P09141

Satellite Thermal Heater Controller

Detailed Design Review Package

Mechanical Engineering Section

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1 Specifications

1.1 Size

The enclosure size is to be minimized. The enclosure must contain the printed circuit board (PCB) and the connectors provided by the customer.

1.2 Mass

The enclosure mass is to be less than 0.3 lb. This includes the enclosure, screws, PCB, connectors and cables.

1.3 Mounting

The enclosure must be able to be mounted to a flat plate and to a cylinder of a radius of 18 inches or larger.

1.4 Vibrations

The enclosure must be able to withstand 23.1 G's of random vibration in the x, y and z directions.

1.5 Thermal

The operational temperature must be -40°C to +55°C.

1.6 Other Requirements

1.6.1 Vacuum Environment

The enclosure must allow for ventilation. There can be no trapped air in the enclosure. The ventilation rate must be less than 1 psi/s. The enclosure must minimize on Outgassing. (Partially met)

1.6.2 Torque on the Screws

Determine the required torque on the screws to withstand the vibrations. (Not met)

1.6.3 EMI Leakage

The EMI leak must be less than 100 kHz. For more information, review the Electrical Engineering Section. (Not met)

2 Properties

The material that was chosen for the enclosure is Aluminum 6061-T6. The cost of the material itself is low based upon the cost of other materials that were reviewed. Handling the material is simple and can be machined quickly and easily even at RIT. The material itself is extremely simple to acquire, it is even available at some local retailers. It is also a light material and has adequate thermal dissipation capabilities.

The size and mass of the enclosure is 2.875” x 2.875” x 1.0625” and 0.18 lb respectively. There are four parts in the enclosure, the bottom, the right side, the left side and the top. The enclosure is held together by sixteen (16) 300 Series Stainless Steel screws. The enclosure itself has direct contact with the heating components on the PCB to act as a thermal dissipation vessel. The holes on the sides are for the connectors to pass through. For more information on the enclosure layout, view the part drawings in Appendix 1. For more information on the materials, view the parts list in Appendix 2.

3 Size

3.1 Properties

3.1.1 Printed Circuit Board (PCB)

Based on customer interactions, the size of the PCB was assumed to be 2.61” x 2.25” x 0.0625”.

3.1.2 Connectors

The connectors on the PCB are one (1) Micro-D 9S, one (1) Micro-D 15S and one DB-9 connector. The cross-sectional dimensions of these connectors are 0.785” x 0.31”, 0.935” x 0.31” and 1.2” x 0.5” respectively.

3.1.3 Total Enclosure

The size of the enclosure is 2.875” x 2.875” x 1.0625”.

3.2 Analysis

3.2.1 Target Size

Minimize the size of the enclosure. The enclosure must contain the PCB and corresponding connectors.

3.2.2 Designed Size

For the enclosure size analysis, view page S 3.1 in Appendix 4. The size difference between the enclosure and the PCB with the connectors is 0.265” x 0.625” x 0.5”. Since the customer has not finalized the size of the PCB, the size of the enclosure will vary as well. This may lead to a redesign of the enclosure.

4 Mass

4.1 Properties

4.1.1 Printed Circuit Board (PCB)

The mass of the PCB is 0.02 lb.

4.1.2 Connectors

The mass of the connectors are 0.0086 lb, 0.01 lb and 0.02 lb.

4.1.3 Screws

The individual mass of the screws are approximately 3.4e-4 lb. The total mass of the sixteen (16) screws is 0.039 lb.

4.1.4 Total Enclosure

The mass of the enclosure is 0.18 lb.

4.2 Analysis

4.2.1 Target Mass

The target mass is less than 0.3 lb.

4.2.2 Designed Mass

For the enclosure mass analysis, view page S 2.1 in Appendix 4. The total mass was calculated to be 0.244 lb, which is 18% below the maximum requirement. The mass of the cables are assumed to be allocated to other weight requirements. Therefore, the total mass of the system fulfills the requirement.

