Comparison of Silicon MOSFET vs GAN for 48V Input Intermediate Bus Conversion Based on Multiphase Buck Controllers

ABSTRACT:

This paper first reviews different solutions of 48Vin to 12V output DCDC conversion, seen in cloud computing and AI application. The implementation schematics and its measurement efficiency curves are compared. After recent success in Lidar and consumer electronics, GaN devices start to penetrate into 48V application space in different topologies. This paper shows the use case comparison of the silicon MOSFET vs GaN device based multiphase buck controller for its size and efficiency.

INTRODUCTION:

As the power demand for cloud computing and AI application increases, 48V bus power delivery starts to show advantages of reducing power delivery loss and overall system efficiency such lessen electrical wattage and cost for datacenters. Trade-offs of higher efficiency and lower cost implementation are crucial for widespread 48V power delivery adoption. There are several types of topologies used in this area.

1. GaN based LLC power module

The GaN based LLC power module is normally used in situations demand high power density and high efficiency at the same time. Its cost is high. It's normally designed and manufactured by DC/DC module maker. The complex PCB winding for layer counts and customized magnetics seems to be key elements preventing direct use in embedded mother boards, thus resulting higher cost to OEMs.

Figure 1 shows an example of 48Vin/12Vout/800W LLC demo module with GaN devices in both primary and secondary side. Its size is 18.5*24*7.9mm^3 with peak efficiency of 98% and full load efficiency of 97% @ fs>1MHz.

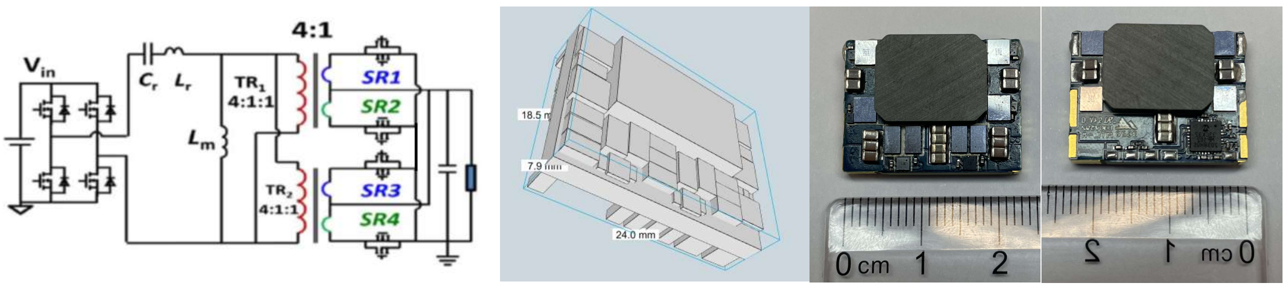

Figure 1. GaN based LLC module with size of 18.5*24*7.9mm^3

2. Switch capacitor topology

The switching capacitor combined with buck converter solution is already used in server applications in production. Its features high efficiency and middle cost. It can be used directly implemented on mother boards. Figure 2 shows 48Vin/12Vout/750W switching capacitor topology approach with size of 25*65*15mm^3. Its peak efficiency is 98.2% and full load efficiency of 97% @ fs=200kHz.

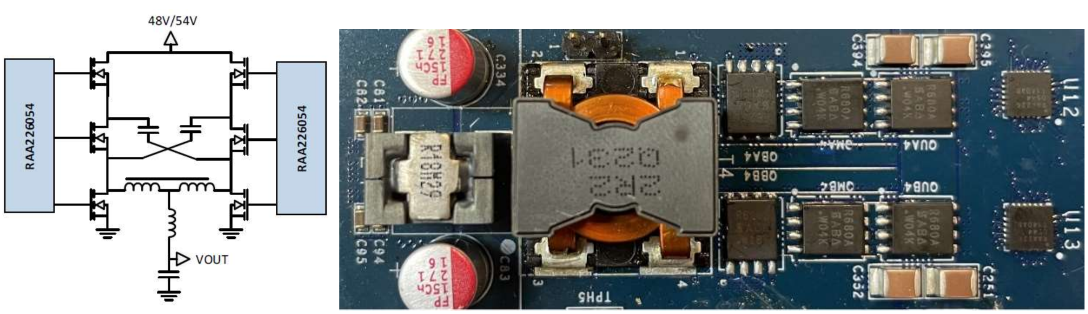

Figure 2. Switching capacitor for 48V application with 4:1 Ratio, size 25*65*15mm^3

