Products Used: NI CompactRIO, LabVIEW FPGA, LabVIEW Real-Time

Developing a Rugged, Embedded Solution for Extreme Altitudes with NI CompactRIO

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The Challenge: Creating a custom airborne instrumentation solution with off-the-shelf hardware that can survive the harsh conditions of high-altitude operation.

The Solution: Developing a compact, embedded, robust solution with National Instruments CompactRIO and reconfigurable I/O (RIO) technology and testing whether it can withstand extremes of high altitudes.

Obstacles of High-Altitude Testing

The harsh environmental conditions of high-altitude testing make it extremely difficult to create a solution for use in custom airborne instrumentation with off-the-shelf hardware. A variety of factors make it difficult for electronics to survive at extreme altitudes and low pressures. Instrumentation electronics must be able to withstand low temperatures and low air pressure. The low air density at high altitudes creates an environment that provides very little inductive cooling. Therefore, electrical components overheating is a big concern for airborne instrumentation.

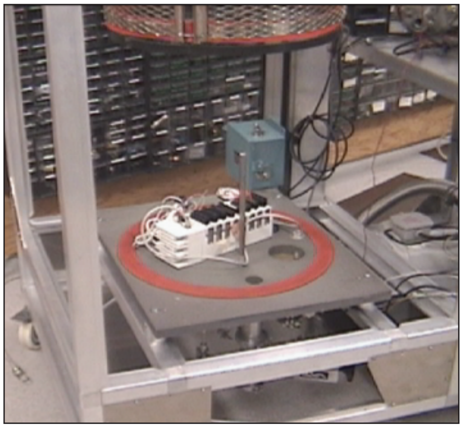
High-altitude testing also subjects electronics and instrumentation to extreme vibration. Thus, an ideal airborne instrumentation solution must be rugged to be able to withstand the physical shock of this type of testing. One specific problem the extreme vibration of airborne testing poses to instrumentation is in regards to mechanical hard disks. Although modern hard disks are designed to withstand significant shock and vibration, the extreme vibration present on some aircrafts can easily render a mechanical hard disk inoperative. In addition, hard disks require an air cushion to float the hard disk head above the disk surface. Although mechanical hard disks are sealed for protection against dust, they are not sealed to withstand extremely low pressure. Thus, mechanical hard disks generally fail at high altitude due to head crashes. Additionally, instrumentation must function in the presence of noisy electrical power often prevalent on airborne platforms. All of these physical and electrical obstacles of high-altitude operation create an extreme environment in which few instrumentation solutions can survive.

Developing a High-Altitude Instrumentation Solution with CompactRIO

The ruggedness of the CompactRIO-embedded system, customization of RIO technology, and deterministic performance of NI LabVIEW Real-Time create an ideal solution that can withstand the environmental challenges of high-altitude testing while providing the ultimate in performance and flexibility.

We found the CompactRIO-embedded system to be the ultimate solution for the extreme environmental conditions of high-altitude testing. The system provides an extended operating temperature range of -40 °C to 70 °C, a dual-redundant power supply that can operate from DC power, isolated I/O signal conditioning modules, and is rated for 50 g of shock. The CompactRIO-embedded system uses less than 20 W of electrical power, which proves very useful for low pressure environments. Normally, instrumentation used in high-altitude testing would require custom cooling that would be rather complicated for a system with multiple electronic components. You would need to enclose a system in a pressure vessel, which would add unwanted volume and weight. At extreme altitudes, we found that the CompactRIO-embedded system survived without the use of custom cooling or a pressure vessel. This is largely a result of the low power consumption of CompactRIO. CompactRIO also contains Compact Flash solid-state disks that have no moving parts and therefore eliminate the hard disk failure dilemma of airborne testing.

__Combined with the physical robustness of the system, these results give us great confidence that CompactRIO is ideal for airborne instrumentation and other harsh environments that require a rugged, embedded solution along with the ultimate in performance and flexibility.__



CompactRIO in Pressure Chamber

CompactRIO uses RIO technology, with which we can create custom hardware using the LabVIEW graphical programming environment. Using the LabVIEW FPGA module, we can develop high-speed analog and digital control algorithms and integrate custom timing and synchronization needed for airborne instrumentation. With numerous high-performance signal conditioning modules available, a CompactRIO system can easily be customized with the functionality required for a wide range of applications.

The CompactRIO-based LabVIEW Real-Time controller has a powerful floating-point processor and contains a powerful LabVIEW Real-Time application. Besides its inherent determinism, LabVIEW Real-Time has the significant advantage of being built on a robust, compact real-time operating system. In particular, this operating system is, in our experience, immune to hard disk corruption upon unexpected power loss, which is a well-known problem for Windows operating

High-Altitude Test Aircraft

systems and is a potential hazard that must be addressed for airborne instruments. In addition, using CompactRIO with LabVIEW Real-Time brings all the development power and ease of LabVIEW, including sophisticated GUIs; numerous acquisition, analysis, and control tools; and built-in support for networking.

Successful in Harsh Environments

To simulate high altitudes, we placed an eight-slot reconfigurable embedded CompactRIO chassis inside a bell jar, with connections through the bell jar for power and network communication. We filled all eight module slots with digital and analog CompactRIO I/O modules. A LabVIEW program continuously tested the digital and analog CompactRIO I/O modules to ensure functionality at different altitudes.

After starting the CompactRIO program with the embedded system inside the bell jar, we lowered the pressure to 300 mb (equivalent to 27,000 ft altitude) and observed the system for an hour. We then observed successful operation for one-hour periods at 150 mb (42,000 ft), 55 mb (65,000 ft), 17 mb (90,000 ft), and 0.53 mb (173,000 ft). We operated the system at 0.53 mb for over eight hours to verify that it could operate for extended times at high altitude.

Although most research aircrafts have flight ceilings below 70,000 ft, for this test, we lowered the pressure to the lower limit of the bell jar operating range. CompactRIO performed flawlessly even at this extreme, and it is likely that removing the last 0.05 percent of atmospheric pressure would not have made any measurable difference.

The operation of the CompactRIO system at extremely low pressure was quite impressive. Combined with the physical robustness of the system, these results give us great confidence that CompactRIO is ideal for airborne instrumentation and other harsh environments that require a rugged, embedded solution along with the ultimate in performance and flexibility. ■

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