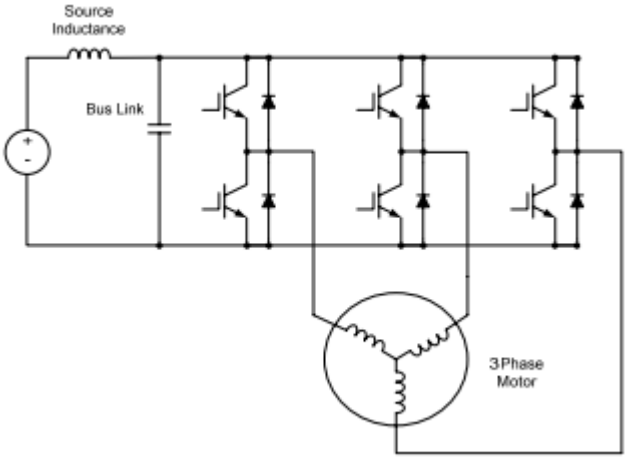
80kW Inverter DC-link capacitors

Introduction

One of the most important part of an electric vehicle (EV) is the drivetrain. Every element of the drivetrain needs to be specifically designed to match each other.

When it comes to motor controllers, an important role in the system plays DC Link Capacitor Bank. It is



used to decouple the effect of DC voltage source bus inductance.

In cheap inverters electrolytic capacitors are often used. Unfortunately due to high ESR we need to use many of them in parallel to reach needed parameters. This fact makes the capacitor bank oversized and overweight. Inverter manufacturers also need to make capacitor banks overparameterized, adapting them to many types of motors and applications.

Calculations

In our solution we decided to redesign the original DC Link Capacitor Bank to reduce mass and optimize it for our motor.

Given data:
Vbus = 567V -> Max source voltage
f = 16kHz -> Inverter switching frequency
L = 183uH -> Motor inductance

At first we need to calculate Ripple Current for one of switched motor phases using following formula:

$$\Delta I_{0.5t} = 0.25 * V_{bus} / (f * L)$$

In our design Ripple Current has a value of ~48.41A. When selecting capacitors we need to make sure that the capacitor bank has Irms greater than this value.

Another important factor is a Ripple Voltage. We wanted Ripple Voltage to have a value less than 1% of Vbus voltage. Using following formula we calculated minimal capacitance of DC Link

Capacitor bank:

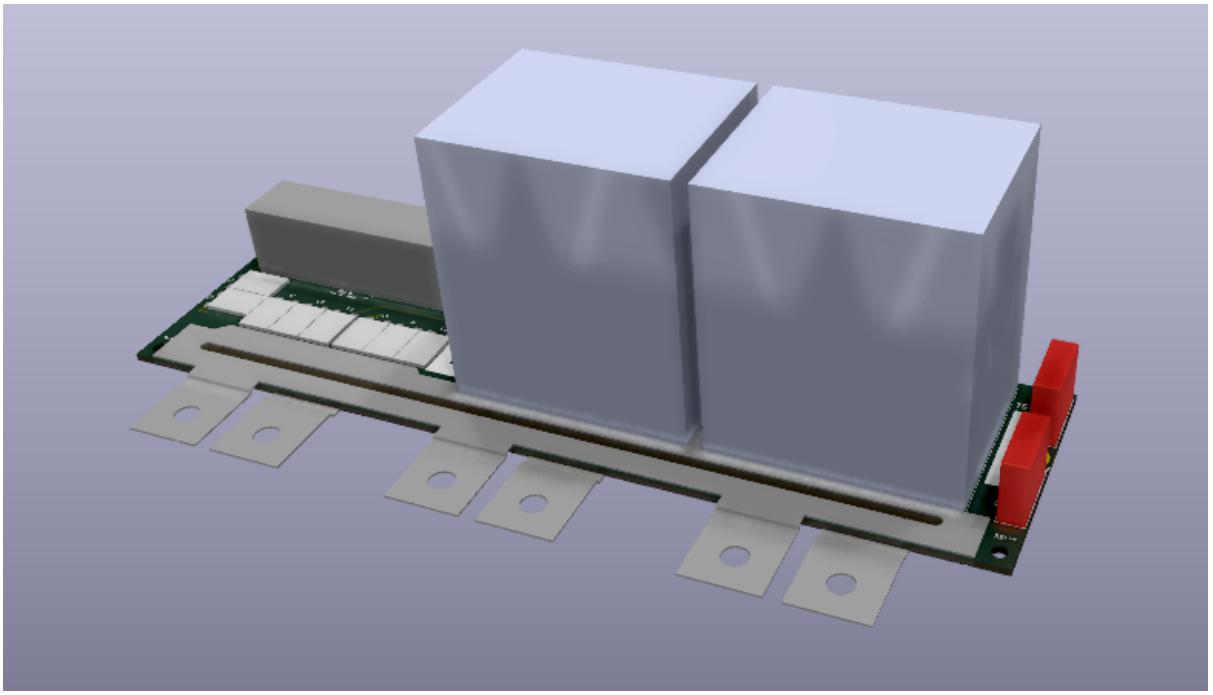
$$C = V_{bus} / (32 * L * \Delta V_{0.5t} * f^2)$$

In our application the minimum capacitance of the bank has a value of ~66,7uF. We want our Capacitor bank to have a capacitance greater than this value.

