Smart Power to Factory Automation!

As in many other definitions, 'Smart Power' has become a marketing buzz phrase and it's sometimes hard to understand what the 'smart' part means. Or put another way - what the benefits are for the end user. It may be equally difficult to identify when Smart Power became trendy, but today, from a power controller IC to a fully automated factory, Smart Power is everywhere and with the growing Industry 4.0 its position as a predominant technology is assured.

The origin of Smart Power

If in the case of the PWM pioneers, 'Smart Power' was born in 1976 when Silicon General launched the famous Pulse Width Modulator SG1524 chip. But for many of us it was in the mid-nineties when the semiconductor industry pushed silicon boundaries by adding more functionality to power control integrated circuits.

In his 1998 book 'Power electronics design handbook low-power components and application', Nihal Kulartna considered that the term 'Smart Power' was more relevant when increasing functionality levels at chip level, reducing the number of surrounding components required by the power controller, simplifying design and reducing the amount of space required on customers' boards. Among the additional functions added to a single chip at that time we could name drive circuitry, thermal protection, over and under voltage protection, current limiting, and diagnostics.

In the late nineties many Smart Power controllers were developed to meet the demanding environmental and cost constraints of the automotive and consumer electronics industries requiring highly integrated levels of functionality to reduce space and cost.

Although within the semiconductors industry the definition of Smart Power may have been obvious, discussions and debates were raging within the power community about 'Smart Power' especially when a new technology, the so-called 'Digital Power' was also the subject of many discussions. Diplomatically, Nihal Kulartna concluded that the term 'Smart Power' was used for institutional rather than technical reasons, and that remains very much the case.

When digital makes power supplies smarter!
For the 21st century power electronics designers, 'Smart Power' started with the implementation of digital power, bringing in a new dimension in the way that a power supply can be controlled to optimize overall performance by using microcontrollers and software in a 'smart' way.

Although in 2020 Digital Power is an established part of the power engineer's toolbox, we should remember that making power supplies smarter has been a long quest and we should recognize the pioneers who sewed the seeds of 'Digital Power' including Trey Burns, N.R. Miller and Chris Henze.

Regarding those inventors I would like to mention an interesting event that took place when the power industry was slowly considering the migration from linear-power to switching power using the SG1524 IC. Trey Burns researched and explored the use of the State-Trajectory Control Law in step-up DC/DC converters and he compared two methods of realization, one employing a digital processor and the other using analogue computational circuits. The results of this research were presented at various conferences but PESC 1977 is considered as the origin of a wave of research into digital methods to drive, monitor and control DC/DC converters and power supplies.

It is now anecdotal but nonetheless interesting to note that an experimental product built by Trey Burs was a boost converter operating at a switching frequency of 100Hz. That now sounds slow, but it had to be so because it took up to 450µsec to execute the digital program per sample. The digital controller was a PDP 11/45 mini-computer, and the boost converter was built using a 10mH cut-C core inductor (very big and heavy) and approximately 13,000µF of capacitance. The research team pushed the circuitry up to the computer on a cart.

Following PESC 1977, power engineers made lots of progress researching how to digitalize power control, and the years 1984 and 1985 are the second cornerstone in the evolution of digital power technology.

One example is when Chris Henze was working on his Ph. D at the University of Minnesota under the direction of Ned Mohan. Chris published some interesting parts of his work at PESC in Toulouse in 1985. In this work Chris was using a microprocessor and was switching at a reasonable frequency for a non-isolated dc-dc converter of that era.

In his paper he identified issues like quantization and the need to dither to get adequate PWM resolution. The application presented by Chris Henze is one among many that are representative of the evolution from pure research to commercially feasible applications based on microprocessors.

In the late 1990s, based on the digital signal processor C2000, TI contributed to develop the first fully digitally controlled UPS. Using a DSP to digitally control the switching and power management of a UPS system was the first practical application for digital power. This real-life application was the first in a long series of experiments aimed at optimizing digital control in power supplies, expanding the scope of opportunities for the DSP.

During the following years semiconductor manufacturers introduced many power controllers with built in digital functionality with different architectures. Although there was some existing I/O communication, the launch of the Power Management Bus (PMBus), standardizing commands to monitor and control a power controller is considered by power designers to have been a major step towards a new level of Smart Power.

Smart energy storage for a Smart Power
If digital power technology made it possible to optimize power switching performance and to control the power supply in every possible way, the growing demand for intelligent power systems integrated within demanding industries having complex loads e.g. repetitive peaks and regenerative energy require 'smart energy storage'.

First commercially introduced by Nippon Electric Corporation in 1978, Supercapacitor technology has made very impressive progress throughout the following years, today benefiting from nanotechnologies that make it possible to create huge capacity storage in smaller packages.

