VXI Data Acquisition Solutions for Automotive Testing

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Abstract—VXIbus has been adopted as the primary instrumentation standard for developmental testing in the automotive industry. In order to meet and exceed the safety, reliability and customer comfort requirements placed on the industry, the sophistication, channel count and data throughput requirements for data acquisition and control systems have increased in the past few years. This paper describes the rationale for the use of VXIbus by this industry, discusses the evolution to VXI and details a number of applications of VXI-based systems for developmental testing.

I. BACKGROUND

In the past a typical electrical test setup included a variety of rack-mountable instruments such as digital voltmeters, signal sources, oscillators and counters. Input signals were manually selected and readings were taken by viewing displays on the front panels of the instruments. The General Purpose Interface Bus (GPIB) covered by IEEE-STD-488 was developed to computer-automate test programs [1]. GPIB-capable instruments can be connected to a host computer, and a software application program can set up the instruments as well as control and monitor those instruments to perform a test. A typical GPIB configuration is shown in Fig. 1.

In 1987 the major instrumentation manufacturers developed the VXIbus standard. VXI is an acronym for VMEbus eXtensions for Instrumentation, now IEEE-STD-1155 [2]. A typical single-chassis VXI system with embedded controller is shown in Fig. 2. The primary benefits of VXI are:

- It is an open standard with extensive multivendor support. There are over 1200 commercial VXI products available from a wide variety of manufacturers.
- Its modular approach allows the configuration of systems with off-the-shelf building blocks to meet specific needs.
- It provides for fully shielded modular instruments, rugged chassis, EMI (electromagnetic interference) protection and tight power supply noise specifications.
- It creates an excellent electrical environment, even for low-level, high-accuracy, analog conversion circuitry.
- It uses the 32-bit VMEbus for primary backplane communication.
- It supports geographic addressing, allowing the host software to interrogate the various modules and perform automatic system configuration.
- It includes a variety of features—such as a Local Bus for intermodule communication, a precision clock for timing and trigger lines for event handling—to facilitate high-performance systems.
- It is easy to configure, use and support because of the range of specifications that have been generated by the VXI*plug&play* Systems Alliance [3].

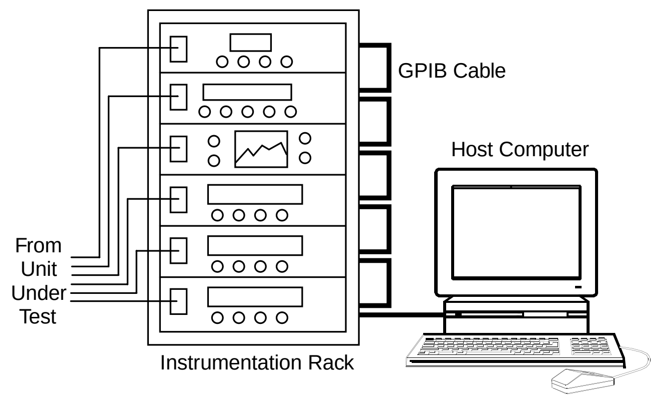

Fig. 1 Rack-and-stack instrumentation using GPIB

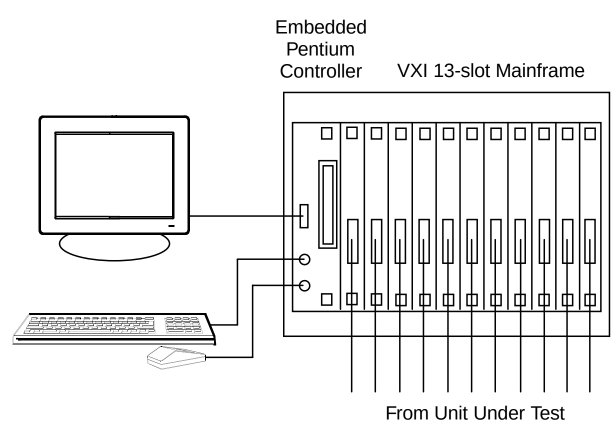

Fig. 2 A VXI system with embedded controller

II. THE EVOLUTION TO VXI—A CASE STUDY

The process for creating new development test stands in the automotive industry—as in most other industries—had been as follows:

- A requirement existed to perform a particular test.
- Specifications were created that defined the test requirements as they related to the DUT (device under test).
- The specifications were given to a particular integrator or were distributed for bids.
- The integrator often provided a proprietary instrumentation system, host computer and user application interface, based upon that particular integrator's preferences.

