Position Paper

Embedded Instrumentation Ushers in a New Era for the Test and Measurement Industry

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Executive Summary

Non-intrusive validation, test and debug technologies have been around since the emergence of boundary scan (IEEE 1149.1 JTAG) in the mid-1990s. Over the years since then, the imperatives dictating probe-less methodologies have multiplied significantly, spawning a trend toward embedding instrumentation in chips, on circuit boards and in systems. Now, the test and measurement industry faces new imperatives even more demanding than those that brought about the first wave of non-intrusive technologies late last century. Today's design validation, test and debug applications are very different than they were not so very long ago. Exacerbated by extremely high data transfer speeds, multiple-core chips, new chip packaging techniques like system-in-a-package (SiP), very dense circuit board and other forces, the industry is turning to embedded instrumentation for solutions to a wide range of difficulties. Because of its almost two decades of leadership experience with boundary-scan technology and the JTAG interface, ASSET InterTech is well positioned to provide automation, access and analysis for embedded instrumentation technology. And the company's track record for successfully integrating its products with third-party technologies and vise versa demonstrates emphatically that the company's products – ScanWorks and MicroMaster – will certainly interface effectively with third-party embedded instruments. Ultimately, ASSET intends to continue its leadership in boundary scan (JTAG) structural test as well as expand aggressively into design validation, test and debug applications involving embedded instrumentation.

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Overview

Starting with the development of the original IEEE 1149.1 Boundary Scan Standard in the mid-1990s and continuing through the intervening years, we at ASSET have been the front runner on a number of groundbreaking trends. Once again, we are pioneering the emergence of embedded instrumentation for design validation, test and debug. Certainly this is a momentous occasion for our company, but it is not without precedent. Over the last several years, we have been aligning our company, products and resources to become the leading embedded instrumentation tools company in the industry and we are well on our way to achieving our goal.

I can't stress this point enough: ASSET is not leaving behind what we were, the leading boundary-scan test company. Our ScanWorks platform and the MicroMaster product line will continue as leaders in boundary-scan structural test and CPU-emulation functional test respectively. We are constantly improving these products. At the same time though, we are transforming our strategic direction to capitalize on the vast potential of embedded instrumentation.

Out of Necessity…

If necessity is the mother of invention, then embedded instrumentation has a long line of forebears. Just as the disappearance of physical access drove the invention, development and adoption of boundary scan and other forms of non-intrusive test like CPU emulation functional testing, so too several imperatives are driving the development and deployment of embedded instrumentation in silicon, on circuit boards and throughout systems. In a certain sense, boundary scan and CPU emulation actually gave impetus to this trend toward embedded instrumentation by proving the concept's validity and, to this day, they can be classified as embedded instruments.

In recent years, as the embedded instrumentation marketplace has taken on greater prominence, we have observed two clearly defined market segments. I call these two segments core instrumentation and SerDes (serializer/deserializer) instrumentation. Core instrumentation addresses the need to validate what the processing core is doing, while SerDes instrumentation validates the signaling moving across high-speed serial I/O (HSSIO) channels.

Why is instrumentation going underground, so to speak? For starters, embedded instrumentation can perform certain functions that external test and measurement technologies can not. And, just as importantly, embedded instrumentation is much more cost-effective, efficient, agile and simply better suited to some of today's emerging computer and communications technologies. Just as the emergence of virtual instruments expanded the total test and measurement marketplace in the mid-1980s, I expect that embedded instrumentation will provide another inflection point for new growth in our industry moving forward.

Out-of-the-Box Thinking

Since the earliest days of the electronics industry, designers and manufacturing engineers have relied upon standalone, external instruments like oscilloscopes and logic analyzers to validate designs, test manufactured assemblies and diagnose failures. Standalone instruments, which invariably relied upon physical probes to determine what was happening on chips, circuit boards and systems, performed their tasks with admirable distinction. But, as complexity and speeds have escalated geometrically, and the size of chips and systems has shrunk just as dramatically, the capabilities of external instruments have been increasingly challenged. As a result, providers of traditional and modular instrument are investing in software to give their instruments what they claim to be visibility into the actual data that is moving around the system. In contrast, we believe that the real challenge for test and measurement instrumentation is to see what the core silicon sees. To do this, embedded instruments are needed between the I/O and the core.

