How to Exceed 98% Efficiency in a Compact 48 V to 6 V, 900 W LLC Resonant Converter Using eGaN® FETs

EFFICIENT POWER CONVERSION

Motivation

The rapid expansion of the computing and telecommunication market is demanding an ever more compact, efficient and high power density solution for intermediate bus converters. The LLC resonant converter is a remarkable candidate to provide a high power density and high efficiency solution. eGaN FETs with their ultra-low on-resistance and parasitic capacitances, benefit LLC resonant converters by significant loss reduction that is challenging when using Si MOSFETs. A 48 V to 6 V, 900 W, 1 MHz LLC DC to DC transformer (DCX) converter employing eGaN FETs such as EPC2053 and **EPC2023** is demonstrated, yielding a peak efficiency of 98.1% with a specific power of 48 W/cm^2 (308 W/in^2) and power density of 69 W/cm^3 (1133 W/in^3) .

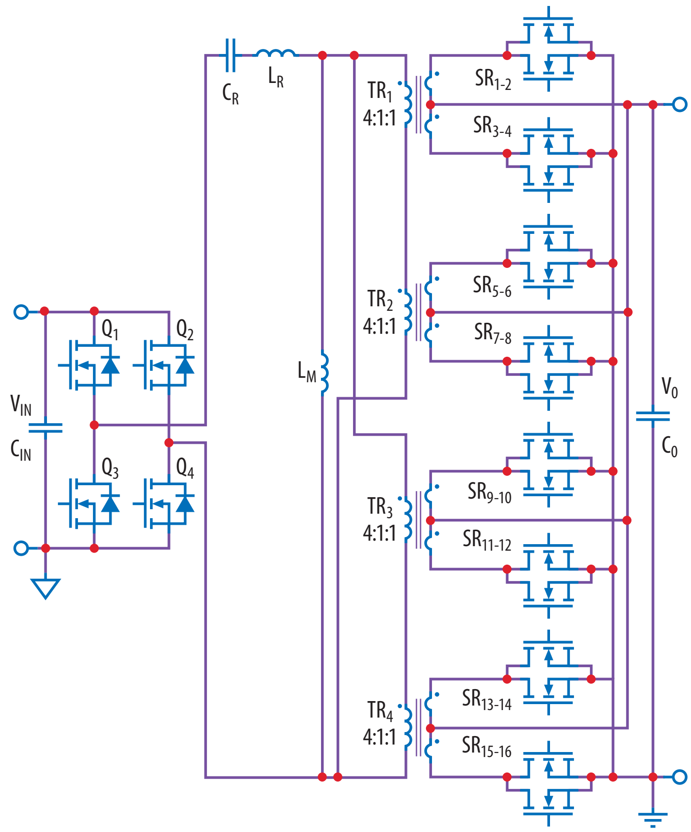


Figure 1: Power architecture schematic of the 900 W, 48 V to 6 V LLC converter

High performance LLC DCX

The power architecture schematic of an 8:1 conversion ratio LLC operated as a DCX is shown in figure 1 and comprises a full-bridge primary and center-tapped secondary with synchronous rectifier. The transformer is composed of a 2x2 matrix with each unit having a conversion ratio of 4:1:1 that ensures low winding loss, low interconnect inductance between the transformer and the synchronous rectifiers, and low profile. All switches can operate in zero voltage switching (ZVS), allowing for high-frequency operation with high efficiency across nearly the entire load power range. Parallel connected synchronous rectifier devices are used to further reduce conduction loss.

High performance eGaN FETs for the LLC converter

eGaN FETs are well suited for LLC converters due to their low gate charge (Q_G) with 5 V gate operation combined that yields very low gate power consumption, low on-resistance, and low output capacitance charge (Q_{OSS}). The lower output charge benefits LLC converters by two mechanisms: 1) lower energy required for the LLC resonant tank to achieve ZVS and, 2) increased effective duty cycle. EPC2053 and **EPC2023**, shown in figure 2, were selected for the primary and secondary-side power devices respectively. EPC2053 is rated at 100 V with 4 mΩ on-resistance, and is capable of carrying a continuous current of 32 A. **EPC2023** is rated at 30 V with 1.45 mΩ on-resistance, and is capable of carrying a continuous current of 90 A. Both eGaN FETs can operate at up to 150 °C junction temperature.

