A Physical Instrument from Virtual Instruments and sbRIO

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NI Product(s) Used:
NI-LabVIEW
NI-9606 sbRIO

Category:
Advanced Manufacturing and Control

Figure 1 - sbRIO based Thermogravimetric Analyzer (shown above) Came Together in 4 Months.

The Challenge
Demonstrate that an NI-sbRIO and LabVIEW is capable of replacing all control hardware and proprietary C# code found in a commercially available Thermogravimetric Analyzer (TGA) and show that it can be accomplished at a fraction of the time and cost.

The Solution
An NI-9606 was programmed to control all of the subsystems of a TGA (see Figure 1) and presented a network interface that made it indistinguishable from the traditional model in a 25% of the time and 17% of the cost.

Introduction
Data Science Automation (DSA) is a premier National Instruments (NI) Alliance Partner that specializes in automating and educating the world leading companies. Clients choose DSA because of DSA's deep knowledge of National Instruments products, disciplined process of developing adaptive

project solutions, staff of skilled Certified LabVIEW Architects and Certified Professional Instructors, and unique focus on empowerment through education and co-development.

The customer (an industry leading manufacturer of TGAs) wanted to decrease the time to market for new models. Initial experiments using NI sbRIO showed that the FPGA approach was a promising approach. While promising, it was observed that the work required to integrate the sbRIO with the existing software analysis package was not trivial. DSA was engaged to ensure the Proof-of-Concept was successful due to "the exceptional talents and professionalism of the DSA staff" (Project Manager, Testimonial Letter). This paper discusses the project, its challenges and how the sbRIO-LabVIEW solution accomplished the "impossible" (Lead developer of traditional TGA).

The Adventure Begins!
A forward thinking product manager was selected to pursue a parallel path of development that operated alongside the traditional team. The requirements for both product solutions had previously been established and documented so the end game was the same for both teams. The work required developing a hardware solution that would communicate with the powerful analysis package currently in use and was being enhanced to control the new TGA and family of devices.

Those components of the instrument that had served well with few failures and high accuracy were maintained in the new systems. These included multi-axis positioners, a precision balance, and a high temperature furnace. The logic and control electronics were targeted as the area where the instrument's supportability could be improved by reducing the quantity of custom components as well as the total number of components. This would simplify troubleshooting in the field and reduce the inventory of spare parts.

The product manager first hired Data Science Automation (DSA) for hands-on, Certified National Instruments Instructor-led Training by our staff of Certified LabVIEW Architects dually certified by NI as Professional Instructors. Later DSA was hired for custom mechatronic engineering services. A custom mezzanine board was developed to provide the electrical interfaces need to control the hardware and DSA was asked to develop the architecture for drivers and embedded software that would bring the TGA to life.

Plan First Code Second
DSA worked from the existing specification that had previously been developed for the product. These specifications included everything from the details of the protocol used to monitor and control the instrument via network connections to the timing and precision of the readings and the resolution of time intervals. In the interest of minimizing the time to market, DSA utilized one developer full-time and three part-time developers to work concurrently to ensure the hardware interfaces were developed as needed.

An architecture was developed (see figure 2) that would support the multiple simultaneous client connections and allowing for "On-The Fly" changes to procedural steps that either had not been executed or were in-progress at the time of the change (e.g. Change target set-point from 350 to 500 while the ramp was in progress).

