Case Study:

Modular ATE System Design

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Abstract - Faced with ever-increasing constraints of budget reductions and tight schedules, test engineers are looking for faster, more cost-efficient ways to get ATE systems up and running. This case study examines a process known as Freedom Series, developed by Racal Instruments, illustrating how the principles of design reuse and automation, applied to ATE systems, can dramatically reduce non-recurring engineering costs and accelerate schedules.

Freedom Series is a modular approach to ATE system design. It exploits design reuse by standardizing components such as test instruments, interface cables, software drivers, and documentation. In addition, Freedom Series provides software tools that automate many non-recurring engineering tasks. The combination of modularity, reuse, and automation accelerates the system integration process and, in many cases, virtually eliminates non-recurring engineering costs.

I. Introduction

In today's fast-paced electronics marketplace, it is ever important to get new products released and shipping on schedule. A critical part of this is getting the production test equipment on-line and fully operational. Test engineers are discovering that modularity and design reuse, now common in product design, can also expedite the development of automatic test equipment (ATE) systems that test those products.

This case study examines a modular approach to the ATE development process known as Freedom Series, developed by Racal Instruments. The objective of Freedom Series is to reduce the time and cost of integrating new ATE systems. This process demonstrates how modularity, design reuse, and automation effectively reduce development time and non-recurring engineering (NRE) costs. Freedom Series now has a track record of moving test systems from customer specifications to the factory floor on accelerated schedules. At the same time, it reduces non-recurring engineering costs to a fraction of what was previously required.

Although Freedom Series deals primarily with VXIbus systems, its principles are applicable to a variety of test platforms.

II. Goals

The Freedom Series developers realized that the entire system development process must change to achieve the degree of improvement they desired. The old methodology, where each ATE system is developed completely from scratch, is too costly and time-consuming. They drew upon their experience in system integration, setting the following goals for the new Freedom Series process.

Make the System Specification Process Easier

ATE customers face a staggering array of test equipment, optional features, cabling methods, and software. There are many interacting rules to follow in making selections. For example, the power drawn by the test equipment must not exceed what the power distribution unit or VXIbus chassis provides. The system layout must accommodate cable harnesses that carry the test signals. The equipment rack must provide adequate cooling for the equipment. Therefore, the first challenge for Freedom Series was to simplify the process of specifying system equipment and hardware.

Incorporate Modularity and Design Reuse

Test systems, which are typically designed from scratch, involve a great deal of NRE. To facilitate the reduction of NRE through modularity and design reuse, a primary goal was to develop a Standard Equipment Library of popular test equipment. For each item, this library contains all data that is required to design it into a test system.

Specifically, this concept addresses two system integration tasks that are particularly labor-intensive. First is the design of cable harnesses that connect test instruments to the VXIbus receiver. Therefore, the goal was to develop a standard library of reusable cable harness designs for each item in the Standard Equipment Library.

Second is the generation of detailed mechanical drawings that document the physical system configuration. These drawings show the installed location of each piece of equipment. To minimize NRE, the goal for Freedom Series was to create a drawing module for each piece of equipment in the Standard Equipment Library. Once these drawing modules are in place, they are easily assembled into system drawings.

Automate the Configuration Checking Procedure

Configuration checking means verifying that the system configuration is feasible, reliable, and technically sound. For example, the selected VXIbus chassis must provide enough electrical power for all modules that it contains. The chassis must also provide sufficient cooling air so that the modules do not overheat. Equipment options must obey certain configuration rules regarding how they may be combined. In addition, some customers require an analysis of the mean time between failures (MTBF) and mean time to repair (MTTR).

It is imperative to check the configuration before work begins on the system. At the same time, configuration checking must be completed quickly to avoid delays in building the system. To minimize the time spent, and to promote accuracy and consistency by eliminating human error, the goal was to automate the configuration checking procedure.

Automate the Production of System Documentation

Another time-consuming task is generating customer documentation consisting of such items as the user manual, parts lists, cable wire lists, and VXIbus receiver pin maps (described later). The goal was to develop a modular approach that not only minimizes NRE costs, but also standardizes the documentation, making it consistent from one system to the next.

Guarantee Reproducible System-to-System Quality

In a test system, quality is affected by more than just the combined specifications of all instruments in the system. It is affected in large measure by the design of the wiring harnesses that connect the instruments to the unit under test. For this reason, one of the design goals for the Cable Harness Library was the establishment of standard connectors, cable lengths, and routing paths, so that all copies of a system have consistent signal handling and, therefore, consistent performance.

