NSREC Notes: Vendor Talks Highlight Advances In Power Devices, Packaging And Reference Designs For Space Applications

by David G. Morrison, Editor, How2Power.com

Though designed to operate in the highest altitudes, radiation hardened power semiconductors and ICs tend to fly under the radar in terms of the publicity they are given through product announcements and coverage in the trade press. Perhaps this is not surprising given the specialized nature of these parts. However, the latest rad hard voltage regulators, silicon power MOSFETs and GaN devices are very much on display at technical forums such as the IEEE Nuclear & Space Radiation Effects Conference. This was the case at this year's NSREC 2021 which was held virtually (July 16-23) for the second time during the pandemic. Exhibitor webinars gave attendees the opportunity to hear about development of the latest rad hard power devices as well as updates on the qualification and production status of previously introduced components.

Companies used these presentations not only to showcase improvements in device performance and packaging, plastic packaging in particular, they also highlighted the use of their components in complex reference designs such as those powering rad hard FPGAs. Furthermore, exhibitors used these talks to discuss their strategies with respect to component development, which included doing more to create system solutions. In describing the newer offerings such as rad hard plastic packages, some speakers focused on manufacturing processes and testing to demonstrate component reliability and space readiness.

Superjunction Technology And System Solutions

IR HiRel, an Infineon Technologies Company, has discussed its R9 family of rad hard power MOSFETs previously at NSREC, which is not surprising given that this family was introduced a few years ago. And as in the company's prior NSREC presentations,[1,2] they compared performance of the R9 devices with the legacy R5 and R6 families. However, this year the presentations on R9 had a slightly different perspective, emphasizing the change in technologies from the planar devices of the older generation R5 and R6 parts, to the superjunction technology used in the R9 MOSFETs.

According to Oscar Mansilla, product marketing director, Space Discretes & ICs at IR HiRel, this emphasis on the new technology reflects the company's change in focus from simply developing new components and their performance to more of "a full-system mentality". This change was driven by the expansion of their rad hard product portfolio beyond MOSFETs, and hybrid and PCB dc-dc converters to include existing RF products from Infineon, and rad hard and hi-rel memory solutions acquired from Cypress Semiconductor.

Speaking after the conference, Mansilla explained, that along with the change to superjunction MOSFET technology, which enables low on-resistance in the R9 devices, the company has improved the package with its introduction of the SupIR-SMD, which contributes further to the performance of the system through its smaller size and lighter weight.

While the SupIR-SMD has been previously discussed, the development of half-bridge eval boards for Infineon and IR HiRel's latest-generation MOSFETs is new and these include rad-hard gate drivers. These gate drivers were not previously announced but the company did make them available to customers. In addition, now there are also eval boards to go with them.

First, there is a half-bridge eval board that pairs Infineon's rad hard 650-V PowerMOSFET with the RIC7S113, a 400-V rad hard high- and low-side gate driver (Fig. 1). IR HiRel is also developing an eval board for the RIC74424, a dual noninverting low-side gate drive, which works up to 20 V. This evaluation board will be paired with the R9 superjunction rad hard MOSFETs and will have options to solder on four different package types including the SupIR-SMD package. A Spice model is available on the IR HiRel website for the RIC7S113, while the company is in the process of developing a Spice model for the RIC74424. These are all additional steps taken in pursuit of the system mentality.

Component	Part number	Description
MOSFET	BUY65CS08J-01	650V PowerMOS rad hard MOSFET
Gate driver	RIC7S113	400V rad hard high and low side gate driver

- Half-bridge configuration
- Footprint compatible with SMD-0.5 and SMD-0.5e
- Bootstrap circuit for high-side gate driver IC
- Supports
  - Single and independent control inputs
  - Independent and combined VDD and VCC supply

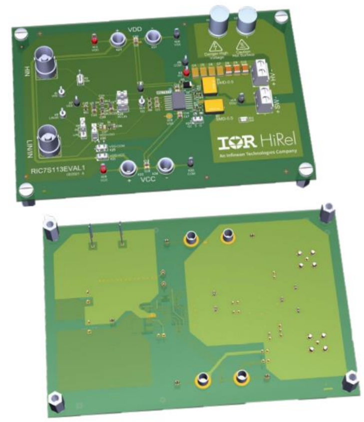


Fig. 1. IR HiRel's 400-V rad-hard gate driver eval board for space power applications.

