RAPIDLY ADAPTABLE INSTRUMENTATION TESTER (RAIT)

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ABSTRACT

Emerging technologies in the field of "Test & Measurement" have recently enabled the development of the Rapidly Adaptable Instrumentation Tester (RAIT). Based on software developed with LabVIEW®, the RAIT design enables quick reconfiguration to test and calibrate a wide variety of telemetry systems. The consequences of inadequate testing could be devastating if a telemetry system were to fail during an expensive flight mission. Supporting both open-bench testing as well as automated test sequences, the RAIT has significantly lowered total time required to test and calibrate a system. This has resulted in an overall lower per unit testing cost than has been achievable in the past.

KEYWORDS

Telemetry System Testing, Instrumentation Testing, Automated Testing, Calibration

INTRODUCTION

Testing and calibration of small quantity (one or few of a kind) telemetry systems has been a long-time challenge. The complexity of these systems has previously made automating a test sequence for such small quantities cost prohibitive; yet non-automated, open-bench type testing is equally costly, because it is very time consuming and labor intensive. What is needed to resolve this paradox is a tester design that is highly configurable, both in hardware and software, which would allow for quick, easy adaptation to existing and future telemetry and instrumentation system designs. Such a tester should also address issues of data management, including the complex problem of maintaining a proper history of retest data. It should also be capable of electronically feeding test results directly to the next step in the overall data management process, thereby reducing the likelihood of human error being introduced into the data. We have developed an embodiment of this solution at Sandia National Laboratories, and termed it the *Rapidly Adaptable Instrumentation Tester* (RAIT). The RAIT completely automates the entire process of test and calibration of a telemetry system -- from the application of artificial stimulus to multiple data channels, all the way through to the creation of files that contain the test results needed for import to the calibration files. These calibration files will convert *Pulse Coded Modulation* (PCM) flight data into calibrated engineering units.

METHODS

The philosophy behind RAIT is to begin with a "base set" of *Test & Measurement* (T&M) instruments and associated software drivers, which represent the core of the RAIT design. With this core design the vast majority of instrumentation testing can be achieved. Then, as unique testing requirements for a specific instrumentation system are identified, an instrument or two can be added to accommodate those specific requirements.

HARDWARE -- To achieve maximum flexibility and configurability on the hardware side, *Commercial Off-The-Shelf* (COTS) T&M equipment was selected. All equipment is fully programmable, and computer controllable via a *General Purpose Interface Bus* (GPIB) interface. The T&M instruments that make up the above mentioned "core" include a four (4) output power supply; a two (2) channel universal source capable of producing both voltage and current signals; a Digital Multi-Meter (DMM); and a switching matrix. A combination PCM decommutation/bitsync card is also a part of the core, as is an oscilloscope or a Multi-Purpose *Data AcQuisition* (DAQ) unit. The Multi-Purpose DAQ unit provides *Analog to Digital* (A/D) inputs, *Digital to Analog* (D/A) outputs, timer outputs, and digital I/O ports. All instruments, including the PCM card and the DAQ card, are under control of a high power computer workstation, running a single or dual Intel® Pentium® microprocessor(s), and the Windows® NT Operating System. All instruments, plus the computer workstation, are mounted in either a single bay, mobile test rack, or a multi bay, not-so-mobile test rack. The tester mounts the computer keyboard and an LCD flat-panel display on a swing-arm, which is mounted directly to the single bay rack for maximum mobility and minimal storage space. The computer is connected to a *Local Area Network* (LAN), so that users can review test results from their desktops, or even via remote login from an off-site location. When temperature testing is required, a GPIB controlled temperature chamber is located directly next to the RAIT test rack.

At the center of all this equipment is an interface chassis. This chassis consists of a front panel that mounts all the connectors that will interface to the *Unit Under Test* (UUT); a rear panel that mounts all the connectors that will interface to the T&M instruments, the PCM card, and the DAQ card; and a *Printed Wiring Board* (PWB) that provides the appropriate interconnectivity between these front and rear panels. Hence, the interface chassis acts as a customized signal routing box, properly connecting every channel of the UUT to the appropriate connection point in the test rack. The PWB may also contain some circuitry, which could provide signal conditioning, voltage dividers, or other various functions. In this fashion, an interface chassis that is specific to each unique Telemetry System design is constructed as the only piece of hardware requiring change.

These chassis are interchangeable among different test racks, by implementing a standard interface design for the rear panel. The front panel is designed to the specifications of the UUT with which it is intended to mate. Along with each unique interface chassis is also a unique cable set, to connect between the front panel and the specific UUT.

