The Anti-Interference Design of Secondary Power in LEO

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Abstract. In LEO (low earth orbit Laser communication) engineering, there is a demand to design a power system of high-reliability, to ensure the life of the LEO and reliable operation. The DC/DC has been widely used in the secondary power supply in LEO engineering with its high reliability, high integration and high efficiency. But in the LEO, it is easy to introduce various forms of interference and noise, affect the reliability of power supply directly, thereby affecting the spacecraft's technical performance. To improve the reliability of the secondary power supply, a number of key technical discussions is taken on the Secondary Power design applications. The main contents include: Select of the DC/DC, Redundancy, Derating, EMC, Heat. After taking such measures, the reliability of the secondary power supply is greatly improved, All the result of the experiment and actual application shows that the anti-interference design are effective.

1. Introduction

Satellite laser communications include deep space, synchronous orbit, low orbit, medium orbit satellite communication, GEO (earth orbit geosynchronous, GEO) - GEO, LEO GEO- (earth orbit low-, LEO), LEO - LEO, LEO- ground and other forms, but also includes the communication between satellite and ground station. With the development of components, satellite optical communication technology has been basically mature, and gradually to the direction of commercial development,

LEO is a new type of space remote sensing, while the secondary power system is the most basic and most important aspect, the reliability of the power system directly affects the reliability of the load system running with the realization of the performance [1], and even determine the success or failure of the entire spacecraft mission.

2. The secondary power supply principle

At present, DC/DC module has been widely used in LEO with its high reliability, high integration, high efficiency features, etc. There are two design ways to use DC/DC module for space secondary power supply: the centralized power supply and the distributed power supply [2]. The different ways of power supply have great influence on the reliability of the system, the choice rely on the actual needs of the power system.

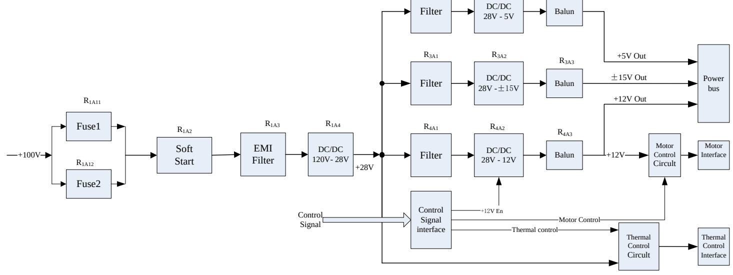

Figure 1. Scheme of secondary power

The advantages of the centralized power supply DC/DC quantity are less conducive to control and reduce the volume and weight of the power supply, and simplifying the cabling between the DC/DC;

While it is difficult to ensure that the power supply output volt ampere characteristics meet the requirement of each load.

Based on this, we select the distributed way to realize secondary power conversion. The block diagram is shown in Figure 1.

3. Reliability design of Secondary power

3.1 DC/DC module selection

The DC/DC module selection should be based on the space requirements of the application environment, combined with the power demands put forward by the research task, considering the DC/DC voltage, power, efficiency and performance of the module itself, as well as the reliability, security and other multifaceted Selection factors. In addition to meet the demand for electricity supply, should also focus on the following aspects from the reliability point of view.

3.2 Redundant Design

In order to guarantee the high reliability, there should be introduce some kinds of reliability design method [3]. Redundant design is one of the important measures to improve the power supply reliability.

When the main power output is increased or decreased to a certain degree, or do not provide the power to switch to backup power continue to supply. Redundant design is generally cold backup or hot backup.

3.3 Soft-start Circuit

When the power on, there will be a great impact on current, known as the inrush current. Secondary surge current will give the spacecraft power system adverse effects, power conversion and filter module has a certain capacity limit, when the impact current exceeds the modules rated capacity, it will make power system does not work properly, it is necessary to take measures to reduce the magnitude of the surge current. LEO products use soft-start circuit to limit input surge current usually.

The soft-start circuit has good inhibitory effect, but it is difficult to choose the power FET and matching resistor, capacitor, which need much adjust the measure. The circuit schematic diagram shown in Figure 2, Q1 is IR's power field effect Tube IRHM7360SE, its gate voltage Vg for the capacitor C1, the voltage of C2 is:

$$V_g = \frac{1}{RC}\int_0^t V_{in}\,dt \qquad (1)$$

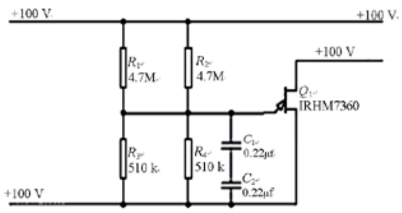

Figure 2. Inrush of the secondary power

After 100V power on, capacitors C1, C2 charged by the resistor R1, the maximum charging current Imax =0.042mA (100V/2.35M), Vg increase from 0 gradually, Q1 conduction resistance decreases, when the capacitor voltage rising to a certain time (approximately 10V), Q1 becomes conductive state gradually, 100V bus is turned on, thus achieve an effect of soft-start for the secondary power. There is a only 0.22W power of consumption when 1A current input, due to the little resistance(0.22Ω) of the IRHM7360SE, there is no much impact on the efficiency of the entire secondary power.

IRHM7360SE does not require too much current to drive the gate, R1, R2 select 4.7M, the capacitor C1, C2 capacitance value of the optional 0.22µF, taken parallel to the resistor, the capacitors in series to improve the reliability of the circuit, this solution control the charging speed of the capacitor by the resistor and capacitor values to control the soft start time, two groups of soft start circuit used in parallel manner to increase reliability. Figure 3 is the actual wave of the inrush.

