Crossing the chasm with success - WBG!

For the power designer any new technology that makes it possible to improve performance whilst simultaneously making products smaller and more energy efficient is a very exciting concept - we're talking holy grail territory. Over the last century the world of power electronics has witnessed many inventions and innovations and without going right back to the Thyratron, the latest major innovation was the move from analog to digital control. However, we are now witnessing a new, huge stride forwards in technology, the implementation of Wide Band Gap (WBG) semiconductors. Gallium Nitride and Silicon Carbide have been used in radio power amplifiers and high voltage diodes for years, but it was only a few years ago that they become part of the power switching chain in the form of transistors. Adopting a new technology is full of challenges that somewhat surprisingly are not always technical. Learning is an important part of the road to success but market adoption and building a new ecosystem are far more complicated than it may seem at first. Let's take a snapshot of where WBG currently stands and what are the remaining challenges.

The Early Adopters boosted GaN adoption!
Inevitably, for new technologies Time-to-Market is a long process, and from original research, patenting, technology introduction and market adoption, this could be more than 10 years. We are all aware of the camel-back curve (Figure 01) and for those of us who belong to the Technology Enthusiasts category, the success of a new technology will come from the pragmatists and conservatives.

Introduced in 2005, digital control in power supplies has been broadly adopted but after 20 years it is still considered by skeptics to be a curiosity. In normal circumstances it would have been the same for the adoption of WBG, but market demand for smaller, lower power consumption, industry modernization, emerging technologies and the famous Artificial

