INTERRUPT INSIDE

An in-depth magazine about embedded technology from Data Respons 1, 2014

Electronics in space

What are the challenges that space microelectronics circuits have to face?

A novel biomass management system

How does technology stop farmed fish from escaping?

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EMBEDDED SOLUTIONS

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ARTICLE SERIES:

The impact of consumer electronics on development of high-reliability products

Article 1: Small pitch packages and high reliability circuit boards

WELCOME TO INTERRUPT INSIDE

Data Respons' vision, ***a smarter solution starts from inside***, is our company's DNA described in one sentence. We really think that we can make the world smarter and we really think that this starts from the inside - whether it be inside the heads of our specialist engineers or new technology embedded into the world's products and solutions.

Our customers are typically excellent technology companies, often champions of their fields and driven by in-depth knowledge, product innovations and technology changes. Our daily work is in close collaboration with these R&D environments, where we often take the specialist role on our core areas.

In this magazine, we want to highlight relevant technology areas and in-depth research. This issue of Interrupt Inside will especially focus on topics related to solving the demands for technology used in harsh environments and hazardous areas such as the oil & gas- and space sector. Additionally, this issue starts off a series of articles discussing the impact of consumer electronics in developing high reliability products.

All of the articles are written by our own specialists and employees. We welcome any feedback and suggestions from our readers.

Enjoy the reading!

KENNETH RAGNVALDSEN

> The project manager needs to be reassured that his project will be finished on time, with the right quality, with transparent communication and inside the agreed cost estimate.

GET THE RIGHT VALUE-ADD

-WITH R&D SPECIALISTS

BY: Ivar Melhuus Sehm,
Director R&D Services
Data Respons AS

A project manager has several factors to consider when hiring R&D resources. Cost is of course one of them, but who you hire and with what kind of expertise and experience is more relevant for the end result.

Our customers want an engineer, or a team, who is more than capable of just doing the job, and who is experienced enough to guide them to smarter and more cost-effective solutions. In other words, the customer wants real value-add.

LOW RISK

By using R&D specialists the total risk on the development project will be reduced. Our specialist engineers are hand-picked into external projects based on their technical competence and industry relevant experience, leaving nothing to chance.

Moreover, Data Respons has solid knowledge of environmental factors and applicable standards required in various applications, whether it is Functional Safety IEC 61508 for subsea installations or MILSTD-810F for military systems.

A project manager needs to be reassured that his project will be finished on time, with the right quality, with transparent communication and within the agreed cost estimate.

An R&D specialist team from Data Respons will have the relevant training, confidence, methodology and tools to do just this.

VERTICAL COMPETENCE NEEDED

A typical example is the Oil & Gas sector; it takes years of experience to truly understand the customers' needs in terms of meeting the industry standards and be a solid expert on areas such as Functional Safety.

Data Respons' engineers are continuously being trained to become better embedded specialists which in return strengthens our collective competence increasing our customers competitive edge.

Our R&D specialist teams will not just complete the task according to technical specification. They will provide feedback on improvements to the customers' design, find ways to perform the task faster and suggest design features that extends a product's life cycle .

Hiring an R&D specialist team let our customers stay focused on their core business rather than worrying about all the details.

THE RIGHT VALUE ADD

Many of Data Respons' customers are leading high-tech companies developing cutting edge technology with extremely qualified in-house R&D departments.

Tight collaboration between Data Respons' specialists and our customers' R&D teams allows us to achieve an in-depth mutual knowledge of systems and technologies. This has over the years built long term beneficial partnerships and created the right value add.

IVAR A. MELHUUS SEHM
is Director of R&D Services and has worked at Data Respons in various positions since 1999.

He holds an MSc in Electronic & Electrical Engineering from the Heriot-Watt University in Scotland and a BSc in Electronic & Electrical Engineering from Oslo University College (HiO).

Ivar Sehm has an extensive background from the embedded industry and has previously worked at the Norwegian Army Material Command, Sysdeco AS, and Geoteam Exploration.

ELECTRONICS IN SPACE

Space electronics is a field of R&D that few people have heard about or had experience with, still it could be interesting to everyone with a minimum of electronics knowledge to get some insight into this field. This article discusses the challenges that space microelectronics circuits have to face, evaluating the latest trends and developments and especially focusing on reprogrammable circuits.

BY: Olav Torheim
Senior Development Engineer
Data Respons

Historically considered, space electronics has been a major driving force for the development of electronics. It was the development of rockets and missiles during the cold war that led to the first mass production of integrated circuits. Today the situation has however been turned upside-down: Electronical components have found their way into all kinds of consumer articles, and there are just a few electronics producers who have specialized in the little niche that space missions have become. A considerable technology gap has therefore evolved between the capabilities of space components compared to those of commercial components.

THE SPACE ENVIRONMENT

Space electronics is subject to very harsh environmental conditions. First of all, the electronics must survive the vibrations imposed when the rocket is launched. Secondly, it has to be able to withstand very high temperature variations. Due to the vacuum in space, there is no thermal convection or conduction taking place, with the only heat transfer mechanism remaining being radiation. A satellite orbiting the earth therefore experiences that the temperature varies from more than 120 Degrees Celsius on the side facing the sun to less than 150 Minus Degrees Celsius on the shadow side of the satellite (out in the cold, interstellar space, the radiated temperature goes as low as 2.7 Kelvin, given by the background radiation). As air cooling is not possible on a satellite, the satellite instruments have to be designed in such a way that the heat is led away to a place on the shadow side where it can radiate out in the cold space.

Outgassing is another issue that has to be taken care of. As space instruments normally are placed as payloads on a satellite together with other instruments, it is not acceptable that the components are releasing vapors and thus interfering with the measurements of other instruments, for example by depositing material on optical components. Space qualified components therefore have to be manufactured using ceramic materials – plastic packages are normally not usable.

Space electronics meets many of the same challenges as the electronics used in offshore installations, like the requirement to withstand very high temperatures. However, in space there are also requirements to meet that we do not see so many other places: For example, the electronics has to withstand much higher levels of radiation than on earth.

In space, there are many sources of radiation. With the solar wind comes both electrons, protons and heavy ions. In addition, there are protons and heavy ions coming from galactic, cosmic radiation. When these particles approach the earth, they are captured by the earth magnetic field, and as a consequence electrons and protons get trapped in radiation belts called the Van Allen belts (the heavy ions are also being deflected by the magnetosphere, but due to their higher energy, only a few of them are actually getting trapped in the radiation belts). For satellites in geosynchronous orbit, the radiation belts are causing significant problems for the electronics.

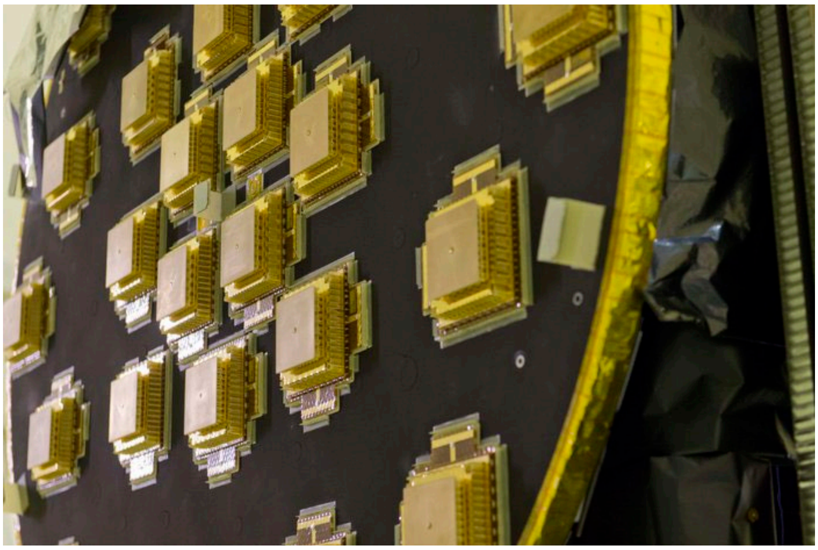


Photo: ESA

RADIATION EFFECTS ON ELECTRICAL EQUIPMENT

Regarding the satellite electronics, there are two ways that the radiation can do harm, either with so-called Single Event Effects (SEE) or with the Total Ionizing Dose (TID). Single Event Effects are, like the name implies, effects cause by one single energetic particle. While the Total Ionizing Dose is a measure of how much radiation the electronics circuits have accumulated over its lifetime.

The reason that the radiation finally destroys the circuits is the following: A particle going through a transistor generates electron-hole pairs in the thermal oxide used in the integrated transistors. While the generated electrons have a high mobility and therefore quickly find their way out of the oxide, many of the generated holes get trapped in the oxide traps that always are present due to impurities. The more the circuit is irradiated, the more traps are being filled up with holes, shifting the threshold voltage until the transistor has been permanently switched on or off.

Regarding the single event effects, one normally distinguishes between three different types of effects: Single Event Effects, Single Event Latchup, and Single Event Burnout.

• Single Event Upsets (SEU) are defined by NASA as "radiation-induced errors in microelectronic circuits caused when charged particles lose energy by ionizing the medium through which they pass, leaving behind wake of electron-hole pairs." SEU does not destroy the circuit, but it corrupts the information in registers and memory elements. But SEU does not have to be harmful as long as one has strategies to meet these effects. To get rid of a SEU, it is sufficient to reset or reprogram the affected memory elements.

• Single Event Latchup is a condition that can occur when charged particles are injected into the substrate material of integrated circuits. They way these integrated circuits are built up (MOS-technology, with their corresponding parasitic, bipolar structures) may cause these charges to enter into a positive feedback loop where more and more current is dragged through the substrate. If there are no mechanisms built in to turn off the power supply in time, the current may simply continue to increase until the entire circuit breaks down thermally. The dangers of latchup were earlier a major obstacle to the development of CMOS based technology.

• Single Event Burnout is a state where a heavy ion has passed through a power transistor and deposed sufficient charge to turn the transistor on. If the transistor remains in this state, the large currents through the transistor can be enough to destroy the entire circuit.¨

As the dimensions of integrated circuits get smaller, the probability of SEU gets higher, since less and less charge is required to reduce the voltage levels in a memory node. For TID, the opposite is true: The smaller the process, the thinner the gate oxide, and the fewer becomes the number of holes that can be trapped in impure states. The process technological development therefore makes it more and more easy to manufacture electronics that can handle high radiation doses, while it becomes more and more important to have good strategies for handling the single event upsets.

> Space electronics meet many of the same challenges as the electronics used in offshore installations, like the requirement to withstand very high temperatures.

