From Thyratron to Wide Band Gap - the Power of Curiosity!

As we said in our presentation at the 2020 Electronica Power Electronics Forum, the history of the power industry is fascinating and one full of amazing, genius level engineers who are making power solutions more efficient, lighter, smarter and much more. Although it is difficult - if not impossible - to name all of them, one thing they all have in common is 'curiosity'. For many of us Albert Einstein influenced our destiny and I cannot mention him without a quote, one that is also my own mantra: "The important thing is to not stop questioning. Curiosity has its own reason for existing." This is the reason why for more than 120 years power designers have performed miracles and will continue to break 'unbreakable limits'.

The passion and curiosity for discovery

What makes a young guy decide to study power electronics depends on many factors but personally, I was probably influenced by the blue light emitted by a couple of thyratrons [1], when at the college in 1974, I visited the Paris "Palais de la découverte" and met a research engineer who in sharing his passion for electronics explained to me how that technology would change our future. It was just fascinating and almost certainly it was the day when my curiosity for discovery was born!

For many power young engineers the word "thyratron" may suggest a time when dinosaurs still walked the Earth, but for the power industry it was an important step forward in its time, and the state of the art (Figure 01).
We should also remember that at the same time as when the power electronics field was deploying electronic tubes, in 1926 the inventor Julius Edgar Lilienfeld patented the principle of what is today known as the Field Effect Transistor. In its patent: "Method and Apparatus for Controlling Electric Currents," he proposed a three-electrode structure using a copper-sulfide semiconductor material. Julius Edgar's research was very interesting but in common with many passionate research engineers he did not realise the importance of publishing and sharing results, making his discovery a case of debate within the

research community and as a result low recognition for himself.

At this point it is pertinent to mention the high level of research undertaken to replace electronic tubes with something smaller, more efficient and easier to control. It is therefore relevant and only fair to mention Russell Ohl, who in 1930 experimented with the use of silicon rectifiers as radar detectors. This discovery was followed by an application for a patent of the photovoltaic principle (US Patent 2,402,662) but Ohl's discovery set up the foundation of what would become the transistor.

In 1947, John Bardeen and Walter Brattain experimented with the first semiconductor amplifier that they duly demonstrated on December 23 to the Solid-State Physics Group at Bell Labs. This confidential presentation was followed by a public announcement regarding the filing of a patent in June 17, 1948 (2,524,035) and a couple of weeks later at a press conference in New York on June 30, the announcement of the 'transistor' by electrical engineer John Pierce. We all know the story and have seen the cover page of the September 1948 edition of the magazine 'Electronics'.

From electronic tube to silicon
The invention of the transistor has been a real revolution, and was implemented in the early fifties in consumer equipment e.g. the transistor radio (1954, the Regency TR-1 in USA ; 1955 the TR-52 from Sony in Japan). Germanium transistors became the norm and power electronics engineers started to develop power solutions based on that technology. In parallel the growing demand from the scientific-computer community to get faster machines boosted the development of a new generation of transistors based on silicon. In July 1961, the first NPN silicon transistor to exceed germanium transistors' speed was released by Fairchild Semiconductor – the 2N709.

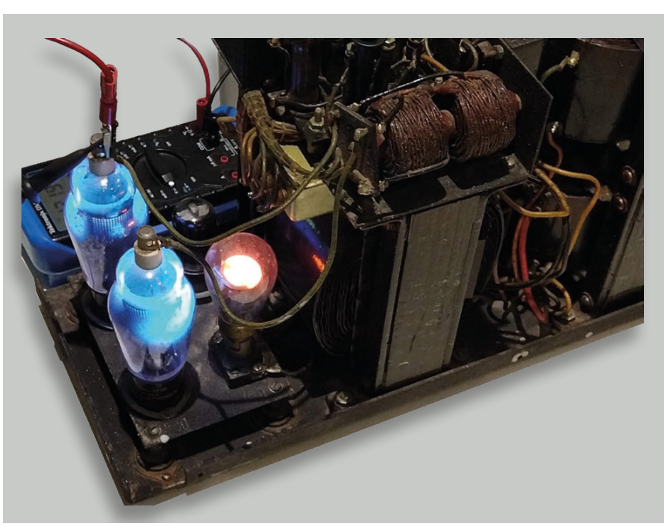

Figure 01 – Thyratron power supply REC-30 for the teletype Model 19 used in the naval communications system in 1940s

The launch of the silicon based transistor accelerated the development of modern power electronics and what we know today as 'linear regulated' power supplies (AC/AC transformer, rectifier, analog regulator stage), replaced electronic tubes. At the same time the race to conquer space and take men to the moon would require greater efficiency, lighter weight and smaller size, and these needs boosted research into new power techniques.
In secret, NASA and the military industry developed a new generation of power supplies based on 'switching technology'. Although it was very confidential at the time, it was later reported that the technology was used in 1962 in the Telstar satellite.
Who launched the first commercial switching power supply is up for debate, but we should mention RO Associates who in 1967 introduced a 20Khz power switcher, followed by Robert Boschert who in 1970 performed research on modern switching topologies. Boschert applied for a number of patents but the two most well-known are 4,037,271 and 4,061,931 that were granted in 1977. From that date the development of switching power topologies accelerated and with the introduction of MOSFET semiconductors and the PWM control IC it became the norm.

