

Qualification and Verification Considerations for Digital Power Supplies

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Technical Paper

The introduction of digitally controlled power supplies have huge impact on the Quality Assurance process and solutions to the issues discussed in this paper will be vital to the success of digital power in the telecom and datacom markets.

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About this paper

Material contained in this paper was first presented on September 10, 2007 at Digital Power Forum 2007 - Plenary session.

This focused three-day international conference served an audience of decision makers who are interested in learning about and contributing to the latest practical advancements related to the use of digital power control techniques in electronic systems and in power converters, and digital energy management and power management in enterprise-level installations and related digital equipment.

1. Introduction

Digitally controlled and managed power supplies represent a rapidly growing part of the power conversion industry. It is an exciting and dynamic part of the market because of the many advantages it offers relative to conventional analog-based control methodologies. Hardware and system impacts of digital power are being addressed in the many conference papers and trade journal articles that have recently been appearing. But this highly configurable new approach to power supplies has other impacts both to suppliers of power hardware and to their OEM customers. One of these impacts is the Quality Assurance process, which faces new challenges with the introduction of digital power supplies.

A conventional power converter or regulator with an analog control system is “hard wired” to perform to a set of documented specifications, and the normal Quality Control processes are designed for this environment. With digital power, the converters and regulators are highly configurable via software resulting in an almost infinite number of possible performance attributes. Some of the Quality Assurance issues that arise from this change include management of software levels, verification of memory operation internal to power supplies, sourcing of critical digital control components, more complex verification testing, lifetime and reliability implications, software upgrade procedures, and failure analysis. Ericsson is one of the industry leaders in the design of digital power and recognizes that solutions to the kinds of Quality Assurance issues listed above will be vital to the success of digital power in the telecom and data-com markets. Ericsson therefore has a commitment to be proactive in identifying and resolving the Quality Assurance implications of digital power. This paper will describe the initial efforts.

2. Digital Control

A comparison of the differences between analog and digital control is shown in Figure 1, which shows a generic example of a power converter, and briefly describes what “digital power” actually means in a typical power supply. Much of the content internal to the converter remains essentially unchanged when going from analog to digital control. Examples are input and output filtering, magnetics, and power semiconductors. The primary impact of digital control is in the control/feedback loop of the power supply. The analog control chip is removed and replaced by a micro controller (μ C), memory support, and an interface bus for communication outside the power supply. Control algorithms for the power supply are contained in software loaded into the internal memory. This approach provides several benefits:

- Higher efficiency
- Higher packaging density
- Increased configurability
- Fewer hardware part numbers
- Field configurability and upgradeability
- Faster system time-to-market

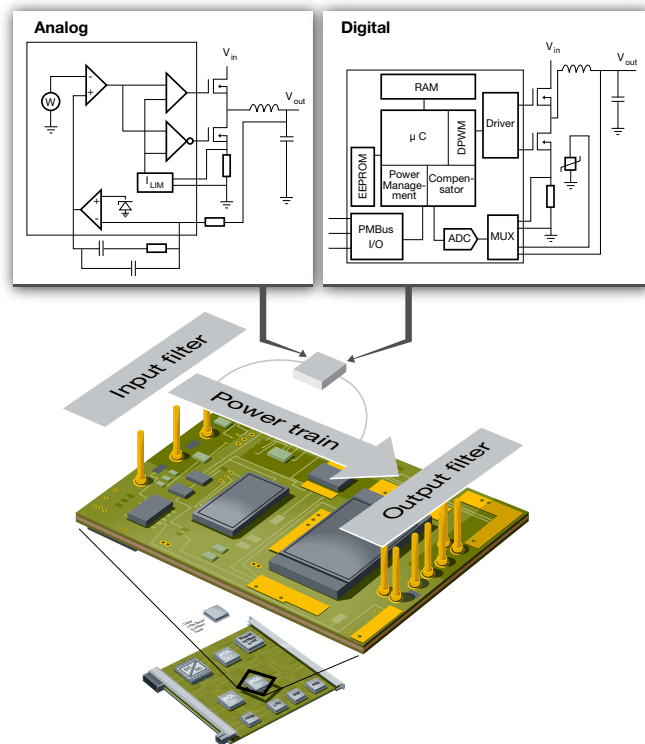


Figure 1 - Digital Power Control

Digital control also raises some risks or potential concerns from a Quality Assurance perspective, including:

- With almost infinite configurability, how are the logistics managed?
- The new software “component” must be verified and qualified.
- The internal memory must be extremely reliable. How is it verified that no data is lost?
- How is the operation configuration of the power supply done during manufacturing testing?