Beyond the eval boards, the company also plans to develop co-packaged solutions which integrate more functionality around the MOSFET to help customers meet their SWaP goals. So the focus for IR HiRel has shifted from just supplying rad hard MOSFETs and dc-dc converter hybrids: "We want to become a solution provider," said Mansilla.

In addition to sharing details of the company's new system strategy, Mansilla explained what motivated the switch from planar to superjunction junction technology, which began with the intro of the first R9 MOSFETs 2 1/2 years ago and now encompasses 16 parts.

Mansilla noted, "Most of these rad-hard power MOSFETs are used in intermediate bus converters or secondary bus converters. Their power output is increasing and performance of planar devices is limited by $R_{DS(ON)}$. So we went to SJ."

However, the change to SJ was also motivated by the system-bus voltages in satellite applications. Mansilla observed that space bus voltages are going up for more power to 50, 70, 120 and 150 V. "If we kept our MOSFETs in the same, planar technology, $R_{DS(ON)}$ was going to go up as voltage went up. Superjunction gives us a modular approach [to raising breakdown voltage]. More voltage, more epi implants."

He added that the adoption of SJ technology had other benefits such as lessening the impact of the parasitic bipolar transistor. "We break that NPN with a vertical p layer, which then lessens single-event burnout. We also included our planar technology under the gate for better SEE immunity." See Fig. 2.

- SJ over planar MOSFETs for space
  - Electrical advantage
    - Planar technology drawback: As V_{DS} increases the drift layer becomes thicker and the $R_{(DS)on}$ increases
    - SJ technology: Vertical pn junction results in low $R_{(DS)on}$
  - Radiation robustness
    - Structure of SJ technology "kills" the parasitic bipolar reducing the possibility of SEB
    - Incorporate our experience with planar technology on the gate for better SEE response
  - Structured for modularity
    - Voltage rating can scale up or down with the number of implants during fabrication

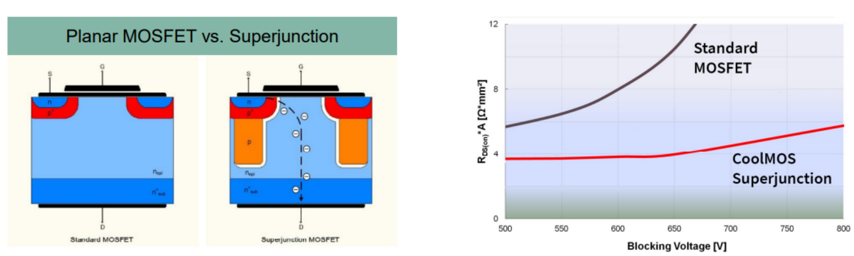


Fig. 2. Superjunction technology offers numerous advantage over planar for space.

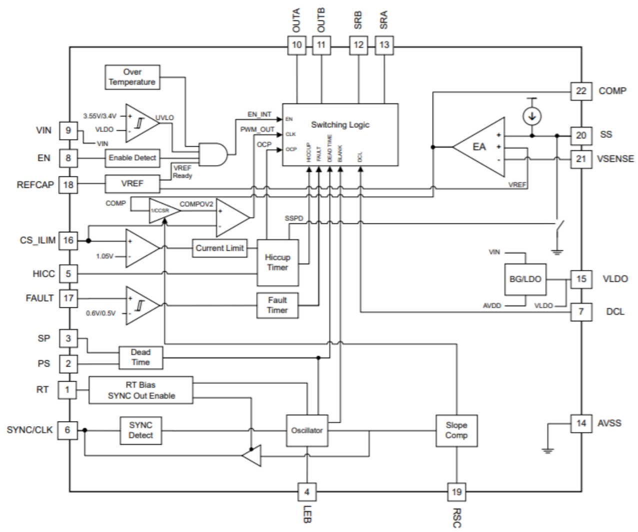
The release of new parts in the R9 family continues with the first p-channel devices expected at the end of this year and a full p-channel portfolio available next year. For more information, see the website or contact [Oscar Mansilla](#).

