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A One Piece Wall Box for Space Electronics

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A One Piece Wall Box for Space Electronics

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Abstract

In extraterrestrial applications, satellite payloads have printed circuit modules that are housed in boxes or chassis. The box may be a one piece wall or a segmented wall. These two wall options are compared for function and cost.

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Introduction

The boxes that house printed circuit boards for consumer products such as personal computers are often made of molded plastic. Instrument type products are usually housed in formed steel sheets. The requirements of consumer type products are low cost and large quantities. The environment of space require the electronic boxes to be lightweight, good thermal conductors, and mechanically rugged to withstand the severe launch loads of shock and vibration. The boxes are usually custom tailored to house the printed circuit board modules, sensors, and electrical connectors in order to fit within the mass and volume constraints of the spacecraft. The electronic boxes that have been designed here at Sandia are made of aluminum with walls and covers that are .050 in (1.3 mm) to .080 in (2.0 mm) thick. The thin walls and covers are reinforced with flanges and ribs that are often 0.5 in (13 mm) high to form strong but lightweight parts. The box walls may be machined from flat plates and joined at the corners to adjacent wall pieces by flanges and screws or the walls may be made as one piece from a single block.

Comparison of Segmented Wall and One Piece Wall Boxes

The advantages and costs of one-piece wall and segmented wall boxes are examined. A one piece wall will be lighter since there is no need at the corners for flanges. Since there is no need to bolt the corners together, the assembly time will be less. An uncommon requirement of a space electronic box is the need to seal all joints to minimize electromagnetic leakage as emission from the box or reception into the box. As there are no joints at the corners of one piece wall boxes, there are less seams for electromagnetic leakage.

One advantage of the segmented walls is the possible reuse of the end walls if the number of modules change. During the development of the electronics, if the printed circuit board count changes, the side wall length will also change and require a new part, but the original end walls could still be used. If the box wall was one piece, then the entire wall would have to be remade when the number of electronic modules changes.

The **suspected** obvious disadvantage of the one piece wall is a higher fabrication cost. This is **not** the case; the fabrication cost for an one piece wall was found to be somewhat cheaper than the segmented walls when electric discharge machining was used to eliminate the gross milling of the interior of the box.

A one piece wall box for nine electronic SEM X modules was designed and built for the Gaona processor. See Figure 1 and refer to SNL drawing R45643. The internal ribs that are seen in the picture are for clamping the electronic modules to lower the electronic temperature as explained by Akau [1]. The box's outside dimensions are 9.26 in (235 mm) tall, 6.97 in (177 mm) wide and 8.80 in (224 mm) long. The walls are .05 in (1.3 mm) thick. The flanges and rib are 0.10 in (2.5 mm) thick and 0.5 in (12.7 mm) wide.

Figure 1. One Piece Box Wall, SNL Drawing R45643

After the block was squared, the outside was milled to leave the rib and top and bottom flanges. Because the block acts as a good heat sink and a solid support, the mill could move much faster than for a .5 in plate that was being machined down to a .05 in thick wall. After the outside features were milled into the block, the wire of the electric discharge machine cut the inside profile. Since an electric discharge machine generates little contact force nor thermal stress in the work piece (unlike milling), the wire speed is not adversely effected by the thin wall of .05 in. The machining operations and times to make the one piece wall are shown in Table 1. In 1994 dollars, the Sandia shops costs \$ 90/hour for a labor charge of \$8200. The raw block of Aluminum 6061-T6 cost \$500. The total production cost was \$8700. As expected the major labor costs are the milling of the outside features and the wire cutting. The wire cutting is slow because the depth of the cut through the box is over 9 in.

