Technical Article

Key Considerations for Advancing Satellite Electrical Power Systems

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Satellite power design has a complex set of trade-offs given that the design has more variables, and the number of semiconductor options are significantly smaller than those in commercial applications. A satellite's primary power supply is especially important, since if it fails, there's little to no opportunity for repair. And with the advancement of space-grade high-performance field-programmable gate arrays, satellites now have significantly higher local computing power, increasing overall power demands.

When developing any satellite electrical power system (EPS), two of the most important trade-offs are the overall thermal design and the mission profile radiation requirements.

Thermal Management for System Efficiency

Component selection, topology selection and switching frequency are all vital when determining the efficiency of a switched-mode power supply (SMPS). The thermal load of the system directly correlates to the efficiency of the power supplies and the dissipation of power losses throughout the satellite.

A satellite's EPS must step down the voltages from the energy generation solar array portion of the system (typically 100 V ±50%) to the battery storage portion (typically 28 V ±20%), and then again to the clean point-of-load power supply (<5 V) for satellite payload cards such as single board computers, instrumentation or communication cards, or radar or communication cards. At each of these conversion stages, achieving the highest possible efficiency will help reduce power losses, as space power losses have far wider overall system and weight implications.

One technique to improve efficiency is synchronous rectification, where replacing a conventional power diode with a gate-controlled transistor significantly reduces the conduction loss of the power path. The forward characteristic of diodes, particularly those suitable for handling the current targeted by newer SMPS designs, often results in a larger voltage drop during the on-state. On the other hand, the synchronous rectification transistor is typically a field-effect transistor with a low on-state resistance, leading to much lower conduction losses at the same current level.

In a satellite's EPS design, pulse-width modulation (PWM) controller-based architectures provide the greatest flexibility to support a range of power-supply topologies at the highest efficiency levels. The radiation-hardened TPS7H5001-SP PWM controller family and radiation-tolerant TPS7H5005-SEP PWM controller family both support synchronous rectification, configurable dead time and other integrated features that enable designers to create smaller and more efficient isolated or non-isolated power supplies. An adjustable duty-cycle limit of 50%, 75% or 100% allows designers to use a single controller in the implementation of DC/DC converter topologies and integrated synchronous rectification outputs enable fully synchronous versions of each topology without additional external circuitry, offering overall system size benefits. Configurable dead time helps optimize power converter efficiency, particularly for gallium nitride (GaN) power semiconductor-based designs. An adjustable leading-edge blank time enables configuration of the controller's internal current sense based on the specific converter parasitic inductances and capacitances, as well as those for the printed circuit board or power module substrates.

Table 1 compares the different devices.

Table 1. Comparing the TPS7H5001-SP and TPS7H5005-SEP PWM Controller Families

Feature		TPS7H5001-SP TPS7H5005-SEP	TPS7H5002-SP TPS7H5006-SEP	TPS7H5003-SP TPS7H5007-SEP	TPS7H5004-SP TPS7H5008-SEP
Primary output configuration		Dual	Single	Single	Dual
Synchronous rectification output configuration		Dual	Single	Single	N/A
Duty cycle limit supported		100%, 75%, 50%	100%, 75%	100%, 75%	50%
Programmability of output dead-time		Yes	Yes	No, fixed at 50 ns	No
Leading edge blank time support		Yes	Yes	No, fixed at 50 ns	Yes
Target GaN FET / Si MOSFET		GaN FET or Si MOSFET	GaN FET	Si MOSFET	GaN FET or Si MOSFET
Topology	Buck, boost	Yes	Yes	Yes	No
	Flyback	Yes	Yes	Yes	No
	Forward and active clamp	Yes	Yes	Yes	No
	Push-pull	Yes	No	No	Yes
	Half-bridge and full-bridge	Yes	No	No	Yes

Mission Profile Radiation Requirements

Because all flight hardware needs to understand the orbit of the satellite and its expected radiation exposure, it is not possible to select satellite devices without reviewing the mission radiation requirements.

Satellite electronics will experience three types of radiation effects while in orbit:

- **Total ionizing dose (TID)** is an accumulated dose of radiation exposure over time. Prolonged radiation exposure can create trapped charges in the oxides of the semiconductor device, which in turn leads to parametric shifts within the device and eventually functional failure.
- **Single-event effects (SEEs)** measure the effects of heavy ions of the device under test. High-energy ion strikes can generate electron-hole pairs that lead to nondestructive events such as single-event transients (SETs) or single-event functional interrupts (SEFIs). These ion strikes can also cause destructive effects such as single-event latch-up (SEL), single-event burnout (SEB) or single-event gate rupture (SEGR).

- **Displacement damage dose** is another type of accumulating dose exposure that assesses damage to the crystal structure of the device from multiple ion strikes. While protons are typically the main cause of displacement damage in space, the neutron displacement damage (NDD) test uses neutrons because protons have TID effects; using neutrons makes it possible to separate displacement damage from TID effects.

It's important to validate how a component will perform when exposed to these types of radiation, especially components in the power supply. The TPS7H5001-SP device family includes TID radiation reports up to 100 krad(Si) and NDD up to 1 × 10^{13} neutrons/cm^2, ensuring that the device passes each of the automatic test equipment test vectors post-radiation exposure that device manufacturers use to guarantee underlying data-sheet limits. For the TPS7H5001-SP SEE testing, destructive SEE testing for SEL, SEB and SEGR immunity is confirmed to a linear energy transfer (LET) equal to 75 MeV-cm^2/mg, with SET and SEFI characterized to a LET equal to 75 MeV-cm^2/mg.

The TPS7H5005-SEP device family includes TID radiation reports up to 50 krad(Si) and NDD up to 1 × 10^{13} neutrons/cm^2 with destructive SEE testing for SEL, SEB and SEGR immunity is confirmed to a linear energy transfer (LET) equal to 43 MeV-cm^2/mg, with SET and SEFI characterized to a LET equal to 43 MeV-cm^2/mg.

Conclusion

Supporting the latest high-performance computing solutions in today's smaller satellites focuses a lot of attention on the thermal design challenges of the system. The new TPS7H5001-SP and TPS7H5005-SEP PWM controller families allow designers to achieve maximum power efficiency and design flexibility. To address the ever-present radiation requirements these two families of devices also have detailed radiation reports for TID, SEE and NDD that highlight how they can support any type of orbit or mission, be it low earth orbit, medium earth orbit or a geostationary orbit.

Additional Resources

- Check out these radiation reports:
- "TPS7H5001-SP Total Ionizing Dose (TID)."
- "TPS7H5001-SP, TPS7H5002-SP,TPS7H5003-SP and TPS7H5004-SP Single-Event Effects (SEE)."
- ""TPS7H5005-SEP Total Ionizing Dose (TID)."
- "TPS7H500X-SEP Single-Event Effects (SEE)."

Download the TPS7H5005-SEP flyback converter calculator.

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