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THERMAL VACUUM TESTS OF A FIVE WATT PSEUDO CHIP IN A SEM-X ELECTRONIC MODULE CLAMPED IN A SATELLITE BOX

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Abstract

A five watt pseudo chip in the middle of a SEM-X circuit card was tested with various heat conduction paths in a satellite type electronic box while mounted in a vacuum chamber. Previous tests showed low temperature differentials with the use of circuit board clamps. Flight hardware with thin box walls, low mass module frames, and thin heat covers were tested to determine the temperature differential at 5.0 watts as well as at lower powers. The smallest temperature differential was 23 degrees Celsius between the 5 watt pseudo chip and the cold plate.

INTRODUCTION

As a SEM-X circuit card size (149 mm x 210 mm) is being used for new satellite payloads, heat transfer methods were investigated to keep the electronic parts at acceptable temperatures while keeping structures at low masses and volumes and adaptable to short design and production times. An earlier set of vacuum tests as reported by Akau tested copper braids, heat pipes, and thin aluminum straps to conduct the waste heat from a source on a circuit card to the walls of an electronic chassis or box and then to a cold plate. While the copper braids and heat pipes were effective in heat conduction, the resulting flight box would be bulky and heavy. The thin aluminum straps were as effective in heat when held with circuit card clamps against integral ribs in the box walls. Furthermore, the thin straps and clamps showed the possibility of little additional box volume and overall weight. The series of tests reported in this paper used thin heat straps, circuit card frame clamps, and box ribs in flight configuration and were tested in a thermal vacuum chamber. The module with a pseudo electronic chip was tested at 0.3, 1.2, 2.5 and 5.0 watts in order to determine when no heat strap is necessary as well as to estimate the temperature rise with heat straps.

HARDWARE

The side view of the circuit card, frame, clamps and heat sink is shown in figure 1. The circuit card is 2.0 mm thick and made of fiberglass epoxy, G 10. The frame is made of aluminum, 6061-T6, and is 1.9 mm thick. The box or chassis that holds the motherboard is shown in figure 2 and its construction is reported by Greenwood. The box is made of aluminum 6061-T6; the box walls are 1.27 mm thick, the box ribs are 2.54 mm by 5.84 mm and run the length of the circuit card frame. The heat strap or frame cover is aluminum 6061-T6 and is 1.27 mm (.050 in) thick.

The heat load is composed of eight resistors that are separated from the circuit card by 0.5 mm. An aluminum sheet (0.8 mm x 38 mm x 38 mm) is bonded to the top of the of the resistors to simulate an electronic chip and is in the center of the SEM-X card. The height of this pseudo chip is 4 mm above the circuit card. The allowable height of the electronic components is 6.6 mm. The gap between the pseudo chip and the heat sink or

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cover to complete the conduction path to the cold plate may be filled with epoxy, thermal compression pads, and an aluminum spacer. Several of the tests will use different methods to fill the gap from the chip to the heat cover.

Figure 1. End View of Circuit Card, Frame and Heat Cover Clamped into Box

The test module with the pseudo chip was placed between circuit cards that had resistors distributed across the card and consumed the same power as the center module with the pseudo chip. The hot neighbor cards will diminish the effect of radiation to the box interior and should be more representative of the actual environment in an electronics box. As can be seen in figure 2, the box has space for many electronic modules, and the test module was placed in the approximate center of the box.

Figure 2. The electronics box with integral ribs for the modules and clamps.

Type-T thermocouples were epoxied to the cold plate, the lower flange of the box (foot), an exterior wall adjacent to the test circuit card, an inside rib next to the test circuit card, the heat cover above the chip, and the underside of the pseudo chip case. Each test was started at the low power levels of 0.3 watts and allowed to come to steady state before the power was increased to the successive levels of 1.2, 2.5 and 5.0 watts.

TEST RESULTS

The results of seven tests are shown in table 1. Tests one through four were conducted with the box poorly attached to the cold plate. The box was held down on three sides by an offset bar clamping the bottom flange of the box to the cold plate. Tests five, six and seven used an adapter plate that allowed the sixteen #8-32 UNC screws to be placed through the bottom flange of the box. The change between test 4 (30 C differential) and test 5 (23 C differential) was the better contact between the box and the cold plate.