SHIELDING AGAINST RADIATION

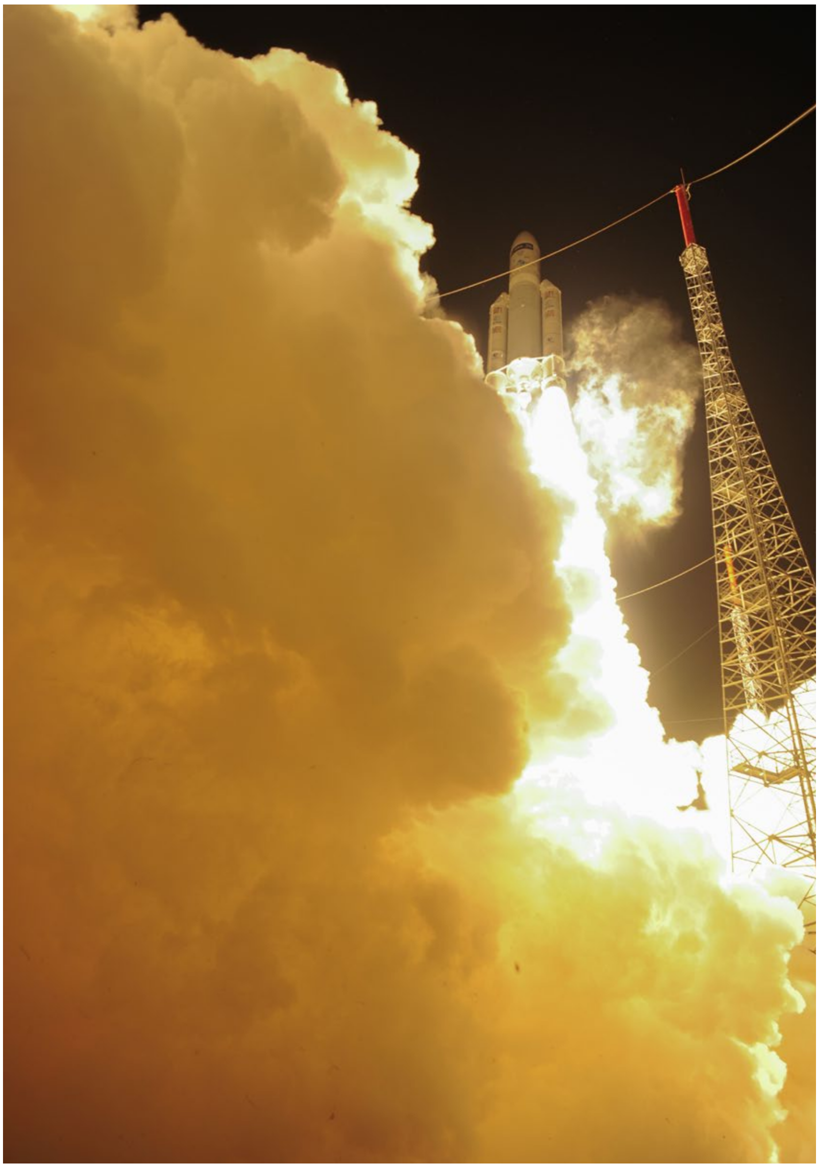
To shield against radiation, one can either try to shield the entire electronics box or one can use so-called Rad-Pak technology, developed by Maxwell, where the shielding is built into the package of the individual integrated circuit.

Shielding gives good protection against particles from solar flares, but have little effect against highenergetic, cosmic radiation. Similarly, shielding can most of all be used to reduce the total ionizing dose (TID). Against single-event effects, it is less useful.

This is related to the stopping power of charged particles (dE/dx): When the particle is slowed down by the shielding, it loses energy. But the lower the energy the particle has left when it has broken through the shielding, the less area it needs to depose the remaining energy. Therefore the danger of single event effects increases in the regions in the circuit that are affected.

REQUIREMENTS ON ESA FLOWN MISSIONS

The European Space Agency, ESA, sets strict requirements to components which are to be flown on an ESA financed expedition. The components should



EXTREME CONDITIONS: Great powers are in motion during liftoff of an Ariane 5 launcher from Europe's Spaceport in French Guiana with ESA's last Automated Transfer Vehicle to the International Space Station. (ESA–S. Corvaja, 2014)

not only be produced in a particular way, they always have to be tested in accordance to very strict standards in order to become qualified for space, and this leads to space components having a cost that is much higher than the commercial one. For example, it can cost thousands of dollars to obtain one single, space qualified clock crystal, while the off-the-shelf commercial crystals can be bought individually for 30 NKR each. The difference is that the space qualified crystal needs its own production line, including months of testing after it was produced, and with traceability throughout the entire process. However, for many components, the packaging and test procedures are the only things distinguishing normal components from space-qualified components.

For use in the qualification process, ESA has defined its own set of standards, called European Cooperation for Space Standardization, ECSS. ECSS has three main branches: project management standards, construction standards and quality ensurance standards.

It is therefore not only electronics that has to be designed, one even has to «design» a large variety of documents aimed at verifying that both the project and the product meet all relevant requirements. The strict ESA system is well-suited for private enterprises which have the infrastructure established to handle orders in this way, but for public research institutions, this can lead to a lot of additional paperwork. Many public research institutions have therefore taken the consequence and outsourced the technical/administrative part of their experiments to private enterprises.

THE ROHS DIRECTIVE AND THE SPACE ELECTRONICS INDUSTRY

Normal soldering tin has until recently been a composition of 63% tin and 37 % lead (eutectic tin). However, the European Union came with an environmental directive, called Reduction of Hazardous Substances (RoHS), that became active from 1st of July 2006. From this date, it has been forbidden to use lead in soldering.

Lead-free solder tin has a higher melting point than eutectic tin, and the components to be soldered lead-free therefore need to withstand higher temperature. But there is even one more problem with lead-free solder tin: It is called whiskers.

Whiskers are electrically conductive crystal structures made of tin which sometimes grow out of metal surfaces. They can grow many millimeters and therefore short-circuit conducting wires. Whiskers grow faster in vacuum than in air, and satellite systems worth millions have been destroyed due to this phenomenon.

It is only pure tin that produces whiskers, and one should therefore be safe with eutectic tin. Until now, the space electronics industry has been allowed to keep using lead-tin alloys for their instruments. However, the ban on lead in the consumer electronics industry has become an increasing obstacle for the space electronics too. The consumer electronics industry has replaced the tin-lead alloys with lead-free tin all over their production line, and there are not many producers that provide a complementary set of tin-lead based components for use in the space segment. Reprocessing the components with eutectic tin is a possible solution to this problem.

PRACTICAL SPACE APPLICATIONS AND PROGRAMMABLE CIRCUITS

Flexibility has always been a keyword when it comes to electronics designs, and it is not less important in space application where the design is locked once the satellite is launched. At the same time, it should be clear that the fewer components that are used in an instrument, the less the probability to introduces sources of failure.

Programmable, integrated circuits, collecting as many functions as possible on the same chip, therefore give major advances. Such circuits are called FPGA's (Field Programmable Gate Arrays). FPGA circuits were originally not so much used in space, as most of them are RAM based and therefore not sufficiently radiation hard due to the single event upsets. But the first FPGA circuits that were developed used antifuse technology, instead of configuration memory, to provide connections, and these circuits proved to be radiation hard. The American enterprise Microsemi (formerly Actel) has specialized on manufacturing

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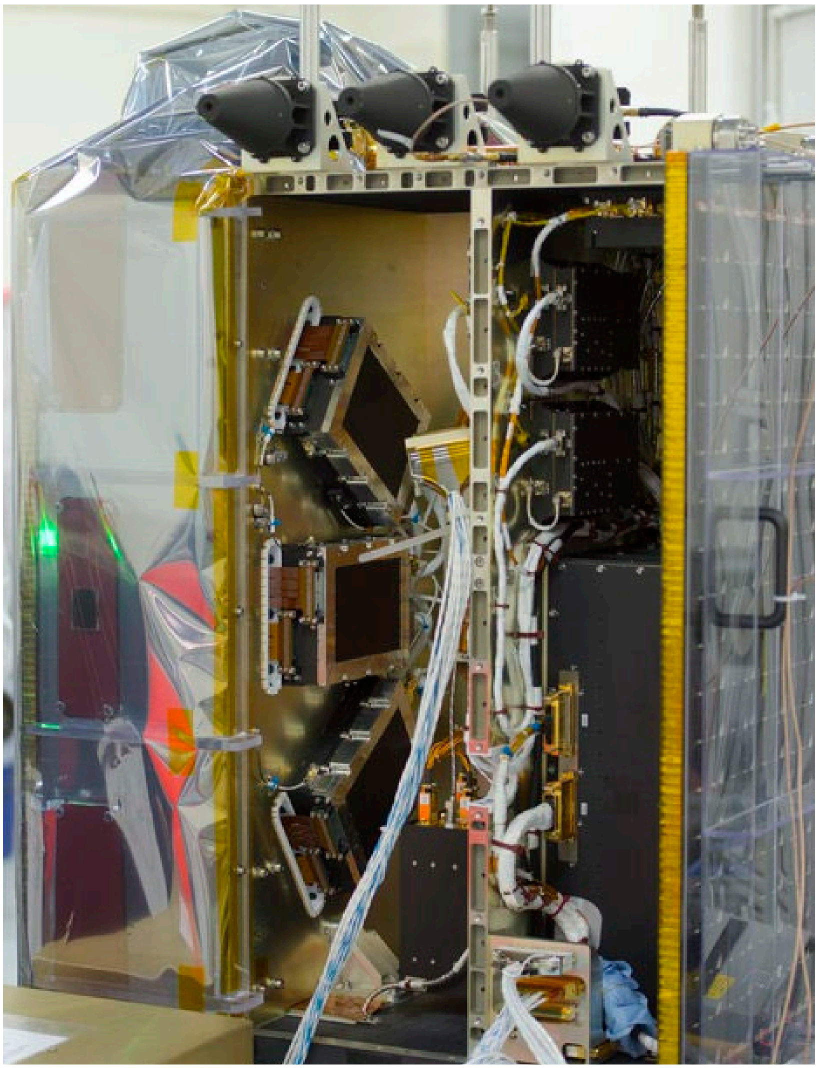
such circuits for the space segment.

The TID required to qualify a component as "radiation hard" or "radiation tolerant" varies from manufacturer to manufacturer. Some manufacturers set a limit of 100kRad to classify their component as radiation hard. Other manufacturers set even higher limits for their "radiation hard products". For example the antifuse based Microsemi RTAX has a TID of 300kRad, classifying as "radiation tolerant".

The TID required for a component used in an aerospace instrument depends entirely on the space mission itself, like choice of orbit and duration of the mission. For example, an instrument in polar orbit is exposed to less than 50kRad during 10 years, so a TID below 100kRad are in many cases acceptable. A safe choice would be to only pick conservative technologies able to withstand hundreds of kilorads. However, by taking the actual radiation environment into consideration, one would in many cases have freedom to pick technologies which normally are excluded due to their lower TID.