3. Software

From an operational point-of-view, the biggest difference between analog control and digital control is the added component of software for the digital case. The software provides many benefits for the developers and users of digital power products, but it also adds complications to the qualification, manufacturing, and logistical support processes.

The μ C used in Ericsson’s digital power products is supported with onboard non-volatile memory. This memory is used to store the basic firmware that allows boot-up and operation of the μ C. Obviously the robustness of this data is critical to the operation of the converter or regulator, as without it the μ C cannot function at all. This basic firmware tends to be relatively stable in regard to change activity for any given hardware implementation of the μ C. This firmware is loaded into the μ C non-volatile memory during the manufacturing process of the μ C.

The more interesting and flexible software in a digitally controlled power supply is the application programming. This code contains operating parameters for the power supply’s feedback control loop, settings for output voltage, fault detector limits, error handling routines, sequencing information, etc. Each digital power supply is capable of operation over a broad range of many of these parameters. During the manufacturing process of a standard digital power supply, default settings are defined, entered and verified before product shipment. In addition, several other representative settings must be tested to insure that the power supply will operate reliably over its

intended range of functionality. A further complication is that some parts of the application programming can be done by the OEM user if they are using the product in a digital power management environment. Thus the software and the processes for its control and Quality Assurance must address usage by both Ericsson during manufacturing and by the customer during product development and field deployment.

4. Quality Assurance Implications

The Quality Assurance implications of digital power extend through all stages of Ericsson’s operational processes from the sourcing of raw materials through field support activities. A flow chart showing the areas affected is provided in Figure 2. Each of these areas will be covered in more detail in the material that follows. The reference section at the end of the paper cites several sources of information about Ericsson’s general Quality Assurance programs. While they do not address digital power specifically, they will give a good overview of Ericsson’s commitment to quality and of our level of attention to operational details.

4.1 Material Sourcing

Ericsson places a high degree of emphasis on quality in all of the material sourcing, as explained in the reference material. In the case of digital power, the biggest new challenge will be the management of the μ C device, both from a sourcing security point-of-view and in terms of managing the included firmware. Digital μ C chips intended for power supply applications are relatively few in number at this time. They are also highly complex devices with no standardiza-

tion from supplier to supplier. Consequently, second sourcing is not an option. Instead, we will insist on “secure sourcing”. The supplier of the chip will have to have two or more manufacturing sources, and regularly ship product from all of them to insure equivalency and to minimize start-up problems at any manufacturing site.

There will be very close contact and substantial dialog between Ericsson and the suppliers of the μ C chips used in digitally controlled power supplies. The following are the types of provisions that will be required:

- Two or more equivalent manufacturing sites for μ C chips
- Inclusion of a very robust non-volatile memory and communication interface
- Built-in fault detection and diagnostic capability of the digital functionality
- Extended quality testing during the IC design and manufacturing processes
- Insurance of level control for firmware loaded during IC manufacturing
- Thorough control of logistics flow during IC manufacturing and shipment

4.2 Design Verification Testing

Design Verification Testing (DVT) is done near the end of a product’s design cycle for the purpose of insuring that the product, as designed, meets all of the requirements and specifications for the product. Both

