

eGaN[®] FET based Wireless Energy Transfer Topology

Performance Comparisons

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4. Electronic Power Converters

Preferred Presentation Form: Oral

Abstract

eGaN FETs have previously been demonstrated in a classic voltage mode class D wireless energy transfer system [1,2] that had a peak efficiency over 70% and provide a 4% higher in total efficiency than a comparable MOSFET version. In this article eGaN FETs are again employed and compared in highly resonant wireless energy transfer where various topologies, such as the current mode class D, single ended class E, and a novel high efficiency voltage mode class D. The comparisons will be based on efficiency and sensitivity to load and coil coupling variations. Each of the topologies will be experimentally tested based on using the same source and device coil set with the same device rectifier. The experimental units will operate with loosely coupled coils at 6.78 MHz (ISM band) and deliver between 15 W and 30 W (depending on topology). The design of the amplifiers will look at ways that the device parameters, such as C_{OSS} can be absorbed into the coil or matching network.

Synopsis

Wireless energy transfer applications are gaining popularity for mobile device charging solutions that demand low profile solutions and high robustness to changes in operating conditions such as coil spacing and alignment. The superior characteristics of eGaN FETs, such as low C_{OSS} , low C_{ISS} , low parasitic inductances, and small size have made them ideal for use in these systems. In this paper three classic switch mode based RF amplifiers will be compared for optimal operation efficiency as well as load variation efficiency. The topologies that will be compared are classic voltage mode class D, the current mode class D, single ended class E and a new, high efficiency voltage mode class D.

The source coil, device coil, device rectifier is in each case the same circuit, which allows for a direct comparison of each of the topologies based on its merits. The load, rectifier, coil set with device side matching is shown in figure 1. This circuit is simplified to a single impedance

parameter for design purposes also shown in figure 1 as Z_{load} . This allows all the designs to be compared simply by the differences required for operation.

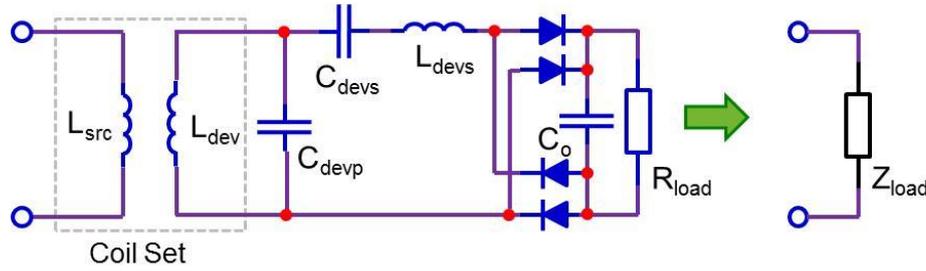


Figure 1: Schematic representation of the source coil, device coil, device rectifier and load (left) converged into a single impedance for the analysis

The topologies that will be compared are shown in figure 2 (a) through (d) together with the ideal operating waveforms.

