



## How Does GaN Impact Magnetic Component Selection?

### Introduction

The development of wide bandgap GaN field effect transistors (FETs) has created opportunities for switching power supplies that offer higher temperature ratings and greater power-density than those using traditional silicon FETs. The effectiveness and reliability of GaN technology has been well established over recent years at voltages up to about 650 V, and GaN adoption continues to grow. Higher power density with GaN particularly translates to reduced size and extended battery life in DC power applications.

For example, because GaN FETs have a wider bandgap than silicon FETs, they can operate efficiently in automotive applications that move from 12 V to 48 V or higher. Higher operating voltage translates to lower current for the same power output, dramatically reducing  $I^2 \times R$  conduction losses. Generally, GaN also has lower switching losses compared to both silicon and silicon carbide (SiC) for mid- and low-voltage applications, contributing to higher overall efficiency<sup>1</sup>.

Carefully choosing inductors and transformers is key to obtaining the promised benefits of high efficiency and power density in GaN-based DC-DC converters. While many inductors remain well suited for GaN applications, new off-the-shelf inductors are being introduced that offer new inductance ranges, new sizes, and better balancing of parameters for anticipated operation with GaN. These new inductor designs assure high reliability, low losses, and small solution size at the higher switching frequencies of GaN.

Higher switching frequencies enable lower inductance values for energy storage, for filtering out EMI, and for current waveform smoothing (reducing ripple current). Using lower inductance may enable a physically smaller inductor to handle higher current, thus improving power density. While higher frequency traditionally can be a cause of higher core and winding losses, proper materials selection and magnetics design in new inductors by experienced manufacturers can result in the lowest

inductor loss and more efficient overall circuit performance, even in a smaller size. At higher frequency, low magnetics loss and the low switching losses of GaN combine to create an efficient, high-power-density solution.

### Reference Design Example: A Non-isolated Dual-phase Buck Converter

Texas Instruments incorporates four GaN FETs in their PMP23392 Dual-Phase Buck Converter Reference Design for 48 V Automotive Applications<sup>2</sup>. This reference design utilizes two synchronous buck controllers switching at 300 kHz per phase to achieve a regulated 5 V, 30 A nominal (60 A pk) output. It uses spread-spectrum switching to reduce EMI, and Pulse Frequency Modulation (PFM) for light-load efficiency. This high power-density eval board achieves high efficiency at both full load and light loads due to high frequency switching of GaN FETs and PFM.

Table 1 illustrates the high efficiencies that can be achieved at both full and light loads in a small solution size by using Coilcraft high-current molded shielded power inductors. The GaN FET solution, that switches at 300 kHz using Coilcraft XAL1010 1.5  $\mu$ H power inductors (1130 mm<sup>3</sup> volume), achieves high efficiency while maintaining a physically compact design.

For the GaN and Silicon FETs switching at lower frequencies, a higher (2.2  $\mu$ H) inductance value is needed to limit the ripple current. The Coilcraft ZE2652-AE inductor has more than 2x the physical volume (2613 mm<sup>3</sup>) as the XAL1010 part, however, by utilizing this larger inductor, higher efficiency can be achieved at the lower 150 kHz and 250 kHz switching frequencies.

With two inductors being used for dual-phase operation, the total XAL1010 inductor volume is about 4.5x smaller than that of the slower switching frequency solutions, still achieving very respectable efficiency values – a significant improvement in power density.

