

Capacitor Problem

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Background: Vicor's suggested application circuit calls for a 100 uF inrush current capacitor (Fig. 1). The requirements for this capacitor is to have a voltage rating >300V and be rated for temperatures down to -55 degC.

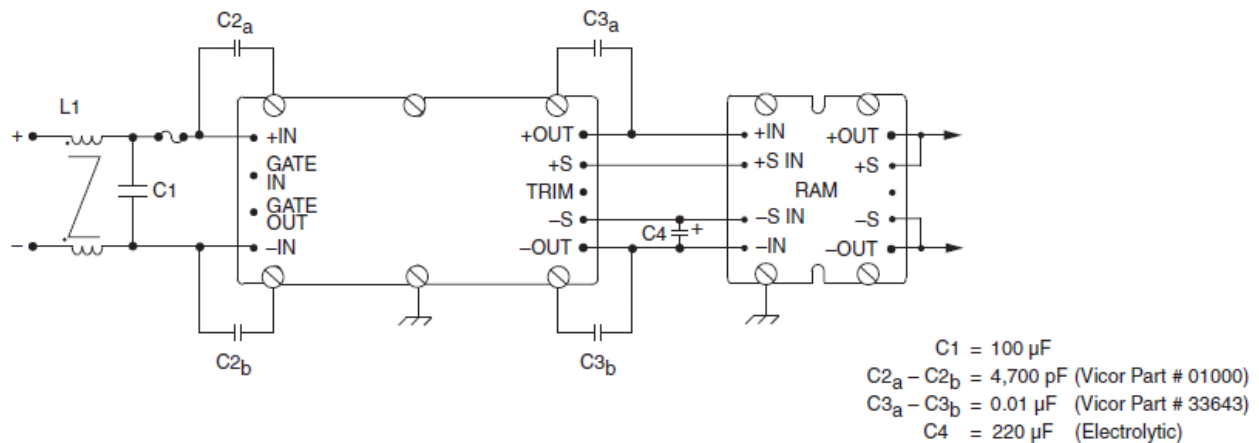


Figure 1. The suggested schematic for the VI-JXX Vicor DC-DC converter line.

Problem: Difficult to find capacitors with a high enough capacitance and high enough voltage rating.

Potential solutions:

Option 1: Put capacitors in parallel to obtain combined capacitance.

Pro: The capacitances just add and don't need to worry about voltage balancing across capacitors.

Con: Digikey doesn't have any electrolytic with a voltage rating above 200 V therefore need to resort to ceramics or film capacitors. Maximum capacitance found is 30 uF in thin film, but costs \$24 each. \$75 in capacitors seems ridiculous for this solution

Option 2: Combine electrolytic in parallel and in series. Use bleed resistors that are much lower than the DC resistance of the capacitor to balance the voltages across each capacitor.

Pro: Would require four 100 uF electrolytic capacitors, two caps in series which are in parallel with a second set. Cost would be about \$25.

Con: Would need to balance the voltage across each capacitor set in parallel. This corresponds to a extra power dissipation in the bleed resistors.

Recommended Solution:

I propose to go with the series capacitor option using bleed resistors.

Questions to answer: How much power will be lost and what resistances should I choose? To answer these questions, we refer to Figure 2.

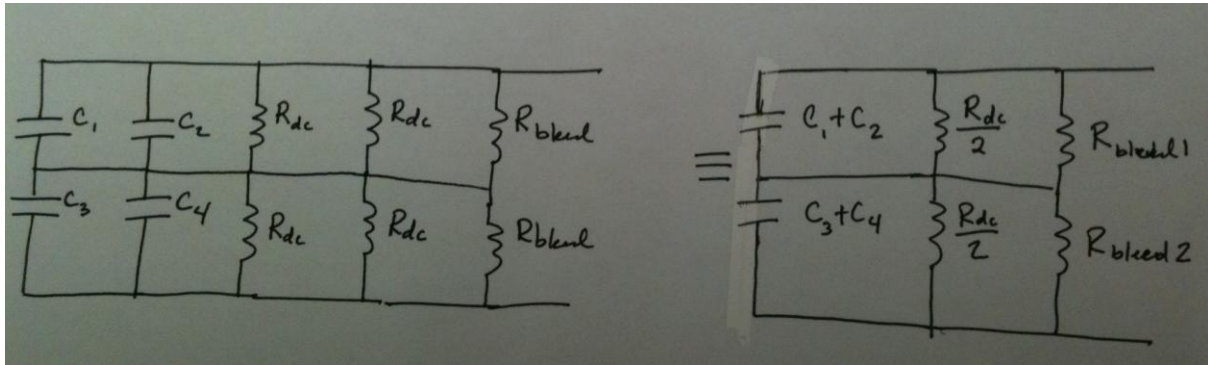


Figure 2. Equivalent circuits for capacitors in series and parallel.

Calculating the DC leakage resistance

The leakage current at the voltage rating of the electrolytic capacitor as specified is 20 uA. So I used ohm's law to calculate the approximate leakage dc resistance,

$$R_{dc} = \frac{V}{I} = \frac{200 \text{ V}}{20 \text{ uA}} = 10 \text{ M}\Omega.$$

Since there are two capacitors in parallel and in series, the equivalent dc leakage resistance for the parallel capacitors is 5 MΩ.

Calculating the bleed resistance and power dissipated

To ensure that the bleed resistors are the dominating resistance when in parallel with the DC leakage resistance of each capacitor, I choose the bleed resistor to be 10 times smaller than the DC leakage resistance. So $R_{bleed} = 500 \text{ k}\Omega$.

The power dissipated by bleed resistors is calculated as the following

$$P = 2 \times \frac{V^2}{R} = \frac{200 \text{ V}^2}{500 \text{ k}\Omega} = 0.16 \text{ W}$$

Calculating the worst case voltage offsets across capacitors

Since the dc leakage current is highly variable, I want to ensure that the bleed resistor values are chosen so that the voltage across each capacitor is insensitive to changes in the dc resistance of each capacitor. The worst case assumes that the dc resistance of one of the capacitors remains constant while the dc resistance of the other capacitor goes to zero. Assuming this situation, the voltage across the bottom capacitor is calculated using the voltage divider equation,

Case 1: $V_{in}=300V$,

$$V_{out} = V_{in} \frac{R_{bottom}}{R_{top} + R_{bottom}} = 300V \frac{500 \text{ k}\Omega}{500 \text{ k}\Omega + (500 \text{ k}\Omega || 5 \text{ M}\Omega)} = 157.1V.$$

Case 2: $V_{in}=325V$,

$$V_{out} = V_{in} \frac{R_{bottom}}{R_{top} + R_{bottom}} = 325V \frac{500 \text{ k}\Omega}{500 \text{ k}\Omega + (500 \text{ k}\Omega || 5 \text{ M}\Omega)} = 170.2V.$$

Both of these cases the maximum voltage across a set of capacitors in parallel is well below the 200V rating.