WHITE PAPER

Space-Compliant Power Supply Scheme for Quad ARM® Cortex®-A72 Processing Module QLS1046 from Teledyne e2v

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TELEDYNE e2v | Semiconductors
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ABSTRACT

Compute intensive devices such as processors, FPGAs, and ACAPs are used to perform the heavy calculations required by Edge computing applications in Space. The applications covered are broad and can range from Artificial Intelligence (AI), automated guidance, and telecommunications to image/video processing for Earth observation. One of the challenges in designing boards with that kind of ICs is to implement the proper power supply architecture:

- Multiple voltage rails are needed to supply the different functional blocks of these complex components,
- The voltage rails need to be sequenced in the proper way during power-up,
- The supplies are required to be low-voltage and high current, due to the thin process nodes involved,
- Due to the Space environment, efficiency has to be maximized to reduce overall system power consumption, and ease the heat dissipation,

Teledyne e2v offers Space-grade digital components, including processors, memories, and processing modules, to support the Edge computing in Space. The QLS1046-Space is a heavy computing processing module featuring a Quad ARM® Cortex®-A72 processor complemented by a 4GB or 8GB DDR4 memory. Texas instruments (TI) offers a range of Space grade power supply ICs, which meet the requirements of supplying Teledyne e2v digital products in a Space radiative environment.

This white paper discusses the methodology and presents a proposed power supply scheme for QLS1046-Space with TI parts. The example taken throughout this paper is the power supply architecture which was sized and implemented for the reference design kit of the QLS1046-Space (QLS1046-xGB-RDK). First, a general description of the Teledyne e2v QLS1046-Space module is provided. Then, the sizing of the supplies is discussed as well as component selection. Finally, the detailed implementation is presented.

TELEDYNE E2V QLS1046-SPACE DESCRIPTION

QLS1046-Space is a Space ready, Radiation Tolerant, heavy processing module. It exhibits a small form factor of 44 x 26mm, while embedding a Space grade processor and Space grade DDR4 memory. The processor is a Quad ARM® Cortex®-A72 (LS1046) running at up to 1.8GHz and bringing 30 000 DMIPS / 56 GFLOPs computing capabilities. L1 and L2 cache memories are ECC-protected for robust behavior under radiations. With integrated packet processing acceleration, high speed peripherals including 1/10 Gb Ethernet, PCIe® Gen3, it can manage large data rates. The DDR4 memory has a 4GB or 8GB density and is connected to the processor, offering rates up to 2.1GT/s (130Gbps).

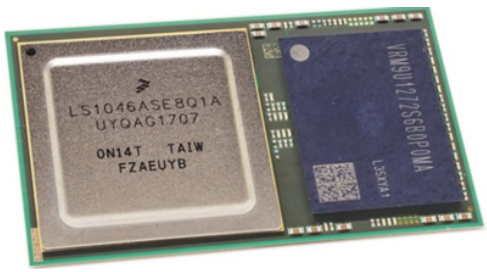

Figure 1 : Qormino QLS1046-Space

The module is offered in NASA Level 1 (based on NASA EEE-INST-002 - Section M4 – PEMs) and ECSS Class 1 (ECSS-Q-ST-60-13C). Regarding radiation performance, it has a SEL LET threshold above 62.5 MeV.cm^2/mg, and can sustain a TID of 100 krad(Si). SEU and SEFI detailed cross-sections are also available in dedicated radiation reports.

