Rev A

Is Digital Power Moving Forward?

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Technical Paper

It is now several years since commercial products with 'added digital performance' aiming to revolutionize the power industry have been around in the marketplace. At a time when energy efficiency and power consumption are becoming more strategic than ever, the debate around how "digital power" will change the face of the world has never been so intense.
Energized by the high marketing buzz surrounding 'the new power revolution', thousand of papers have often strongly expressed the details and benefits of implementing such technology. However, a certain market perception gives the feeling that behind the noise generated by the media, digital power seems not to have moved as fast as expected. Wrong Perception or Reality?

ERICSSON

TAKING YOU FORWARD

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About this paper
The material contained in this paper was presented on March 18 at PCIM China 2008.

1. When did digital power get started?

1.1 The Pioneers

Before reviewing today's situation, it is important to remember the origins of digital power, and how from early research work conducted in the mid seventies by Trey Burns, N.R. Miller, and others, digital power gradually took its place in the power industry to reach a level of maturity that makes sense for a designer to consider such technology.

In the seventies, at time the power industry was slowly considering the migration from linear-power to switching-power, 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 [1] [2] [3].

The results of this research were presented at various conferences but PESC 1977 is considered as the origin of a wave of research in digital methods to drive, monitor and control DC/DC converters (e.g. Bell Labs engineers, Norman Richards Miller presented an innovative approach to digitally control a switching regulator [4], and Victor B. Boros presented a novel serial digital implementation of feedback control circuits for power conditioning equipments [5]).

At that point of time it is anecdotic but interesting to note that an experimental product built by Trey Burs was a boost converter operating at a switching frequency of 100Hz, given sounds slow - but it had to be slow because it took up to 450µsec to execute the digital program per sample.

The digital controller was a PDP 11/45 mini-computer (figure 1), and the boost converter was built, using a 10mH cut-C core inductor (very big and heavy) and approximately 13,000 µF of capacitance. The research team rolled the circuit up to the computer on a cart…

Figure 1 - PDP 11/45 computer

Considering PESC 1977, it is interesting to remember few words from the introduction of the paper Victor Boros presented :
"Today, digital controllers are economically and technically feasible. The control function is not more complicated that circuits found in hand calculators and costs are comparable for LSI circuit reduction."

1.2 Technology Impulse

If today, digital technologies are nothing new, we should remember Trey Burns using a PDP-11/45 to control and simulate his model, and that the most advanced micro-processors available in those days were 8 bits (e.g. Intel 8080 - Figure 2).

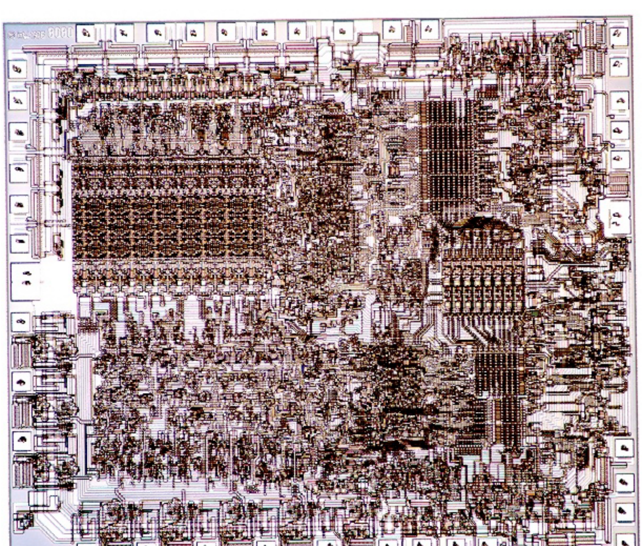

Figure 2 - Intel 8080

There is no doubt that the rapid development of the micro-processor industry boosted research in digital power management and control.

From PESC 1977 onwards, year-after-year, papers presented at various conferences confirmed the growing interest from the research community for digital techniques applicable to power systems.

Researched progressed very fast though it was only in the mid eighties that we could consider that from the huge amount of research conducted for more than twenty years, that possible commercial applications would emerge.

As we consider PESC 1977 to be the ignition-point for research into digital-power, 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 issues and the need to dither to get adequate PWM resolution. [6]

The application presented by Chris Henze is one among many that are representative of the evolution; from pure research to possible commercial applications based on micro-processors.