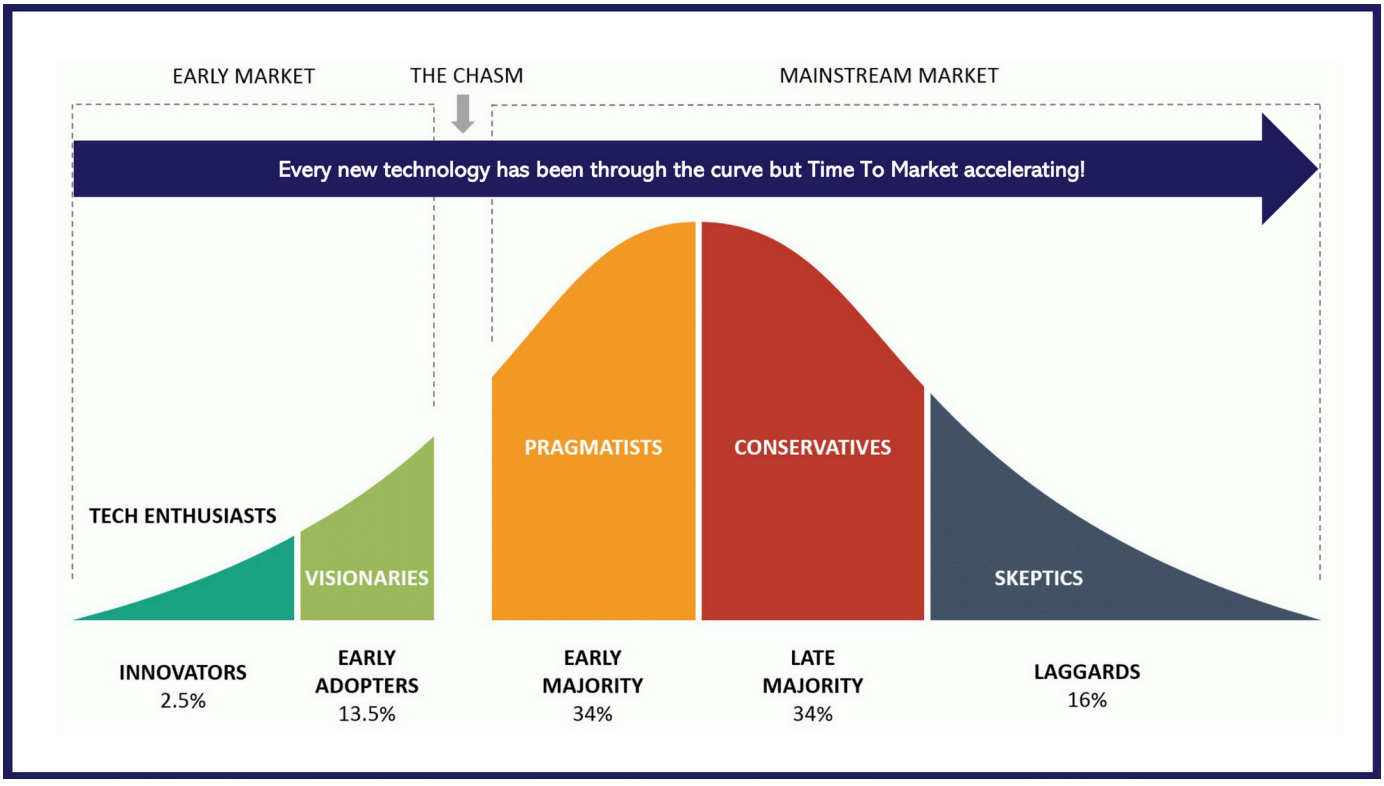

Figure 01 - Experienced power designers have crossed that technological chasm many times and GaN adoption follows the same pattern (Source: PRBX/Geoffrey A. Moore)

Intelligence have contributed to the speed of the learning and implementation processes.

As the Applied Power Electronics Conference (APEC) is celebrating its 40th anniversary, it is good to remind that for many technology analysts, the cornerstone of WBG took place at APEC-2018 when 'challengers' demonstrated the commercial potential of WBG technology. It is not possible to name all of them but among the leaders promoting GaN I would say that the Efficient Power Conversion's (EPC) idea to implement GaN in LiDAR was really interesting, especially with that technology becoming preponderant in the new generation of vehicles (Figure 02).

LiDAR, an acronym for "Light Detection And Ranging" is a technology that uses laser pulses to map out an environment. When the pulse contacts an object or obstacle, it reflects or bounces back to the LiDAR unit. The system then receives the pulse and calculates the distance between it and the object based on the elapsed time between emitting the pulse and receiving the return beam. LiDAR systems are capable of processing

Figure 02 – GaN Laser diode control in nanoseconds for advanced automotive autonomy (Source: PRBX with courtesy of Efficient Power Conversion (EPC))

a high volume of pulses with some systems emitting millions of pulses per second. As the returning beams are processed, the system generates a comprehensive view of the surrounding environment, enabling the use of sophisticated computer algorithms to discern shapes and identify objects such as cars and people.

Due to their high-frequency operation, which enables faster laser pulse modulation, LiDAR applications were part of the early adopter of the GaN technology. Their capacity to manage high-currents with minimal losses is paramount for enhancing accuracy and extending range in LiDAR systems. GaN's efficiency and power density advantages enable the development of smaller, lighter LiDAR systems, making it a suitable solution for various applications, including automotive, security, robotics, drones, and aerospace. Behind the scenes, the development of LiDAR applications has contributed to the adoption of GaN and is representing a significant volume.

2018 was also the year in which USB adapter manufacturers started to consider implementing WBG technology to offer more power in smaller packaging and to gain a competitive advantage. I mentioned EPC but Navitas Semiconductors is another example of an innovative company that in the early days pushed GaN integration to a higher level by packaging drivers and switches on the same substrate.

Making Complex Simple – The Key to success!
When first presented, WBG power semiconductor utilization was limited by the number of drivers available, making it difficult for power designers to consider the technology. Also, new technologies are always questioned regarding reliability and sustainability. Market adoption depends on how simple it is for power designers used to conventional MOSFETs to use WBG, and semiconductor manufacturers' speed in developing 'ready-to-use' solutions that include driver, protection, monitoring and many other functionalities into a single chip. This not only simplifies implementation but also reduces the overall size of the power stage, and combined with higher switching frequencies make it possible to reduce the size of magnetics, thus increasing power density whilst reducing the overall volume and mass of the power supply.

As mentioned, among the many products that could benefit from the implementation of WBG technology, we could pinpoint portable equipment chargers. As end-users we all expect USB chargers to deliver more power, to charge faster and to be smaller and lighter.

In 2020, this wish became a reality and one example of the benefit of using WBG GaN to achieve that is a 110W Mini fast charger that is over 12 times smaller than the 96W charger supplied with the Apple MacBook Pro 16 launched by OPPO (Figure 03). This has been made possible by combining the Navitas GaNFast power ICs with a planar transformer, an optimized topology and a higher switching frequency. At the same time, EPC released a GaN IC integrating everything to make it simple for power designers to implement into their new designs (Figure 04). Those examples illustrate how WBG GaN manufacturers rapidly moved from 'complex' to 'simple' to implement the technology, contributing to generate volume and market adoption.