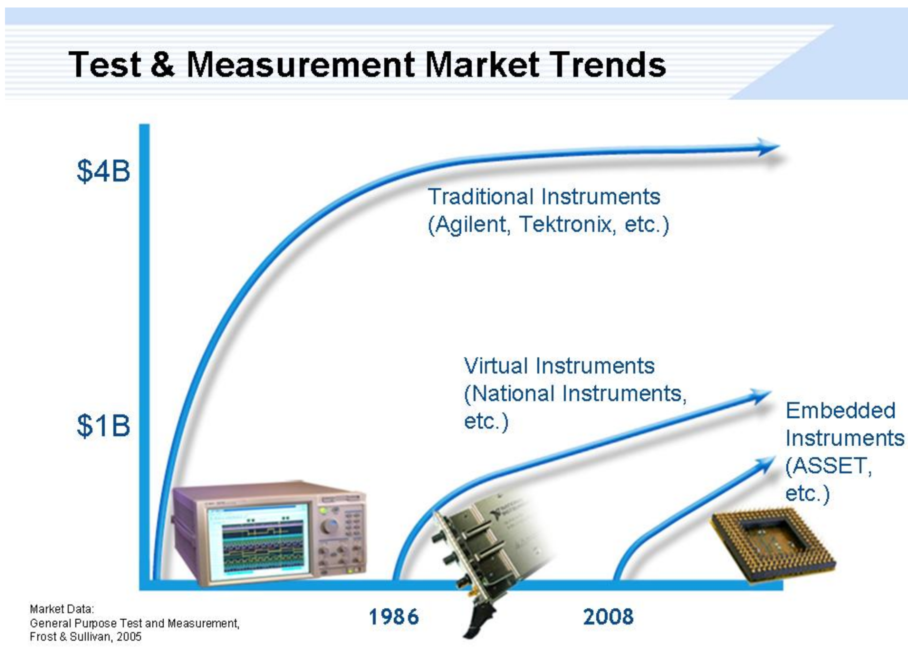

Figure 1 – Trends Toward Embedded Instrumentation

Why do we believe this? Consider these facts:

- Placing an oscilloscope's probe on a test pad on a high-speed serial bus like PCI Express 2.0 or 3.0, Fibre Channel, 10-Gbps Ethernet, InfiniBand or Intel®'s QuickPath Interconnect (QPI) architecture introduces capacitance anomalies on the bus. The validation or test engineer can't tell the difference between an instrument-induced anomaly and a fault in the design or on the manufactured assembly.
- Traditional standalone instruments are finding it difficult to keep up with the ever increasing data transfer speeds and frequencies of chip-to-chip interconnects and I/O buses. In addition, semiconductor vendors are designing in signaling

enhancements such as pre-conditioning, pre-emphasis and equalization to help move signals at higher frequencies. Unfortunately, these techniques ma0ke it more difficult for traditional instruments to take accurate measurements.

- Sub-100 nanometer chip fabrication processes have dramatic effects on device-level parametric performance characteristics and traditional characterization and testing techniques are ineffective at identifying the problems. External instruments at the corners of a chip can not see the rampant variations across the chip. Only on-chip instruments can effectively monitor parametric characteristics such as thermal conditions, timing issues, clock propagation delays, power distribution and others.
- Traditional and modular measurement techniques typically only measure signal integrity margins on one or a few high-speed serial lanes at a time. Embedded instruments such as Intel®'s IBIST (Interconnect Built In Self Test) can test and measure all lanes on all buses concurrently. This makes the test more robust and more complete, and it drastically reduces the amount of time required to validate the system.
- Embedded instrumentation can perform design validation, test and debug routines that existing strategies cannot. An example of this would be Intel's IBIST technology which can stress and thereby test high-speed I/O buses well beyond the capabilities of traditional OS-based testing.