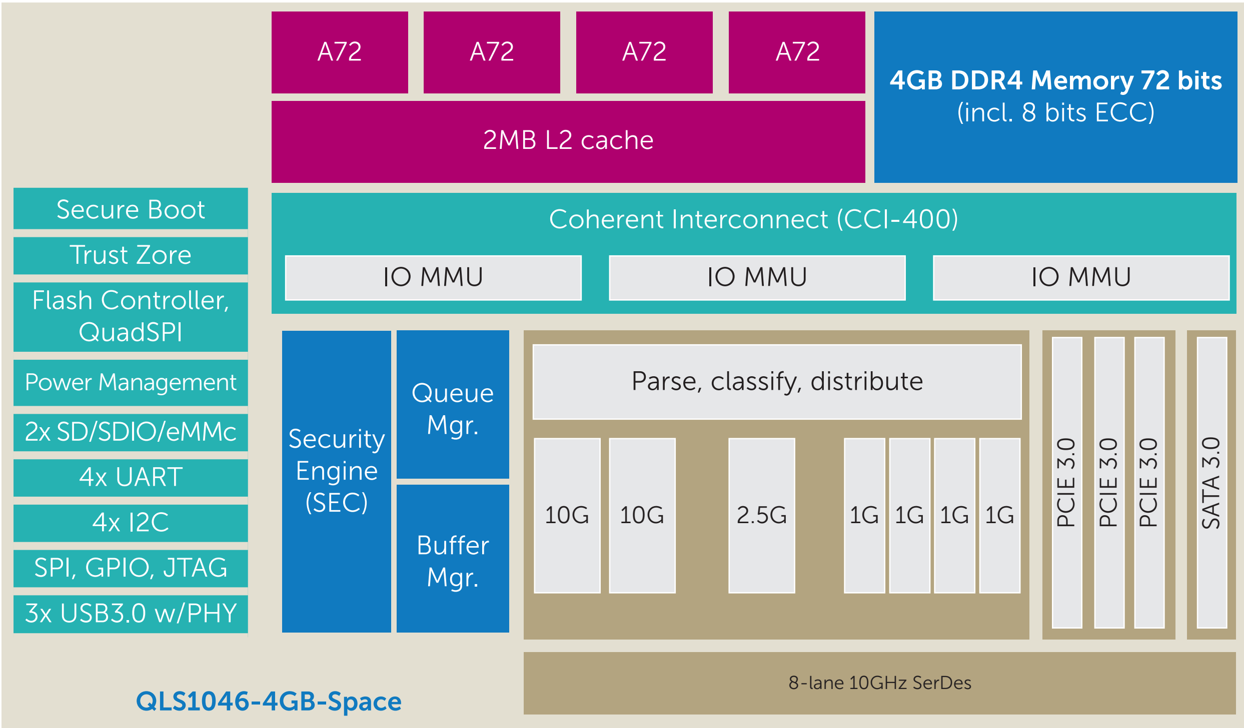

Figure 2: QLS1046-Space block diagram

QLS1046-Space can serve various applications requiring high compute capabilities in Space. It can be used for Space systems embedding Artificial Intelligence use cases, as it can run deep learning AI algorithms, for image processing in Space for example. It brings all the technical benefits of pre-processing information at the edge and reduce the downlink bandwidth when sending to the ground. QLS1046-Space is particularly relevant for project teams willing to reduce their development time, risk, system size, and bill of material. The module targets end applications such as autonomous landing, docking, launching, communication satellites, science missions, early warnings, earth observation Satellites.

POWER SUPPLY SIZING

Prior to select the components for the power supplies, the maximum total power requirements for each supply need to be estimated based on board design and use cases. QLS1046 module is typically used in Space computing boards, which feature additional ICs such as memories, external interfaces, and logic working with the QLS1046. The supplies are generally mutualized for the whole board, hence the power consumption for each supply is the QLS1046 consumption and the consumption of the other devices sharing the same voltage. For the other devices of the board, the consumption will be provided in their respective datasheets. For the QLS1046, its power consumption is the sum of the processor and DDR4 consumptions:

- The processor power consumption on the different supplies is provided in the product datasheet. For the 1V core voltage, which has the highest power consumption, a dedicated document explains how to estimate power consumption based on the use case (available under request).
- The DDR4 power consumption strongly depends on the usage profile. A power calculation spreadsheet is used to provide an estimation (also available upon request).