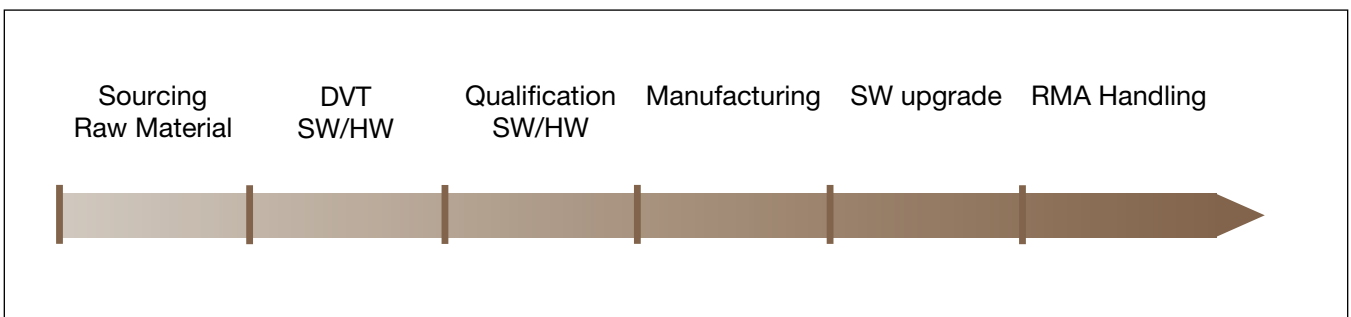


Figure 2 - Quality Assurance process

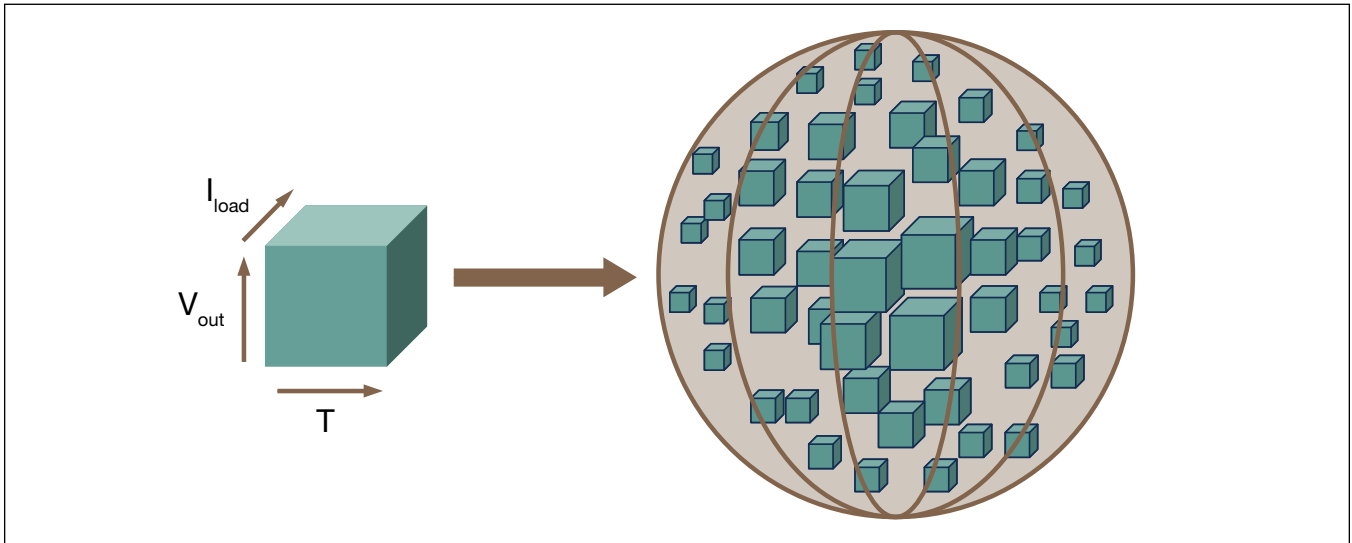


Figure 3 - DVT complexity

functionality and performance must be verified. With digital power, the DVT will also apply to the software content of the product. An analog product has a few well defined “corners” of its specification space. For example the parameters of output voltage, output current and temperature might be the key elements of the specification for an analog power supply. These three parameters define a three dimensional space such as the cube shown in Figure 3. By making measurements at each of the eight corners of the cube, operation of the product can be insured over the entire operational ranges of the three parameters.

The situation is entirely different with digital power. Because the software is highly configurable and can control dozens of individual parameters, the number of possible combinations is essentially infinite, and the number of “corners” expands exponentially as indicated by the graphic in Figure 3. In essence, the software makes it possible to define an almost infinite number of “products”, not just one. Ericsson addresses this problem by using an “intelligent DVT” process.

The concept of an intelligent DVT is to define software for multiple platform implementations spanning the expected applications for the power supply. Each of these implementations will include specification of the external functionality of the product such as output voltage and fault monitoring/handling behavior. Each implementation will also define parameters and functionality within the power supply such as control

loop compensation settings. A checksum will be generated for each configuration so that the operation of the memory can be verified.

Another area requiring exceptional focus during DVT is the electromagnetic susceptibility (EMS) performance of the μC and memory. These are very complex, small geometry ICs that are critical to the operation of the power supply and are located in close proximity to the large currents and fields resident within a switching power supply. Their robustness in such an environment must be carefully verified so that data integrity is not compromised. Ericsson plans to utilize a special test board for this purpose and conduct EMS testing at levels in excess of 10 volts per meter. X-ray, neutron and proton radiation testing will also be done.