III. Implementation

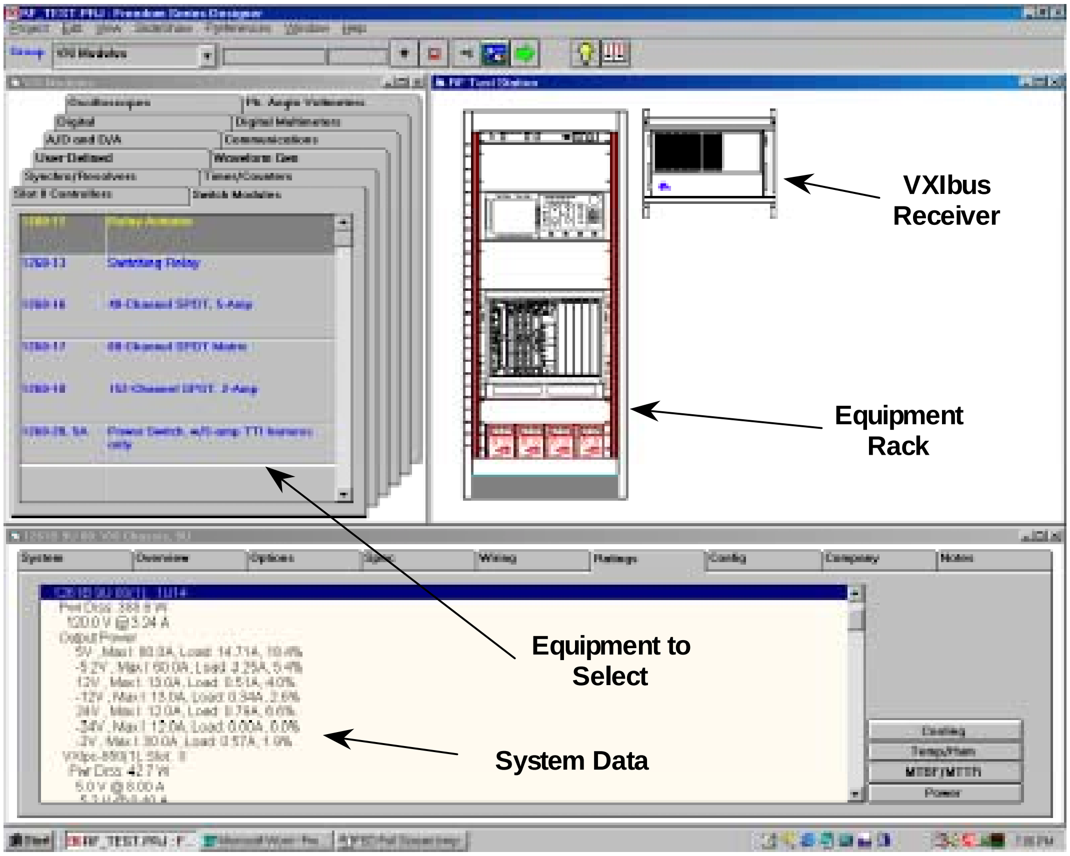
With the goals in place, the Freedom Series developers set out to implement the Freedom Series process. They accomplished their goals in the following ways.

Making the System Specification Process Easier

To make the specification process easier for the customer, the Freedom Series developers put together a standardized library of VXIbus and rack-mounted equipment. This provides a wide selection of equipment and software from different ATE vendors. They researched all available options for each piece of equipment, and created a configuration rule set to ensure that the user selects only valid combinations of options.

Next, they developed a graphical software tool, the Freedom Series Designer, for the salesperson to use alongside the customer. The Freedom Series Designer presents the user with a categorized list of all items in the Standard Equipment Library, organized by equipment type (see Figure 1). The user selects equipment from the list (at the left) with the mouse, dragging and dropping it into the graphics window (at the right). In this manner, the user builds a picture of the system.

Figure 1: Freedom Series Designer Software Tool



For each piece of equipment that the user selects, the Freedom Series Designer software displays the available options for that item. The software constantly checks the configuration rule set and allows the selection of only the options that are valid for the present system configuration.

The software maintains a system parts list, and updates it whenever the user adds equipment to or deletes it from the graphical display. When the user selects an option for a piece of equipment, the software automatically modifies the corresponding equipment part number so that it includes the selected option.