1.3 The first wave of applications

Since the original results of research presented in 1977, throughout the years the number of papers and patents relating to digital power management and control has increased impressively, confirming the growing interest for such technology.

In the late 1990's based on the digital signal processor C2000, TI contributed to develop the first fully digital 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 aiming to optimise digital control in power supplies, expanding the scope of opportunities for the DSP.

At the same time, based on the communication Bus I2C developed by Philips, Telecom Power Manufacturers (e.g. Ericsson Energy Systems) introduced communication features that made it possible for operators to monitor and manage energy at site level.

2. The Millenium turns Digital Power ON

2.1 Millennium Milestone

Since PESC 1977, twentyfour years have passed, and, with the millennium, digital power reached a new cornerstone.

Fundamental and important research conducted by those pioneers, and the rapid development of new components based on micro-processor technologies (e.g. Digital Signal Processor DSP) have made it possible for power supply designers to access suitable controllers and topologies that simplify the migration from analogue to digital.

The list of initiatives would be too long to cover under this paper, though from 2000 to 2004, we could consider some of the more important steps that contributed to the digital power migration from research to real life applications.

October 2001
Within the scope to co-develop digital power management solutions for high-end desktop PCs, servers and notebook PCs, Intersil and Primarion formed the Digital Power Management Alliance (DPMA).

December 2002
Texas Instruments introduced the industry's first digital signal processing (DSP) Development Kit (MDS3P701235DPS) dedicated to Power Supplies.

March 2004
With the introduction of the Z-One™ Digital IBA architecture, Power-One announced the integration of power conversion, control, and communications in point-of-load power units.

September 2004
Market Analyst Darnell established the first forum dedicated to digital technologies applicable to power systems and solutions: Digital Power Forum (DPF).

2.2 Millennium Forward

From the millennium, the number of papers presented at various conferences demonstrating the benefits of digital control and energy management increased tremendously.

The semiconductor industry started to announce products expected to make the development of digital control and digital power management as simple as it was for analogue, and some end-user-ready products started to appear on the market.

Unfortunately, the lack of standardisation, and the multiplication of different communication protocols added a level of complexity when designers considered using this technology.

2.3 Do you speak EasyBus?

As for other industries, the development of a new technology always generates new demands, requiring new ways of working and standardisation.

For example, among new technologies introduced over the last decade, there is the short-range radio Bluetooth, which is an illustration of a new technology that in 10 years has moved from laboratory research to commercial success.

Everything started in 1994 when Ericsson initiated a study to investigate the feasibility of a low-power low-cost radio interface between mobile phones and their accessories. In February 1998, five companies, Ericsson, Nokia, IBM, Toshiba and Intel formed a Special Interest Group (SIG). 10 years later, 1.5 billion Bluetooth devices are in operation worldwide. [7]

Bluetooth is an illustration of a new technology born from the willingness of Industry leaders to share knowledge, working together to develop new solutions that make life easier, and more efficient.

Bluetooth could seem to be an odd example though it proves the efficiency of a new way-of-working when companies are collaborating to develop new technologies, making it possible to develop interoperable units by creating a standard.

The new possibilities and simplicity offered by the addition of digital control into power supplies revealed the lack of efficient communication protocols dedicated to this new domain of applications emerging in the power industry.

Introduced by Philips in the early eighties, the Inter-IC-BUS (I2C) cohabited with RS-232, RS-485, SMBus, SPI Bus, CAN Bus, and many proprietary protocols and formats.

In this jungle, components manufacturers, power industry leaders, and end-users began considering how to develop and standardise a common vehicle and a package of instructions to support this new technology.

In the same spirit as Bluetooth, in May 2004, Artesyn Technologies, Astec Power, and a group of semiconductor suppliers (Texas In-struments, Volterra Semiconductors, Microchip Technology, Summit Microelectronics, and Zilker Labs) formed a coalition to develop an open standard for a communication vehicle and protocol dedicated to power systems. A standard named PMBus was born (Figure 3).

Figure 3 - PMBus™

At the end of 2007, the PMBus Implementers Forum (PMBus-IF), comprised about 30+ adopters with the objective to provide support to, and facilitate adoption amongst users.

3. Digital Forward

From 2004, in parallel to the development of PMBus, step by step companies started to introduce new products and solutions to facilitate the evolution from analogue to digital.