By using this approach a major automaker has 60 component-laboratory test stands in one test laboratory, with a wide variety of proprietary hardware, application software, user interfaces and operating methods. This approach causes a variety of problems. Some of these are:

- Extensive operator and technician training is required for the maintenance and application of these incompatible systems.
- With a downsized workforce, each worker can only be trained on some of the systems. When workers are on vacation, or when there is any turnover, it is extremely difficult to keep all of the test stands operating.
- Analysis of the data can consume more time than that required for a particular test. With the current system the presentation of the data varies widely between test stands, increasing analysis time and making data correlation between test stands very difficult.

A major upgrade for this component laboratory will result in the replacement of most test stands. The approach taken for these new test stands is shown in Fig. 3. This approach is outlined here:

- VXIbus has been chosen as the recognized standard for all test stand data acquisition and control. The robust nature of this standard is a primary factor in this choice.
- One VXI mainframe is allocated to two test cells. With a total of 13 slots and one used for the controller, the remaining 12 slots can be divided between the two cells.
- The VXI mainframes are networked by Ethernet to a number of host computers located in the test laboratory. Thirty VXI chassis will be required to meet current needs when the modernization is complete.
- A common runtime software environment is downloaded to each of the VXI embedded controllers.
- All test code is written using a common software application program and downloaded to the appropriate VXI controllers.
- To initiate or monitor each test the operator can log onto any of the networked computers. Common services are used for storing the test data and for printing test reports.
- The computers associated with the test stands are also interconnected to the network serving the overall facility, allowing data to be transmitted anywhere within the company or to noncompany facilities, if desired.

This standardized approach is expected to reap extensive benefits. The reduction in lifecycle cost and the increase in productivity will be substantial. The uniformity of the data and the ability to better correlate the data from a number of test stands, along with the networking capabilities, should lead to better test results. New test stands can be added much more easily than before.

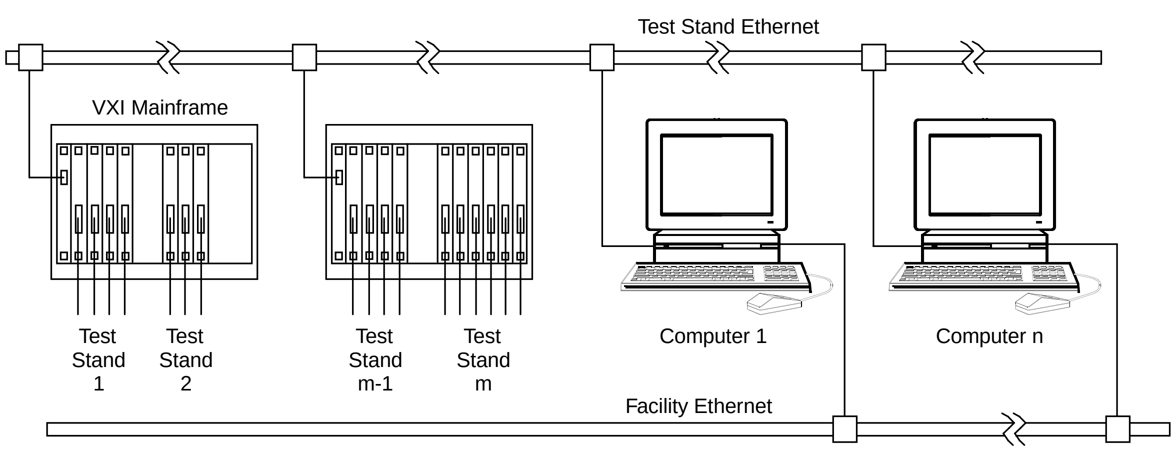

Fig. 3 A networked component test stand system with VXI for controlling and monitoring the tests

III. BODY ENGINEERING

This area in a major automotive company involves a wide range of tests, including the effects of slamming the doors, the response to shock by various parts of the car body, operation of electrically powered windows during lifecycle tests, and so forth. Previous test systems were individually constructed for each test to be performed, with no form of standardization between systems. This resulted in almost as many different test systems as there were types of tests. A senior test engineer in Body Engineering developed a VXI-based universal test data system on a roll-up cart. As there are needs for more test systems, additional "clones" are built. Based on the cart instrumentation, a seatbelt anchorage test system was developed. It is described here:

This test system applies a force profile the anchors that retain the seatbelts to the floor of a vehicle. The force is increased until the anchors give way. The anchors must hold firm in the event of a crash. The front panel of the this test system is shown in Fig. 4. The VXI mainframe is in the rear.