Table 1. High Frequency Switching Efficiency of GaN vs Lower Frequency GaN and Si

48 Vin Efficiency Comparisons PMP23392 *							
FET	Inductor	Lnom uH	L x W x H mm	Inductor Volume mm <sup>3</sup>	Frequency kHz	Load Current A	Efficiency %
<b>Light Load (5A)</b>							
GaN	XAL1010-152ME	1.5	10.0 × 11.3 × 10.0	1130	300	5	85.8%
GaN	ZE2652-AE	2.2	13.4 × 15.0 × 13.0	2613	250	5	92.2%
GaN	ZE2652-AE	2.2	13.4 × 15.0 × 13.0	2613	150	5	92.2%
Si	ZE2652-AE	2.2	13.4 × 15.0 × 13.0	2613	150	5	90.8%
<b>20A Load</b>							
GaN	XAL1010-152ME	1.5	10.0 × 11.3 × 10.0	1130	300	20	91.0%
GaN	ZE2652-AE	2.2	13.4 × 15.0 × 13.0	2613	250	20	94.8%
GaN	ZE2652-AE	2.2	13.4 × 15.0 × 13.0	2613	150	20	94.6%
Si	ZE2652-AE	2.2	13.4 × 15.0 × 13.0	2613	150	20	92.3%
<b>Full Load (60A)</b>							
GaN	XAL1010-152ME	1.5	10.0 × 11.3 × 10.0	1130	300	60	92.0%
GaN	ZE2652-AE	2.2	13.4 × 15.0 × 13.0	2613	250	60	93.8%
GaN	ZE2652-AE	2.2	13.4 × 15.0 × 13.0	2613	150	60	94.4%
Si	ZE2652-AE	2.2	13.4 × 15.0 × 13.0	2613	150	60	93.6%

\* PMP23420 is the Si FET design equivalent of PMP23392

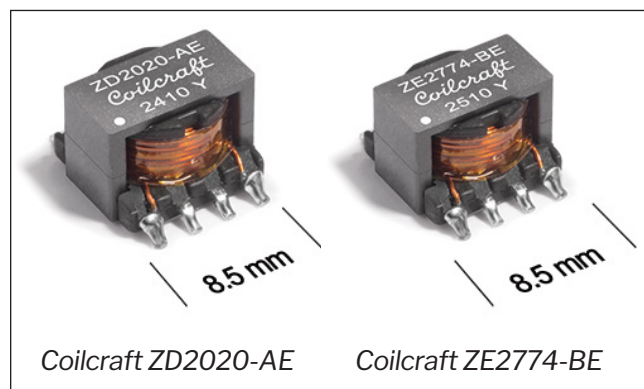
## Transformers for GaN – Isolated Gate Drive Bias Supplies

Like non-isolated designs, major improvements in power density can also be achieved in isolated bias supplies with buck, boost, push-pull, half-bridge, full-bridge, and LLC topologies using high-frequency GaN FETs and expert-designed transformers. These small transformers provide high electrical isolation between the high voltage switches and the control circuit. The small-size and higher power density benefits of GaN high-frequency switching are seen over a wide range of applications and power levels.

## GaN and SiC Optimized Transformers for 5 W Isobuck-boost Converter

One GaN example solution is STMicroelectronics STEVAL-6986YT2DL evaluation board (UM3496), which is a 5 W dual-isolated output synchronous isobuck-boost converter designed to fit a small SIP7 package<sup>3</sup>. Based on the ST automotive grade A698681 buck converter IC, the UM3496 is designed for isolated IGBT/SiC/GaN FET gate drive supplies and provides a compact solution for an isolated GaN gate drive supply for applications such as on-board chargers (OBC) for HEV/EV, electric traction systems, and industrial applications.

Coilcraft's ZD2020-AE is an isolated buck transformer optimized for the SiC FET switched STEVAL-6986YT-2DL eval board, providing +20 V and -5 V outputs, while the Coilcraft' ZE2774-BE transformer is optimized for the GaN FET switched solution, providing +6 V and -3 V outputs<sup>5,6</sup>. Both transformers operate at 250 kHz and provide 1.5 kV pri:sec isolation.



The ST evaluation board solution provides a 5 W dual-output isobuck-boost converter in a compact 0.77" x 0.3" x 0.49" (~ 0.113 cubic inch volume) SIP7 package size, demonstrating how high-frequency SiC- and GaN-switched isolated power supplies can be reduced to a small size vs traditional lower-frequency silicon FET constructions.