3. Multiphase buck topology

The interleaved multiphase buck topology is a mature control approach. It uses regular magnetics can be easily designed and manufactured on card or large computer board. It is a low-cost approach. Its efficiency is not as high as LLC module or switching capacitor topology with silicon MOSFET. The multiphase buck efficiency gap can be reduced when GaN device is used, this is shown in the next section.

USE CASE FOR INTERLEAVED MULTIPHASE BUCK CONTROLLERS FOR 48V CONVERSION:

1. 48V to 12V Fixed Vout

The following shows an example of 48Vin/12Vout/240W dual phase Si MOSFET buck module. Its size is 36.83*34.04*15 mm^3. Its peak efficiency of 96.7% and full load efficiency of 96.1% @fs=210kHz. This dual phase buck can be extended to 4 or 6 phases parallel interleaving with same efficiency performance and the PWM controller can be scalable to multiple phases.

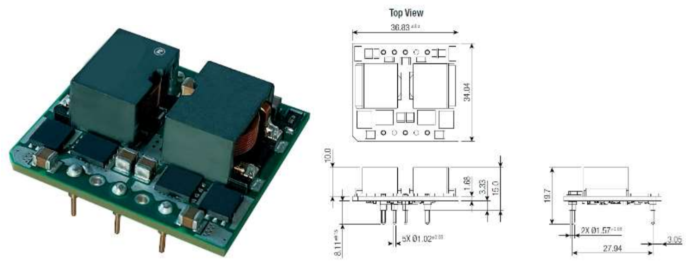

Figure 3. Dual phase interleaved Buck DC/DC module with silicon MOSFET size 36.83*34.04*15mm^3

Compared to the application above, Figure 4 shows 48Vin/12Vout/300W dual phase GaN buck module size is 33*22.9*9mm^3 with peak efficiency of 95.7% and full load efficiency of 95.7% @fs=500kHz. If the switching frequency decreases to 250kHz. The inductor height will increase by 4mm. The module size will be 33*22.9*13 mm^3 with peak efficiency of 96.6% and full load efficiency of 96.5%.

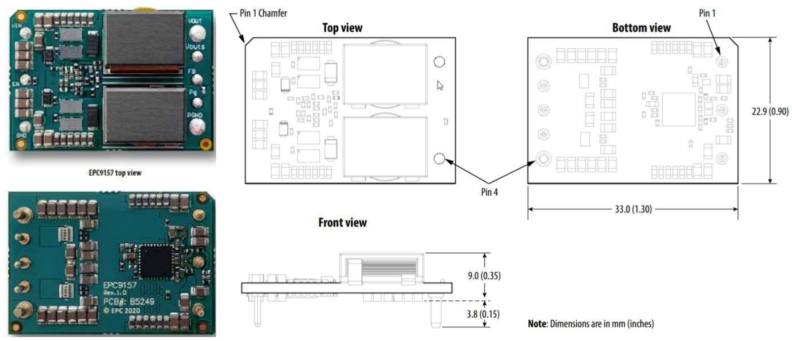

Figure 4. Dual phase interleaved Buck DC/DC module with GaN size 33*22.9*9mm^3

2. 48V to a voltage near 12V

As intermediate bus converter, if the intermediate bus voltage is not regulated to exactly 12V, such as 8V, 9V, there is also benefit to the down stream converters for its reduced switching loss. Since the down stream converter generally operate at higher switching frequency. Figure 5 below shows 2 phase interleaved buck converter for 270Watt applications with output voltage at 8V, 9V, 10V, and 12V. The 2 phase GaN device solution due to it higher switching frequency has smaller board area. Detailed BOM of this implementation will be shown in final paper.