In this white paper, the power budget presented corresponds to the power budget of the QLS1046 reference design for Space (QLS1046-xGB-RDK). Since the reference design can be used in various applications, the power budget is estimated in the **worst-case scenario where all peripherals, devices (including QLS1046-Space) and interfaces are operating simultaneously at their maximum capabilities and maximum temperature**. Table 1 summarizes the maximum total power budget assessment for the QLS1046 alone and the whole board:

Voltage	Regulation Tolerance	Isolated	QLS1046 current (A)	QLS1046 power (W)	Total board current (A)	Total board power (W)
12		No			2.1	25.2
5		No			3.3	16.5
3.3	±165 mV	No	0.051	0.17	4.3	14.19
2.5	±120 mV	No	0.2	0.5	1.4	3.5
1.8	±90 mV	No	0.344	0.62	1	1.8
1.35	±67 mV	No	0.907	1.22	1.2	1.62
1.2	±60 mV	No	2.634	3.16	4	4.8
1	±30 mV	No	20.582	20.58	32.5	32.5
0.6	±6 mV	No	0.23	0.14	0.23	0.14
Total				**26.39**		**100.57**

Table 1 : Power budget estimation

It can be noted that the total board power consumption is much higher than the QLS1046 alone due to the multiple external interfaces and peripherals offered on the reference design, including up to 6 Ethernet 1/10Gbps interfaces, PCIe interfaces, ... For a real Space use case, the power budget needs to be recalculated using the same tools. In a real application, the total board power budget is expected much lower, since the numbers of interfaces may be lower, and the QLS1046 doesn't necessarily operate at full capabilities and maximum temperature.

ARCHITECTURE AND COMPONENT SELECTION

Based on the detailed power requirements, the general supply architecture can be defined, and power ICS can be selected for each supply. In the reference design, a 5V DC supply is the main input power supply for the board, meaning that it is used by the power converters to build the required lower voltage rails. If the satellite bus only offers 28V, an intermediate step-down DC to DC converter can be used to lower the voltage from 28V to 5V. The 5V is also used directly for the USB connectors (for development purposes on the ground). The 12V supply is only required for any PCIe devices connected on the board.

The power supplies should be able to operate with the input voltage of 5V, and they should feature "enable" and "power good" signals for chaining them to realize the proper power-up sequence as required by the QLS1046. On top of these requirements, efficiency is the main driver for selecting the Space grade supplies, since power consumption and heat dissipation is a challenge is Space environment. Based on these criterions, the following Texas Instruments ICs were selected to achieve the power supply scheme on the reference design:

- TPS7H4003-SEP, switching, up to 18A output current, with parallel configuration capability to source more output current,
- TPS7H4010-SEP, switching, up to 6A output current,
- TPS7H1111-SEP, LDO, up to 1.5A output current,
- TPS7H3302-SEP, DDR4 termination regulator,

These devices feature a plastic package which is easy to handle and assemble. They are guaranteed for a TID of 20 krad(Si), and a SEL immunity of 43 MeV.cm2/mg. When facing applications requiring higher quality grade and radiation performance, TI also offers ceramic flatpack versions with a TID of 100krad (Si) and SEL immunity of 75 MeV.cm2/mg.

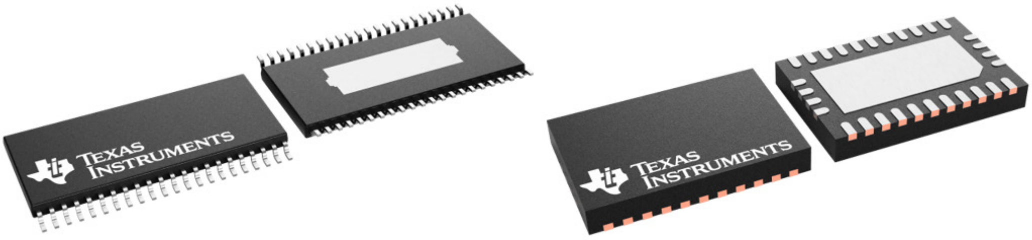

Figure 3: TPS7H4003-SEP (left) and TPS7H4010-SEP (right). Courtesy of Texas Instruments.