Antifuse circuits have the disadvantage that they can only be programmed once, and the FPGA architecture is therefore locked during the space mission. To keep the functional flexibility, an FPGA solution with an embedded microprocessor is a sound solution. Quick and simple functions can be built directly into the FPGA firmware, while more complicated control and regulation algorithms may be put on an external Flash ROM and run on the embedded processor. By using the Flash ROM for storing the software, one has the advantage that the system can be reprogrammed directly in orbit from the ground station. The LEON3 processor is 32-bit SPARC compliant embedded microprocessor, developed particularly for space missions and used especially on ESA funded missions. It is available as synthesizable source code for a variety of different FPGA circuits, including the RTAX.

> "...the fewer components that are used in an instrument, the less the probability to introducing sources of failure.



ESA's Proba-V satellite, ESA-S. Corvaja, 2012

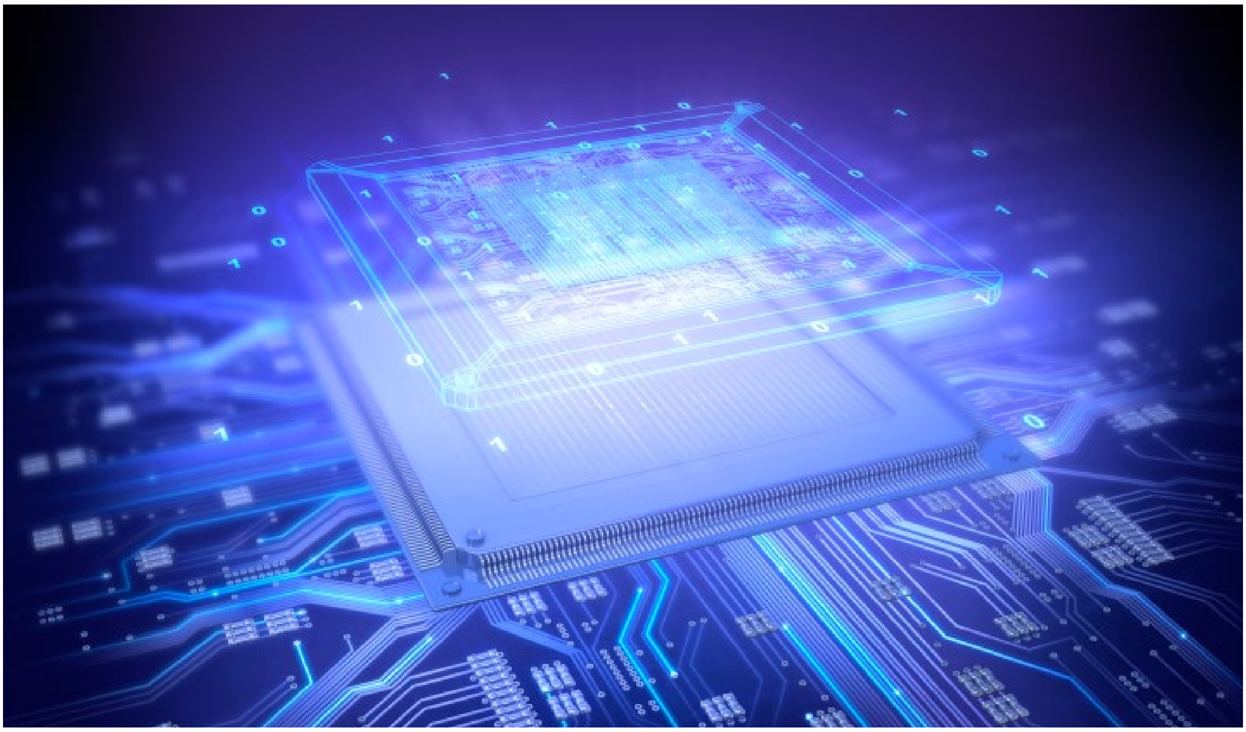
Although one does not want more components than necessary, one does not want any "single points of failure" either. On the contrary, it is often desired to build in redundancy, i.e. two or more modules serving the same function, to obtain a system that is fault tolerant. Triple Modular Redundancy (TMR) is a classical example of this: Instead of driving a signal with one single driver, one uses three. If one of the drivers is malfunctioning, for example due to single event upsets caused by radiation, the two other drivers force the third one back into the right phase.

TMR is an approach where the electronics building blocks themselves are made radiation hard. Another approach is to try solving the problem on a higher, logical level. For example, the software can build redundant, cyclical codes (CRC) into its data. Such codes preserve the digitized information even if one or more bits have changed value.

The Microsemi RTAX is an example of a circuit that uses both techniques to obtain radiation hardness. Ordinary logical elements like registers are protected with TMR while memory elements like RAM can be protected with error correcting codes where bit failures can be detected and corrected automatically by hardware.

ADVANCES IN FPGA DEVELOPMENT FOR SPACE

The last ten years there have been significant achievements in radiation hardening FPGA technologies based on Flash and SRAM. Today, Microsemi does not only provide antifuse based FPGA's for space, but also Flash based FPGA's. And now even Xilinx provide SRAM based FPGA's which are commercially available for the space segment, their state of the art designs being the Xilinx Virtex-4VQ and Virtex-5VQ.



Flash based FPGA

The reason that the Flash-based FPGA's have become radiation tolerant, is partly due to improved processing technology. The thinner the silicon oxide, the fewer holes get trapped in the oxide when a particle passes through, and hence, the higher becomes the Total Ionizing Dose. The RT ProAsic3 FPGA from Microsemi has been found to remain functional after 100kRad, and can therefore be considered radiation hard.

More impressive, however, are the advances made for SRAM based FPGA's. The advantage of SRAM based FPGA's is not only that they are reprogrammable, contrary to the antifuse based circuits. They even have a much high logic density than their flash based counterparts, and therefore they can house much larger and more complex digital designs.

As long as the single event upsets remained an unsolved problem, the SRAM based FPGA's were a technology that could not be counted on at all in the space segment. In an SRAM based FPGA, single event upsets do not only corrupt data, they can destroy the entire configuration – and therefore the functionality – of the circuit. Xilinx has come far in addressing these problems, using a variety of sophisticated techniques, on both logical as well as transistor level.

On the logical level, TMR is used to protect flip-flops against bit failures. At the same time, the configuration memory is constantly being rewritten, even during the normal operation of the FPGA. The technique is called scrubbing. The scrubbing can be used for both partially or full reconfiguration. When running partial reconfiguration, CRC codes are used to detect failures, and the parts of the configuration memory that contain failures are overwritten with correct configuration data. The correct configuration data is loaded from a radiation hardened Flash memory.

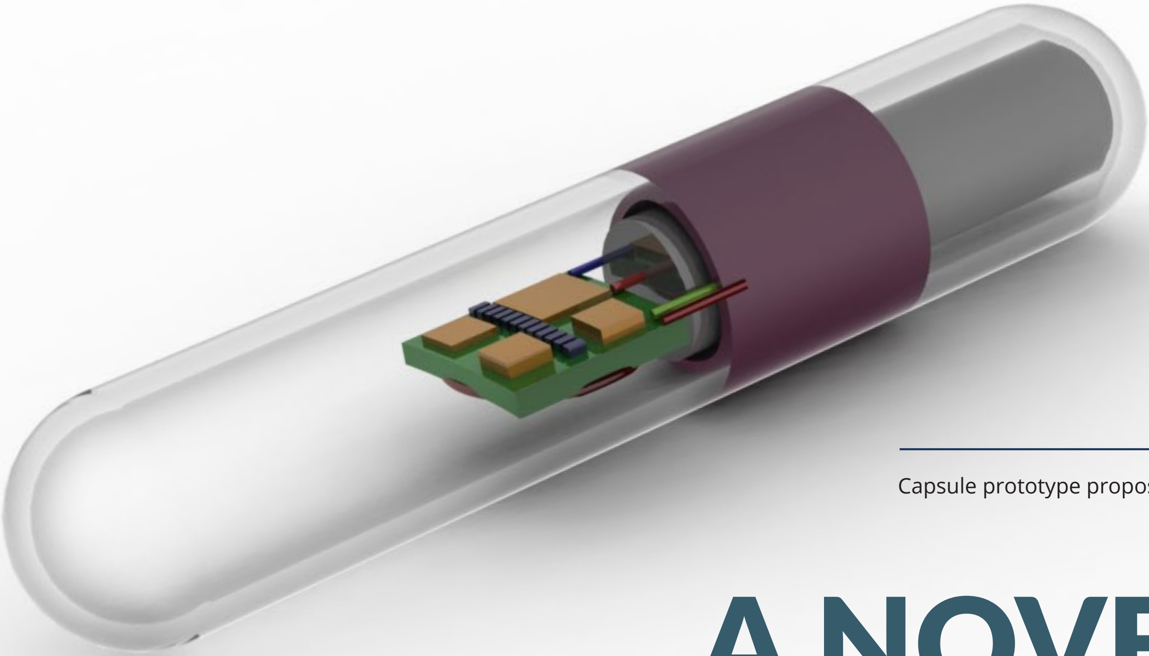
On the transistor level, Virtex-4VQ and Virtex-5VQ take advantage of an SRAM structure which is a bit different from the ordinary one. While an ordinary SRAM cell is comprised of six transistors, the radiation hardened structure uses 12 transistors, with all the 12 transistors interlocking with each others. This construction makes it much more difficult for a charged particle to flip the polarity of the entire cell, and it has dramatically reduced the probability of a single event upset.

When it comes to the total ionizing dose, the results are at least as good for the Xilinx circuits as they were for the Microsemi RTAX. Xilinx 4VQ has a TID of 300kRad, the same as for Microsemi RTAX, while the Xilinx 5VQ can withstand even a TID of 1MRad.

CONCLUSION

Microelectronic circuits for space have to meet requirements which are very different from those of ordinary consumer electronics, one of the most particular is the requirement to withstand radiation. The driving force of electronics development today is the consumer electronics, while space electronics developers prefer solution that are already proven safe and reliable. Considering the choice of components and practical circuit solutions for the space segment, one could say that the space electronics lags behind the consumer electronics with approximately 10-15 years.

In the latest 10 years, we have seen that the reduced dimensions have made normal microelectronics circuits more robust to withstand higher and higher radiation doses, increasing their TID. At the same time, new techniques at both logical and transistor level has made it possible to handle a much higher flux of single event upsets. These advances in technology and techniques has made it possible to pass on from antifuse-based FPGA designs to large and reprogrammable SRAM-based FPGA designs. The last decade we have therefore seen a development within microelectronics for space that is similar to the one already seen within ordinary consumer electronics.



Capsule prototype proposal

A NOVEL BIOMASS MANAGEMENT SYSTEM

Every year fish escapes from fish farms and pose a new form of environmental pollution. An active multi-purpose capsule device, remotely controlled by a surveillance and control system placed on the fish pen is under development to stop escaping fish doing any damage.