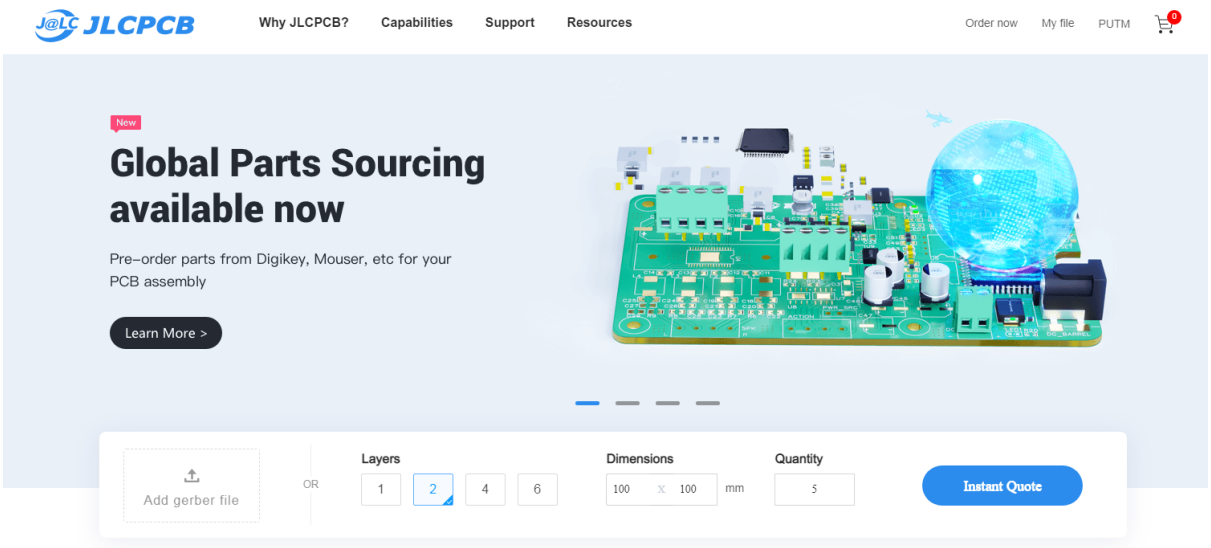
As a result of calculations we decided to use two C4AQIEW6100A3BJ KEMET capacitors with 100uF capacity and 40,6A I_{RMS} each. It makes our DC Link Capacitor Bank small, light and a bit overparameterized for safety reasons.

Application

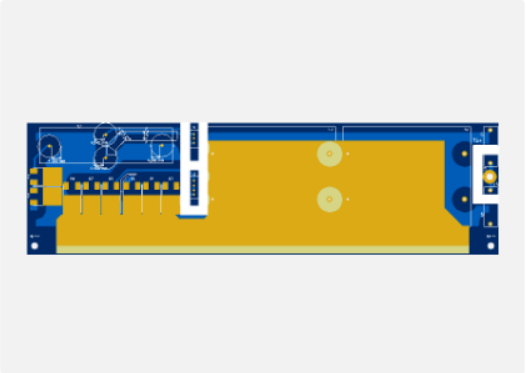
To ensure high precision and consistent spacing between high voltage elements we decided to use a PCB as a template for all components. Some PCB manufacturers, like **JLCPCB** give the ability to order high quality PCBs for low price. To make connection to IGBT transistors even better we soldered laser-cutted copper terminals. They are making resistance between terminals and capacitors much much lower.

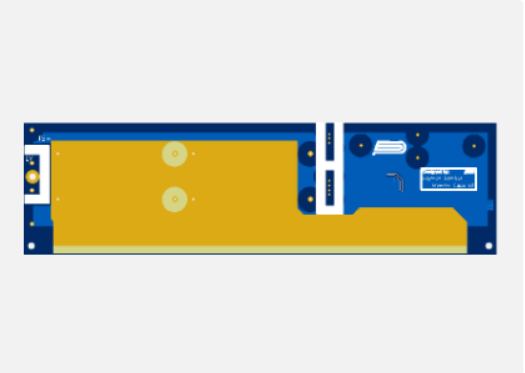


Manufacturing

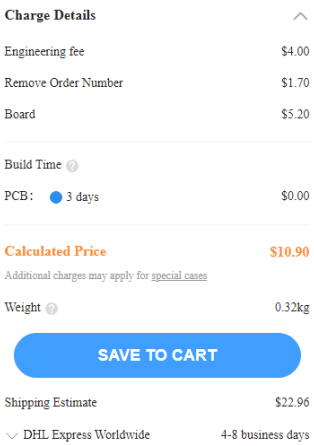


Manufacturing is done by [JLCPCB] you just need to drag your Gerber file .zip into the *'Add gerber file'* slot and press *'Instant quote'*(useful links below). All further steps are pretty self explanatory - if you are not sure about something you can click on a question mark to learn more.





We choose 1oz, 1.6mm thick FR-4 PCB, with a Blue solder mask(the base settings are a 'good to go' in most cases).



As you can see, the boards are really affordable. The above price is not for a single PCB, but for five(minimal quantity) which makes it even a greater deal. Standard build time is 1-2 days, in our case due to non-standard solder mask color it is extended to 3 days.

If you need help with PCB manufacturing, here are some useful links:

- **How to create Gerber files in KiCad (https://support.jlcpcb.com/article/149-how-to-generate-gerber-and-drill-files-in-kicad)**
- **JLCPCB** (https://jlcpcb.com/HAR)