Figure 03 – Implementing GaN into USB-C chargers makes possible to reduce size weight whilst increasing power density and efficiency (Source: PRBX with courtesy of Navitas Semiconductor)

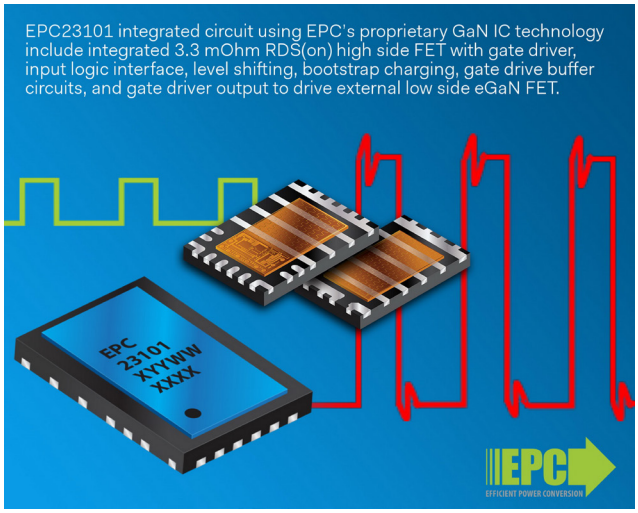

Figure 04 - EPC23101 integrated circuit using EPC's proprietary GaN IC technology made design easier (Source: PRBX with courtesy of Efficient Power Conversion (EPC))

High power GaN setting-up a foundation for future!
As we have seen, driven by the consumer segment, power designers soon realized the benefits offered by GaN to offer more power in smaller packaging. Power designers had to face several challenges to develop high switching frequency using GaN technology in very compact packaging but that was a really exciting time for many of us.

Presented examples addressed low and mid power applications but as well, WBG received high interest for high power applications such as Electric Vehicles (EV), renewable energy and many others.

Electric Vehicles (EV) have seen a significant uptake of WBG technology and as of today it is the dominant technology in battery chargers, power trains and as already mentioned, equipment such as LiDAR. EV is often presented as the showcase for the adoption of WBG though less well-known is the role of Information and Communication Technology (ICT) in supporting research on GaN and SiC.

This research aimed to develop the next generation of power supplies to support hyper-processors applications and data centers for Artificial Intelligence (AI). The rapid adoption of AI is accompanied by a significant growth in data volume and increased computing requirements. By 2025, the data volume is projected to reach 180 zettabytes, up from 15 zettabytes in 2015. According to OpenAI researchers Dario Amodei and Danny Hernandez, the amount of computing power used for deep learning to train state-of-the-art AI models has been doubling every 3.4 months since 2012. This continuous increase in computational power directly impacts electricity consumption, with AI data centers expected to account for up to 7% of global electricity demand by 2030.

Optimizing energy utilization has always been a concern for the ICT manufacturers, requiring all suppliers, from infrastructure to components to reduce energy consumption. From the early days of research to improve the power supplies, AC/DC or DC/DC energy efficiency, power electronics designers explored new technologies and partnerships with semiconductors manufacturers. Several papers have been presented at APEC and other conferences. It's worth mentioning Navitas Semiconductors, who at APEC 2022 presented "Electrify Our World" introducing the benefits of WBG in ICT and, in 2024, the materialization of the utilization of that technology in power supplies for datacenters, where they predicted that power demand per unit will ultimately reach 10kW (Figure 05 insert). Exploring the optimum benefits of combining GaN and SiC, the company released a 8.5kW, 98% efficiency reference design, complying with the with Open Compute Project (OCP), Open Rack v3 (ORv3) specifications and ready for stringent energy efficiency standards (Figure 05). This is a good representation of what has been achieved when combining WBG and other advanced technologies to power today and tomorrow ICT applications and more to be expected.