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BY: Andre Firing
Development Engineer
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HOW DOES IT WORK

The AquaFarmControl project will build a system to optimize the efficiency of fish farming. This will be acquired by adopting Precision Livestock Farming practices and eliminating the fish escape problem. The technology under development is centered on an active multi-purpose capsule device, remotely controlled by a surveillance and control system placed on the fish pen.

AquaFarmControl is an integrated technological solution for complete biomass management for fish farming. Behind the project is a consortium made up of Innovative European SMEs and leading research and development centers. Data Respons R&D Services is contributing to this innovative project, through both research and development phases.

SYSTEM OVERVIEW

AquaFarmControl includes two main functions; breach control and biomass metrics. The systems on the pen are monitored and controlled remotely by a control center.

Breach control is based on triggering a capsule device to terminate the escaped fish. The capsule device will be injected into the fish as it is initially vaccinated. When a hydroacoustic link is broken, the device will terminate the fish. This means that the capsule will need to stay active during the whole salmon growth period of 26 months. In addition, the size of the capsule is restricted by maximum size of implant without surgery. This puts high demands on compact design of electronics and extreme demands on low power usage. Minimizing power consumption is absolutely central in all choices of components, acoustic data link protocol and efficiency of software running on the capsule controller.

The advanced biomass metrics system monitors the fish population inside the pens in real-time. The main goal of the bio¬mass estimation is to determine the fish weight distribution. The result is increased control of biomass development and target sales weight, providing significant operational benefits. In addition, it allows for accurate dosage of fish feeds and improves the overall cost efficiency

BACKGROUND: Seafood Security AS is the project coordinator and instigator of the AquaFarmControl project. Seafood Security was founded in 2010, and its vision is to provide protection of aquatic biomass assets using sustainable "green" technology.

WHAT HAPPENS WHEN FISH ESCAPE: The escape may lead to adverse environmental impacts, because farmed fish can cross with wild fish. It is uncertain how this will affect the wild fish populations, but it is known that escaped fish has a lower survival rate. In addition, the escaped fish can transmit diseases and parasites. A financial loss for the aquaculture business is also an effect of this escaped fish. There are several reasons for fish escaping from the plants; technical failure, misuse of equipment, vessels damaging the net and extreme weather that damage the facilities.

of fish farming. Both hydroacoustic (low frequency resonant, tradi¬tional sonar, ultrasonic imaging sonar) and optical methods (stereo camera, time-of-flight cameras, laser based) are being evaluated as solutions for biomass measurement. Research is still ongoing to find the best method.

The system is scalable and designed for all possible size ranges of fish farming facilities. The unit placed on each fish pen includes a local area network connection to all units in the farm facility. Standard data connection between fish pen units is a wired connection. Each AquaFarmControl-installation store growth trends, size distribution, alarms and events during the full lifetime of the unit. All data on the pen unit is synchronized with a web service database.

SOFTWARE

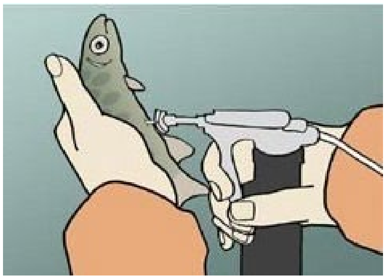
The AquaFarmControl software package is planned to consist of the two main components; fish pen system software and the surveillance and control system. In addition, there will be a web service database containing all data from all fish farms.

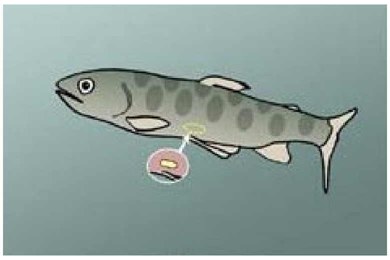
The fish escape handling software is considered the most critical part of the pen system software. This is due to the potential catastrophic outcome of a system failure. This software handles control of the capsule through a communication protocol and the overall monitoring of capsule states at the pen.

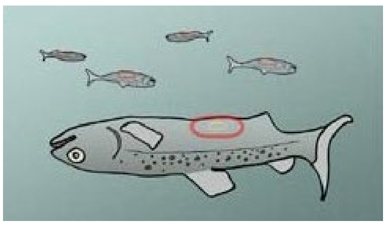
The capsules implanted in the fish will also include a tiny receiver and signal processing software in an ultra-low power microcontroller. This software will determine if the fish is still in the fish pen, or if it has escaped. In the case of an escape, the capsule software will terminate the fish. The biomass estimation software will also alert the pen alarm system, which can notify the maintenance crew that a breach has been detected.

The biomass estimation is handled in a separate signal processing software, which calculates the biomass property based on measurement data. This system will also be responsible for uploading and synchronizing the measurement data to an external data center.

The fish farm surveillance software provides an overview of the farm status in relation to farm yield, fish growth rates and pending alarms. Farm data can be accessed through a web interface or locally on a farm through a local area network. This software handles all human interaction with the system.



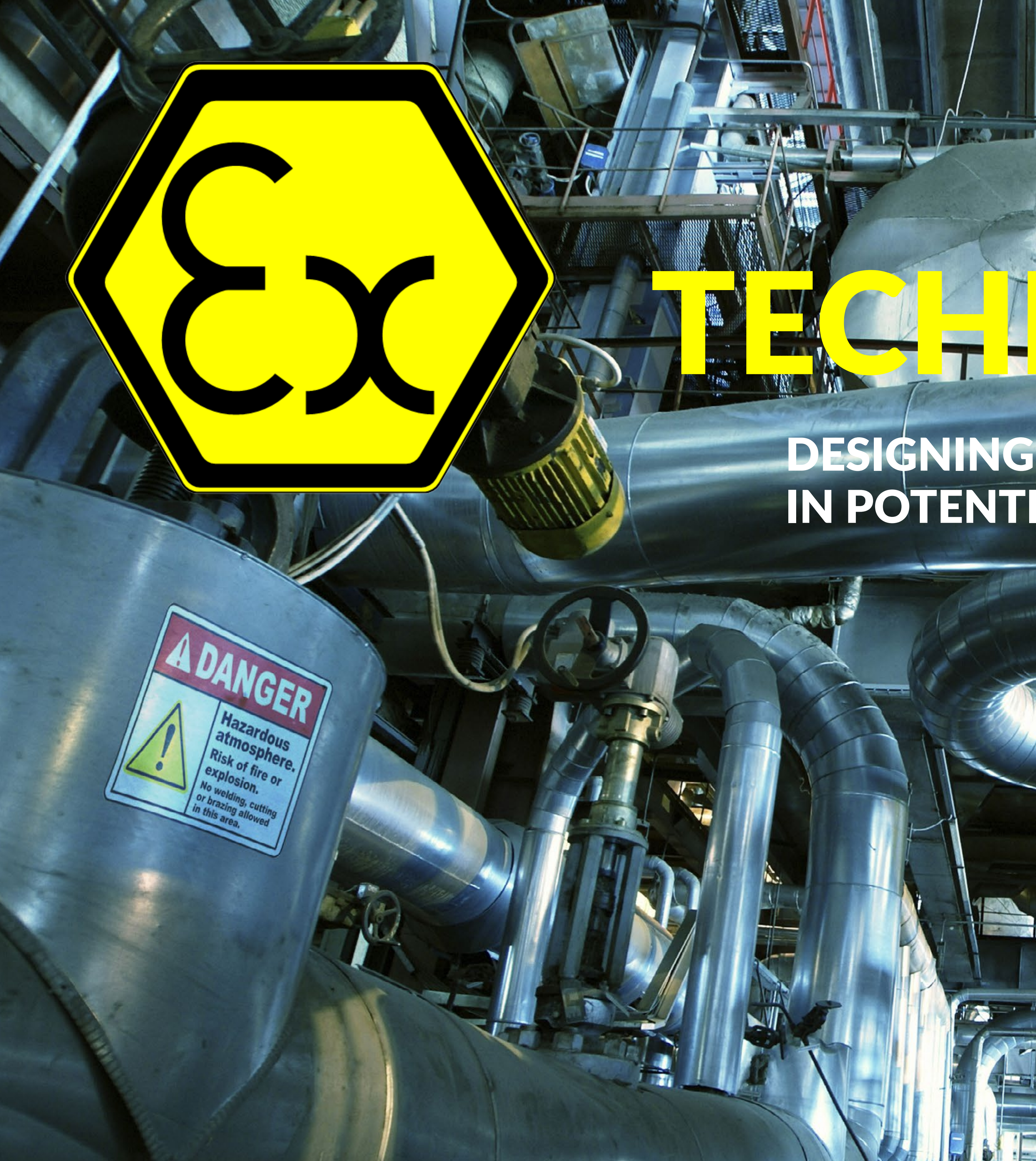




DATA RESPONS' ROLE IN THE PROJECT

Data Respons R&D Specialist Services have high hopes for this project going forward through research to a development stage. We have been handed the assignment of developing an acoustic communication link to the capsule, the fish pen system that communicate with the capsule and the system on the fish pen that estimate biomass. The capsule electronics is developed by the consortium partner ACREO, electronics production by K314, and Data Respons is responsible for capsule embedded software.

The capsule device is injected into the fish belly at initial vaccination and is triggered when the fish escapes from the pen.



TECH

DESIGNING
IN POTENTI

When designing electronic equipment for industrial environments such as oil rigs or chemical production facilities, the design has to be safe to use within potentially explosive atmospheres (hazardous areas). This article looks at the requirements for such designs and how to meet them.

NOLOGY

EQUIPMENT TO BE USED
ALLY HAZARDOUS AREAS

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WHAT ARE “HAZARDOUS AREAS”?
Hazardous areas are defined as places where concentrations of flammable gases, vapors, or dusts may occur. Electrical equipment that is installed in such locations must be specifically designed, tested and certified to ensure it does not ignite an explosion.

Enterprises handling flammable gases, liquids or dusts, are obliged to consider the explosion risk and perform a zone classification according to the Norwegian guidelines of ATEX-directive 99/92/EC. The potentially hazardous areas are divided into 3 different zones, determined by the likelihood of the presence of an explosive atmosphere. Each zone has its own rules for applying protection methods and precautions.

One distinguishes between two types of explosions: gas explosion and dust explosions. For gas explosions, the zone classification is as follows:

Zone 0:
An area where an explosive gas atmosphere is present continuously, or for long periods.

Zone 1:
An area where an explosive gas atmosphere is likely to occur in normal operation.

Zone 2:
An area where an explosive gas atmosphere is not likely to occur in normal operation, and if it occurs, will only exist for a short amount of time.

