

# Power Tips: How GaN Devices Boost Resonant Converter Efficiency



Wide-bandgap power devices such as gallium nitride (GaN) and silicon carbide (SiC) field effect transistors (FETs) have become commercially available in recent years. Compared with high-voltage ( $\geq 600\text{V}$ ) silicon FETs, GaN and SiC FETs generally have lower on-resistances ( $R_{ds(on)}$ ), lower output capacitances ( $C_{oss}$ ) and fewer/no reverse recovery charges ( $Q_{rr}$ ). Due to their lower switching losses, you can greatly increase the efficiency of a hard-switching converter with wide-bandgap power devices.

Applying GaN FETs to resonant converters improves efficiency by reducing magnetic losses. Let's take an inductor-inductor-capacitor series resonant converter (LLC-SRC), shown in Figure 1, as an example. An LLC-SRC uses the energy stored in the resonant inductor ( $L_r$ ) to discharge MOSFET output capacitors in the input switch network. If the output capacitor voltage discharges to zero before the MOSFET gate signal goes high, you can achieve zero turn-on loss.

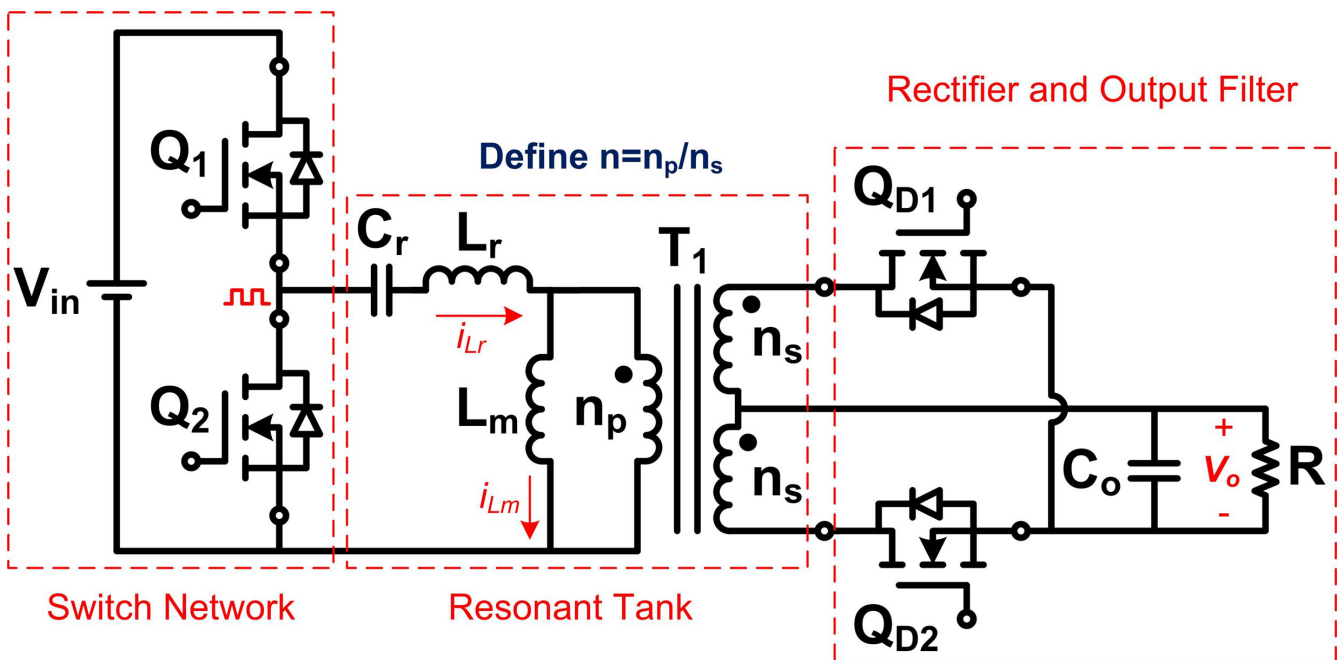


Figure 1. An Llc Src

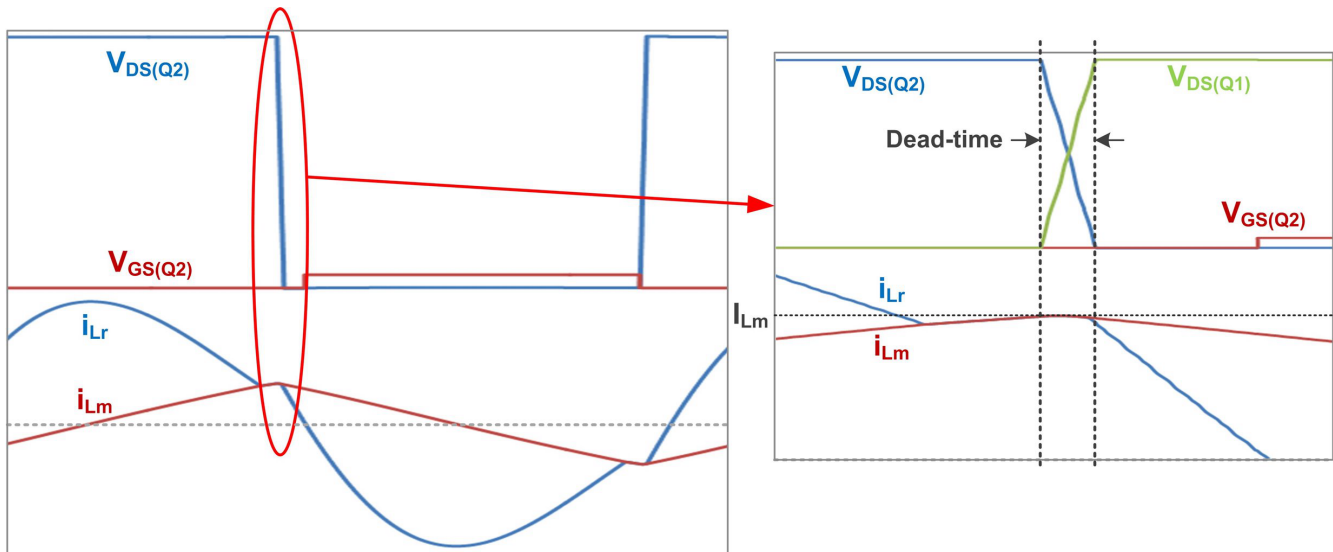
Figure 2 shows key waveforms of an LLC-SRC. During the MOSFET's switching transient,  $i_{Lr}$  equals the maximum current flow through  $L_m$ , expressed as Equation 1:

$$i_{Lr} \Big|_{\text{deadtime}} = I_{Lm} = \frac{nV_o}{4L_m f_{sw}} \quad (1)$$

The current  $I_{Lm}$  – assumed constant during dead time – discharges the  $C_{oss}$  of one MOSFET and charges the  $C_{oss}$  of another MOSFET. Assuming the  $C_{oss}$  of the two MOSFETs of the half bridge are the same and that you

can ignore the interwinding capacitance of the transformer, Equation 2 expresses the maximum inductance with which you can achieve zero turn-on losses:

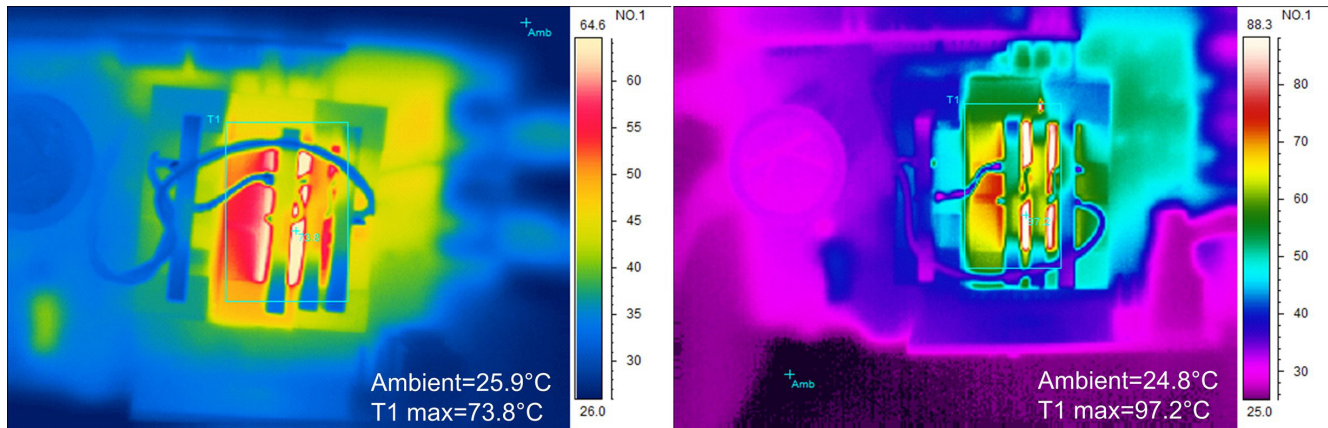
$$L_{m,max} < \frac{n^2 V_o^2}{32 C_{oss} V_{in}^2 f_{sw}^2} \quad (2)$$



**Figure 2. LLC-SRC Switching Waveforms**

Now let's presume you're choosing between a GaN FET and silicon FET on the same  $400V_{IN}$  to  $12V_{OUT}$  conversion specification using an LLC-SRC. TI's [LMG3410](#) GaN device has a  $70m\Omega$  on-resistance and a  $95pF$  output capacitance (energy related). One  $70m\Omega$  silicon FET I found has a  $140pF$  output capacitance. If your selected turns ratio is  $n = 16$  and the target maximum switching frequency of the LLC-SRC is  $750kHz$ ,  $L_{m,max}$  will be  $134\mu H$  for TI's LMG3410 and  $91\mu H$  for the silicon FET with the  $140pF$  output capacitor. As the input switches, the air gap of the LLC-SRC transformer with the silicon FET will be wider than the transformer with the LMG3410 if you apply the same core. Because of the wider air gap, there will be more eddy current losses on the transformer wires.

[Figure 3](#) shows the thermal performance of the same LLC-SRC with different transformer air gaps under the same test conditions. As you can see, the wire losses on the transformer with the wider air gap are much higher than the one with the narrower air gap. Therefore, using GaN devices with lower  $C_{oss}$  can help reduce magnetic losses in resonant converters.



**Figure 3. LLC-SRC Transformer Thermal Performance at  $400\text{V}_{\text{IN}}$ ,  $12\text{V}/42\text{A}$  Output with  $L_m = 100\mu\text{H}$  (Narrower Air Gap) (a); and  $L_m = 70\mu\text{H}$  (Wider Air Gap) (b)**

While in this post I discussed a benefit of using GaN devices on resonant converters – lower output capacitance enabling fewer transformer losses – TI GaN devices such as the LMG3410 offer not only low  $R_{\text{ds(on)}}$  and  $C_{\text{oss}}$  but also incorporate several protections such as overcurrent and overtemperature protection. With all of these protections, converter reliability improves greatly.

In my next post, I will discuss power-supply reliability with TI GaN devices in more detail.

#### Additional Resources

- More detail information of TI GaN devices can be found in the following articles:
  - [Advancing power supply solutions through the promise of GaN](#)
  - [Optimizing GaN performance with an integrated driver](#)
  - [A comprehensive methodology to qualify the reliability of GaN products](#)
- If you are interested in using TI GaN devices in your power supply designs, take a look at the following reference Design
  - [400V – 12V/500W High-Frequency LLC Series Resonant Converter reference design \(PMP20289\)](#).
  - [GaN FET-Based CCM Totem-Pole Bridgeless PFC](#)

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