5 Mounting

5.1 Enclosure

The standard method to mount an attachment to a satellite is through an adhesive. Based on the geometry of the enclosure, the enclosure may be easily mounted to a flat plate through its base. Analysis was performed on mounting the enclosure to a cylinder of a radius greater or equal to 18 inches in Appendix 4 page S 1.1. If the enclosure is mounted tangent to the cylinder at the midpoint of its base, then the distance between the edges on the base and the cylinder is less than 1/16 in. Adding an additional amount of adhesive on both ends is a simple but effective solution to this requirement. This requirement will not be tested in MSD II. This requirement is for theoretical purposes only.

5.2 Printed Circuit Board (PCB)

The PCB is mounted to the base through four (4) screws of the same type that were mentioned in the properties section of the report. For more information on the materials, view the parts list in Appendix 2.

5.3 Connectors

The mounting of the connector directly depends on the specific part chosen by the customer. The customer has not identified the specific connectors that will mate with the right angle connectors located on the PCB. The sides will need to be redesigned to fit the specific connector. The connectors will be mounted to the sides through brackets or welding.

6 Vibrations

See Appendix 6 for modal simulations and Appendix 7 for Ansys simulations of random vibration. The first six modes of the enclosure are at 1507.6 Hz, 1600.3 Hz, 1856.7 Hz, 2706.8 Hz, 2927.3 Hz and 3035.7 Hz. Based on the simulations, the maximum deformations range between 1/16 to 3/16 of an inch. The deformations occur primarily on the Top, Side A and Side B parts. The sides will be reinforced when the connectors are mounted to them. This will significantly reduce the deformations on the sides. A deformation on the top of the enclosure will not contact or damage any parts within the enclosure. The top and side sections are to be discussed in the design review.

Since the screws were not concerned in the analysis, the parts were bonded around the edges of the screw holes. When a load is applied to the part, the stress at these contacts is significantly higher than what would be experience by the screws. The stress on the screws will also be discussed in the design review.

7 Thermal

See Appendix 5 for Thermal Analysis and Appendix 8 for Ansys simulations of thermal loading. The documents contain information on assumptions and the conditions used in the analysis. For the simulations, the entire enclosure was treated as Aluminum 6061-T6 including the PCB for simplicity. The screws were excluded from analysis. All areas of contact were thermally bonded, which implies contact resistance was neglected. The simulations are Steady State with Initial Conditions of 25°C on all surfaces.

The goal of the Condition 1 simulations is to distinguish the effect of heat generation in the PCB versus the heat flux through the aluminum heat sinks. As the heat flux through the aluminum heat sinks increases, a larger temperature difference occurs in the enclosure. The heat sinks are experiencing the highest heat flux and temperature gradient and therefore the highest amount of thermal stress.

When the overall heat generation in the PCB is increased and the heat flux decreased, the temperature difference of the system decreases and the heat flux is more evenly distributed. The maximum temperature difference as seen from the ‘worst case’ simulations for the system is less than 45°C. With respect to the yield stress, the thermal stress on the material is approximately 70% below its yield stress. As shown in the analysis section, the stress caused because of the temperature gradient is well below the yield of the material.

The goal of the Condition 2 simulations is to distinguish the effect on the heat flux through the bottom surface of the system, which most closely simulates a space environment with conduction through the bottom plate. These simulations compared closely to the thermal analysis in Appendix 5. The temperature difference was approximately constant during these simulations. This indicates that the temperature difference and thermal stress due to a temperature difference is not a function of the heat flux through the bottom plate. The overall enclosure is cooler due to the increased heat flux out, but the temperature difference is not significantly different.

The goal of the Condition 3 simulations is to analyze the system as if it is in a thermal chamber (cooler) with convection on all boundaries. The temperature difference decreases as the convection coefficient increases.