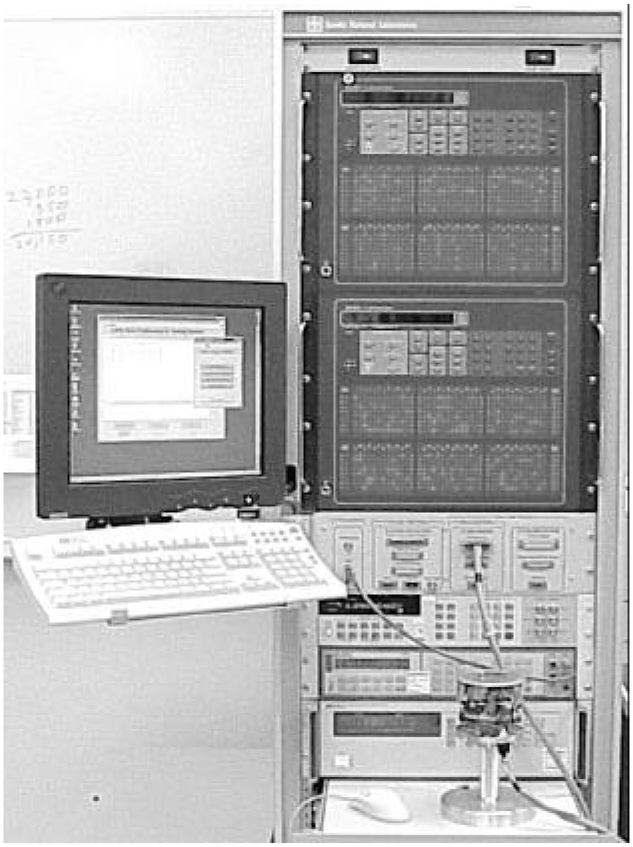

Figure 1. RAIT with UUT connected

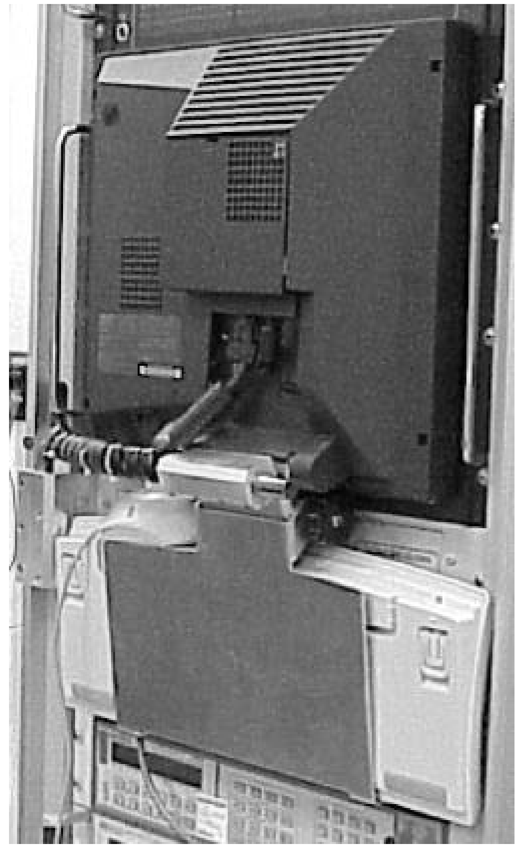

Figure 2. RAIT with display and keyboard folded in for storage

To achieve total automation, some method of switching a variety of T&M equipment to/from a variety of UUT data channels was needed. This was accomplished with the implementation of a switching matrix chassis (Keithley® model 707), populated with general purpose, plug-in matrix cards. This matrix can be configured to operate in either a row oriented or column oriented mode. Much consideration goes into making the appropriate decision on which configuration mode to use. We eventually concluded that the column oriented mode would best suit our purpose, based mostly on the fact that row oriented mode limits the number of T&M instruments to the number of rows that are available (in this case 8), and because column oriented mode provides for better future expansion.