In this way, the software captures the system specification, along with any special notes from the customer. It stores the specification in a single MS-DOS computer file. This file may be hand-carried to the system integrators or sent via e-mail. Through this process, the user can specify the entire system, and print a picture of it, in a matter of minutes.

Incorporating Modularity and Design Reuse

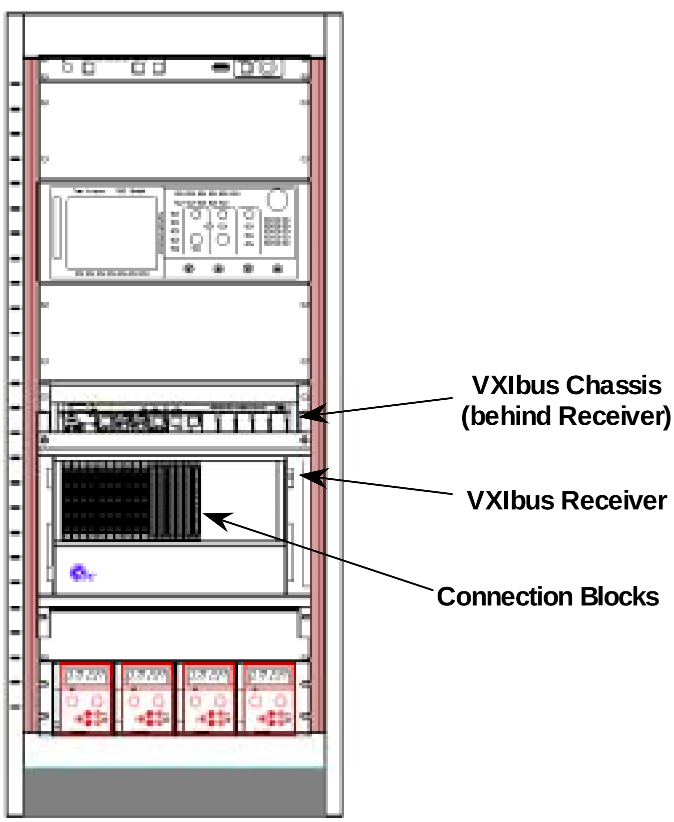
One of the most tedious jobs in configuring an ATE system is dealing with the wire harnesses that connect the test equipment to the VXIbus receiver. This begins during the specification process. How does the customer know what capacity the VXIbus receiver must have to accommodate all wire harnesses in the system? This question cannot be answered accurately until the harnesses have been designed. Only then can the customer know the types and quantities of connector blocks that the receiver must accommodate.

It became apparent that an effective way of dealing with this is to develop a standard library of reusable cable harness designs. This Cable Harness Library contains pre-designed cable harnesses for every instrument in the Freedom Series Standard Equipment Library. This includes harnesses for interfacing with a Virginia Panel VP-90 Series receiver, and separate harnesses for a TTI Testron receiver. The Cable Harness Library documents each harness design with a complete parts list, wire list, and detailed mechanical assembly drawing. Since each design will be reused over and over, the developers were able to document them with a higher level of detail than they otherwise could have afforded.

Using the standard library of harness designs, the Freedom Series Designer software now makes wire harnesses simpler to deal with.