The examples could go on and on, but the important point is that validation and test engineers are investigating and adopting embedded instrumentation because it offers them viable, efficient and agile solutions to their problems. They need the solutions that only embedded instrumentation can provide. And ASSET InterTech will provide the open tools that they need to automate, access and analyze embedded instrumentation.

The Industry Responds

A quick examination of our industry reveals swelling support for embedded instrumentation. It starts with chip vendors, who are following sound business practices by responding to both their own validation needs as well as the needs of their customers, the system suppliers.

The following are some examples throughout the industry of embedded instrumentation initiatives undertaken by companies and the special focus that each company has adopted.

- **Intel**: Focus on platform validation for its customers -- IBIST is Intel's next-generation embedded instrumentation technology which is being deployed throughout the company's high-end chips and chipsets. ASSET's ScanWorks platform was the first and is still the only third-party open tools platform that supports IBIST.

- **Synopsys**: Focus on chip test during design and, as a complement, support for automatic test equipment (ATE) systems during chip manufacture -- The DesignWare® Verification Library consists of embedded instrumentation intellectual property (IP). Some of the modules in the library integrate into Verilog, SystemVerilog, OpenVera and VHDL testbenches to generate and respond to bus traffic, check for protocol violations and generate coverage reports that can be incorporated into chip designs. Instruments like digital and analog converters, pattern matchers and generators, voltage and phase controllers, limit comparators and others are included to provide test coverage within chips, not just at the pins.

- **Rambus**: Focus on complementing ATE processes -- This memory company has integrated a programmable pseudorandom-pattern generating instrument and bit-stream comparators into I/O blocks on its memory chips. This was prompted by high-speed receivers that make it virtually impossible to see what is going on inside a memory block.

- **Xilinx**: Focus on customer board validation -- This company's ChipScope Pro real-time debug and verification tool inserts logic analyzer, bus analyzer, and virtual I/O instruments directly into an FPGA, allowing the engineer to view any internal signal or node, including embedded hard or soft processors.

- **Altera**: Focus on supporting PCB designers early in the design process -- Altera recently made its Pre-emphasis and Equalization Link Estimator (PELE) available to EDA companies such as Mentor so that designers could embed PELE and deploy it in signal integrity applications on Altera's Stratix® II GX FPGAs.

- **Vitesse Semiconductor**: Focus on signal integrity validation -- This networking/communications chip vendor has devised a two-channel approach to obtain an eye diagram or other instrumentation plots that validate the performance of high-speed receivers. The primary channel is set up as the center of the eye diagram while the secondary channel collects phase and amplitude data to populate the diagram and compute bit error rates.

- **Maxim**: Focus on embedded system-level monitoring -- A family of power managers from this chip company features monitoring instrumentation so that the devices can monitor, sequence, track and margin multiple system voltages, adjusting voltages according to pre-programmed limits and storing fault data for further analysis.

- **DAFCA**: Focus on chip design -- DAFCA is an EDA software company with tools that allow chip design teams to seamlessly incorporate compact and reconfigurable instrumentation from this company's IP library.

- **Logic Vision**: Focus on IC design and support for ATE systems -- This chip tools company's ET*Serdes* product is described as an embedded SerDes loop-back solution that structurally characterizes the parameters which determine signal eye distortion tolerances, verifying the parameters designers consider during a SerDes core design.

This list is by no means complete or comprehensive. Several others companies, including Tundra, Texas Instruments, LSI, Avago and others are also providing embedded instrumentation.

Life-Cycling

Certainly there is no denying the fact that the momentum behind embedded instrumentation has gotten a big push from necessity. That is, without embedded instrumentation certain critical measurement functions could not be performed. But, on the positive side, there are just as many benefits that are pulling chip and system suppliers toward embedded instrumentation. One of these is the life-cycle efficiency benefits that accrue to embedded instruments starting in chip design and extending all the way into field repair in deployed systems.

