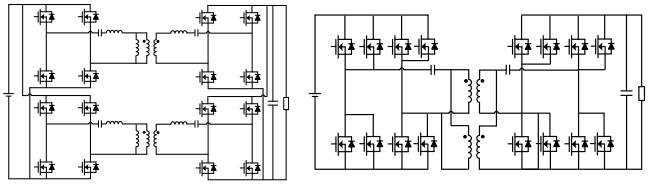
A 22 kW Onboard Charger (OBC) with an Integrated Planar Inductor and Transformer

Resonant converters are used extensively for voltage regulation and isolation purposes in the ongoing development of OBCs for electric vehicles (EV). In [1], the resonant inductance is integrated into the transformer with an unbalanced winding structure and verified in an 11 kW OBC. However, for higher power operation parallel windings must be introduced, and the current distribution needs to be analyzed. In [2], a current sharing method for PCB transformers is introduced with extra full-bridge circuits added to the resonant tank. In [3], [4], efficient current sharing is realized by arranging the position of the parallel windings. All the above references need extra effort to have efficient current sharing. In this paper, the current distribution between the parallel windings of both sides of the device is analyzed. Finally, a transformer with an integrated resonant inductor and efficient current sharing without extra effort is designed and implemented in a 22 kW OBC. The two 22 kW OBC design candidates are shown in Fig. 1. Fig. 1(a) uses two parallel 11 kW modules. Fig. 1(b) uses one 22 kW module with parallel devices. From the gain curve shown in Fig. 2, the Q value for Fig. 1(a) is only half of that of Fig. 1(b), so its switching frequency in the worst case is 18% higher than Fig. 1(b). Fig. 1(b) is chosen for further analysis. A 22 kW hardware prototype is built. The devices are NTC020N120SC1 with PCB-based packages. For the transformer, Lk = 4.7 µH, Lm = 33 µH, matching the simulation and calculations. Perfect current sharing is realized as the currents are almost overlapping with each other. With the proposed integrated planar transformer, the peak efficiency could reach 98.4% and the power density could reach 10.3 kW/L.

Table I - Converter Parameters

Parameters	Value	Parameters	Value
P_{rated}	22 kW	$n_1 = n_2$	1
f_o	250 kHz	$L_{m1} = L_{m2}$	66 µH
V_{in}	750-850 V	$L_{r1} = L_{r2}$	8.8 µH
V_{out}	600-850 V	nV_{out}/ V_{in}	0.8~1



(a) (b)

Fig. 1. (a) Two parallel 11 kW modules (b) One 22 kW module

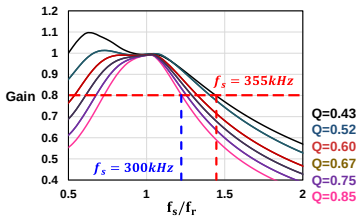


Fig. 2. Gain curve for the CLLC resonant tank

Commented [EN1]: Consider using the names of the references if this abstract is going to be displayed by itself without the index.