Many Voltage Regulator Options

In his presentation at NSREC, Texas Instruments' Kurt Eckles offered descriptions of several new power ICs for space. The first new device he discussed was the TPS7H5001-SP, a rad hard current-mode PWM controller. This controller works with an external gate driver to support both silicon and GaN FETs and supports both isolated and nonisolated topologies. The latter includes single-ended converter topologies by providing the user flexibility to control the maximum duty cycle. The controller's high level of functional integration is said to minimize radiation risks and overall solution size for dc-dc converters (Fig. 3).

Key electrical specs include an input voltage range of 4 to 14 V, a switching frequency range of 100 kHz to 2 MHz, and ±1% accuracy over line, load, temperature and TID on the controller's 0.6-V voltage reference. For radiation performance, the part is radiation hardness assured (RHA) up to a TID of 100 krad(Si) (RHA qualification in progress). The TPS7H5001-SP is SET and SEFI characterized and SEL, SEB, and SEGR immune to a LET of 75 MeV-cm^2/mg.

Features include a sync pin for external synchronization, 5-V outputs, synchronous rectification outputs that are deadtime and duty cycle limit configurable, configurable soft start and various forms of protection. Parts are packaged in a thermally enhanced, 22-pin ceramic DFP. The TPS7H5001-SP is sampling now, with the release to market planned for Q1 2022. For more technical details, see the TPS7H5001-SP datasheet.



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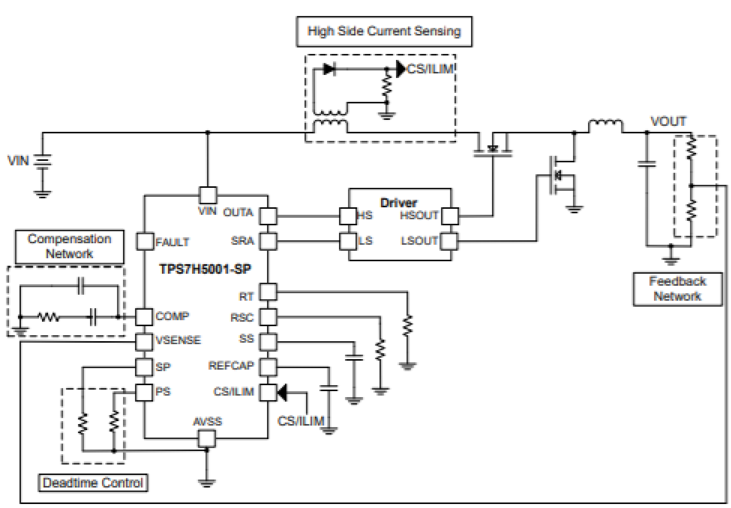

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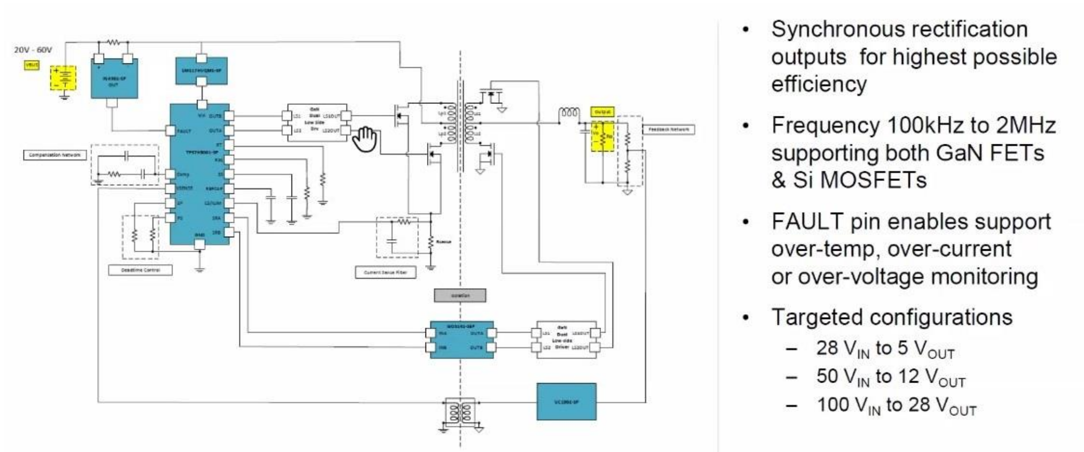