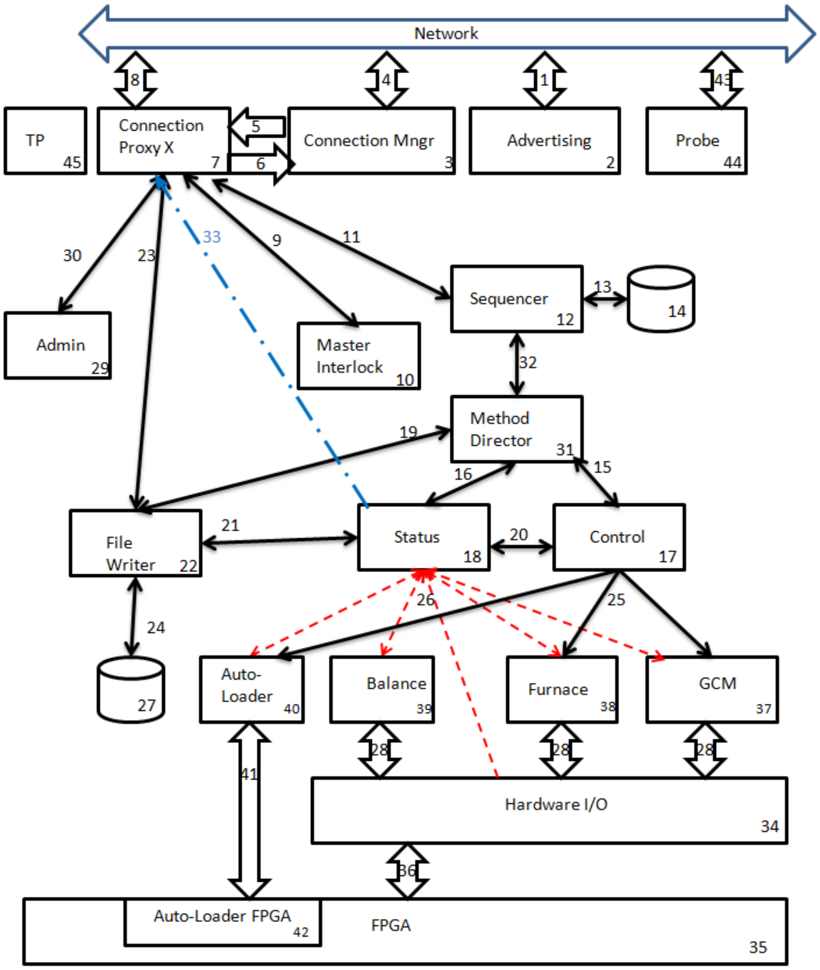

Figure 2 - The Native Multithreading of LabVIEW Allows for Complex Architectures.

The application design took advantage of LabVIEW's strength of being able to easily develop multithreaded applications to realize in software what had previously required multiple interacting Printed Circuit Boards. The support of ".dll" files was leveraged to take advantage of the Intellectual Property (IP) present in the temperature control routines needed to control the furnace temperature precisely.

Development started in earnest with developers working on the interfaces to the chips that would be on the custom mezzanine board while the architecture was being developed. Most of the interfaces were completed, short of verification testing, before the design was complete. Verification testing was deferred due to a delay in the manufacture of the mezzanine PCB. At that point the development team was reduced to a single, nearly full-time developer.

LabVIEW's Cross-Platform Capabilities

An early milestone was demonstrated to verify the TGA code adhered to the network interaction requirements. LabVIEW allowed for the first interactions between the control software and the LabVIEW version within weeks. This worked to the advantage of the over-all development needs by providing multiple tests of the control software to be run utilizing a "virtual TGA" that ran on a PC long before the first of the traditional device ever booted and flashed lights. These early tests revealed short-comings in the control software that were fixed before the version being developed in parallel was completed. LabVIEW allowed for a head-start not possible with the traditional approach.

VI-Server Enabled Remote Monitoring

An additional feature implemented in the NI-LabVIEW based approach was included to address a need that had been discovered while supporting the previous TGAs, "Poor monitoring and reporting". These issues had been bandaged over by inserting additional status and error messages in periodic diagnostic messages. While the additional information did report the internal state of the instruments, it required careful review by field personal to review all other available reports and manually rebuild the failure scenario. The new architecture of LabVIEW based application leveraged the power exposed via VI-Server to monitor the internal working state of every subsystem shown in Figure 2 (above). A separate stand-alone executable was developed that would allow interested individuals to "Probe" the status remotely, the "Remote Probe".

Figure 3 – The Interior of the TGA Features an NI-9606 That Brings the Product to Life.

As the hardware components (See figure 3) were completed and PCB's populated, the RealTime (RT) application was enhanced to include the newly available sub-systems. The Product Manager was able to test, verify and correct any discrepancies that prevented proper operation at his facility while the more complex virtual sub-systems came to life.

Final Integration

Before long the application was deployed to the NI-9606 with its accompanying custom mezzanine board for integration testing. A single week-long visit by the primary developer was enough to complete the testing and tie the entire package together into a working Thermogravimetric Analyzer (see figure 1).

The final point of interest worthy of reporting happened after the integration testing was completed and the work began to create a presentation for senior management that featured the new system. The product manager reported trying an operation that was never included as part of the initial Proof-of-Concept requirements. When hearing of this experiment the primary developer braced for a change request but was overjoyed to learn that the feature worked on its first attempt. Discovering un-tested code works on the first try is just one of the advantages that developing in LabVIEW offers.

Conclusion

National Instruments LabVIEW and the sbRIO hardware allowed for a traditional instrument to be realized using virtualized sub-systems. This reduced development time and costs as summarized below;

1) 1 mezzanine board vs. 4 PCBs in the traditional system
2) Highly complex custom control protocol for multiple clients in a short time.
3) Flexible sequence engine that permitted "on the fly" changes even while operations in-progress.
4) Integrated existing legacy algorithms for temperature control to eliminate need to recreate from scratch.
5) All software development was performed without the advantage of a physical instrument for developmental testing, only final integrated testing.
6) Complete all tasks with development only taking four man-months of effort over a seven month period. The traditional approach is projected to take eighteen months (it is still on-going at the time of this writing)
7) Final application delivered for less than 17% the cost of the traditional methodology.

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