One important "lessons learned" that was discovered during the first RAIT design, and was thus corrected during the second, was the realization of the importance of *Design for Test*. The first RAIT was created to test an **existing** telemetry system, known as the

Light-Weight Instrumentation System (LWIS). Since the UUT was an existing system, there was no opportunity to influence its design, and we had to use the predetermined approach for making a connection to the UUT. This approach was a *bed-of-nails* fixture, one fixture custom built for each board type to be tested, which proved difficult to implement. Precise alignment of boards on the fixture was required, and even with this achieved, proper electrical continuity was troublesome to maintain. When the original LWIS design evolved into the LWIS 2 design, the opportunity to incorporate *Design for Test* was seized. The *bed-of-nails* fixtures were replaced by tiny connectors, surface mounted directly on the boards to be tested. In most cases these tiny connectors were not incorporated into the design for the sole purpose of providing a connection point for testing, but shared their function between being a test port, and providing connection to other boards and sensors in the next level subassembly. For diagnostic monitor points that do not require an off-board connection to the next level subassembly, these tiny connectors **were** incorporated into the design for the sole purpose of providing a connection point for testing.

SOFTWARE -- To achieve maximum flexibility and configurability on the software side, a *Commercial Off-The-Shelf* (COTS) software development environment is utilized. LabVIEW® (National Instruments) was chosen for its Graphical Programming nature, which leads to ease of use; its Object Oriented nature, which leads to reusable, modular code; and for its extraordinary Instrument Control capabilities, which made it extremely well suited for this application. The vast majority of the RAIT software is written in LabVIEW®'s native "G" programming language. However, the driver that communicates with the PCM card was written in Borland® C++, and provides an ActiveX interface, which LabVIEW® accommodates quite well. The ActiveX protocol is also used by the RAIT software to exchange information to and from Microsoft Excel® worksheets, which contain channel lists, PCM format definition, etc., as well as the test and calibration results. Report generation is accomplished using HiQ® (National Instruments), which integrates easily with LabVIEW®, again via ActiveX function calls.

Each test, such as read a voltage, read a current, read a PCM frame, etc., as well as each routine that performs a check and/or calibration of the read data, is written as a modular subroutine. This methodology provides a high degree of "adaptability", which will allow for rapid reconfiguration as the software is applied to the testing of diverse telemetry systems, each with differing testing requirements. Furthermore, each of these test routines can be run as a stand-alone test, providing for open-bench style testing without manual reconfiguration.