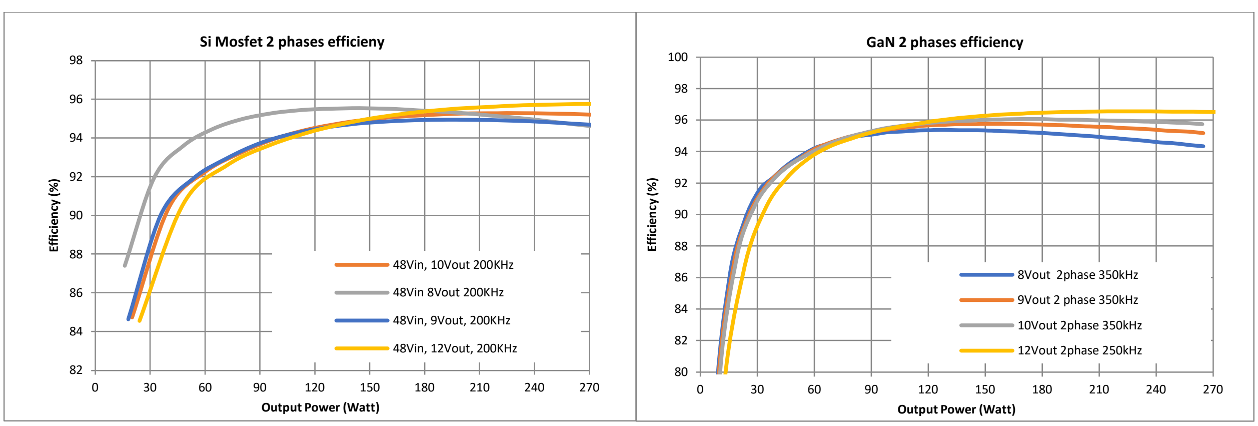

Figure 5. 2 Phase Buck Converter Efficiency Comparison for Silicon MOSFET vs GaN MOSFET for 270 Watt

3. Optimizing Efficiencies with GaN Based Multiphase Buck Topology

The above efficiency comparison is based on two GaN devices per phase leg for the buck converter. Figure 6 shows an implementation with using more GaN devices in the buck converter. In this application, two GaN devices are used as bottom switch. It is targeted for a 48Vin/12Vout/1200W. Its implementation size is 58x60x10mm^3 with peak efficiency of 97.8% and full load efficiency of 97.4% @fs=350kHz.

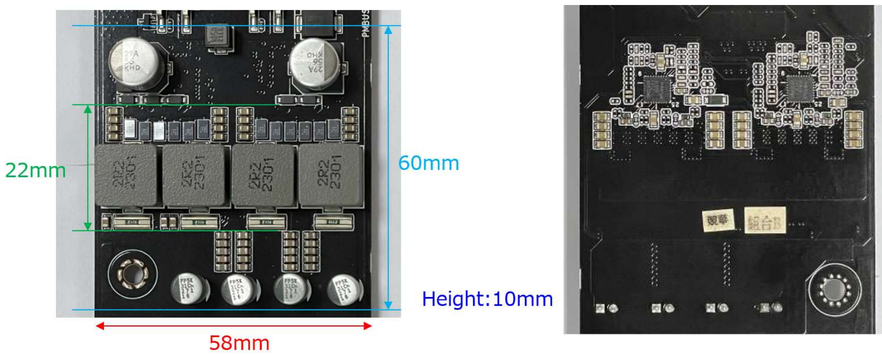

Figure 6. Four-phase interleaved Buck converter with 3 GaN devices per phase leg, estimated 58X60X10mm^3

OVERALL COMPARISONS:

Efficiency comparison of different approaches seems to be complex in that each approach has its cost basis. However, Figure 7 still summarized all the efficiency into one plot for easy comparison. The 4 Phase interleaved GaN buck converter has been pushed to higher power with its efficiency curve extends to greater than 1000 watts.