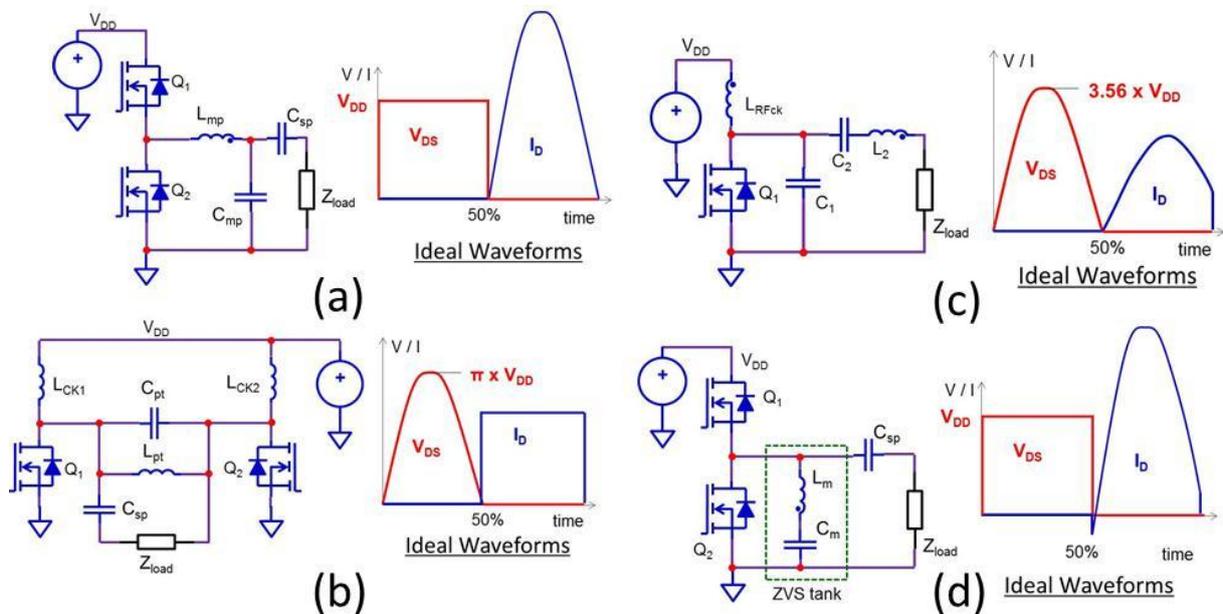


Figure 2: Wireless energy transfer topologies (a) Voltage Mode Class D, (b) Current Mode Class D, (c) Class E, (d) ZVS Voltage Mode Class D

In the final paper the important design equations will be provided for each of the designs and how the fixed load impedance impacts the operating conditions for each converter and hence the choice of suitable device. The paper will also introduce a new voltage mode class D design that separates the two key functions of the circuit that lead to an improvement in overall efficiency. This new feature centers on the addition of a series tank circuit that is used to absorb the COSS of the devices allowing the coil to be tuned to resonance at the operating frequency unlike the classic design that must operate above resonance.

Many wireless energy transfer solutions also require complex controls that ensure optimal

operation for all load conditions. Load conditions are affected by coupling and DC load resistance changes. In the final paper the effect of these changes will be shown for each of the designs and the impact on the power losses of the devices. From this analysis it can be shown the optimal operating point alone is not a sufficient indicator of performance and high efficiency.

Experimental Verification

Figure 3 shows one of the eGaN FET based class D wireless transfer systems that was built and tested. It operates with an input voltage of 3 V through 24 V and can deliver up to 15 W into the load.

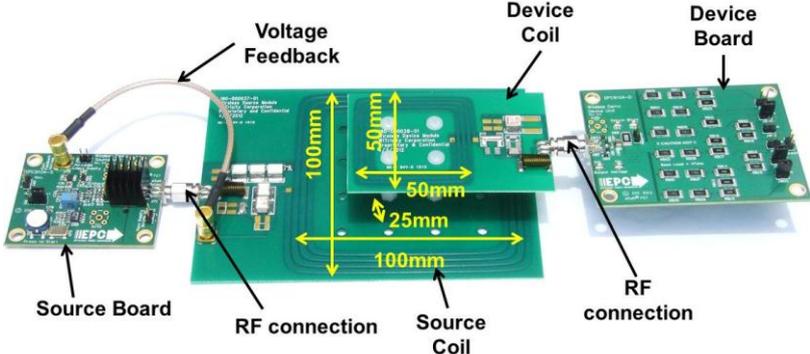


Figure 3: Classic Voltage Mode Class D Experimental Wireless energy transfer evaluation system

Similar systems were built and tested for the other topologies and will be presented in the final paper. Figure 4 shows the experimental efficiency results for two versions of the classic voltage mode class D systems and the class E. The final paper will present all of them.

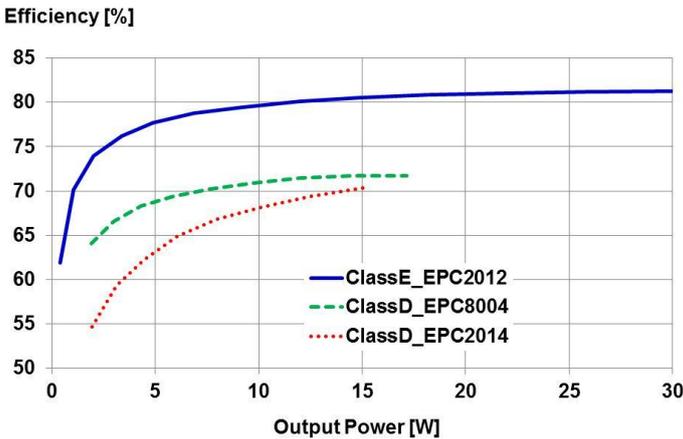


Figure 4: Experimental efficiency results for the Classic Voltage mode Class D Wireless energy transfer systems based on two different devices and compared to a similar Class E based system

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