A block diagram of the system is shown in Fig. 5. The V387 is a discrete I/O module. It provides digital control for the test unit. The V285 is an arbitrary waveform generator. The force profile is stored in this module. Its output is used to drive the actuator control system. The V246 is an 8-channel strain gage module. Two of these modules are used in this application. They are used with strain gages to measure forces during the test. The V246 channels are multiplexed, and the analog voltages are digitized by a V207 500,000 sample/second ADC module. The VXI Local Bus is used for the communication path between the strain gage modules and the ADC. The application was created using LabVIEW®, a graphical programming environment. The test is fully automated, including calibration.

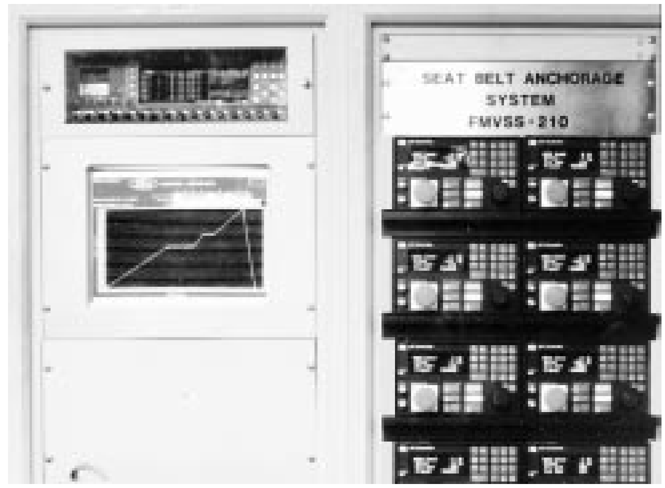

Fig. 4 Front panel of the anchorage test system

The primary reasons for choosing VXIbus for this and other Body Engineering test stands are:

- It is a widely accepted standard, and acceptance is expected to continue for a long period of time.
- It is a modular standard, with a wide array of instrumentation modules available for mixing and matching to meet a particular test requirement.
- It is a robust standard. Characteristics such as EMI (electromagnetic interference), power supply noise and cooling are well specified.
- VXI modules are available that allow computer control of end-to-end calibration. This is very important for repeatability and productivity.
- Software drivers are available for using these modules with the LabVIEW programming environment.

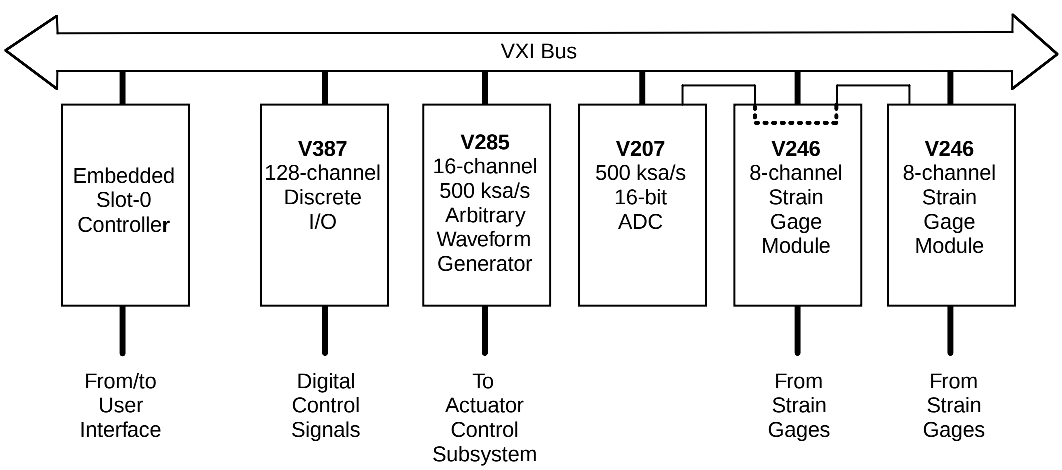

Fig. 5 A module-level block diagram of the anchorage test system

IV. SAFETY ENGINEERING

This area involves a wide spectrum of tests, all related to safety. Some of the test programs that use VXI are:

- *Full-vehicle crash tests.* For these tests, instrumented vehicles crash into a barrier. The condition of the vehicle and forces on crash dummies are examined during these tests. Special shock-hardened instrumentation is needed for onboard systems. VXI is used on many ground-based systems with a tether connected to the vehicle.
- *Crash sled tests.* These tests involve the use of a sled on a track that crashes into a barrier. These tests evaluate the effects relating to a portion of a vehicle—dummies crashing into a dashboard, for example.
- *Bumper barrier tests.* Federal law mandates that tests be performed to crash a vehicle bumper into a barrier at 5 miles per hour, and the resulting effects on the vehicle are determined. This test is performed by pulling a vehicle at 5 miles per hour into the barrier or with a stationary vehicle and a pendulum that is raised, then crashed into the bumper at 5 miles per hour.
- *The "crusher."* This device slowly crushes a vehicle. Forces are measured on many elements of the vehicle as the crushing continues.
- *Air bag reliability tests.* Tests are performed on the air bag subsystems. For example, tests monitor the performance of the release of the gas to inflate the air bag in the event of a crash.

The reasons for choosing the VXI standard for the safety engineering instrumentation are similar to those given for the powertrain component test cells and the body engineering test systems described earlier. For safety-related tests the integrity of the data and proper calibration are of utmost importance. Full-featured, accurate strain gage instrumentation is extremely important as strain gages are the most critical sensors for these tests. Instrumentation to meet these needs is available in VXI format.

V. COMPANY-WIDE STANDARDIZATION

One of the major automakers has chosen to standardize on VXIbus for their developmental testing in areas such as safety engineering, body engineering, powertrain, combustion analysis and advanced research. This company has determined that VXI should be used for such testing unless a good reason exists to use some other instrumentation format.

Company-wide standardization has many benefits. These include:

- *Software reuse*. Application software developed for tests in one area could be used as a basis for applications in another area.
- *Employee training and productivity.* As described earlier, the use of a common approach to test instrumentation in a given area greatly reduces the training load and increases productivity. In any large company, employees move from one area to another as needs change. If a similar type of equipment is used throughout the company, employees from another department will require less training and will become more productive at a sooner date.
- *Volume purchase agreements.* When the same products are being purchased by a number of departments, volume purchase agreements can reduce overall costs.

VI. CONCLUSIONS

The use of instrumentation based upon recognized standards increases productivity and decreases lifecycle costs. VXIbus has been shown to be an ideal standard for the instrumentation associated with developmental test systems used by the automotive industry.

VXI has received broad acceptance for a wide variety of tests within the automotive industry. These areas include safety engineering, body engineering, powertrain, combustion analysis and advanced research. VXI is a robust standard with parameters such as shielding, EMI protection and power supply noise tightly specified. The completeness of the specifications help assure hardware interoperability. The specifications created by the VXI*plug&play* Systems Alliance help assure software and user-level interoperability.

BIOGRAPHY

Bob Cleary co-founded KineticSystems Corporation in 1970 and is its Chief Executive Officer. He has developed many of the high performance CAMAC and VXIbus data acquisition and control products in the KineticSystems product line. He is a co-author of the book, "High Performance Data Acquisition and Control," has given many seminars on VXIbus and has presented numerous technical papers. Mr. Cleary has been granted 18 U.S. and 24 foreign patents.

REFERENCES

[1] IEEE-STD-488, "IEEE Standard Digital Interface for Programmable Instrumentation," Institute of Electrical and Electronic Engineers, 445 Hoes lane, Piscataway, NJ 08855.

[2] IEEE-STD-1155, "IEEE Standard for VMEbus Extensions for Instrumentation: VXIbus," Institute of Electrical and Electronic Engineers, 445 Hoes lane, Piscataway, NJ 08855.

[3] VXI*plug&play* Systems Alliance, http://www.vxipnp.org.