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Fig. 3. A block diagram of the TPS7H5001-SP illustrates the high level of functional integration in this controller IC (a). Application circuits show the use of the controller in a buck converter (b) and in an isolated push-pull converter (c) that can step down various bus voltages encountered in space systems.

Eckles also provided information on a new monolithic QMLV point-of-load converter IC or POL. The TPS7H4002-SP is a 3-A POL that accepts 3- to 5.5-V input and produces an adjustable output down to 0.804 V (Fig. 4). This device is based on the TPS50601A-SP, but has a lower current limit. The two devices have the same package—a thermally enhanced, 7.37-mm x 12.7-mm 20-pin CDFP.

Switching frequency for the TPS7H4002-SP is programmable from 100 kHz to 1 MHz and the regulator features a 0.804-V reference that is accurate to within ±1.5% over line, load, temperature and TID. Radiation performance is similar to that of the controller described above: it's radiation hardness assured (RHA) up to a TID of 100 krad(Si); and SET and SEFI characterized and SEL, SEB, and SEGR immune to a LET of 75 MeV-cm²/mg.

This regulator achieves 95% efficiency and is optimized for low output voltages. Its small die size and package enables a smaller overall regulator design size. With its power good and enable pins, it eases power sequencing. The POL's thermal performance is also touted as $\theta_{JC(bottom)}$ is specified at 0.514 °C/W. Other features include configurable soft start and external compensation.

The TPS7H4002-SP was released to production in September. For more technical details, see the TPS7H4002-SP datasheet.

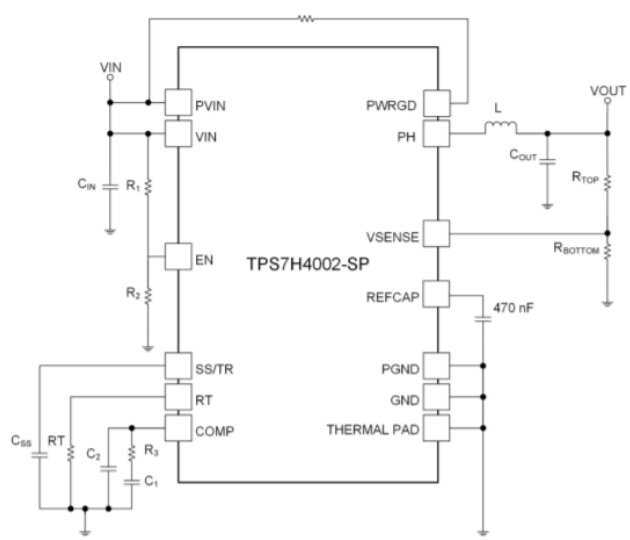


Fig. 4. An application circuit for the TPS7H4002-SP point of load regulator.