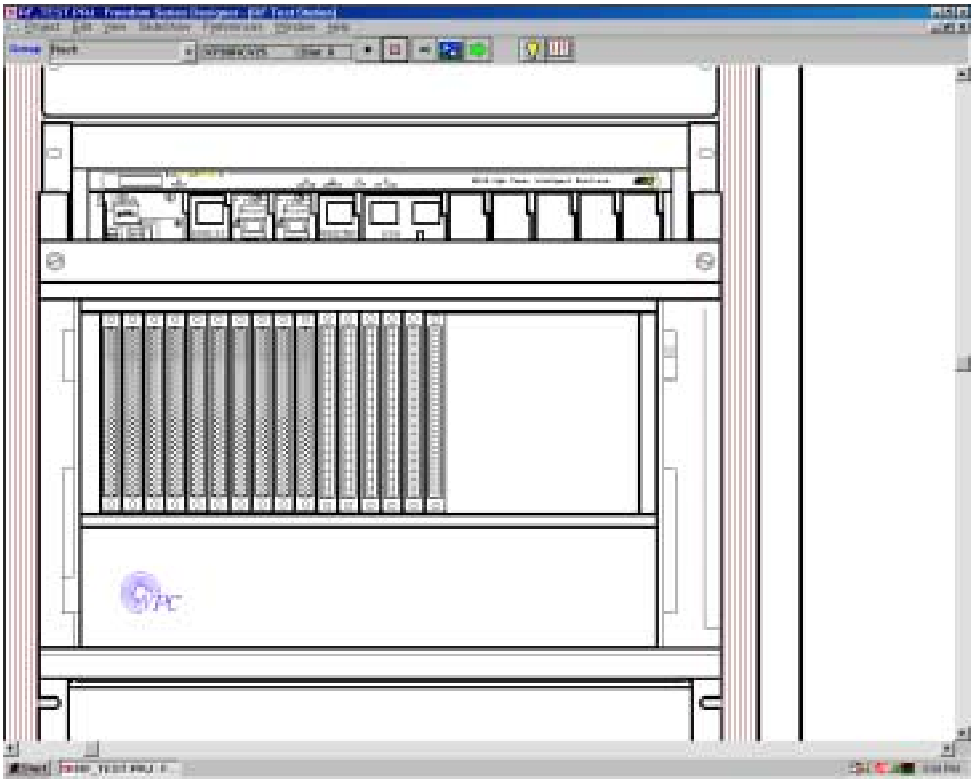
To automate the selection and placement of cable harnesses, the developers enhanced the Freedom Series Designer software to automatically place the VXIbus receiver blocks into the receiver. The user selects a Virginia Panel or TTI Testron receiver from a list, and uses the mouse to drag and drop it to its place in the system rack, in front of the VXIbus chassis (see Figure 2).

Figure 2: VXIbus Receiver in System Rack



Then, for each instrument in the system, the Freedom Series Designer selects the appropriate harness from the Cable Harness Library. Using the harness data from the library, the software determines the required types of connector blocks, and determines their appropriate locations in the VXIbus receiver. It displays this graphically (see Figure 3). If the receiver is not large enough to hold all of the blocks, the software displays a warning message stating that a larger receiver is required. Once the system has been specified, the user is therefore assured that the selected receiver is large enough, but not larger and more expensive than it needs to be.

Figure 3: Display of Connector Blocks in VXIbus Receiver



Automating Configuration Checking

When specifying a test system, the system configuration must be checked to ensure that the combination of equipment and options, and their physical arrangement, obeys the rules for a reliable, robust design.

There are four configuration checks:

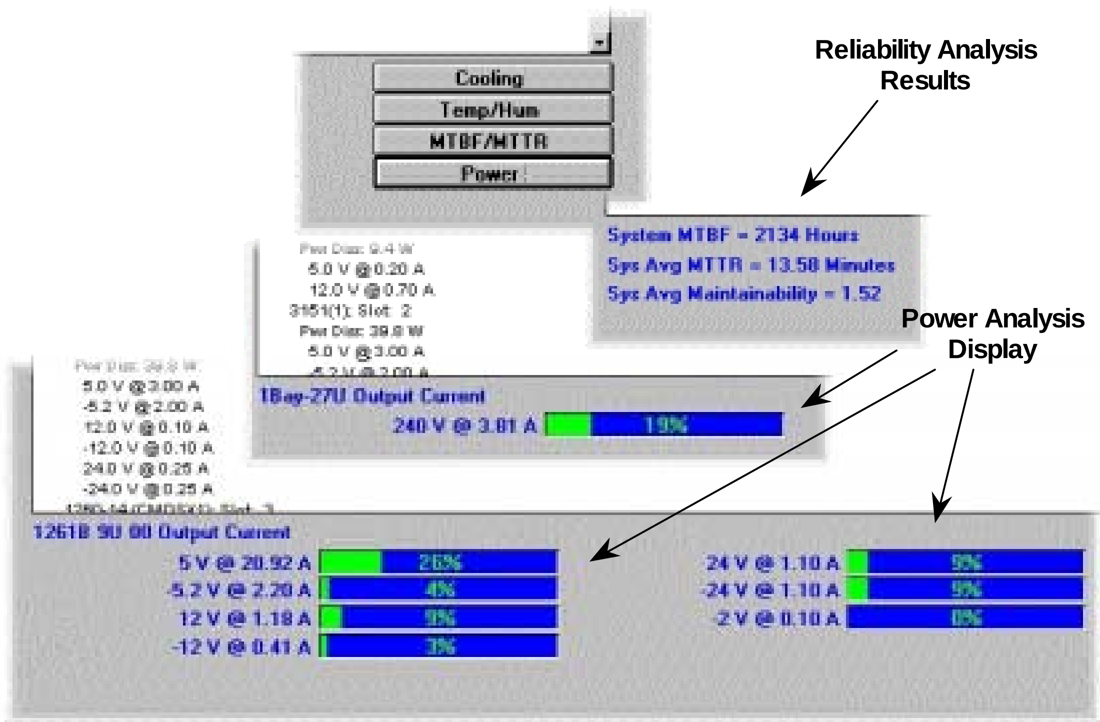
1. Power analysis
2. Cooling analysis
3. Reliability assessment
4. Physical configuration checking

