Parallel, No discharge
- ...
- Parallel – Serial, No discharge
- Serial – Parallel, No discharge
- Parallel – Parallel, Discharge
- ...

The energy source is a 12V laboratory power supply in parallel configuration with the recovery capacitor. The power supply is current limited at 500mA.

A 100 ohm resistor (R10) in series with the energy source limits current during testing. RLOAD is 100 ohm when testing.

Each of the 5 IGBT gates are connected to an Arduino microcontroller output port through an IGBT gate drive IC and a pre-amplifier. Each IGBT gate drive IC is powered by an isolated DC-DC-converter.



Desired operation

In parallel/serial configuration, Q7=ON, Q8=OFF, Q5=ON, Q6=OFF, Q4=OFF. In serial/parallel configuration, Q7=OFF, Q8=ON, Q5=OFF, Q6=ON, Q4=OFF. In parallel/parallel/discharge configuration, Q7=ON, Q8=OFF, Q5=OFF, Q6=ON, Q4=ON.

When Q4=ON, at discharge to C19, the circuit capacitance is expanded by the availability of C19 in parallel with C15 and C16. This lowers the circuit voltage according to $E=\frac{1}{2}CV^2$. Electrons are accelerated through the load conductor.

For the two parallel circuits, C15 or C16 is charged from C19/V9. If C19 has sufficient energy left over from the previous discharge (i.e. the voltage across the terminals of C19 is larger than the voltage across V9/R10/D15), then part of this energy is re-used during the next charge cycles, thereby increasing the efficiency of the device.

For the two series circuits, we have V9/C19 in series with C15 (C16) charging C16 (C15) respectively. C19 should source as much energy as possible and V9 should only source enough energy to compensate for the energy losses in the circuit.

Observations/problems

The circuit draws 170mA and ~270mA of current (at very low frequency, 10 serial/parallel configuration swaps per discharge, 100ms charge time per serial/parallel configuration swap, 1000ms discharge time, 1000ms after discharge wait time). Almost all of the power is consumed by the 5 isolating DC-DC converters for the 5 IGBT gate drive ICs (each drawing ~30mA when idle).

The voltage across each 100uF capacitor (C15, C16) never gets above 17.2V. Since energy is pumped into the circuit in bursts, it seems like much energy is wasted in the circuit rather than charging C15 and C16 to a high voltage. I expected and wanted the voltage across each of C15 and C16 to increase more rapidly. Comments are welcome.