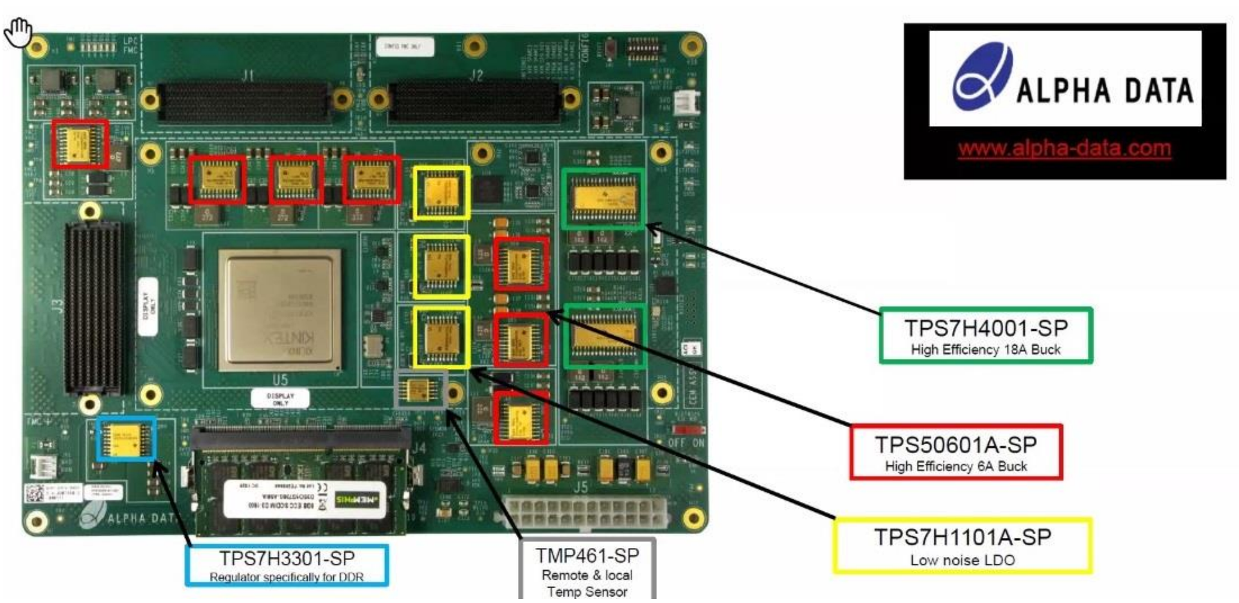
Eckles also discussed a higher-current POL, the TPS7H4001-SP, which is a 3- to 7-V input, 18-A current-mode monolithic QMLV point-of-load regulator. This part, which was released in November of last year, is now in full production and an eval module is available. The TPS7H4001-SP was introduced previously at NSREC 2020, as discussed in a previous NSREC Notes article.[1]

Along the same lines, Eckles presented information on the TPS7H4010-SEP, a 3.5-V to 32-V input, 6-A current-mode monolithic POL—a rad tolerant part in a plastic package. This part was also released last November, introduced publicly at NSREC 2020 and subsequently described in a NSEC Notes article.[1] (The ‘4001 and ‘4010 were also mentioned in a TI press release issued last December announcing the availability of TI’s high-rel components for online purchase.[3])

Two other older parts (but relatively new by space application standards) that were discussed were the TPS7H2201-SP, a 1.5-V to 7-V input, 6-A 35-mΩ smart load switch with reverse current protection and current limiting, which was released in May 2019 and the TPS73801-SEP, a 20-V, 1-A fast transient regulator, which was released in December 2018. According to Eckles, the radiation performance of the latter part was recently recharacterized. The TPS73801-SEP now specifies a TID of 50 krad and is SET and SEFI characterized and SEL, SEB, and SEGR immune to a LET of 43 MeV-cm^2/mg.

Besides offering details on the various new and existing space-grade power ICs, Eckles also discussed their application in powering a Xilinx FPGA. The company has developed an eval board that uses a combination of its voltage regulators to power Xilinx’s Kintex UltraScale XQRKU060 FPGA (Fig. 5). According to Eckles, this reference design represents one of the highest power density solutions available for this FPGA application and is capable of a 100-krad TID. The eval board and its block diagram are pictured below. For more information, contact Kurt Eckles.

Note that STMicroelectronics, announced in August that it is collaborating with Xilinx to build a power solution for the Xilinx Kintex UltraScale XQRKU060 radiation-tolerant FPGA, leveraging QML-V qualified voltage regulators from ST’s space-products portfolio. See the announcement for more details.