Figure 05 – WGB contributes to efficient power supply for AI datacenters (Source: PRBX with courtesy of Navitas Semiconductor)

Industrial applications in transition mode.
LiDAR, USB charger and ICT are representing a significant part of the market but other segments such as industrial, railway, medical are also investigating the benefits of that technology though have some concerns about the reliability and availability of new technologies.

As presented by the market analysts, despite GaN having been on the market for several years the market remains fragmented with each GaN manufacturer offering different combinations of products and services addressing specific segments. To get the best out of GaN, power designers must work in close cooperation with semiconductor manufacturers and embrace one-stop solutions (GaN transistor, driver, protection, etc.) tightened to a single source, albeit raising concerns about the risks of using products from a new supplier with limited history and financial background. That, without mentioning some applications e.g., railway apps requiring 25 years lifetime and products availability for maintenance, requiring a solid and sustainable supply chain are part of complex equation when considering a new technology.

Due to that, the adoption in industrial, railway and medical applications may be slower than in EV, ICT and consumers but the obvious benefit of WBG motivated designers to explore that way. One example is the outcome from COSEL research to combine digital control, GaN and planar magnetics that makes it possible to offer very compact power solutions that are easy to integrate into small space environments (Figure 06). That will make it possible to house the power supply and a battery backup in the same volume as the conventional version of a similar power supply. As we are moving forwards to new applications requiring higher performances, WBG will gain market shares and follow the same path followed by the early adopters.

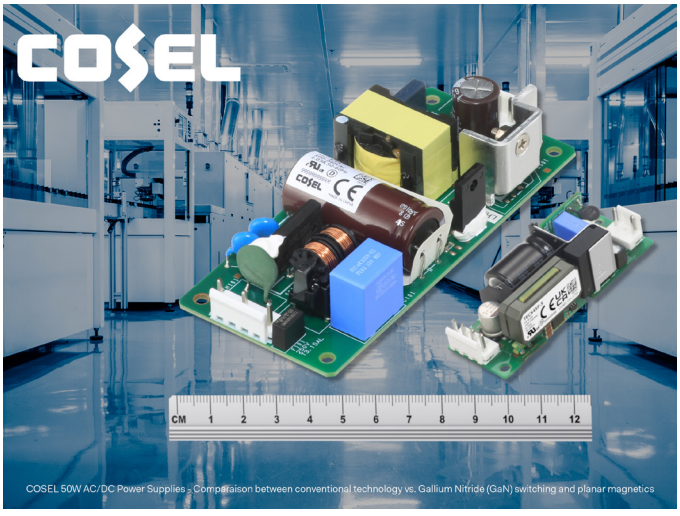

Figure 06 – COSEL industrial power supplies adopting GaN and integrated magnetics make it easier to integrate in small space environment (Source PRBX/COSEL)

Conclusion

Many of the challenges faced by power designers when WBG technology was presented eight years ago at APEC have been overcome and there is no doubt that GaN and SiC successfully crossed the chasm. The number of applications adopting WBG will continue to grow although at the same time new disruptive technologies are reaching the market offering power designers exciting opportunities for research and development. Starting my career within the power industry more than 40 years ago when moving from linear to switching power conversion, I crossed the chasm several times with passion and I would like to encourage young engineers to do the same, cross the chasm to approach the mythical 99.99% efficiency.

About Powerbox

Founded in 1974, with headquarters in Sweden and operations in 15 countries across four continents, Powerbox serves customers all around the globe. The company focuses on four major markets - industrial, medical, transportation/railway and defense - for which it designs and markets premium quality power conversion systems for demanding applications. Powerbox's mission is to use its expertise to increase customers' competitiveness by meeting all of their power needs. Every aspect of the company's business is focused on that goal, from the design of advanced components that go into products, through to high levels of customer service. Powerbox is recognized for technical innovations that reduce energy consumption and its ability to manage full product lifecycles while minimizing environmental impact. Powerbox a Cosel Group Company.

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About the author

Chief Marketing and Communications Officer for Powerbox, Patrick Le Fèvre is an experienced, senior marketer and degree-qualified engineer with a 40-year track record of success in power electronics. He has pioneered the marketing of new technologies such as digital power and technical initiatives to reduce energy consumption. Le Fèvre has written and presented numerous white papers and articles at the world's leading international power electronics conferences. These have been published over 450 times in media throughout the world. He is also involved in several environmental forums, sharing his expertise and knowledge of clean energy.

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