As mentioned above, the QLS1046-Space requires a specific power-up sequence. For this purpose, the "enable" and "power good" signals of the different converters are used. Figure 4 illustrates the complete power supply scheme of the reference design board with the way the regulators are chained to achieve the proper sequence. It has been chosen to use the TPS7H4010-SEP (6A) for the 2,5V/1,4A and use it to deliver the 1,8V/1A and 1,35V/1,2A with LDOs to reduce the dropout, which achieves better overall efficiency than dropping directly from 5V.

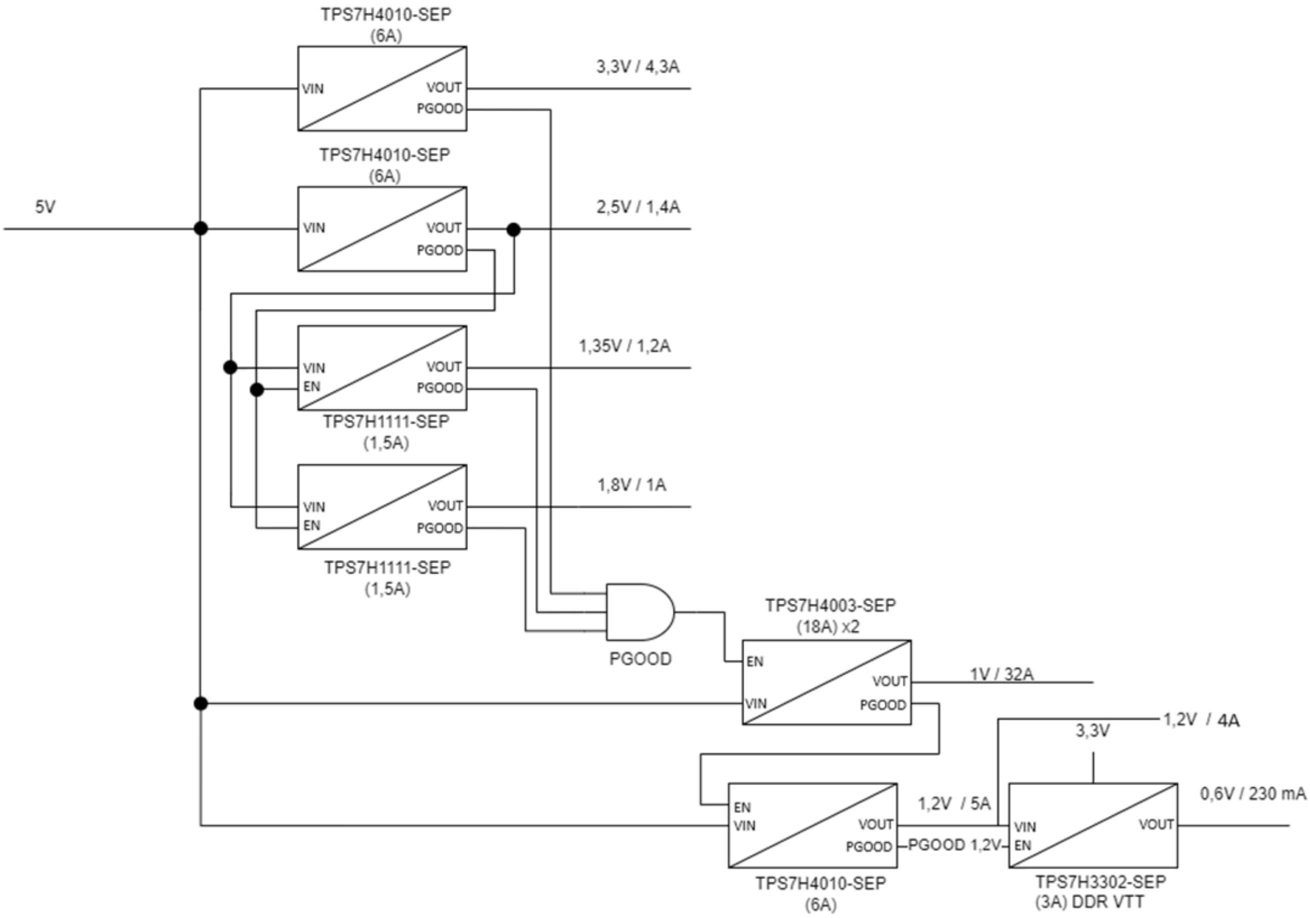

Figure 4: Complete power supply scheme

DETAILED IMPLEMENTATION

When the complete power supply scheme is defined, the detailed implementation can be realized for each supply individually. The schematics are drawn based on the application information from Texas Instruments. The implementation is tuned to consider the specific requirements of the QLS1046 and the board, including regulation accuracy, ripple, as well output current. On top of this, the efficiency of the switching converters keeps driving the design tradeoffs. When schematics are finalized, the performance of the power converters can be validated in simulation.

Figure 5 shows the schematics of the 1V power supply which implements a parallel configuration to be able to source the high current required by the processor. Another specificity of this supply is that it uses a Vsense feedback that is directly connected to the silicon die to have a measurement on the load side. Since the current is very high and tight regulation is needed, the converter regulates the voltage applied on the die (instead of at its output). This allows compensating for the voltage drop across the parasitic resistor of the supply line between the output of the supply and the silicon. A differential measurement is implemented using a Radiation-Tolerant amplifier to increase further accuracy.