As in the previous example, the following events listed in this paper are for information, provided as an illustration. Many more could be added.

July 2005
Atmel, C&D Technologies, and Power-One, announce the launch of z-alliance.org. Roal announced a digitally controlled 2KW power supply, the PS194

September 2005
Artesyn announced its first digital POL, the DPL20C series

Astec is the first to use bi-directional PMBus into a dc/dc converter, the DTX series

March 2006
Linear Technology introduced a digital dc/dc controller IC with PMBus interface

July 2006
Zilker Labs launched a 3A controller IC that integrates digital power management and PMBus

Maxim to release digital power supply controller that uses PMBus

March 2007
Intersil announced PWM controller PMBus™ enabled, the ISL8601

April 2007
With the UCD9240 Texas Instruments introduced the First 'Digital Power System Controller'

Primarion launched Industry's First Dual Output Digital Synchronous DC/DC Controller (dual-phase PX7522)

May 2007
TI released a new concept, "PowerTrain" combining UCD9240 and termination module PTD08A010W. This combination of control IC and semi-finish products modules is a unique approach, which some consider as a midway solution between pure discrete solution and modules.

August 2007
Power-One launched a digital POL providing 60A (ZY8160)

September 2007
Primarion announced a reference design for its PMBus™ compliant PX7522

October / November 2007
Different forums (USA and Europe) confirm the positive trend in digital power, supporting the idea that, as for other industries, standardisation will be a strategic decision factor for end-customers when migrating from analogue to digital.

This short overview should comfort the opinion that digital power has moved forward though, despite signs of evidences that technology is now ready and mature, supporters from both camps, "Analogue Forever" and "Digital For Future" are still debating.

4. Revolution or Evolution?

Novelties, new ideas and concepts are always a source of debate, bringing pros and cons arguments to defenders and challengers.

The number of papers, articles, technical summits, products and solutions released from the Millennium should be enough to demonstrate the benefits of implementing digital technology into an industry that has for some time been considered as a commodity, and slow moving in terms of innovation when compared to others.

However, fuelled by the force of marketing led arguments about the inevitable replacement of analogue by digital, digital aficionados predict that as it has been for other market segments, the power industry will not be able to avoid the inevitable digital revolution, comparing it to other industries such as the music industry and the death of vinyl, replaced by the CD [9].

Looking at the other side of the argument, analogue aficionados claim that digital power is nothing new, and that adding digital functionalities to a power supply is as old as the launch by Philips of the world famous Inter-IC Bus (I2C) introduced in early eighties [10], and that nothing will drastically change just because digital marketing is in the air.

Taking into consideration the arguments from both camps, the power industry generally behaves similar to others, following the same rules in terms of technical evolution, technology transition, and marketing.

The transition from vinyl to recordable CD has always been highlighted as a reference, but that is without considering other products and standards, where despite technical benefits and leading edge technology haven't encountered expected market recognition. As the data-storage industry presently battles with the standardization of the next generation of high density DVD format (Blue-Ray versus HD-DVD), we should remember that a few years ago Betamax lost the battle against VHS - despite Betamax's better performance.

As it was for the adoption of a video standard, even at it's relatively modest level, digital power conversion is following the same rules and the principle of 'R.G. Cooper's Law' [11]; "for every four products that enter development, only one becomes a commercial success."

5. Conclusion

Driven by growing concerns about energy preservation and reduction of CO_2 emissions by the Information Communication Technology (ICT) industry, power supply manufacturers have taken seriously the measure of the situation and initiated a number of projects that contribute to reduce the environmental impact.

The development of efficient power conversion systems associated with active energy management, made possible by digital technologies, is the most evident way to go, contributing to the rapid development of commercial "digital power solutions."

Despite the belief in some that one technology will prevail over another, it will not be a war between analogue and digital, but more a cohabitation between both, and a smooth transition when equipment manufacturers consider new systems or major updates.

We should remember that volume applications such as radio base stations or datacentres have longer lifecycles than most consumer products, and that the interoperability requirement increases the design time of such products as well.

Whatsoever, and to conclude, as it has been for other industries (remember how Bluetooth turned into success), the migration to digital power will require the power industry to consider new ways of working and efforts to standardize the basic principle.

That is the only way to go to guarantee market adoption by designers and end-users of digital power technology; nothing will happen by magic.

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