For gas explosions, there are three different gas groups (IIA, IIB and IIC), dependent on the spark energy sufficient for ignition. There are also six different temperature classes (T1-T6), dependent on the surface temperatures sufficient to cause an explosion in the flammable atmosphere.

HOW TO AVOID EXPLOSION
In general, there are three different methods to prevent explosions:

- Prevent an explosive atmosphere from being formed.
- Prevent flames from expanding.
- Prevent sparks, discharges and self-ignition.

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ATEX Certified server

These three methods represent three different design approaches. The first approach is an environmental approach, for example by assuring sufficient ventilation or by adding an inert gas to the atmosphere of the installation. The second approach is to find appropriate ways to encapsulate the equipment in the installation, preventing it from interacting with the explosive atmosphere. The third and last approach is to construct equipment that is designed not to behave in a hazardous way.

When designing electronic equipment for hazardous environments it is crucial to prevent sparks, discharges and self-ignition.

For electronics designers, the most important ignition sources to be aware of are surface heating and electrical sparks. However, there are also other ignition sources to be aware of, like mechanical sparks (from moving parts coming into contact), static electricity, ground currents, electromagnetic fields and electromagnetic radiation (both ionizing and non-ionizing).

INTRINSICALLY SAFE DESIGN

Intrinsically safe equipment is composed of intrinsically safe circuits that neither give sparks energetic enough to ignite an explosion, nor do they consume power high enough to heat surfaces to a dangerous level. An intrinsically safe circuit is safe by design, and in principle it does not need any additional protection.

Intrinsically safe circuits must also be provided with clearly defined input and output parameters, allowing the user to calculate which combinations of other circuits are acceptable, and which are not.

When designing intrinsically safe circuits, power consumption must be kept to a minimum to prevent surface heating. The power consumption of a device is typically kept under control by using current limiting Zener barriers. However, even with a very low power consumption, components like inductors and capacitors may store energy sufficient to give sparks. All nodes in the schematics therefore have to be analyzed using their worst-case values plus safety factors. Capacitors and inductors storing too much energy must either be reduced in value, or a resistor must be inserted in series to increase the discharge time constant of the node, which reduces the effective capacitance or inductance.

The required level of intrinsic safety, also called Equipment Protection Level, is determined by the zone where the electronics are to be installed. Installations in Zone 0 are required to be explosion proof even when there are two failures at the same time (Intrinsic level 'ia'). Zone 1 installations must remain explosion proof during a single failure (Intrinsic level 'ib'), and Zone 2 installations must remain explosion proof during normal operation (Intrinsic level 'ic'). Zone 0 and Zone 1 requirements can be fulfilled by inserting redundant circuits, for example by using three zener diodes in parallel for an Intrinsic level 'ia' Zener barrier.

EX CERTIFICATION

Equipment to be used in potentially explosive areas need to be certified according to the relevant standards. In North America, the Ex standards are defined in ANSI/NFPA 70 NEC Article 500 or Article 505. In Europe, the Ex standards are defined by IEC 60079. The ATEX directive 94/9/EC obliges all EU member states to incorporate this standard in their own national standards, and Norsk Elektroteknisk Komite has harmonized the IEC 60079 into NEK EN 60079. Equipment that is to be installed in hazardous areas must comply with the general standard IEC 60079-0. Depending on the Equipment Protection Level and methods used, equipment shall in addition comply with one or more sub-standards (i.e. IEC 60079-11 for intrinsic safety).

EX PRODUCT DEVELOPMENT

Data Respons has dedicated engineers with professional expertise that develop products with the required certifications for the oil and gas industry. Years of experience delivering embedded solutions with high quality and low cost to worldwide customers make Data Respons a strong partner for product development.

Offshore oil rigs are typical installations that has various zones classified as hazardous areas.

USING BIOIMPEDANCE

TO MEASURE AND ANALYZE TISSUE DATA

With correct instrumentation, bioimpedance theory can be used to measure and discriminate between different biological materials, including human tissue. Some examples of bioimpedance in use in medical applications are imaging of newborns lungs, measuring respiration rate and measuring sweat activity.

BY: Patrick Hisni Brataas
Development Engineer
Data Respons

A non-medical application can be a fingerprint sensor where it is possible to measure the difference between living and dead tissue. This can in some cases be important as an increased security measure to make sure the finger is still attached to the person it belongs to or to ensure that it is not some kind of copy. In this article, we shortly explain how we can use a needle as the measurement tool to distinguish between e.g. fat and muscle tissue or determine the quality of a piece of meat.

This article will highlight the most important bioimpedance theories, how bioimpedance can be measured and how to analyze the data.

WHAT IS BIOIMPEDANCE?

Bioimpedance is the term used when referring to the electrical impedance of a biological material. Bioimpedance describes the passive electrical properties, which in an electrical perspective, differs in many ways compared to metals.

The charge carriers in metals are freely moving electrons, while in biological materials it is the ions outside and inside the cells. When doing measurements, the transition between the electrons and ions is at the electrode. In addition, the cells have significant mass and therefore a current flow implies a movement of mass, which in itself results in changes in the biological material. The cell membrane separating the outside from the inside has a very low conductance and therefore acts as a dielectric and the whole cell acts as a capacitor. Because of this, biological materials have capacitive properties.

At low frequencies (less than 10 kHz) the path outside the cells dominate, but at higher frequencies the cells capacitive properties gradually allows alternating current to pass through. A general trend is that the impedance decreases as the frequency increases.

When the biological material is polarized by an external power source, ionic polarization occurs. This is the displacement, not the change in charge, of the positive ions with respect to the negative ions and does not occur instantaneously. The frequency of the applied signal is a critical factor of how much polarization impedance will be measured and depends on the time the ions need to change their position in the material. If the frequency is low enough, it means that all ions have enough time to change their position and the resulting polarization impedance will be maximal. This also means that polarization will decrease as the frequency increases.

Dispersion is another important phenomenon and is the dependency between the permittivity and frequency in a polarized material. There are four known dispersion areas, and different biological materials exhibit a varying degree of dispersion. For example, muscle tissue exhibits a large beta-dispersion while in fat there is none. This can be used in algorithms to discriminate between different biological materials such as human tissue.

ELECTRODES AND MEASUREMENT SETUP

To be able to measure bioimpedance, an interface between the biological material and the electronics is needed. Electrodes provide this interface. At the electrode is where the shift in charge carriers occur, between the free flowing electrons in the metal to the ions in the biological material, and vice versa.

In most measurement setups, electrode polarization impedance is measured in series with the measured bioimpedance. It is therefore important to understand how the measurements are influenced by this. In general, the electrode polarization impedance decreases as the frequency increases.

Electrodes with a gel containing ions are often used. If the measuring electrode has a large metal-electrolyte interface area, it results in a low electrode polarization impedance. A large electrolyte-skin interface area implies an averaging effect and a loss in spatial resolution, but with less noise in the measurements.

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A monopolar measurement means that the impedance contribution mainly comes from one of the electrodes. When using two or more electrodes one may achieve a monopolar measurements by making one of the electrodes dominant. In practice, this can be done in a two-electrode setup by increasing or decreasing the size of one of the electrodes relatively to the other. A three-electrode configuration is inherently slightly monopolar and can be further enhanced by changing the electrode sizes.

By using a relatively small measurement electrode, for example an insulated needle electrode with a small exposed area on the tip, a very monopolar measurement is achieved. If we also combine this with a three-electrode configuration, the measurement would be even more monopolar. It has been shown in published papers that approximately 97 % of the contribution originates from a few millimeters radius from the needle tip.

This means that it is possible to accurately measure the bioimpedance at the tip of the needle when it is inserted into biological materials.

MEASUREMENT OVERVIEW

There are several ways to measure bioimpedance, of which only one method will be explained here. The explained method assumes a two-electrode or three-electrode configuration.
The biological material is excited with a stable sinusoidal voltage signal with a known frequency and amplitude through the reference electrode, or reference and counter electrode for a three-electrode configuration.

The measurement needle electrode is inserted into the biological material and picks up the sinusoidal excitation current after it has propagated through the material. A voltage is excited upon the biological material and the current is measured, therefore we have the current-to-voltage ratio, which is the admittance or inverse of impedance. IQ demodulation can now be used to retrieve the real and imaginary components of the admittance and the impedance modulus and phase can be calculated using complex numbers theory. Different biological materials will alter the excitation signal in different ways at different frequencies.

It might be necessary to calibrate the system depending on the implementation of the IQ demodulation, analog electronics and digital electronics.

IMPLEMENTATION

On the designed device an ARM microcontroller was used with a minimum of analog components. A direct digital synthesizer (DDS) was used as the signal source to excite the biological tissue. The device is designed to be portable, powered by a standard lithium battery and uses Bluetooth for control and data transfer to a computer or tablet. The computer or tablet displays real-time measurement data. One graph shows impedance modulus and phase as a function of time at a single frequency, which can be set by the operator. Another graph shows the impedance modulus and phase as a function of frequency.

A two-point phase calibration was performed to remove known linear phase errors. Calibration was performed by measuring a resistor, which was assumed to be an ideal resistor with no phase delay. Also the microcontrollers internal ADC was calibrated before use.

DISCRIMINATING TISSUE

Interpretation of the measured data makes it possible to discriminate between different biological materials. The most evident method is comparing the impedance modulus and phase of the biological materials one wants to distinguish from each other, and determine a valid range for the values. This simple approach can work in many cases, but is susceptible to errors due to electrode impedance polarization, change in the material over time and other biological factors.

The next step is to do exactly the same, but compare at two or more different frequencies to get a better discrimination. This means it will be possible to discriminate between two biological materials that have similar characteristics at one frequency, but not at another.

A step further is to use the knowledge about the dispersion regions. These regions in different biological materials can affect the measured values in a narrow frequency area, and be a very characteristic trait. By combining these parameters and knowledge about dispersion regions, it is possible to design smart algorithms that can discriminate between many different types of biological materials.

As an example, a measurement on a boiled egg was performed. By measuring the phase difference at two frequencies, 3kHz and 30kHz, it is possible to discriminate the egg white from the egg yolk, as well as accurately determine when the tip of the needle electrode is at the boundary in between. The algorithm for discriminating between the different parts of a boiled egg has used the phase parameter at two frequencies in the beta-dispersion region, which is strongly present in egg yolks, but not as much in egg whites.

> "...it is possible to accurately measure the bioimpedance at the tip of the needle when it is inserted into biological materials.

Areas of application for bioimpedance is yet to be discovered, but has a lot of potential. Some of its medical applications are measuring respiration rate or sweat activity, lung imaging of newborns, diagnosis tool for skin disease and as a parameter for detecting restrictions in blood supply to organs.

Some of the less medical and non-medical applications include body composition analysis, sometimes performed at your local gym, determining meat, wood or soil quality, monitoring the fermentation process in breweries and monitoring volcanic activity.