To make these configuration checks easier, they were incorporated into the Freedom Series Designer software, as follows.

<u>Power Analysis</u>

When configuring an ATE system, it is crucial that each piece of equipment has an adequate supply of electrical power. The Freedom Series developers incorporated an automated power analysis into the Freedom Series Designer software. The power analysis checks the entire power path, beginning with the VXIbus modules. Each module has seven voltages available to it from the VXIbus chassis. The power analysis computes the total current that the chassis modules draw from each of the seven power supplies. It compares the results with the capacities of the chassis supplies. The result appears in a graphical display that shows the power drawn from each supply (see Power Analysis Display in Figure 4).

Figure 4: Analysis Displays



Next, the software calculates the current the chassis draws from its AC power input, taking its loading and power supply efficiency into account. The total AC current drawn by the chassis and all other items in the equipment rack is then calculated. The software uses this figure to automatically select a power distribution system with the appropriate capacity.

<u>Cooling Analysis</u>

A reliable test system must provide enough cooling air for each of its components. VXIbus systems have two areas of concern: the VXIbus chassis fans that provide cooling air for the VXIbus modules, and the blowers that force air through the rack.

The Standard Equipment Library contains data indicating the cooling demand for each VXIbus module, and the cooling capacity of each VXIbus chassis. A software algorithm analyzes the backpressure vs. airflow characteristics for the selected chassis, and the cooling demand of each VXIbus module it contains, to determine whether the modules receive adequate cooling air.

In addition, the software calculates the total power dissipated within the equipment rack, and verifies that the forced-air blower provides an ample volume of air.

The software can display and print the results of the above two verifications, and includes a warning message if the cooling is not adequate.

Reliability Assessment

The reliability assessment consists of calculating the system MTBF, MTTR, and system maintainability. To automate these calculations, the Freedom Series Designer database includes MTBF and MTTR data for each item in the Standard Equipment Library. The software applies industry-standard formulas that calculate the system MTBF, system average MTTR, and system average maintainability. It then reports each of these figures (see Reliability Analysis Results in Figure 4).

Physical Configuration Checking

The Freedom Series software checks the physical layout to verify that the system complies with certain physical constraints. For example, when using Racal Instruments 1260-Series switch modules, a smart card controller, known as Option-01, must be installed in the left-most switch module. The software checks for compliance with this and other rules, alerting the user if it finds a violation. This saves time by detecting errors early, before the system is built.

Incorporating the power and cooling analysis, reliability assessment, and physical configuration checks into the Freedom Series Designer software has two major benefits. First, it automates tasks that are tedious and prone to human error. Second, the test equipment customer can see the results of these analyses at the point of sale. This assures the customer, before committing to a purchase, that the system design is valid.

Automating the Production of System Documentation

System documentation lends itself particularly well to automation and modularization. A second software program, the Freedom Series Post-Processor, accepts the system specification from the Freedom Series Designer, and derives several design documents, as follows.

System Parts List

The system parts list shows every physical part required for building the system. To enable the software to produce this list automatically, the Standard Equipment Library includes complete data for each item, including such minute details as the required mounting hardware (bolts, washers, nuts, etc.). The software determines, from the database and list of selected equipment, a complete inventory of the hardware needed. The key advantage of this approach is that the data, although extensive, was researched and entered into the database only one time. Under the old methodology, this information was researched and used manually for every test system, rather than reused.