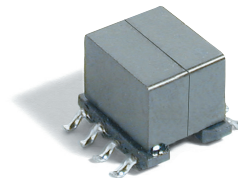
# HTX7045C

- 63% smaller footprint
- Only 5.3 mm tall



HTX7045C

vs.



Traditional Core and Bobbin

	<b>L<sub>nom</sub></b>	<b>Turns Ratio</b>	<b>Interwinding Capacitance</b>	<b>Dimensions L x W x H mm</b>	<b>Footprint</b>
<b>HTX7045C-753ARC</b>	<b>100 µH</b>	<b>1 : 1</b>	<b>0.90 pF</b>	<b>7.2 × 4.85 × 5.3 mm</b>	<b>35 mm<sup>2</sup></b>
Traditional core & bobbin	100 µH	1 : 1.67	2.5 pF	10 × 9.15 × 12 mm	95 mm <sup>2</sup>

Figure 1. Coilcraft HTX7045C – For Isolated Gate Driver Bias Supply

## Transformers for Isolated Gate Driver Bias Supplies using GaN FETs

Another example isolated circuit incorporates the Texas Instrument UCC25800-Q1 Ultra-low EMI Transformer Driver for Isolated Bias Supplies, switching at frequencies up to 1.2 MHz for GaN, IGBT and SiC gate transformer driver bias supplies. This transformer driver integrates the switching power stage, control, and protection circuits to simplify design. The design utilizes a very low parasitic pri:sec capacitance transformer and a soft-switching feature to enable an order of magnitude reduction in CM current injection, minimizing high-speed switching EMI.

Coilcraft HTX7045C LLC Half-Bridge Transformers are optimized for the UCC25800, making them ideal for isolated gate drive bias supplies<sup>7</sup>. Low interwinding capacitance (as low as 0.7 pF) makes these transformers particularly well-suited for use in isolated gate driver bias supplies employing the open-loop LLC topology to achieve ultra-low EMI noise and high CMTI (Common Mode Transient Immunity).

The chip-style construction and streamlined manufacturing process of the HTX7045C transformers results in a smaller, more cost-effective transformer solution vs traditional core and bobbin construction. Figure 1 demonstrates the dramatic reduction in footprint resulting from the HTX7045C construction vs traditional core and bobbin, and the GaN FET high switching frequency of the UCC25800 solution. This makes the HTX7045C especially beneficial for high-frequency switches including GaN, SiC and IGBT technologies.

Building on the proven HTX family chip style, Coilcraft has also developed the HTX8045C series. HTX8045C LLC half-bridge transformers have higher isolation voltage vs HTX7045C (5000 Vdc / 3535 Vrms, one minute) and lower interwinding capacitance (as low as 0.55 pF).

Both HTX7045C and HTX8045C series are AEC-Q200 qualified for automotive applications.

## Conclusion

Properly designed inductors and transformers are essential components for optimizing the use of wide band-gap devices like GaN FETs. A wide variety of off-the-shelf magnetics optimized for specific use cases are readily available for prototype and volume production requirements.

## References:

1. <https://www.globalsmt.net/advanced-packaging/examining-gan-and-sic-applications-in-evs/>  
*This is the link to the original article:*
2. Texas Instruments *PMP23392 Dual-phase buck converter reference design using GaN FETs for 48 V automotive applications*
3. STMicroelectronics *STEVAl-6986YT2DL SiP7 compatible isobuck-boost converter evaluation board UM3496*
4. *Find the optimal inductor for your high-frequency GaN switcher using Coilcraft's MagPro® Power Inductor Finder and Analyzer tool*
5. Coilcraft *ZD2020-AE Isolated buck transformer optimized for SiC FET switching*
6. Coilcraft *ZE2774-BE Isolated buck transformer optimized for GaN FET switching*
7. Coilcraft *HTX7045C LLC Half-Bridge Transformers*