Table 1. Temperature Differentials for Five Watts, Various Structure

Condition	Chip	Cover Center	Rib	Foot	Cold Plate	Delta
4/5/95 card w/o Cu No Cover, 2.5 Watts	160 C	NA	45 C	35 C	32 C	NA
4/11/95, spacer screwed to cover, 5.0 watts	74	59 C	51	44	32	42 C
4/27/95, card w Cu, one part cover & spacer	67	57	50	43	32	35
5/02/95, spacer epoxied to chip & screwed to cover	62	59	48	42	32	30
-- Above Tests with Box clamped at three points; Later Tests clamped at 16 points ---						
5/22/95, spacer epoxied to chip & screwed to cover	54	52	38	38	31	23
5/23/95, cover is graphite epoxy & K1100	58	54	38	38	31	27
5/25/95 card w Cu no cover, 5.0 watts	129	NA	35	35	33	96

In the preliminary tests, the circuit card had solid copper planes on both sides. Simple one dimensional heat transfer models indicate substantial heat conduction from the resistors to the circuit card edges, especially since the resistors were epoxied directly to the card in the preliminary tests. In tests one and two, the fiberglass epoxy card had no copper planes. In test three through seven, a printed circuit board that was intended for flight was used which had many copper traces as well as interior copper ground planes. As stated in the hardware description, the resistor bodies were not epoxied to the circuit cards. The principal change between test 2 (42 C differential) and test 3 (35 C differential) was the better heat conduction in the circuit card of test 3.

The attachment and the consequent conduction path to the heat cover is a difficult task because the cover should be thin for mass reduction and also readily disassembled for late testing. A thin (1.27 mm) heat cover is flexible and will deflect rather than compressing thermal pads. A good attachment method is explored in tests three and four. A 2.5 mm spacer is screwed to the heat cover to take up the gap to the pseudo chip. Two layers of 0.4 mm thermal pad is used to complete the heat conduction path from the heat strip and spacer and the top of the chip. After assembly some visible bowing is seen and suggest that the thermal pad is only compressed near the edges. In test 4 the spacer is epoxied to the top of the chip and the thermal pads are compressed between the spacer and the heat cover by screws. This gives a five degree differential improvement from 35 C in test three to 30 C in test four.

Simple one dimensional heat conduction models for a heat strap that is 75.2 mm wide for five watts predicts a temperature differential of ten degree Celsius. A more conductive material for the heat cover is desirable. Copper can be used but the weight increase is not good. A graphite epoxy heat cover with K1100 was tried in test 6 but with an increase in the temperature differential.

In addition to developing a low mass heat sinking method, we sought to develop guidelines at what power heat straps are needed. Different electronic components have different maximum temperatures before reliability falls off rapidly and spacecraft and internal structures also have different temperature profiles. In table 2, the results of the temperatures from the chip to the cold plate are displayed for chip powers of 0.3, 1.2, 2.5 and 5.0 watts for the printed circuit card without copper and with copper trace planes.

Table 2. Temperature Differentials for Cards with No Covers at Various Powers

Condition	Power	Chip	Rib	Foot	Cold Plate	Delta
4/5/95 card w/o Cu no cover, box poorly clamped	0.3 watts	53 C	34 C	32 C	32 C	21 C
	1.2	105	39	34	32	84
	2.5	160	45	35	32	128
4/26/95 card w Cu no cover, box well clamped	0.3 watts	39	32	32	32	07
	1.2	65	33	33	32	33
	2.5	94	35	35	33	61
	5.0	129	38	38	33	96

The effect of the copper trace and ground planes in a real printed circuit card is most favorable and shows that electronic components at one watt of power dissipation need not be heat strapped in most circumstances.

CONCLUSIONS AND RECOMMENDATIONS _

For satellite applications where electronics operate in a vacuum, heat covers or straps serve as good conduction paths to transfer the waste heat to the satellite structure or radiators. Waste heat as high as 5.0 watts can be conducted away through aluminum heat covers that are 1.27 mm thick allowing a low volume and low mass electronics box. The lowest measured temperature differential is 23 degrees Celsius with 5 watt load and the pseudo chip located in the center of the 149 mm x 210 mm x 2.0 mm fiberglass epoxy G10 printed circuit card. Good thermal contact between the electronic chip and

the heat cover was obtained by epoxying an aluminum spacer to the chip and then using screws to compress thermal pads between the spacer and the heat cover.

With the printed circuit card frame and clamps structure, heat covers or strips are not necessary in many cases for waste heat as high 1.2 watts if a temperature differential of 33 degrees Celsius is acceptable.

The high waste heat electronic components should be located on the frame side of the printed circuit card as the conduction path is direct from the cover to the box rib. Electronic components located on the open side of the card can be heat strapped, but the heat strap conduction path will have more joints and choke points at the clamp or frame.

Acknowledgments

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