Profitability of rugged design in small quantity

Overview

Designing rugged field equipment in small quantities often raises the question of profitability due to the high costs associated with custom mechanical solutions. This article presents a TrigoPi case study involving a technician field programmer designed for an FPGA board, housed within a rugged enclosure. The device incorporates external JTAG and RS232 cables for debugging and a USB 3.1 connector for PC interface. Internal electronics include a dedicated JTAG pod, a USB 3.1 HUB, and protocol converters such as RS232 to USB. The study highlights the technical and business strategies used to deliver a cost-effective rugged design in small quantity production.

Problem Context

Small quantity production of rugged equipment typically makes custom mechanical design prohibitively expensive due to tooling and setup costs. Customers expect ruggedness and reliability, but the economics of bespoke mechanics often do not align with limited production volumes. This situation demands innovative approaches that maintain ruggedness and functionality while controlling costs.

Approach

For the TrigoPi field programmer, instead of investing in costly custom mechanics, an off-the-shelf rugged enclosure was selected. Minor modifications—specifically machining small holes—were performed in-house to accommodate cables and connectors. This approach balanced cost and ruggedness effectively, allowing the project to remain profitable despite the low production quantity.

Figure 1: Field programmer USB 3.1 connector on the rugged enclosure.

Thermal Management Considerations

Although the enclosure is rugged, it was not designed for extreme environments such as proximity to fire (a humorous aside). Nevertheless, a thorough thermal budget calculation was essential to ensure heat generated by internal electronics was effectively dissipated. Thermal budgeting involves analyzing power dissipation, heat transfer mechanisms, and enclosure thermal resistance to guarantee safe operating temperatures for electronic components.

The internal electronics, including the JTAG pod, USB HUB, and protocol converters, generate heat that must be managed within the enclosure's thermal constraints. The thermal analysis guided decisions on enclosure selection and modification, avoiding costly redesigns or cooling solutions that would have increased the project cost beyond customer acceptance.

Figure 2: Field programmer JTAG and auxiliary cables connected to the rugged enclosure.

Key Findings

- Small quantity production typically necessitates the use of off-the-shelf enclosures to keep costs manageable.
- Small quantity runs inherently result in higher per-unit costs due to tooling and setup expenses.
- Thermal sanity analysis and budget calculations are always required to validate enclosure suitability and ensure reliability.
- With the right in-house skills and workmanship, rugged designs can be delivered at a fair cost even in small quantities.

Practical Guidance / Do’s & Don’ts

- **Do** conduct early thermal budget calculations to avoid costly redesigns and ensure component safety.
- **Do** consider off-the-shelf rugged enclosures and modify them in-house to reduce tooling costs.
- **Do** leverage in-house machining and assembly capabilities to maintain cost control and quality.
- **Don’t** overlook the importance of environmental and thermal testing even for small production runs.
- **Don’t** compromise on sealing and ruggedness features that protect electronics in the field.

Safety & Reliability Notes

Ensuring that the enclosure meets environmental protection standards is critical for field reliability. Thermal management must prevent overheating that could damage electronics or create safety hazards. Even in small quantities, compliance with relevant standards and thorough testing is essential to guarantee long-term operation in demanding environments.

Figure 3: Thermal considerations for rugged enclosures illustrated humorously by placing near a fire.

Conclusion

The TrigoPi case study demonstrates that rugged design in small quantities can be both technically feasible and profitable. Success depends on early business risk analysis, thorough thermal budgeting, and leveraging in-house

skills to adapt off-the-shelf solutions cost-effectively. This approach avoids the high costs associated with custom mechanical tooling while maintaining the ruggedness and functionality required for field applications.

At TrigoPi, we love testing the edges of rugged design challenges. It’s the kind of problem that keeps our engineers awake at night—in a good way.

Call to Action

If you are exploring rugged field equipment design for small production runs and want to learn how to balance cost, ruggedness, and technical requirements effectively, contact TrigoPi. Our expertise in rugged electronics and enclosure adaptation can help you navigate the technical and business risks to a successful outcome.

References

- https://www.electronicproducts.com/thermal-budgeting-helps-select-components-before-prototyping/
- https://www.tglobalcorp.com/news/blog/calculating-heat-sink-size/
- https://www.nwengineeringllc.com/article/using-thermal-analysis-of-pcbs-to-design-rugged-electronics.php
- https://www.nvent.com/sites/default/files/acquiadam/assets/HOFFMAN-WPCS-WP00073-ManagingTempInEncl-EN-1905_0.pdf
- https://galleonec.com/cooling-of-rugged-electronics-and-cooling-techniques/
- https://www.allaboutcircuits.com/technical-articles/junction-to-ambient-thermal-resistance-ic-package-thermal-performance/
- https://www.ddbunlimited.com/outdoor-enclosures/wod-series/
- https://www.protocase.com/products/electronic-enclosures/
- https://beechat.network/product/kaonic-rugged-enclosure/
- https://www.mobilityengineeringtech.com/component/content/article/52885-design-considerations-for-rugged-naval-equipment-enclosures
- https://www.polycase.com
- https://www.macrofab.com/blog/nema-vs-ip-differences-explained/