Never ending curiosity is key
Because power supplies are used in applications ranging from deep sea to deep space, power designers face many challenges, some of which seem to be almost impossible. Regulations and consumer demand for smaller and lighter equipment placed a high demand on power designers to increase efficiency. In the eighties, with high levels of curiosity, power designers explored high frequency switching resonant topologies and one of the most commercial success stories is Vicor, founded by Patrizio Vinciarelli in 1981. At the same time the hard-switching community explored a new path, replacing diodes with power MOSFETs. Papers were presented at many conferences, e.g. PESC-1988, APEC-1989 but the main architect of market adoption is definitely James Blanc from Siliconix Inc. who with both passion and enthusiasm promoted synchronous rectification technology.

New components and topologies made power supplies more efficient, and trail blazed by Trey Burns, Chris Henze and the others who in the late seventies worked tirelessly to develop digital control of power supplies, it was in 2000 that power designers and semiconductor manufacturers finally broke a new 'unbreakable' limit. 'Digital Power' was born and it was now possible to control 'bit-by-bit' the performance of a power supply.

But the power designers' curiosity is strong and unceasing, and with the market demand for even smaller components and greater efficiency, they are now busy exploring out of the silicon box, researching new materials with higher performance levels, the so call Wide Band Gap (WBG) semiconductors. In that respect, high voltage applications have gained benefits firstly from the use of Silicon-Carbide, followed by Gallium-Nitride (Figure 02).

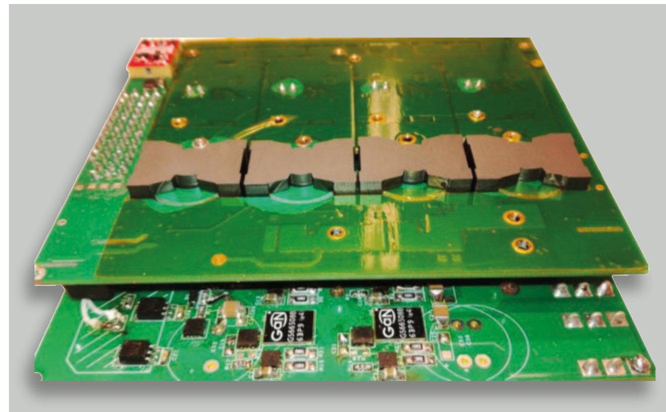

Figure 02 – PRBX multi-cores auto-tuned power converters with advanced digital control and GaN FET transistors

What is amazing with WBG is the rapid take up of the technology in commercial applications. Earlier I mentioned James Blanc who for years promoted the use of synchronous rectification. With that same level of passion I should now mention Alex Lidow (Efficient Power Conversion) who has strongly advocated in favor of GaN, making this technology easy to learn and to implement.

Smaller, faster, lighter and more efficient

Every decade has witnessed major steps forward in reducing energy consumption, weight, space, and price. Combining all of those, power designers have squeezed more power into smaller spaces and for example we all see the benefit in the latest generation of USB chargers. Year after year we get ever closer to the mythical 99.99% efficiency and that is the result of genius level power designers who are curious and never stop asking questions.

At the beginning of this article I quoted Albert Einstein, and so it's relevant to end with him saying:

"The important thing is to not stop questioning. Curiosity has its own reason for existing. One cannot help but be in awe when one contemplates the mysteries of eternity, of life, of the marvelous structure of reality. It is enough if one tries to comprehend only a little of this mystery every day."

This is what power designers have done for centuries and what is motivating all of use to break 'the unbreakable limits'.

Note:
Paper first presented in Power Electronics News (www.powerelectronicsnews.com)

References:
[1] Teletype Model 19 Thyratron Power Supply - https://youtu.be/WX74GoHuwHk
[2] China Power Supply Society (CPSS) - http://www.cpss.org.cn/en/
[3] Power Sources Manufacturers Association was incorporated (PSMA) - https://www.psma.com/
[4] Applied Power Electronics Conference and Exposition (APEC) - https://apec-conf.org/

POWERBOX (PRBX): https://www.prbx.com

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 35-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 250 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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