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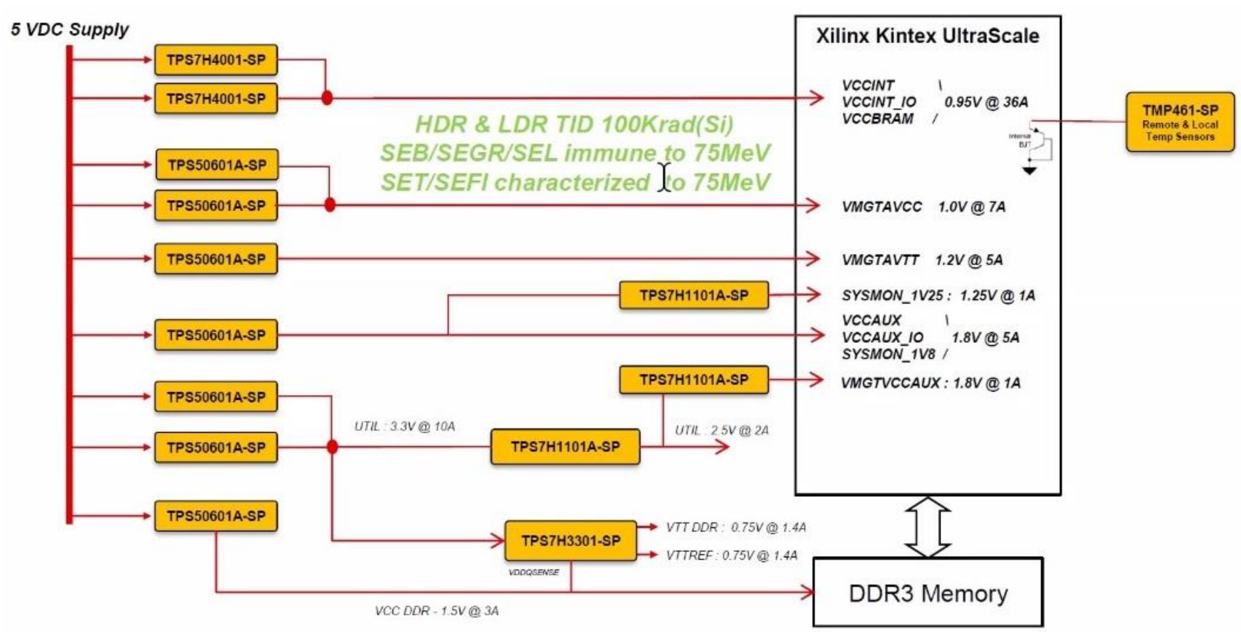


(b)

Fig. 5. The Xilinx Kintex UltraScale Development board uses multiple TI regulators as called out in the board photo (a) and block diagram (b).

More Progress In Plastic

Just as he did at NSREC 2020, Steve Singer of Renesas gave a presentation on the company's plastic parts for space. However, this later talk at NSREC 2021 was notable for a few reasons. First, it went into more detail on the history behind these parts—the company's space heritage; and the market demands that led to development of the rad tolerant parts and then more recently the plastic parts developed on the rad hard production flows.

It also delved further into the characteristics and reliability of the so-called "radiation hardened plastic products". The latter description is not intended as a criticism of the rad hard label, but more as an acknowledgement that these rad hard plastic parts are in somewhat uncharted territories because of their newness and the fact that the DLA specification for rad hard plastic, referred to as Class P, is still in development. Finally, this talk was notable for its being one of the most highly attended exhibitor sessions at the conference—I counted 46 participants in this zoom session.

Clearly, this level of interest among attendees attests to market's interest in plastic packaging for rad hard components, and Singer's talk went into detail to make the case that Renesas' rad hard plastic parts are not only sufficiently reliable for the type of new space, LEO satellites, but also for the MEO and GEO satellites and other long-life space missions that until now have required hermetically sealed devices qualified under the QMLQ, QMLT and QMLV DLA standards for microcircuits.

Customers want to move from the hermetic devices, which are large, heavy and costly to plastic encapsulated ICs. The latter are up to 50% smaller in board area, lighter both because molding compound weighs less than ceramic and because gold lids are eliminated, and less expensive to produce.