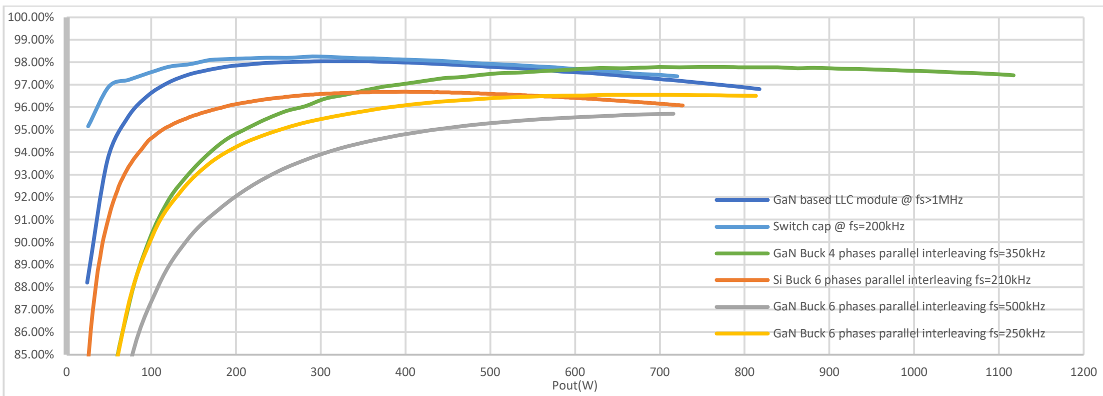

Figure 7. Overall efficiency comparison for 48V down conversion

To contrast the efficiency comparison, the table below shows the key BOM components and overall implementation area used for the above different implementations. The cost is more related to the component volume of use. However, based on the BOM components, the solution relative cost can be compared for which solution will be higher cost vs the other given the same individual device price.

48Vin/12Vout/800~1200W DCDC Solution	Topology	Peak efficiency	Full load efficiency	BOM	Size	Manufacture ability
GaN based LLC module @ fs>1MHz	LLC	98%	97%	1*MCU+2*Half bridge driver+4*80V GaN+1*transformer+4*low side driver+8*40V GaN (Si Mosfet)	24*18*7.9mm	Hard
Si based switch cap @ fs=200kHz	Switch cap	98.2%	97%	1*controller+2*driver+1*transformer+4 *80V Si Mosfet +2* 60V Si Mosfet	25*65*15mm	Middle
Si based Buck with 6 phases parallel interleaving fs=210k	Multiphase Buck	96.7%	96.1%	3*Buck controller+12*80V Si Mosfet +6*Inductor	36.83*100*15mm	Easy
GaN based Buck with 6 phases parallel interleaving fs=250k	Multiphase Buck	96.6%	96.5%	3*Buck controller+12*80V GaN +6*Inductor	33*69*13mm	Easy
GaN based Buck with 6 phases parallel interleaving fs=500k	Multiphase Buck	95.7%	95.7%	3*Buck controller+12*80V GaN +6*Inductor	33*69*9mm	Easy
Si based Buck with 4 phases parallel interleaving	Multiphase Buck	TBD	TBD	2*Buck controller+12*80V Si Mosfet+4*Inductor	TBD	Easy
GaN based Buck with 4 phases parallel interleaving	Multiphase Buck	97.8%	97.4%	2*Buck controller+12*80V GaN +4*Inductor	58x60x10mm	Easy

Summary:

This paper introduced the different solutions of 48Vin/12Vout DCDC converters at different power levels. The efficiency, bom, size and manufacture ability are discussed. According to this comparison, each solution can be a choice to meet different requirements. While the LLC implementation and switching capacitor approach shows better efficiency. LLC approach seems to have a best power density. Comparing to the implementation cost, multiphase buck converter has lowest implementation cost and can be embedded in the mother board. Its efficiency can be optimized with more GaN devices per phase leg and reduces the implementation area compared to its counterpart Si MOSFET.

We would like to thank all customers who allowed us to use their product information and share their test data.

AUTHOR BIOGRAPHY: Teng Xu received bachelor's and master's degree from the Huazhong University of Science and Technology, Wuhan, China. After graduating, he joined Delta and LG RD center in 2009 and 2014 respectively focusing on wind power converter and WBG device applications. He joined in Renesas as an application engineer since 2020. Now he is working on the 48V system solutions based on Si and GaN devices.