Micro-Sized Power Controllers for Space

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ABSTRACT

The explosion in SmallSat and CubeSat deployments has led to a need for miniaturized cooling solutions for sensors that require cryocooling. Since there are limited opportunities for miniaturization in the thermal mechanical unit (TMU) portion of the cryocooling system, much of the pressure to reduce size falls on the cryocooler control electronics (CCE). In the world of digital electronics, continuous size reduction is the expected norm, however, in the world of space power electronics this is not the case. Additionally, when building space grade electronics, there are a smaller number of components available for use that are generally larger than their commercial equivalents, making space grade electronic solutions much larger than an equivalent circuit made of commercial grade electronics. In this paper Iris Technology proposes a way to reduce the size of the space based power controller through switching at higher speeds.

Keywords: space, power, cryocooler, GaN, electronics

1 THE NEXT GENERATION CCE

The current generation CCE devices built by Iris Technology utilize MOSFET power transistors to perform power conversion. The characteristics of the power MOSFETs limit the switch rate to something on the order of 100 kHz, thus driving the energy storage requirements of the capacitors and inductors. Switching at faster rates would reduce the required energy storage and thus the size of the inductors and capacitors. One solution to the switching frequency problem is the use of Gallium Nitride (GaN) FETs which can be switched on the order of 1 MHz. GaN FETs are inherently radiation tolerant, however recently GaN FETs have become available with space grade packaging. The space grade packaging is available with an integral radiation hardened high/low side driver. This integrated part provides further size reduction to the electronics design. Additionally, higher performance space grade microcontrollers have recently become available. These parts offer another integration opportunity, as the FPGA and ADC functions can be combined into a single smaller chip. Space grade GaN FETs when combined with the space grade microcontrollers provide an opportunity for significant reduction in the volume required for the CCE portion of a cryocooler system.

2 SIZE REDUCTION TARGETS

Space electronics, due to the limited number and larger size of components available for space use, are usually much larger than an equivalent commercial grade circuit solutions. In this paper we will explore the possibilities for size reduction of the current Iris Technology miniature Low Cost Control Electronics (mLCCE). We will be looking at three primary areas for size reduction; (1) Power Conversion circuits, (2) System Processing circuits, and (3) Signal Sensing circuits. Each of these areas will be discussed in detail in the following sections.

2.1 Power Conversion Circuits

The power conversion circuits are an area that provides potential for significant size reduction. This will be accomplished by changing our conversion circuitry from a MOSFET based architecture to a GaN FET based architecture. Generally, GaN devices have a smaller size for a given on resistance and breakdown voltage [1]. However, the first generation space grade GaN FETs and drivers currently available do not by themselves provide significant size reduction compared to existing MOSFETs and their drivers. The size reductions are achieved in the passive components (inductors, capacitors and resistors). Recall that we are proposing increasing the system switching speed from 100 kHz to 1 MHz. Since the switching rate is increased by a factor of 10, the energy needed to be maintained per switching period is reduced by a factor of 10. This means that inductor and capacitor values can be reduced by a factor of roughly 10. Since the size of capacitors and inductors scales with the value and power handling capability of the component, the size of the passive components required to support the GaN FET design are going to be much smaller than those required for an equivalent MOSFET design [2].

2.2 System Processing Circuits

The current generation mLCCE uses a space grade FPGA to perform the processing required to control the system output power. The output power is either defined by the system user via command messages or defined by the CCE processing based on a measured temperature versus a desired temperature set point. For the next generation design, the FPGA is replaced by a space grade microcontroller. These two devices are on the same order of magnitude as far as real estate on the circuit board. The microcontroller Iris Technology has selected for the next generation CCE has a 32-bit ARM Cortex core. This provides a rich instruction set allows for additional features that would not be possible in an FPGA based processing architecture. The microcontroller also has built-in peripherals used to replace currently external components as well as providing opportunity to add features not previously achievable.

2.3 Signal Sensing Circuits

The mLCCE senses input, output and internal voltages, and external temperature using an analog to digital converter (ADC). The microcontroller selected for the next generation CCE has a built in ADC, which removes the need for the external ADC and some of the signal conditioning circuitry. The microcontroller also has a precision current source which can be used in the Kelvin connection the CCE provides to the temperature sensor. In addition, the microcontroller provides digital to analog converters and comparators that could be used to provide additional features that were not previously possible.

2.4 Design Goals and Status

The goal of the next generation CCE effort is a size reduction of greater than 30% in required circuit board area using space grade components. The next generation CCE prototype is in design at the time of this writing and is planned for completion in 3rd quarter 2018.

3 CONCLUSIONS

In this paper we have described a smaller next generation space grade cryocooler controller that is facilitated by the use of recently available space grade GaN FETs and microcontrollers. The new architecture also provides the opportunity for additional features, not previously possible. These newly available space grade components help to partially mitigate the large size and lack of variety in components available for space flight applications.

REFERENCES

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