Ericsson will also put emphasis on insuring that the communications bus interfacing the power supply to the outside world meets all the requirements of the appropriate specification. This is important to guarantee that the power supply will interface seamlessly with host controllers in customer systems and provide compatible communication with all other devices on the bus.

4.3 Qualification

Qualification testing insures that the design and manufacturing processes produce a product that

will provide long-term reliability under a variety of environmental conditions. This testing can be done at more than one level in the process flow, both at the component supplier and after final assembly of the power supply, for example. The key qualification challenge for digital power will be the long-term performance of the μC and memory with regard to software data integrity.

The hardware qualification testing of a digital power product will be very similar to that of a conventional analog product, but with additional emphasis on those elements that can affect the reliability of the stored data. The IC supplier is of course required to conduct and document extensive qualification testing at the chip level. These tests will include Write Endurance and Data Retention.

Ericsson will also test the data retention and integrity of the memory by comparing the memory content via checksum both before and after the standard hardware environmental tests such as 1000 hr 85°C/85% RH and Life Testing. Extended EMS environmental tests will be defined to insure long-term reliability in a variety of intended application environments.

4.4 Manufacturing

The purpose of the quality focus during the manufacturing process is to eliminate all quality risks in every manufacturing step to ensure that customers receive products on time and within specification. “Making it right the first time” will save time and money for both Ericsson and customers in the long run. The changes to the manufacturing process to enable production of digital power products are actually rather minor. Changes relate to the software control component in terms of dealing with the software and memory verification. Software customization also means that now the same physical hardware can represent multiple part numbers. This customization will be done during the manufacturing electrical test process when the application software is loaded into the power supply memory.

To facilitate loading and verifying the software, the Automated Test Equipment (ATE) will be modified to include a standardized communication interface. An integrated intelligent logistics system will be used during the manufacturing test process to insure that the correct application software is loaded into the

power supply depending upon its intended purpose and functionality. The ATE will, by means of the communications interface, then conduct a memory check to verify that the software loaded into the power supply is the same as the memory content of the power supply. This is done via a bit-by-bit comparison of the input data and stored data read from the power supply memory as shown in Figure 4.

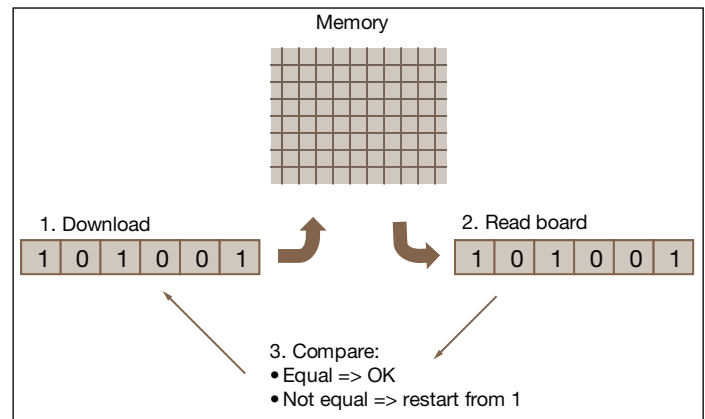


Figure 4 - Memory verification

4.5 Software Upgrades

Our focus on Quality includes the period after the product is shipped. Software performance and functionality enhancements could occur after the product is in the customer’s equipment. These changes could be driven by improvements developed at Ericsson or they could be the result of specific customer requests due to a change in the system requirements for their particular application. It is important to have a reliable system in place for managing this software change and upgrade activity.

Software upgrades can be distributed to the end user by multiple methods, as shown in Figure 5. A CD containing the new software can be sent via mail. A quicker option is to send the software as an Email attachment. Another possibility which may be explored in the future is the ability to have download files available on the Ericsson Power Module website. Regardless of the distribution method used, the new software version is first loaded into the customer’s host computer. This computer, which could be part of a development system or the control computer in the system application, can then provide the update to the affected digital power supply via the standardized communication bus.