Although Renesas is on the standards committee developing Class P, Singer explained that with customers asking for rad hard plastic parts now, "We don't have time to wait until the DLA approves a new [class P] flow" to start producing these parts. In his talk, Singer delved into how the company builds in high reliability and how it screens the parts. Comparisons were made between the rad hard and rad tolerant production flows (see the table) and between space and automotive qualifications.

Singer noted that one of the factors that enables Renesas to ensure the reliability of these space-grade plastic parts is that manufacturing process control has advanced greatly in the past 15 years. "Nowadays if you have MSL-1 (moisture sensitivity level rating 1, an IPC/JEDEC standard for IC packaging) it's not true hermeticity, but it's close."

Singer's talk also presented specs on the rad hard plastic components previously discussed at NSREC 2020—the ISL73033SEH low-side driver and 100-V GaN FET, the ISL71001SLH/SEHM 6-A synchronous buck regulator and the ISL71610SLHM digital isolator with passive input. For further information, contact [Steve Singer].

Table. Comparing Renesas' production flows for its rad hard plastic parts versus its rad tolerant plastic parts.

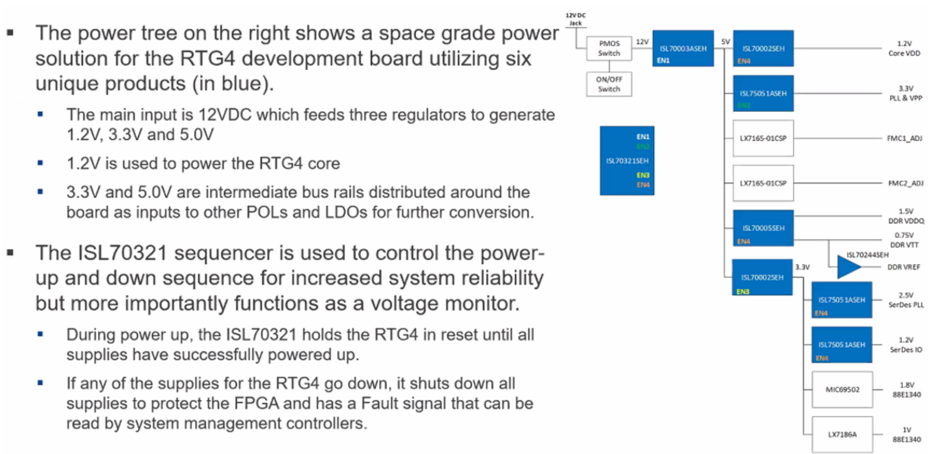
COMPARISON OF DIFFERENT PRODUCTION FLOWS Topic of Today's Discussion

Test	Class V	RH Plastic	RT Plastic
Wafer Lot Acceptance	YES	YES	YES
Nondestructive Bond Pull	YES	NO	NO
Visual Inspection and Serialization	YES	YES	NO
Radiography(pre- and post-stress)	YES	YES	NO
Acoustic Microscopy (C-SAM, pre- and post-stress)	NO	YES	NO
Temperature Cycle	YES	YES	NO
PIND	YES	NO	NO
Constant Acceleration	YES	NO	NO
Interim Electrical Test (Pre- and Post-Burn in)	YES	YES	NO
Burn-in (Static and Dynamic)	YES	YES	NO
Final Electrical Test (Tri-temp, -55C, +25C, +125C)	YES	YES	NO
Percent Defective Allowable (PDA) Calculation	YES	YES	NO
External Visual	YES	YES	NO

One of Singer's colleagues, Kiran Bernard went into further detail on Renesas' rad hard power parts, presenting an overview of the company's power management components for space, and how various devices from this portfolio are used to create what the company describes as a "best-in-class" power solution for Microchip's RTG4 rad hard FPGA. Bernard discussed the power requirements for the RTG4 and how specific Renesas ICs generate the required supply rails and provide the required sequencing of these supplies during power up and power down (Fig. 6).