EPC2053

EPC2023

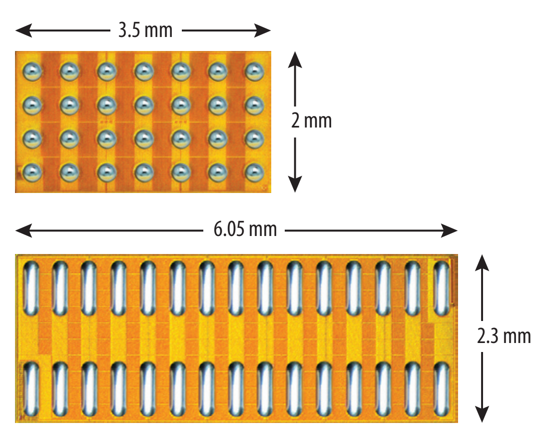


Figure 2: Photo of the bump side of EPC2053 (top) and EPC2023 (bottom)

Experimental validation

An 8:1 ratio, 900 W capable LLC converter configured as a DCX, was built using EPC2053 for the primary-side switches (Q1-Q4) and EPC2023 for the secondary-side synchronous rectifiers (SR1-SR16, with SR9-SR16 on the bottom side of the board) shown in figure 3. The board included an embedded 2x2 matrix transformer on the 14-layer board with a four-pole UI core.

The measured switching waveforms, at full power and 48 V input are shown in figure 4. Perfect ZVS was achieved as evident by the absence of overshoot and ringing on both primary and secondary side devices.

The efficiency as function of output power for 40 V, 48 V, and 60 V input voltages is plotted in figure 5. It demonstrates that the LLC converter has a peak efficiency of 98.1% and 98% at 60 V and 48 V input respectively, and maintains high efficiency over a wide operating range.

The thermal performance of the LLC converter operating at 54 V input, 900 W load, and with an air flow of 400 LFM, is shown in figure 6. The excellent thermal performance achieved shows that all major component temperatures are far below their maximum operating limits.

Conclusions

A 48 V to 6 V LLC intermediate bus converter built using eGaN FETs capable of delivering 900 W had a peak experimental efficiency of 98%. The low gate capacitance, low output charge and low on-resistance of the eGaN FETs were key to achieving this at a power density exceeding 1100 W/in^3.

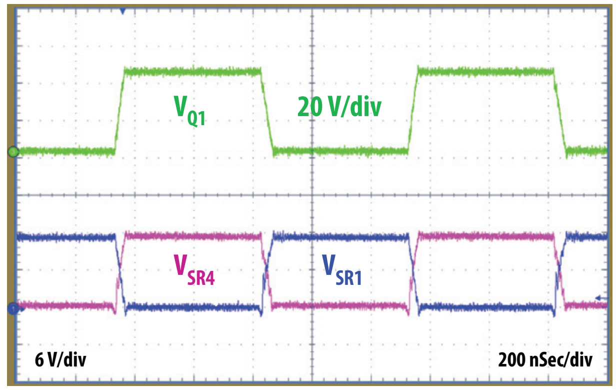


Figure 4: Switching waveforms at 48 V input voltage and 900 W load condition

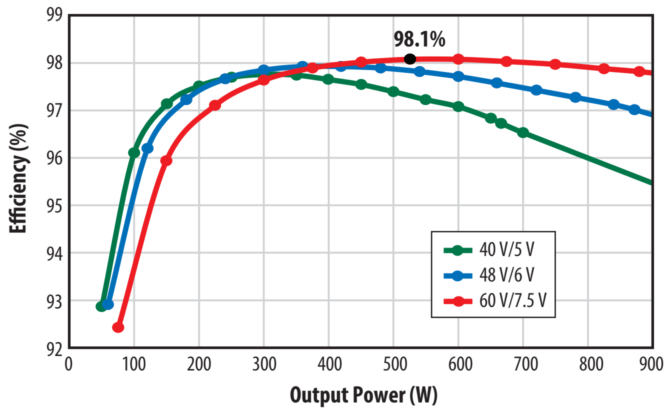
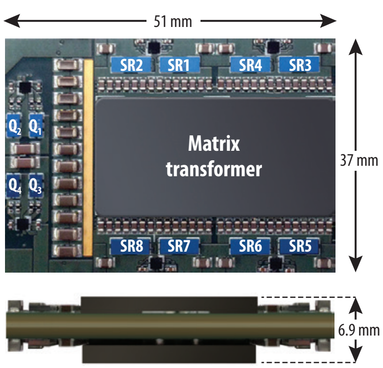


Figure 5: Power efficiency as function of output power at 40 V, 48 V, and 60 V input voltage



Q_1– Q_4	EPC2053
SR1– SR16	EPC2023
V_{IN}	48 V – (40-60 V)
V_O	6 V – (5-7.5 V)
F_S	1 MHz
L_M	2.2 µH
C_R	16 • 0.22 µF = 3.52 µF
PCB Layers	14

Figure 3: An 8:1 ratio, 900 W, LLC DCX using EPC2053 and EPC2023

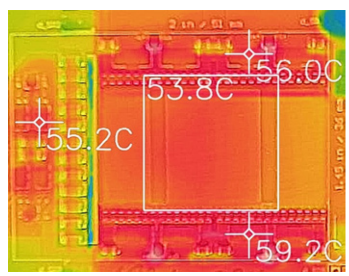


Figure 6: Thermal image of the LLC converter operating at 54 V input and 900 W load

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