EXAMPLES OF USE OF BIOIMPEDANCE

Skin water content
Impedance imaging
Body composition
Impedance cardiography
Meat quality
Tissue ischemia monitoring
Fingerprint sensor
Oil exploration
Skin diagnosis
Find joint angle
Volcanic activity
Lie detector
Skin cancer detection

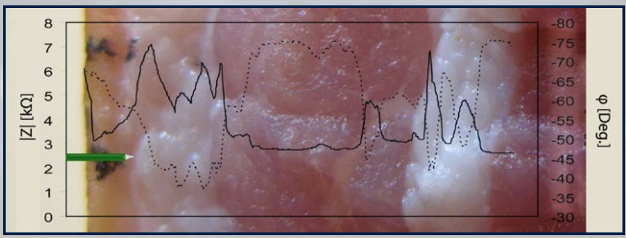
More information about the device can be found in the master thesis by Patrick Hisni Brataas [1] and general information about bioimpedance can be found in the "Bioimpedance and bioelectricity basics" book [2].

[1] "Wireless Embedded Microcontroller System for Bioimpedance Measurements", Master Thesis, Patrick Hisni Brataas, 2014. Link: http://urn.nb.no/URN:NBN:no-45539

[2] "Bioimpedance and Bioelectricity Basics", 3rd Edition, Sverre Grimnes and Ørjan Grøttem Martinsen, Elsevier Academic Press, 2014.

[3] "Needle Guidance in Clinical Applications based on Electrical Impedance", Phd paper, Håvard Kalvøy.

Some of its medical applications are measuring respiration rate or sweat activity. This could be used while conducting lie detector tests.



The figure shows a 3 kHz impedance measurement as function of distance through a porcine tissue model (Modulus |Z| solid line and Phase angle φ dashed line). The typical high modulus and relatively small phase angle in fat can easily be differentiated from the lower modulus and larger phase angle in muscle. The green needle indicates the starting point of the horizontal needle insertion path.

Figure is used with permission from Håvard Kalvøy [3]

WHAT IS

Qt is a cross-platform application development framework. Its history dates back to 1991 and the Norwegian company Quasar Technologies, which later became Trolltech. Trolltech was acquired by Nokia in 2008, but sold to Digia in 2012. According to Digia, 500 000 developers use Qt.

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FUNCTIONALITY

Qt is a cross-platform framework for developing applications for computers, mobiles and devices. Platform specific functionality is implemented in the Qt framework which allow you to implement your application without focusing on platform specifics and deploy to multiple platforms without code changes. For instance, an existing Qt application originally targeted for Windows can be deployed to Mac OS just by rebuilding the application.

The Qt framework contains a massive set of classes providing functionality for amongst the following:

- Graphical User Interfacs
- Multimedia
- Networking
- Database access
- File access
- Threads
- Cloud services
- Unit testing
- Qt Quick

The Qt Quick modules consists of the QML declarative language, QML elements and a runtime. It allows a quick and easy development of applications with a custom appearance.

In addition there are several other modules and addons from Digia and other vendors. Some of Digia's own addons include Bluetooth, NFC (Near field communication) and serial port communication. Addons from other vendors and open source projects vary in quality and support.

CROSS-PLATFORM

Qt supports several development environments, both Windows, Mac and Linux, as well as more exotic operating systems. In addition to offering the choice between a range of development platforms, compiled Qt software will execute on an even broader spectrum of platforms. Amongst those are Embedded Linux, Android, iOS, Windows Phone, QNX and VxWorks. Qt allows developers to chose environment, and delivers a uniform experience across a wide range of devices.

APPLICATION AREAS

Qt is used by a wide variety of applications, devices and organizations. To illustrate the diversity of Qt usage some are mentioned here. Examples of devices that use Qt are: printers (HP Photosmart Premium AiO), medical devices, chartplotters for boats (Lowrance HDS range), multimedia remote controls, coffee machines and digital picture frames.

Some well-known computer applications that use Qt are: Skype, VLC multimedia player, Google Earth, Spotify for Linux, Oracle VirtualBox and Mathematica. In addition, Qt has been used for the following applications: air traffic control, games, collaboration tools, visual effects, animation, modeling, office applications, simulation and in-flight systems. Organizations that use Qt include Samsung, Philips, Panasonic, Volvo, European Space Agency and Blizzard Entertainment.

DEVELOPMENT ENVIRONMENT AND TOOLS

Qt Creator is Qt's own development environment that is frequently used for developing Qt applications. Another common option on the Windows platform is Microsoft Visual Studio with Qt's Visual Studio addon. Both options include an integrated Qt Designer tool, which is used for visually designing user interfaces. You're not required to use this tool and if you prefer the same design can be implemented using C++ code. Application logic is implemented using C++ (or QML). In addition, Qt has multiple language bindings, for instance for Python, Java and C#, and can therefore be used as a graphical framework in a multitude of projects.

Qt Enterprise Embedded contains tools for developing embedded software. These tools allows you to get started quickly by providing the "Boot to Qt" software stack. Pre-built images exist for several platforms such as Google Nexus 7, Raspberry Pi and BeagleBone. For other platforms the software stack must be customized using the accompanying tools. When the "Boot to Qt" stack has been customized and deployed to your device, your application can be deployed and debugged conveniently using Qt Creator.

LICENSES AND CONTRIBUTIONS

Qt is available under open source and commercial licenses with support. This allows Qt development projects to scale well, from small projects on a low budget to enterprise teams with commercial licensing and support.

It's also possible to contribute to Qt. Such contributions could be bug reports, feature requests or code changes. This involvement is described in "The Qt Governance Model".

DATA RESPONS' EXPERIENCES

Data Respons has used Qt in many projects and it has become our preferred framework for GUI development. C++ is typically used as most developers in Data Respons is familiar with this language. Data Respons adopted QML early and has used it in some projects with good results. Higher productivity has been pointed out as a strong point of QML.

THE IMPACT

OF CONSUMER ELECTRONICS ON DEVELOPMENT OF HIGH-RELIABILITY PRODUCTS

In this and the next issues of Inside we will be publishing articles discussing the impact of consumer electronics related to developing high-reliability products. Below is an overview of what's to come:

BY: Haldor Husby
Principal Development Engineer
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DEFENCE LED THE COURSE

Electronic printed circuit boards and package technology development was traditionally driven in large part by the defence sector. Only the large defence and infrastructure projects had the means and need to push the technology barrier further, and commercial segments benefited from the work and investment in the defence sector by adopting technology as it matured. As commercial and consumer electronic segments gained economical significance, more and more of the innovation took place in the commercial segments of the industry.

NEW DRIVERS

Today we find ourselves in a situation where developers of products for industrial and defence segments work within frames largely set by the consumer segment. On one hand we benefit from the incredible level of affordable performance and integration which has only been possible to achieve through the enormous volumes represented by laptop computers, multimedia devices, smart phones and tablets. But these segments operate with requirements that are vastly different from the professional segments. Most significantly perhaps with respect to the time horizon of development and product life, but also with respect to environmental requirements and reliability.

As developers we also find that ubiquitous consumer products influence customer expectations to cost of industrial and defence products even though volumes may differ by 4 or 5 orders of magnitude, and product qualification is a world apart.

SMARTER APPROACH

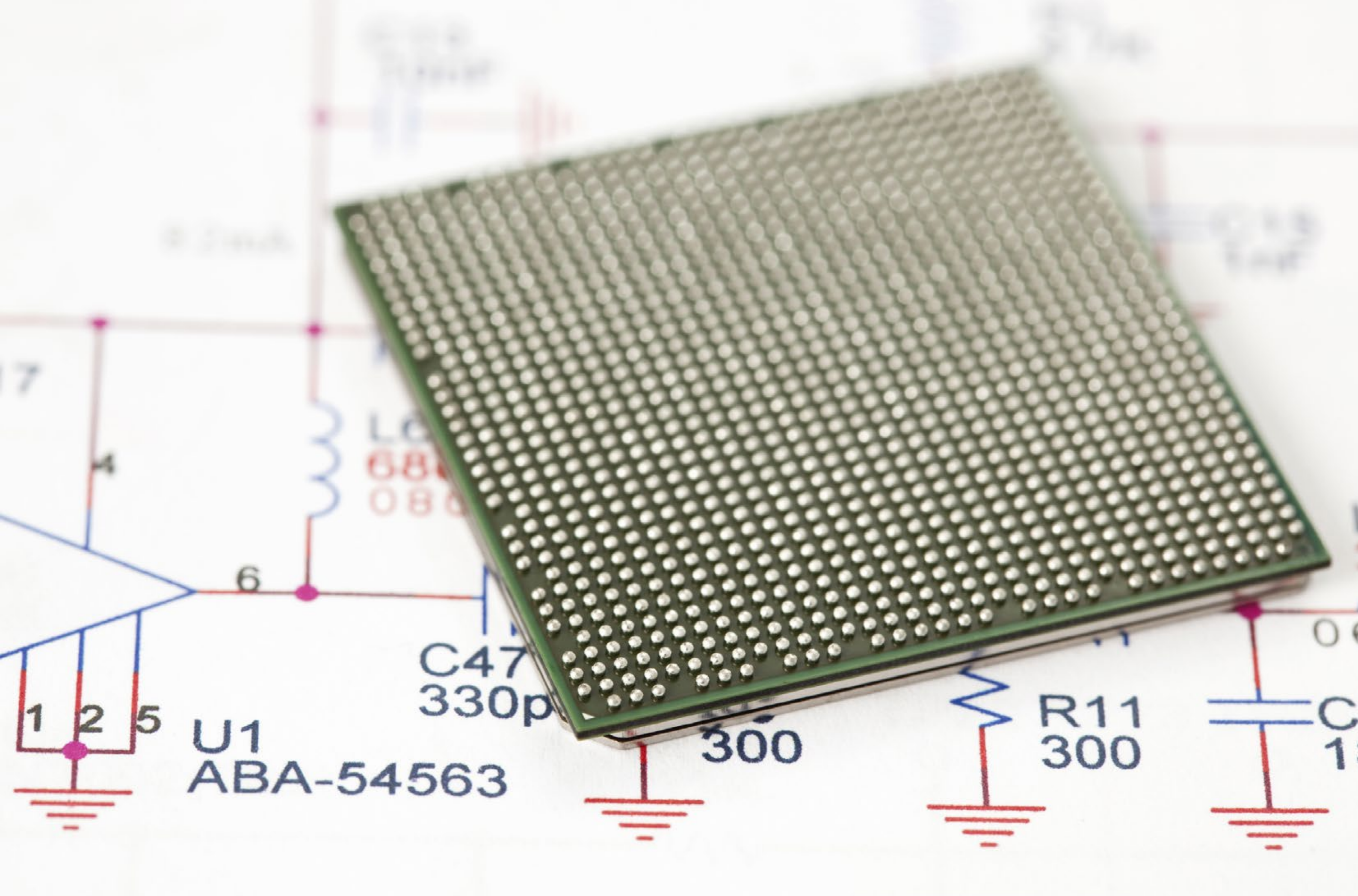
When the frames we develop within are largely set by the consumer segment, we need to work smarter in order to benefit from the technology development and at the same time comply with the stringent requirements we meet over product lifetimes counted in decades rather than months.