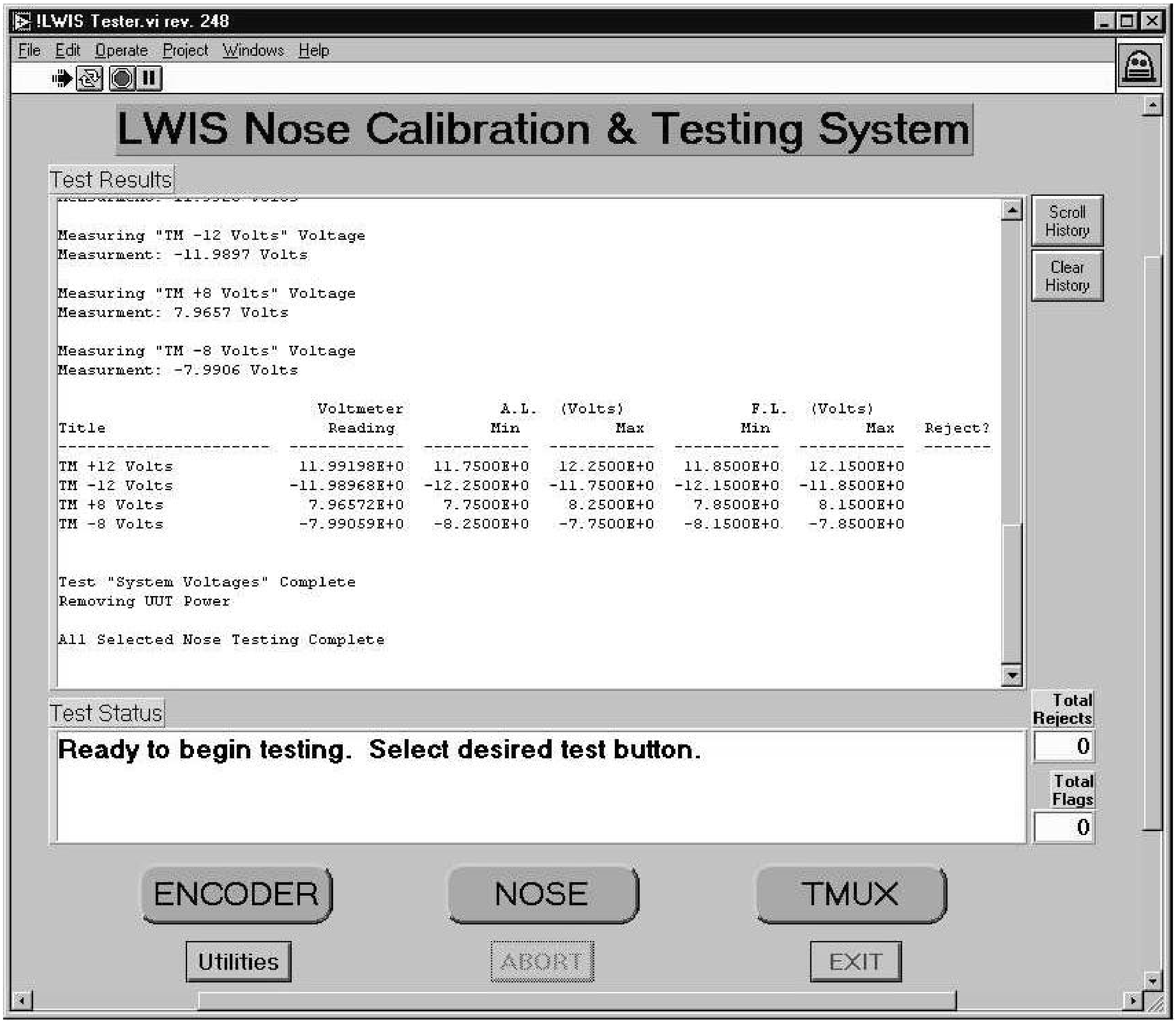

Figure 3. Front Panel user interface

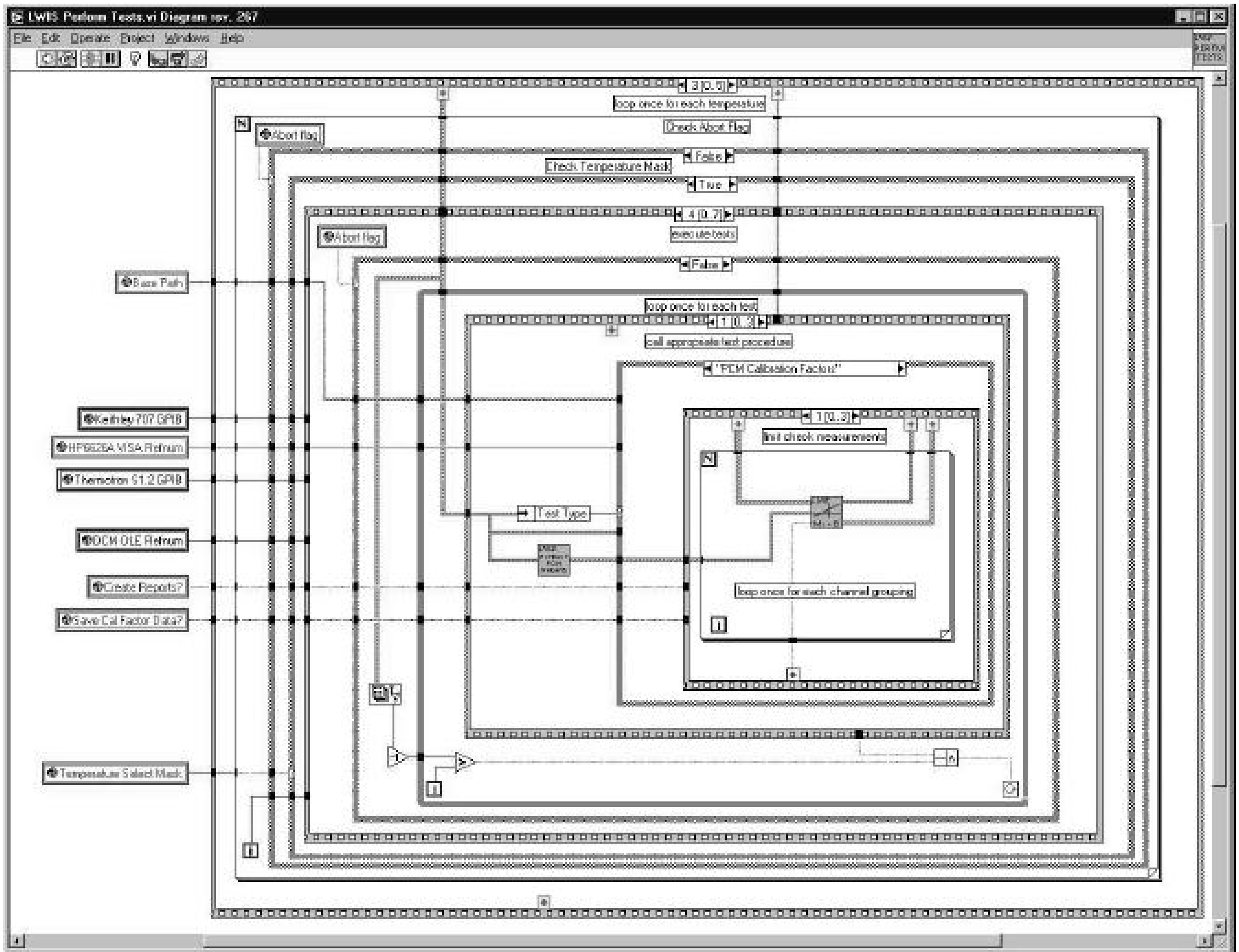

Figure 4. LabVIEW® Diagram showing main execution engine

RESULTS

An intuitive operator interface was designed to allow the operator to enter in some initial data such as the serial number of the UUT, the "object type" of the UUT, the operator's name, and other documentation type information. Once this data is entered, the operator then selects the "test level" that is desired (selects between various board level or subassembly level testing), then selects which channels are to the tested (all by default), and at what temperatures to perform testing (all by default). This entire data entry process requires approximately one (1) minute, then the testing can commence with the push of a single button. The amount of time required to complete a full test sequence varies with the "test level", but typically takes between 10 - 50 minutes, per temperature run. The test time has been reduced so dramatically from what it used to take to perform the same tests manually, that the temperature soak time is now the most time dominant part of a full test sequence. Regardless of the time required to complete a full test sequence, the man-hours required remains at about ten (10) minutes, since once started the test performs automatically and unattended until finished.

The development of the RAIT has produced a great deal of LabVIEW® code, almost all of which is Object Oriented, modular, and reusable. The core hardware design is also reusable. The expandability of the Keithley® switching matrix allows for easy augmentation of additional channels, if needed.

One major goal driving the development of this tester was to reduce the total cost of testing and calibration of each test unit, by reducing the total labor required. Another goal was to improve data reliability, and therefore the customer's confidence in the data. Prior to the RAIT, it required approximately 24 man-hours and 500 manual steps of open bench testing to conduct the nine LWIS tests/calibration procedures required for each flight unit. Most of this time was spent waiting to manually switch connections during the test. Because literally hundreds of wires were reconnected during a full test sequence, even the most experienced technicians made on average two switching errors per unit, which meant two (2) retests at a cost