With permission from Microchip and working in collaboration with Ibeos, Renesas modified Microchip's RTG4 development board and layout to replace Microchip's power solution with Renesas' full QML-V qualified power management solution. The resulting reference design makes it easier for designers to prototype and get to flight hardware much faster, according to Bernard.

The RTG4 development kit with QML-V power solution is available now as part number ISLRTG4DEMO1Z. All of the required design files for this kit (user guide, schematic, layout, Gerber, etc.) are available online. For further information, contact [Kiran Bernard].



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Part Number	Description	Input	Output Name	Output	Load
ISL70003ASEH	Radiation and SEE Tolerant 3V to 13.2V, 9A Buck Regulator	12V	5V Intermediate Rail	5V	9A
ISL70002SEH	Radiation Hardened and SEE Hardened 22A Synchronous Buck Regulator with Current Sharing	5V	VDD Core	1.2V	15A
ISL75051ASEH	Power for eight corner PLLs, PLLs in SerDes PCIe/PCS blocks, and FDDR PLL.	5V	VDDPLL & VPP	3.3V	1A
ISL70005SEH	Radiation Hardened Dual Output Point-of-Load, Integrated Synchronous Buck and Low Dropout Regulator	5V	DDR VDDQ	1.5V	3A
		1.5V	DDR VTT	0.75V	±1A
ISL70002SEH	Radiation Hardened and SEE Hardened 22A Synchronous Buck Regulator with Current Sharing	5V	3.3V Intermediate Rail	3.3V	10A
ISL75051ASEH	3A, Radiation Hardened, Positive, Ultra-Low Dropout Regulator.	3.3V	SERDES_x_ Lyz_VDDAIO	1.2V	3A
ISL75051ASEH	3A, Radiation Hardened, Positive, Ultra-Low Dropout Regulator	3.3V	SERDES_x_ Lyz_VDDAPLL	2.5V	2A

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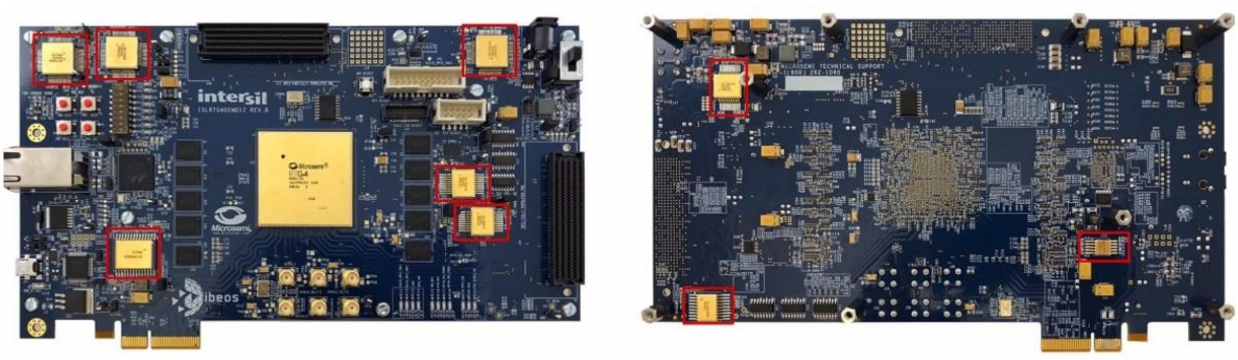

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Fig. 6. With permission from Microchip Technology and in collaboration with Ibeos, Renesas modified Microchip's RTG4 development board schematic and layout, replacing its power solution with a fully QML-V qualified power solution. The Renesas regulator ICs used to generate the rails required by the RTG4 FPGA are shown in the diagram (a) and the chart (b) with photos of the development board below them (c).

References

1. "NSREC Notes: Space Power Components Answer Calls For Higher Performance, Lower Cost" by David G. Morrison, How2Power Today, March 2021.
2. "NSREC 2019: Rad Hard Power IC Portfolios Add New Functions And Higher Performance Options" by David G. Morrison, How2Power Today, September 2019.
3. "Texas Instruments makes high-reliability products immediately available for purchase on TI.com," TI press release, December 9, 2020.