From huge cranes requiring high energy levels when lifting heavy loads, in electrical vehicles helping to boost performance when accelerating and storing energy back when decelerating and braking, to micro-supercapacitors built into portable equipment, they are silently contributing to a new level of Smart Power when transient energy storage comes into the loop.

Combining the benefits of digital control and supercapacitors make it possible to develop very advanced power systems (Figure 01), able to dynamically manage peak energy demands, reducing the impact on the grid as well as guaranteeing a longer life time for strategic components and industrial equipment. By having the ability to store regenerative energy this is also a very important contributor towards reducing energy consumption.

Figure 01 – PRBX S-CAP BOOST supercapacitors bank with digital control and communication interface able to deliver peak energy to load and to store backward energy.

We now have the bases to move to the next step, Smart Power for a Smart Industry.

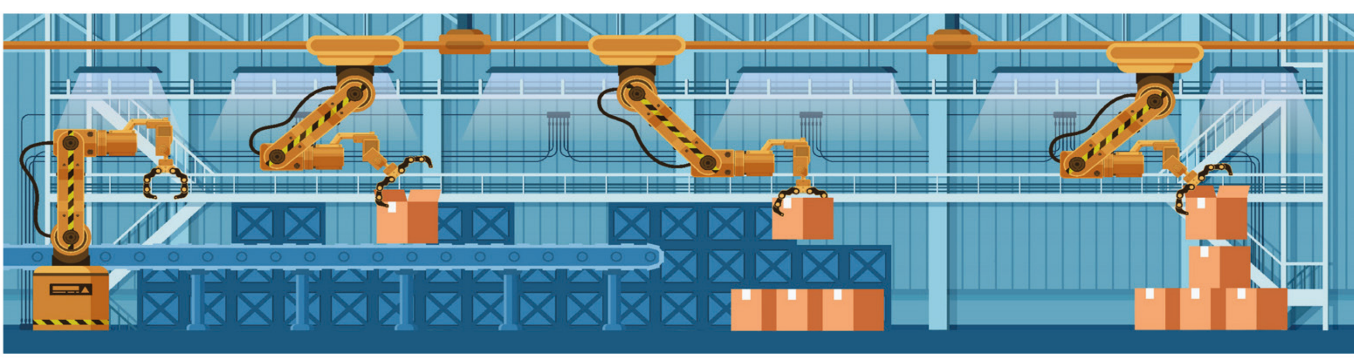
From Smart Power IC to Smart Industry

Often associated with the migration of Industry 3.0 to Industry 4.0, factory automation embraces a huge variety of power solutions. Often standalone, powering specific items of equipment, power supply performances have benefited from new technologies and there is no doubt that digital power associated with the latest generation of power semiconductors and magnetics have made it possible to package more power into a smaller footprint. However, to make a factory truly 'smart' whereby energy consumption is optimized to match load demand, that is not enough and additional technology is required.

From shelf to truck

If we consider a typical smart factory (figure 02), a number of systems and sub-systems are used to carry and handle parts and parcels during the process. At every step, conveyors and fixed or mobile robots will handle different types of loads, from light to heavy, each requiring different amounts of energy.

The concept of the smart factory is to optimize, from a single, contributory process to the overall one in order to reduce both time and energy consumption. In the case of the example presented in figure 02, the process is to



Power unit example	First handling	Following handling	Overall
	• Conveyer, or arm, sensor scale the parcel and sent weight information to hub process control (HPC) • HPC sent power profile to PSU with energy profile • Supercap charged in advance • Recycled energy stored back	• Load sensing and cross-check with HPC • Power profile for next handling station send directly from station one (check with HPC) • PSU configure to manage load • Energy profile sent to next station	• This process is repeated as many as the number of handling stations • Overall energy consumption per line/process analysis for billing and predictive maintenance • More PSU integration within process management

Figure 02 – Smart Power operation in Smart Factory with machine-to-machine communication.

carry parcels from a warehouse to a final shipping point. In that process parcels are tagged (Bare code or RF ID) and identified at the start of the process by sending volume, weight and special handling information (e.g. fragile, no-flip) to a central database part of the Hub Process Controller (HPC). From that point, during its journey from the warehouse to the shipping platform, the energy required at every station will be known and communicated from the HPC to the specific station.

One example is energy-optimized conveyors that are based on a succession of belts powered by brushless DC motors. As the parcel moves forwards the energy profile of each power system (figure 03) powering the DC motor will be communicated by the HPC to the specific section of the conveyor, making it possible to pre-charge the supercapacitor bank when peak energy is required, or adjust other parameters such as voltage, current limitation.

Very advanced systems utilize machine-to-machine communication and for example, when a parcel is approaching a handling robot on the conveyer belt, the last station sends energy profile data to the handling robot to preset all parameters in advance.

In all of those steps the power supply forms part of the eco-system and communication links with the HPC. Of course we are talking about power systems that are much more complex than the stand-alone versions that we have been used to in the past. But factory automation designers are expecting power supply manufacturers to not only think out of the box, but to make it possible for them to be part of the machine-to-machine network.