Table 1: Machining Hours for the One Piece Wall

1. Programming	5 hours
2. Square Raw Stock	4
3. Mill Radius of Wall Corners	3
4. Mill Exterior, Rough and Finish	16
5. Drill and Tap Holes	6
6. Mill O-Ring Grooves	4
7. Drill Through Holes in Center Block for Weight Reduction and for Pilot Hole to Thread Wire	10
8. Wire Electric Discharge Machine the Inside Profile	35
9. Mill Ribs Inside of Box at Bottom	4
10. Setup and Cleanup	4
<hr/>	
Total = 91 hours	

The machining operations and times to make a similar box but with four wall pieces for a segmented wall were estimated by Sandia machinists and are shown in tables 2, 3 and 4. In 1994 dollars, the combined labor estimate is 112 hours at \$ 90/hour for a labor estimate of \$10,100. The four raw plates of Aluminum 6061-T6 are estimated to cost \$100. The total production cost estimate is \$10,200. Note

that the machining time for the side walls greatly exceeds the end walls, because the milling of the internal ribs on the side walls are additional features that must be finished.

Table 2: Machining Hours for the Two Side Walls

1. Programming	5 hours
2. Square Raw Stock	2
3. Surface Both Sides	4
4. Rough Mill Inside Face	10
5. Rough Mill Outside Face	7
6. Finish Mill Inside Face	14
7. Finish Mill Outside face	8
8. Mill O-Ring Groove for Wall Joints	7
9. Drill and Tap Holes for Wall Joints	7
10. Setup and Cleanup	7
<hr/>	
Total = 71 hours	

Table 3: Machining Hours for the Two End Walls

1. Programming	2 hours
2. Square Raw Stock	2
3. Surface Both Sides	3
4. Rough Mill Outside Face	7
5. Finish Mill Inside Face	2
6. Finish Mill Outside face	6
7. Drill Holes for Wall Joints	2
8. Setup and Cleanup	5
<hr/>	
Total = 29 hours	

Table 4: Hours for Segmented Wall Assembly and Finish Machining

1. Align, Fasten, and Pin Four Walls	2 hours
2. Mill O-Ring Groove in Top and Bottom Flanges	5
3. Drill and Tap Holes in Top and Bottom Flanges	5
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Total	= 12 hours

The above costs and estimates are based on aluminum 6061-T6 which is considered a good alloy for machining. The machinists have experience with aluminum 7075 which is used at times because of higher tensile strength than 6061 but tends to warp with machining. If aluminum 7075 is used with either design, expect more machining hours due to slower feed rates, more passes, and possible scrapping.

For parts such as these with moderate complexity, the machinists estimate that a second part or greater number of parts can each be done at approximately two-thirds the time of the first part if the parts are processed at the same time since the programming and fixturing need not be repeated. The reduced times for the second side wall and the second end wall are reflected in the estimates for the segmented walls.

The one piece wall cost was favorable because of the use of the wire electric discharge machine. There was little milling needed after the internal block was removed. If the box design has internal ledges or grooves that are cross-wise to the wire travel then milling operations will be needed and, these could be difficult or impossible on the inside of a box with a continuous wall. Likewise, if the part is made at a shop without a wire electric discharge machine, then the cost will no doubt be adverse for a one piece wall versus a segmented wall box because of the time-consuming interior block removal by milling. One common feature that is missing from the nine module box, figure 1, is an electrical connector bench, one and one-half inches wide, along one side at the bottom. This bench would be an interior feature that would be done by milling and would increase the cost by 10 to 20 hours. However, a segmented wall would have this same feature and the additional milling time would be comparable.

For the nine module box, the one piece wall weighs 2.18 lbm. Adding flanges at the four corners would contribute an additional .26 lbm if the segmented wall design were used. While not a major weight savings, the .26 lbm is not insignificant because of the low mass requirements of the spacecraft.

Conclusion

The printed circuit board box for space applications is compared with a one piece wall versus a segmented wall design. The one piece wall has advantages of weight reduction and fewer joints for less electromagnetic leakage. In addition, the one piece wall design can be cheaper to fabricate if the internal cuts can be made by a wire electric discharge machine.

I acknowledge and thank Rick Anderson and other Sandia machinists in building 840 for their careful processing breakdowns and time estimates that are contained in this report as well as their helpful suggestions for the many parts that they have made for me.

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1. Akau, R.L. et. al., "Thermal Design of a Prototype Electronics Circuit Board," SAND94-2520A, Sandia National Laboratories, Albuquerque, New Mexico.

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