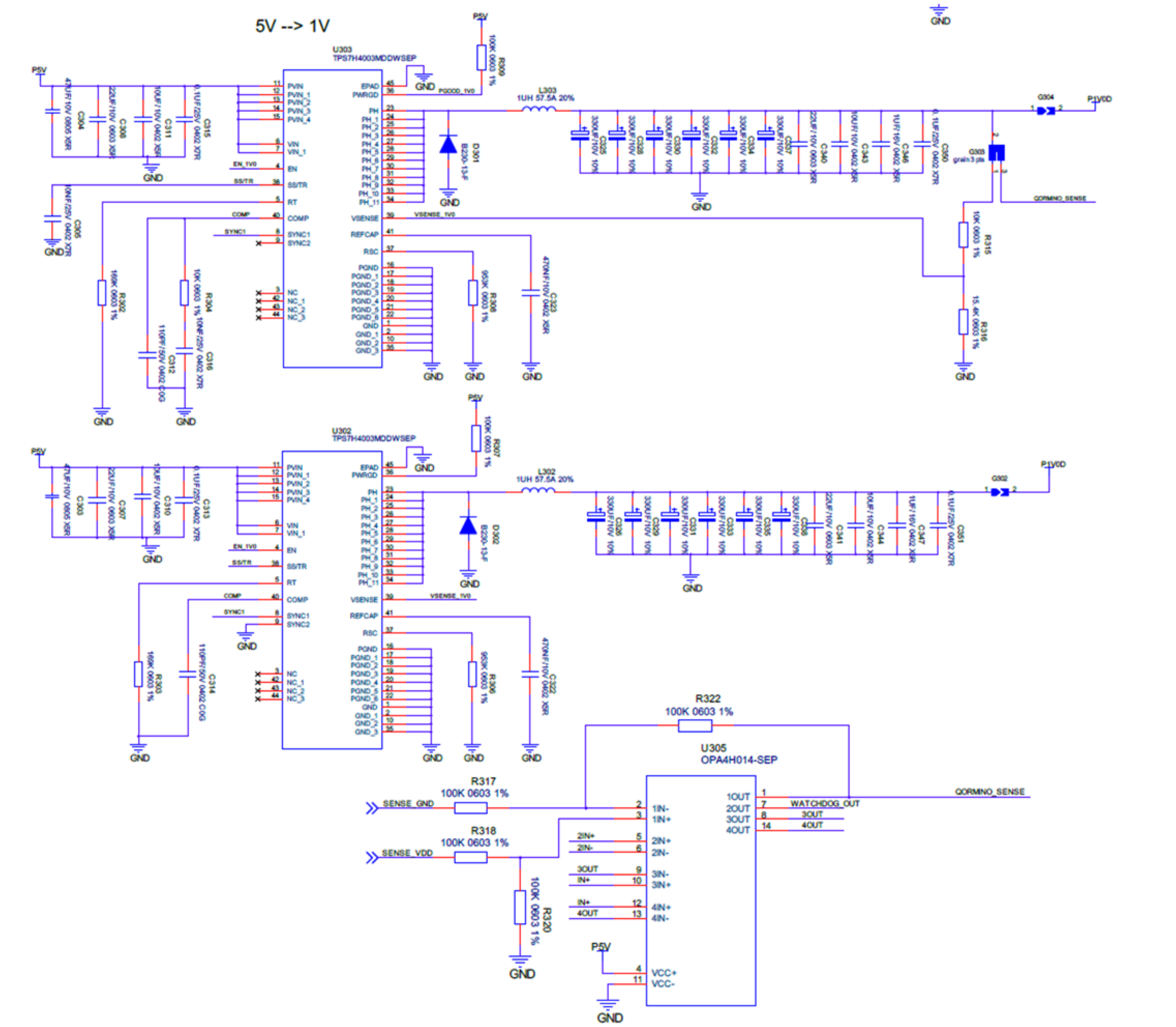

Figure 5: 1V core power supply schematics using parallel configuration.

As a second example, the implementation of the 1.8V power supply using a LDO is shown on the Figure 6:

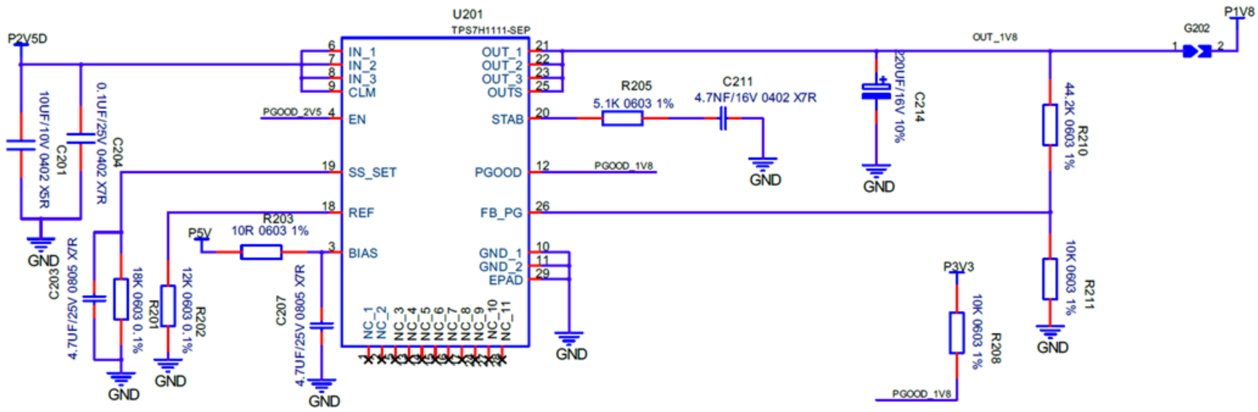

Figure 6: 1.8V power supply schematics using LDO.

The DDR4 memory featured in the QLS1046 has specific power requirements. The details on the implementation of the power supplies for the DDR4 memory are provided in a dedicated white paper available here .

The final stage of the design is the layout, which considers the application guidelines from TI and EMC aspects.

SUMMARY

This white paper has presented the different steps to implement a complete power supply scheme for a QLS1046-Space, and more generally for a Space board featuring it. The QLS1046 reference design kit for Space (QLS1046-xGB-RDK) was taken as an example to illustrate how this can be done in practice. This offers designers a complete Space-grade implementation using TI power supply ICs. The detailed design files of the QLS1046-xGB-RDK including the power supplies are available from Teledyne e2v. As discussed in the previous sections, the power supply scheme needs to be adjusted based on the custom board requirement, especially in terms of output current capability.

This power supply scheme can also mostly be re-used for a board using the LS1046-Space in standalone. In the case of the LX2160, the same strategy can be applied, and some supplies need to be reinforced, especially the core supply which draws significantly more current.

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