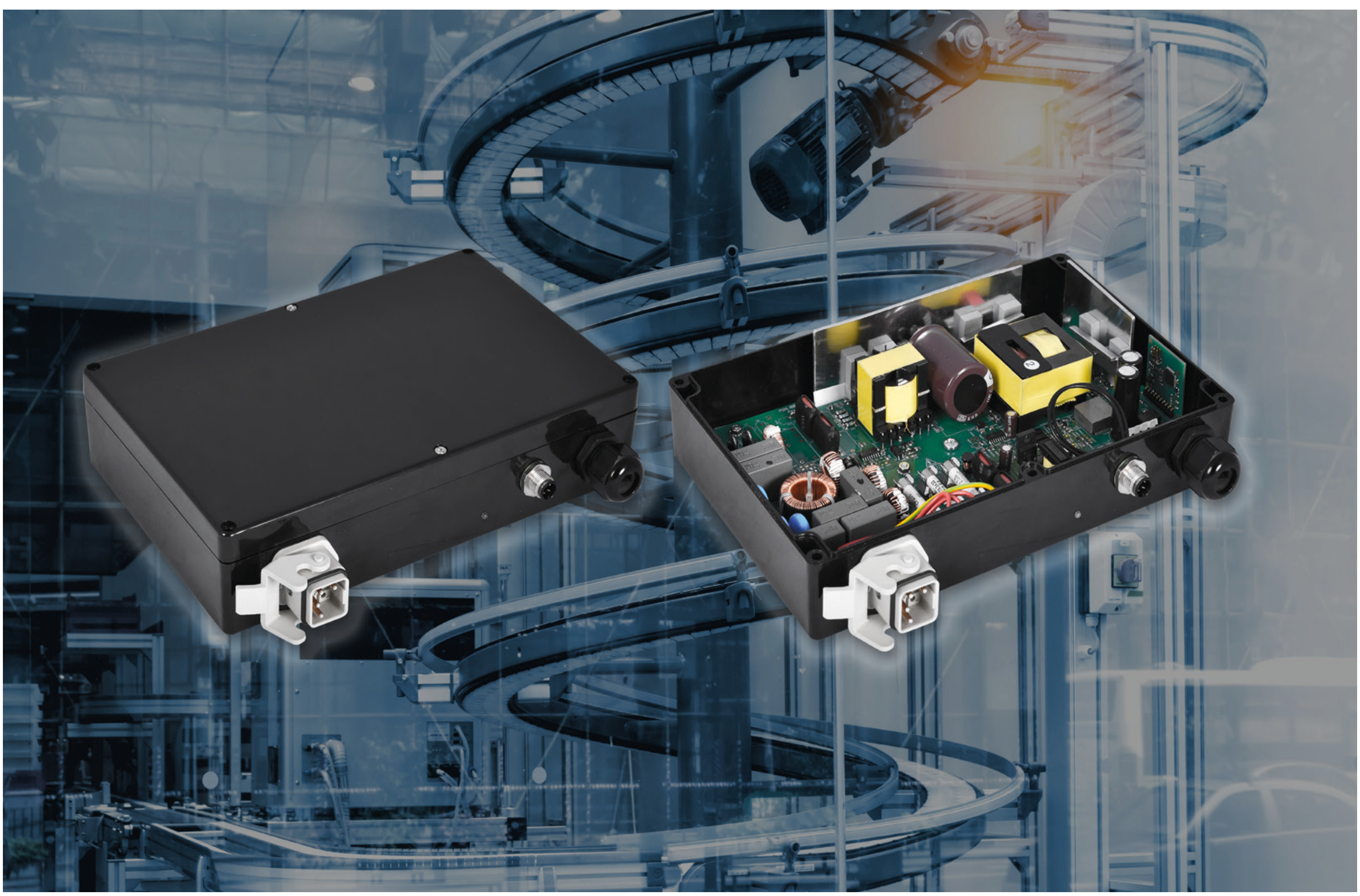


Figure 03 – PRBX Smart Power supply digitally controlled by microprocessor and built in storage capacitor for peak load and backward energy.

In conclusion
From a control IC to a complete factory, Smart Power is everywhere and as we used to say, Smart Factories will be powered by Smart Power, designed by curious and innovative 'Smart Designers'.

Note:
This paper was first presented, in 2019, in ASPENCORE - Power Electronics News and updated July 2022.
https://www.powerelectronicsnews.com/

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

Patrick Le Fèvre
Powerbox Chief Marketing & Communication Officer

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.

For more information
Visit www.prbx.com
Please contact Patrick Le Fèvre, Chief Marketing and Communications Officer
+46 (0)158 703 00

PRBX white paper 030 EN Rev A
2022-09-15