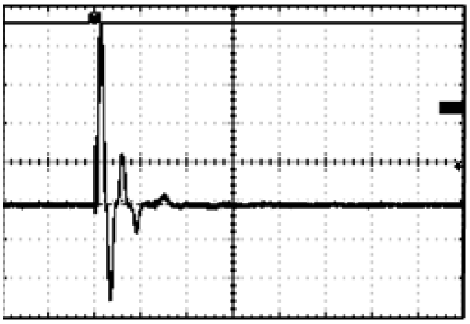

Figure 3. Inrush of the secondary power

Soft start design can not only effectively suppress the inrush current, but also contribute to the reduction of electromagnetic interference, can reduce the power circuit power devices di / dt and dv / dt, which can reduce the level of EMI [4].

3.4 Thermal Design

The application environment influences its reliability, the failure rate of the component lies on its junction temperature, the internal temperature of circuit is the greatest parameter to the reliability. For any kind of DC/DC module, there must be a heat exchange channel, to dissipate the internal heat and prevent the temperature rising. If the device is overheating, the performance, reliability and life will reduce. Especially when multiple DC/DC module is centrally installed in a system or even a PCB board, thermal design must be an important consideration in.

Example: The Interposing DC/DC temperature range from -55 to +125℃, the relationship of shell temperature and output power percentage shown in Figure 4 [5].

In Figure 4, the shell temperature below +125 ℃ DC/DC can be full loaded, while it must be linear derating when the shell temperature exceeds +125 ℃, and drops to 0 when exceeds +135℃.The safe operating area lies in under the red solid line, the module in this range will not cause damage to the module.

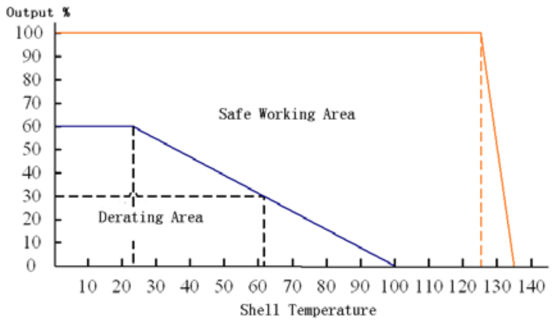

Figure 4. DC/DC Secure and Derating Area

3.5 Derating design

The derating of DC/DC module is different from other components, manufacturers claim DC/DC itself has derating design; On the other hand, most of the DC/DC module manufacturers given efficiency curve when the module output power is more than 30% in order to achieve a relatively high output efficiency, and less than 30% is not recommended to use. Derating guidelines based on Class I U.S. Navy recommended voltage regulator, derating the work area should be located below the solid blue line shows in Figure 4, it can take reasonable derating design combined with the actual ambient temperature and cooling, when in actual use. The shell temperature must be strictly limited within the expected temperature. It is generally recommended that range from 30% to 70% of the rated power is appropriate, DC/DC module has a good performance and adequate reliable in this range.

3.6 EMC design

Electromagnetic interference is a main problem designer must face in the secondary power system. The design must consider conduction, radiation, common mode and differential mode noise, common mode noise is the most important system noise [6]. For DC/DC module, common mode noise is caused by the current flow between the primary and secondary. Circuit design should take reasonable ground design as well as additional filters to meet the requirements of noise conduction.

A chassis with good electrical properties can reduce electromagnetic radiation, the intensity of the electromagnetic interference can be attenuated to the original one percent to more than one millionth usually [7].

3.7 Anti-radiation design

More stringent anti-radiation requirements are needed for DC/DC in LEO applications, standard modules have a radiation typically 2 × 104Rad (Si), which is sufficient for the low-orbit satellites. When use in high orbit, this point must be pay attention to the anti-radiation reinforcement.

For resistance to Single Event Effects, DC/DC module cannot use protective methods to enhance. But system-level measures can be used in the design such as redundant design and software protection.

3.8 Fuse design

In order to select a proper fuse, it is needed to determine the maximum rated current, select the the corresponding derating factor, and then, depending on the type of fuse, rated current value multiplied by the derating factor S is not less than the maximum rated operating current, and then according to the selected fuse Specifications table, choose a slightly larger than the current specifications.

After completion of the above calculation, but also the pulse current (surge) in line, to ensure that the duration of the pulse current on the power bus to meet:

$$I_p^2 \times t_p \leq \frac{1}{2} \times \left(I^2 \times t \right)_{\min} \tag{2}$$

In this design, we use a Schulte (SCHURTER) MGA-S series fuses, MGA-S 0.65 shell temperature exceeds 85 ℃, for additional derating 0.6% / ℃.

4. Conclusion

This article briefly describes secondary power system reliability design of a space optical remote sensor, includes DC/DC selection, redundant design, thermal design, fuse design, EMC derating design, all the above design has sufficient reliability calculation and verification.

The result of surges value and output ripple in conduction through the power supply line emission testing and chassis radiated emission testing, the measurement values are lower than the limits specified in the national military standard; The secondary power system work reliably after prototype and sample stage. Experiments and engineering applications show that the reliability design measures meet the high reliability and high-performance requirements of LEO products, play a vital role in the stability of the spacecraft and realize the technical indicators, these will be beneficial to similar power design applications.

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