The first order of the day is to be familiar with the terrain of this new landscape in order to manoeuvre it safely. We need to know the limitations of this order of business as well as the opportunities.

As a contribution Interrupt Inside will bring a series of articles that treats several aspects related to the pressure exerted by consumer segment technology on the industrial and defence segments.

The first article appears in this issue and discusses how component package miniaturisation complicates design for high reliability. In a later issue we will look at how technology labelled as High Density Interconnect (HDI) will be necessary to address this issue in the long term. It is followed by an article on component obsolescence and strategies for handling the rapid component turnover in programs spanning years and decades.

Counterfeit components entering the supply chain is a growing problem and a consequence of the enormous demand for components. One article will discuss this topic, the consequences of it and the measures taken to address it. Finally we will look at some more exotic processes used in very high volume production. Processes that may or may not be adopted in our segments but interesting to be aware of in either case.



SMALL PITCH PACKAGES

AND HIGH RELIABILITY PRINTED CIRCUIT BOARDS

BY: Haldor Husby
Principal Development Engineer
Data Respons

The silicon die of active electronic components are with rare exceptions mounted in packages for mechanical support and solder connection to Printed Circuit Boards (PCBs). For processors, FPGAs and other components with very high number of connections, the dominant package is the Ball Grid Array, or BGA. In a BGA the traditional component pins around the edge of the package is replaced by an array of solder bumps underneath the package which is then mounted to a PCB by reflow soldering. Packages with solder bumps emerged from the Pin Grid Array (PGA) as miniaturization made the pins fragile and difficult to mount without bending.
Packages with solder bumps were used in high-end computer systems by the mid 1980's, while the first series produced BGAs made it onto PC-boards in 1992. BGAs with well over 1000 individual connections are commonplace today, and there are examples of packages with more than 2000 solder bumps. In addition to the size of the array, the BGA is characterized by its pitch; the centre to centre spacing between solder bumps in the x and y directions. While the first BGAs had a pitch of 1.78mm (50mil), 1mm has been a common pitch for a long time. The consumer segment has long since made the transition to sub-millimeter pitch (0.65mm, 0.4mm or even smaller). driven by increased pin count due to higher levels of integration, and the demand for miniaturization. However, sub-millimeter pitch BGAs creates real challenges for products that require high reliability. >>

IPC PERFORMANCE CLASSES

Institute of Printed Circuits or IPC is an international industry organization serving those who design and manufacture printed boards and assemblies. It is widely known as an issuer of standards on all aspects of printed boards. The standard IPC-6011 defines generic performance specifications for printed boards, and it establishes 3 performance classes of products:

Class 1 General Electronic Products - Includes consumer products, some computer and computer peripherals suitable for applications where cosmetic imperfection is not important and the major requirement is function of the completed assembly.

Class 2 Dedicated Service Electronic Products - Includes communications equipment, sophisticated business machines, instruments where high performance and extended life is required and for which uninterrupted service is desired but not critical. Certain cosmetic imperfections are allowed.

Class 3 High Reliability Electronic Products - Includes the equipment and products where continued performance or performance-on-demand is critical. Equipment downtime cannot be tolerated and must function when required, such as life support items or flight control systems. Printed boards in this class are suitable for applications where high levels of assurance are required and service is essential.

Circuit board specifications usually make reference to standards issued by IPC. IPC-6011 establishes three performance classes distinguished by the reliability requirements for each (see above box).

Class 3 is for products where downtime cannot be tolerated or where the end-user environment is uncommonly harsh. It is the equipment vendor who decides which class a PCB should be manufactured to, sometimes guided by customer requirements.

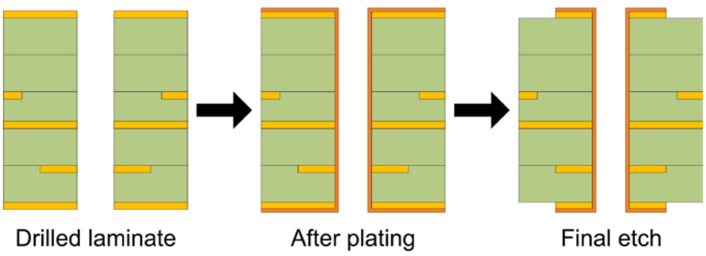
The acceptance criteria for Class 3 are significantly more difficult to meet than for Class 2, and a massive process monitoring and test regime must be followed by the PCB manufacturer. Hence a Class 3 PCB may well cost 10 times more than an identical board manufactured to Class 2 requirements. No matter the cost; a PCB cannot be manufactured to Class 3 requirements unless it is designed for it.

The incompatibility between Class 3 requirements and small-pitch BGAs arise from the so-called via. The via makes connections between different layers of a PCB possible, and is formed by plating a hole through pads on outside layers of the board and on any other layer that require a connection (see right fact box).

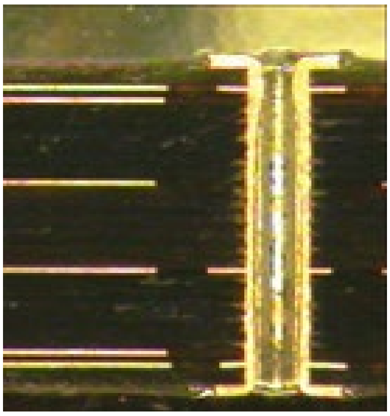
Cracks between the pads and the copper barrel is one of the major reliability concerns related to Printed Circuit Boards, particularly PCBs that require a lead-free process. Class 3 differ from the

THE VIA

A reasonably advanced PCB today comprises between 10 and 20 layers of copper separated by fiberglass or another dielectric material. Electrical connections on each layer are made by etched copper tracks while vertical connections between layers are accomplished by a fabricated feature called via. Vias are formed by drilling holes in the laminated PCB prior to etching of the outer layers. The walls of the drilled holes are then plated to form a copper barrel through the board. Pads and tracks intercepting the drill perimeter make connections to the copper barrel. The outer layers are then etched to complete the circuit before the board continues through the finishing processes.

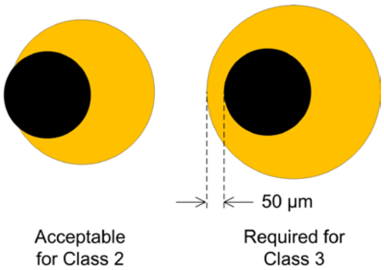


> Cracks between the pads and the copper barrel is one of the major reliability concerns related to Printed Circuit Boards...

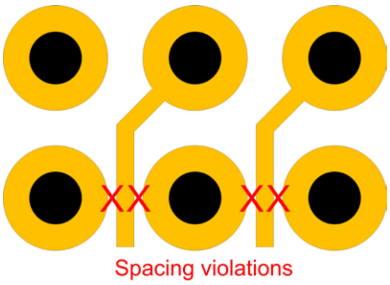


Cross-section of plated through hole via.

other classes on the relation between the via pad and the drilled hole. The drill bit will generally not hit each pad in the nominal centre due to production tolerances.



In Class 2 the drill is allowed to partly miss any pad as long as a defined majority of the drill falls within the pad perimeter (so-called breakout). The plating process will still assure electrical connection where required. Class 3, on the other hand, not only require that he entire drill falls within the perimeter of every pad, but even demands a guard band of 50µm, a so-called annular ring. As a consequence a Class 3 via pad is larger than a Class2 pad for a given drill diameter and process tolerance.



IPC-2221 is the design standard that provides guidance on the dimensions of via pads based on drill diameter and other design and production parameters. Assuming a very small but still reasonably available drill diameter of 0.3mm, and assuming the highest level of Producibility (Level C, tight tolerances) the recommended pad diameter is 0.6mm.

On every layer where a connection to the via is not required, copper must be voided in radius around the nominal centre in order to avoid accidental connection. This so-called antipad is always bigger than the pads of the via. In the PCB under a BGA there will, at least in some areas, be a grid of vias with centre to centre spacing equal to that of the BGA. Class 3 pads on a 0.8mm grid will only leave 0.2mm airgap between the pads,not enough to allow for routing of traces between the pads considering that tracks and spacing also must allow for Class 3 production.

As a consequence it is not possible to route connections out of the BGA area. While 0.8mm pitch pushes the limit of a class 3 design, a 0.75mm og 0.65mm pitch is out of reach completely. A secondary problem is the large antipads on power and ground planes which perforates these planes to such an extent that Power Integrity suffers.

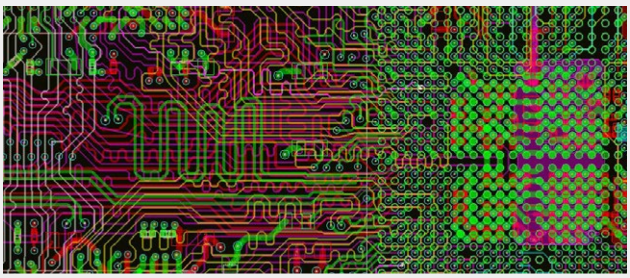
This state of affairs is a classic example of a standard lagging behind technology development. So what can we do to remedy the situation in the meantime? One approach is to avoid selecting components in BGA packages with pitch smaller than 1mm. This strategy has an expiry date as the selection of available components will be unacceptably limited over time.

As an example the popular and versatile processor series i.MX from Freescale is already now only available in packages of 0.8mm pitch or less. Another approach is to try and push the technology limit in terms of tolerances and line and track spacing. It carries a high cost as it limits the choice of PCB manufacturers able to produce the boards and will in any case incur the cost of a higher yield loss in addition to the heightened risk of forcing the manufacturers to operate at the limit of their capability.

The only viable solution in the longer term is to make judicious and informed use of the technology known as High Density Interconnect (HDI) using laser drilled microvias. Clever application of HDI demands a high level of process knowledge by the designer, and is the topic of an article in a later issue of Interrupt Inside.

NEXT ARTICLE IN THIS SERIES

High Density Interconnect (HDI) is defined as printed circuit boards with higher wiring density than conventional boards. A central feature of HDI is the microvia, blind vias defined by hole diameters smaller than 150µm and normally drilled by laser. The microvia is by many considered an exotic and expensive feature with poor reliability to be avoided unless the package density leaves no other alternatives. But in the consumer segment HDI is actively used to reduce cost and in a given case the use of microvias may even improve reliability. In the hands of knowledgeable designers microvias are also used to improve signal and power integrity, and to improve noise and EMC performance. While conventional printed circuit boards often are specified in general terms, HDI requires decisions on the part of the designer that calls for detailed knowledge of materials and production processes. We take a closer look at HDI in the next issue of Interrupt Inside.