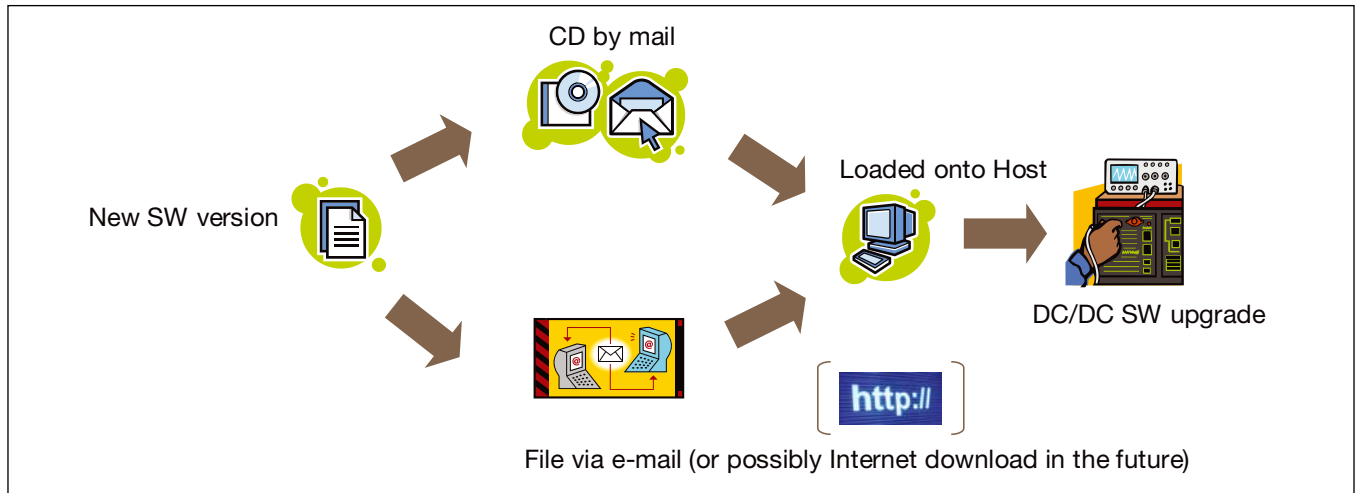


Figure 5 – Software upgrade process

4.6 Customer Support

The extensive Quality Assurance efforts within Ericsson that are described in this paper will guarantee product quality in the field environment. In case of a quality problem in the end-user product it may be related to a failure in the power supply hardware, or it could be created because of some anomaly in the end-user's product or system. In either case, it is important to have processes in place to make the proper determination accurately, quickly and with the minimum amount of disruption to the customer. All customer inquiries and concerns should be handled in a professional manner and resolved with a closed feedback loop so that corrective action is effectively communicated to the customer.

The method used by Ericsson for this process is the Return Material Authorization (RMA). It turns out that digital power actually will offer some advantages for this process relative to a conventional analog power supply because of the digital supply's ability to capture operational information within the customer's system and store it in memory. Analysis of the memory content of the power supply should be quite helpful in locating the cause of the problem. This can be accomplished quickly because of the ability to transmit this data electronically in real time rather than waiting for shipment of a power supply back to Ericsson. Furthermore, root-cause analysis and fixes for corrective action can also often be done while the power supply is still installed in the customer's application system, providing for very rapid response and resolution.

5. Conclusions and Summary

Ericsson's initial efforts at establishing Quality Assurance processes that address the new challenges that are a part of digital power have been described. There are indeed challenges, but the approaches outlined in this paper help to guarantee reliable digital power products. The following observations and conclusions can be made:

- Digital power has many benefits, and will become a major trend for telecom and datacom systems.
- Conversion from analog to digital control in a power supply results in new demands for the verification and qualification processes.
- The Quality Assurance of the critical μ C and its sourcing will be very important.
- Verification of the internal memory operation and reliability will be critical.
- Software is a component of the power supply and will need to be managed during the supply chain and product life cycles.
- Both DVT and production testing will be more complex due to increased product configurability.
- A system for managed software upgrades is possible.

- RMA activity will actually be enhanced due to the ability of digital power supplies to capture data in the application environment and communicate with Ericsson in real time.

Being proactive in facing these Quality Assurance challenges is in the best interests of the customers, and maintaining an open dialog is the best way to proceed. Ericsson will continue to document and publish progress in this exciting new endeavor, and invite customers to share their experiences and ideas so that the benefits of digital power can be maximized in the transition from an analog to a digital environment.

Trademarks

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6. Glossary

ATE	Automated Test Equipment
DVT	Design Verification Test
EMS	Electromagnetic Susceptibility
HW	Hardware
IC	Integrated Circuit
MCU	Micro Controller Unit
PMBus™	Power Management Bus
PWM	Pulse Width Modulation
RMA	Return Material Authorization
SW	Software
μC	Micro Controller

7. References

More information on related topics and some additional in-depth descriptions of the technology that this paper addresses can be found in the papers listed below.

- [1] Performance Improvements for OEM System Designers – A Digital Control Case Study, DPF '07, Dallas USA, Sept 2007
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