System Drawings

The system drawing shows the equipment rack as it will appear with the equipment installed. This was previously drawn manually. Since the equipment in the Standard Equipment Library is used over and over again in different systems, the drawing process is a prime candidate for modularization and reuse. The developers created a CAD drawing of each piece of equipment in the Standard Equipment Library. These drawings serve two purposes. First, they easily convert into Microsoft Windows metafiles, which are used in the graphics display of the Freedom Series Designer. Second, the system integrator can easily assemble the complete system drawing from these individual drawing modules.

VXIbus Receiver Pin Maps

The next step was automating the placement of connector blocks into the VXIbus receiver, and the mapping of instrument signals to individual connector block pins. The Freedom Series Designer includes an algorithm that accesses the Cable Harness Library and uses this data to calculate the positions of the VXIbus receiver blocks in the receiver. It then references the wire lists for each cable harness to determine the specific block and pin number where each instrument signal connects. It generates the pin map in a user-friendly format.

I/O Connection List

The I/O Connection List is a wire list for the entire system. It provides a comprehensive list of all signals, indicating the instrument connection at one end and the VXIbus receiver connection at the other. This is useful when maintaining or troubleshooting the system.

To automate the compilation of this list, the Freedom Series Developers created a separate wire list for each harness in the Cable Harness Library. The software retrieves the wire lists for the individual harnesses used in the system, and automatically compiles and formats the system wire list.

Guaranteeing Reproducible System-to-System Quality

The use of standardized cable harnesses does more than decrease NRE costs. Since the cables are standardized, each cable is built the same way for each system. Also, cable routing from the instruments to the VXIbus receiver is predetermined by the harness designs. This promotes consistent performance from system to system.

Accommodating Non-Standard Equipment

Some test systems require equipment that is not in the Freedom Series Standard Equipment Library. To support these situations, the Freedom Series process allows user-defined equipment modules. Using the Freedom Series Designer, the user inserts a user-defined module into the rack, then enters the required data manually.

Although a user-defined module does not benefit from design reuse, it does benefit from several of the automated processes. For example, if the user enters data for power consumption and cooling requirements, then the software will include the user-defined module in the power and cooling analyses. Also, the user may enter the types and quantities of VXIbus receiver blocks that the module requires. The software then includes the user-defined module when placing connector blocks into the receiver.

User-defined equipment requires NRE labor for tasks such as designing cable harnesses, generating drawings, and identifying mounting hardware. However, these labor costs apply only to equipment that is not in the Standard Equipment Library. The overall system NRE costs remain significantly lower than when using the conventional approach.

IV. Results

Freedom Series has had a substantial and lasting impact on the cost and delivery time of ATE.

Through modularity and design reuse, the Freedom Series process makes it easier to specify a system. Many systems can now be completely specified using the point-of-sale software. Sales representatives can now provide the customer with a complete power analysis, cooling analysis, reliability assessment, and physical configuration check at the point of sale. This helps find and correct problems before work on the system begins, avoiding costly rework. Meanwhile, the customer is assured from the beginning that the system being specified meets all configuration guidelines.

In addition, the modular approach to cable harnesses, documentation, and drawings has enabled the development of software tools that automate much of the integration process.

These advantages combine to reduce the NRE for an integrated test system to approximately eighteen hours, exclusive of equipment that is not in the Standard Equipment Library. This contrasts with the three- to six-week development time using conventional methods. The substantial cost savings are passed on to the customer, making the ATE system more competitive.

Reductions in cost and cycle time did not come at the expense of quality. As with many design reuse processes, the result is high quality that is consistent from system to system. {May we cite an example of a system we built in large quantities with very few problems?}

V. Conclusion

Freedom Series eliminates much of the NRE cost from system integration. Rather than simply streamlining a few of the tasks, Freedom Series was developed from the beginning to address the entire system integration process, from initial customer contact to system delivery.

Implementing Freedom Series has provided a welcome side benefit. Since the system integration process is now well-defined and documented, the company’s ISO-9000 audits are done more smoothly and efficiently, and it is easier to identify opportunities for continuous improvement.

Freedom Series is an example of how design reuse and modularity is beneficial not only in product development, but in other areas such as ATE development. As in other disciplines, the application of modularity and design reuse to ATE system design required a significant up-front investment, but will continue to pay dividends for some time to come.

About the Author - Tim Elmore supervises the Test Engineering Department at Racal Instruments, and is a project engineer working in ATE product development. He received his BSEE from California State Polytechnic University in Pomona, California, and has been involved in the conception, design, and development of ATE for over twenty years.