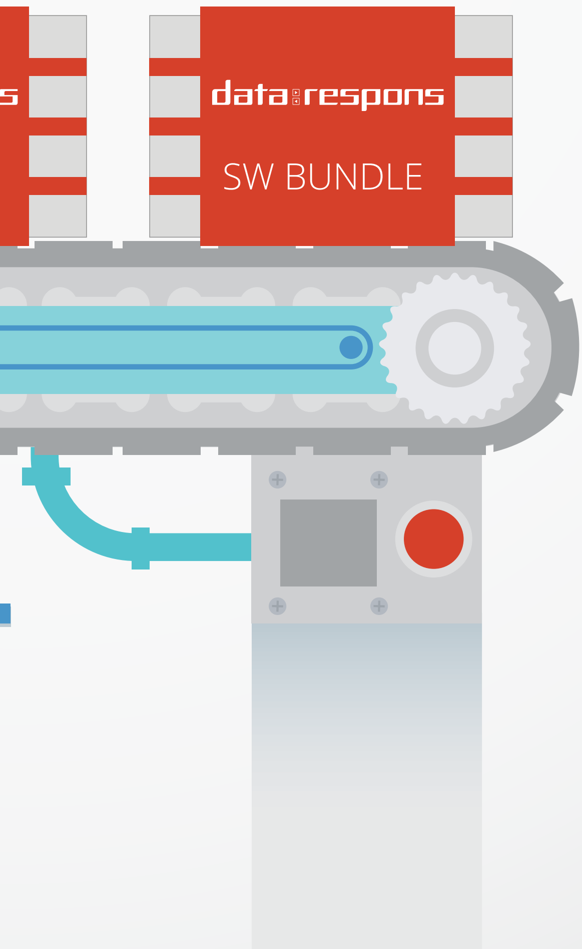


THE INEV
YOCTO PRO

ITABLE
OJECT

BY: Lars Ivar Miljeteig
Development Engineer
Data Respons

When dealing with customizing embedded solutions, Yocto is the one word that simply cannot be ignored. In this article we aim to explain what the Yocto Project does, why it's needed, and how it can be applied when working with an FPGA/ARM platform such as the Xilinx Zynq.



WHAT IS YOCTO

"It's not an embedded Linux distribution – it creates a custom one for you"

The Yocto Project is an open platform that provides templates, tools and methods to help in making custom Linux based systems for embedded products. It combines BitBake and OpenEmbedded to create specialized Linux distributions. Using the Yocto tools, the process of setting up a Board Support Package (BSP) gets tidier and more modular than attempting to keep track of the large amounts of third party source code manually. This process used to be different for each hardware platform, while Yocto aims to be a generic, supplier independent solution.

A MODULAR APPROACH

Yocto splits large software modules into layers, such as distro, BSP and software layers. Hardware manufacturers typically provide a BSP layer for their products, complete with drivers and kernel configuration. The embedded specialist then adds a custom layer that inherits the hardware layer, adding and removing components to fit the end product. User level software is kept in one or several separate layers. If the developers do a good job separating the layers, they behave like building blocks, and can be switched on and off depending on hardware, customer requirements and version varieties. Due to this modularization, the Linux kernel and software can be kept up to date through the product life-cycle without depending on the hardware manufacturer.

Yocto can fetch, build, configure and install all software used on an embedded product, such as the kernel, bootloader, root file system, driver modules and device trees. It uses recipes to describe how these steps are performed. Recipes can be inherited from other layers and appended. A layer can contain configurations for several different hardware platforms, separated into "machines". Machine configurations are part of a BSP layer that are board-specific. Typically, bootloader, Linux kernel configuration, device trees and boot parameters

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must be customized to fit the targeted board. Machine configurations can set build variables and select non-default recipes to be used for building e.g. the Linux kernel, to customize the resulting product. Which machine to build for is chosen before the build process is initiated.

LIVING WITH LICENSES

When using open source software, developers are often faced with the trouble of keeping track of licenses. Accidental use of the wrong license can lead to costly trials and trouble. Each Yocto recipe has to specify which license the software shall use, and the build process fails should the recipe apply open source code within a closed software module. Yocto keeps track of all licenses, not only during development, but throughout the products life-cycle.

FETCHING AND BRANCHING

Being developed simultaneously by several different parties, the different flavors of Yocto and subsequent layers have to be split into branches in Git. Most BSP layers will only work with OpenEmbedded-Core of the same branch. Xilinx, for instance, uses the Dora or Daisy branches, while other suppliers have their own branches. Fetching the correct branch for all components and keeping track of which branches will work together is a part of the Yocto based development process.

Yocto Linux and the Xilinx Zynq platform
Xilinx is one of many vendor companies that provide a Yocto layer targeting their products. The meta-xilinx layer adds on top poky and open-embedded meta layers to provide Yocto support for Xilinx' Zynq and Microblaze architectures, along with machine configurations for some of their development boards. Once you have made Bitbake aware of your layers you can target different Xilinx boards by simply setting a variable in your local configuration file which tells Yocto which machine configuration to use.

Device trees are used to provide the Linux kernel with information on the hardware it is running on. It is a convenient way to use the same kernel on slightly different hardware configurations. For the Zynq platform the standard kernel is compiled with drivers for all of th PS/SoC peripherals, common board components and some drivers for Xilinx FPGA IPs. The device tree will make the kernel aware of which components are present and how they are configured so that drivers are loaded and initialized correctly. Also board components can be described. Be describing the topology of i2c buses, including switches and node addresses, Linux will be able to reach and configure each node in the i2c network (provided the drivers are compiled in the kernel).

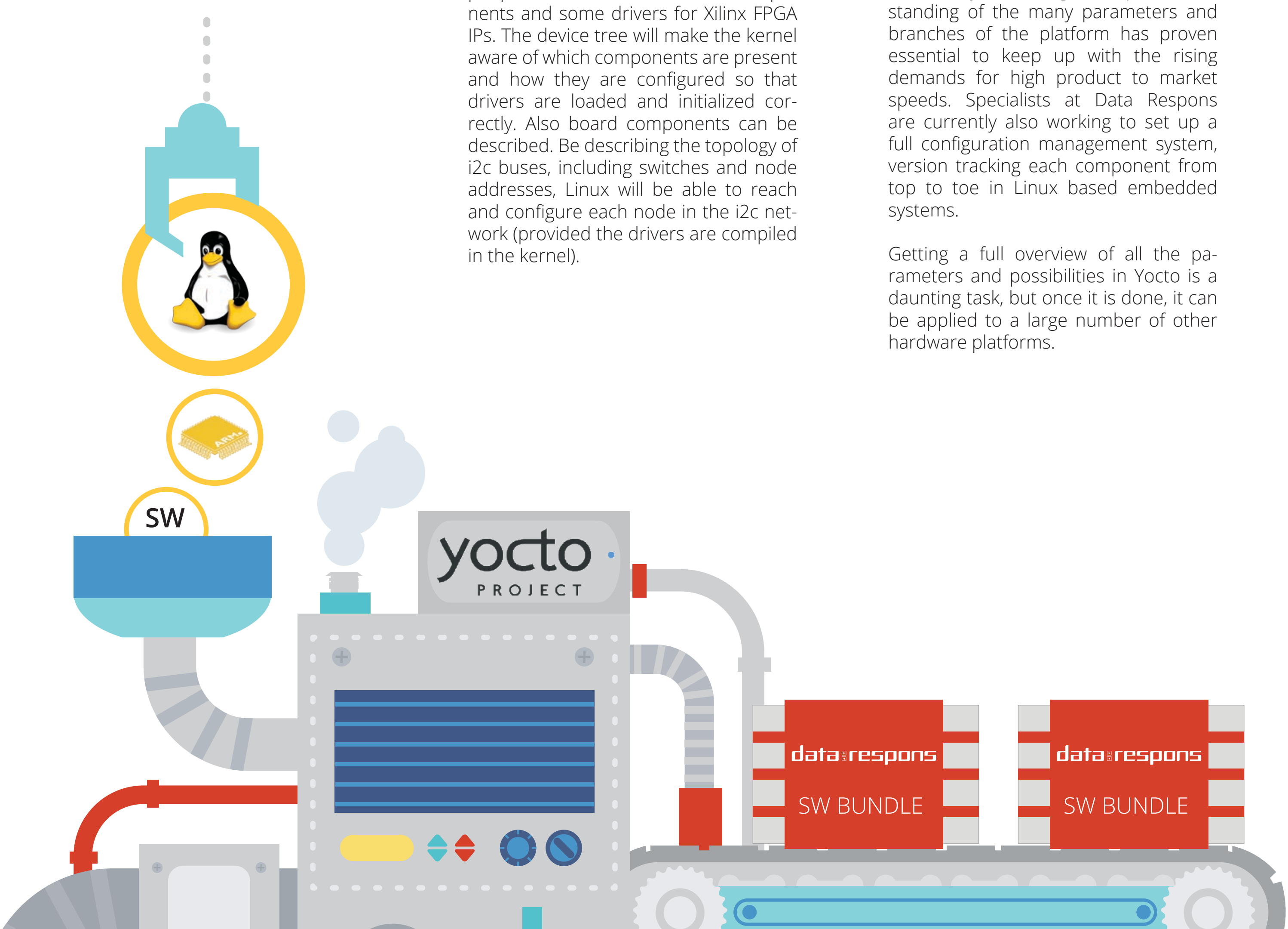
When the time comes to deviate from the standard configurations and recipes provided by a vendor you create your own Yocto layer on top of your vendors'. You then inherit all of their functionality but you are free to add your own customizations. In this layer you typically maintain your custom device trees, kernel configurations, patches, drivers, machine configurations etc. This approach makes it easy to maintain your BSP layer and transition from a vendors' evaluation board to your custom built board.

> Data Respons has seen that their early adoption of Yocto is bearing fruits, as an increasing number of hardware manufacturers drop their own tools for the Yocto Project.

YOCTO AND DATA RESPONS

Data Respons has seen that their early adoption of Yocto is bearing fruits, as an increasing number of hardware manufacturers drop their own tools for the Yocto Project. Having a deeper understanding of the many parameters and branches of the platform has proven essential to keep up with the rising demands for high product to market speeds. Specialists at Data Respons are currently also working to set up a full configuration management system, version tracking each component from top to toe in Linux based embedded systems.

Getting a full overview of all the parameters and possibilities in Yocto is a daunting task, but once it is done, it can be applied to a large number of other hardware platforms.



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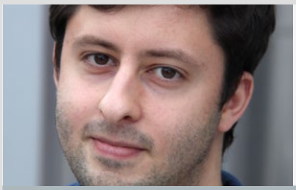

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