of approximately four (4) hours per unit. After the RAIT was introduced to the process, total test/calibration time dropped to about 12 hours per flight unit, including six (6) separate temperature soak times of one (1) hour each. Out of these 12 hours of total test/calibration time, only about 0.5 man-hours are required to connect cables to the unit in three different configurations, and to start the test process for each of these three configurations. During the remaining 11.5 hours, the tests run unattended. Using the computer controlled switching matrix to automatically perform the hundreds of necessary connections virtually eliminates retests due to human error. Using the RAIT, total test/calibration man-hours now takes 1.8% of the original man-hours required.

CONCLUSIONS

The RAIT design has proven to be both efficient and cost effective at testing multiple telemetry system designs. As new RAITs are built to accommodate more instrumentation systems, its flexibility and adaptability will evolve with each iteration. Already, issues have been identified that can be improved upon with the next implementation. These issues include abandoning the custom built user interface in favor of a COTS product, called TestStand (National Instruments). This product was created with integration to LabVIEW® in mind, and should enhance the RAIT's ability to be rapidly adapted to each new application. The TestStand product will also provide superior Report Generation capabilities over the HiQ® product now being used, and will completely eliminate the need for HiQ®, which has proven clumsy and difficult to use for this purpose. Additionally, TestStand will provide an even better method of managing test parameters and test limits, by supplying a COTS editor with an import/export capability. Currently, the management of test parameters and test limits is accomplished with a custom editor, coded with LabVIEW®. Other areas for future enhancement include a tool to better manage the storage of test result data, in a way that can track retest history and provide an audit trail; and the implementation of *Telemetry Attributes Transfer Standard* (TMATS), an IRIG specification to standardize how telemetry data is to be defined. The incorporation of *Design for Test* into new telemetry system designs can further exploit the RAIT's efficiency.

ACKNOWLEDGMENTS

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