The figure below illustrates this point. The usefulness of an instrument embedded during IC design does not cease with verification of the chip's design. This is merely the beginning of the useful life of that instrument. Its benefits ripple throughout chip development, including IC test and characterization.

Then, as chips are rolled onto printed circuit boards and into systems, additional benefits stemming from the ability of embedded instruments to measure and monitor performance characteristics are achieved throughout the product life-cycle of the system. During design, embedded instruments can be used to validate high-speed serial IO buses. For example, conditions like crosstalk emanating from poorly routed traces might be present in a new design and only detectable with embedded instrumentation. Significant cost savings can be achieved and time-to-market reduced drastically if the design team can identify and correct these conditions earlier rather than later in the design process.

These sorts of benefits will extend right through to volume manufacturing where the OEM will be able to take advantage of on-board instrumentation to measure and monitor quality control processes. Moreover, final functional test or system burn-in tests can make use of embedded instrumentation to quickly diagnose and isolate faults and failures. Ultimately, field repair personnel will be able to plug into instrumentation already present in the system to troubleshoot and quickly return systems to their optimum operating levels.

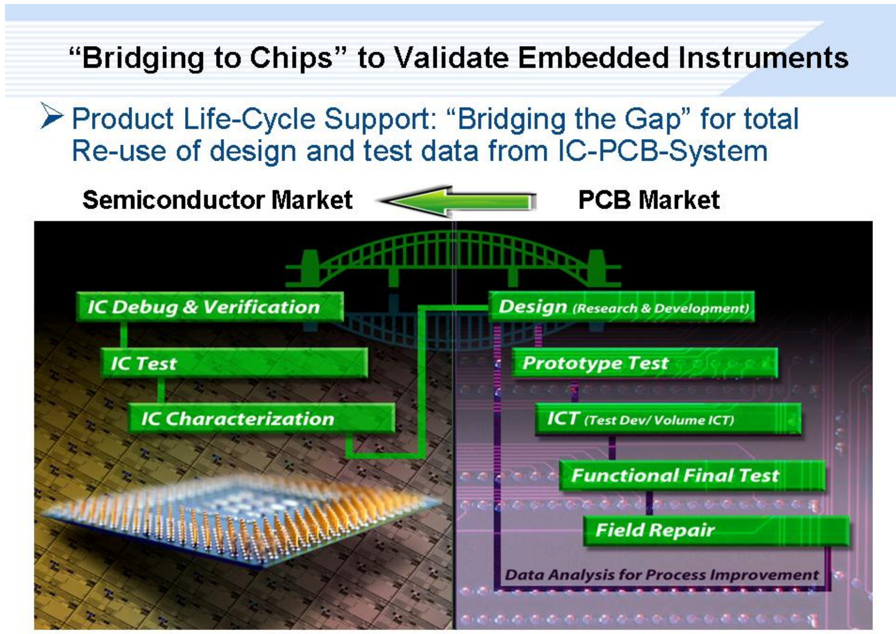

Figure 2: Life-Cycle Benefits of Embedded Instrumentation

Open tools for Embedded Instrumentation

The immediate effects that our new direction will have on our customers are minimal. We are still and will certainly continue to be the leader in boundary-scan technology. We have worked too hard and invested too much effort into our boundary scan structural test capabilities to relinquish our position in this market segment. Moreover, the goodwill that our support department and application engineers have built up in our user base will not be frittered away. In fact, we realize that the total satisfaction of our users is our ultimate goal and one that we will always work diligently to achieve.

Over the longer term, you will see a broadening of our product technologies as we add more tools for embedded instrumentation to the ScanWorks platform. Given the enhancements we've announced over the last few years, this should surprise no one. After all, we've pioneered tools for embedded test standards such as the IEEE 1149.6 standard for high-speed AC-coupled buses as well as embedded intellectual property (IP) like Intel's IBIST technology. We were the first boundary-scan company to support 1149.6 and IBIST. In fact, we are still the only tools vendor to support IBIST.

More recently, we announced an expansion of our IBIST-supported tools and our commitment to developing tools that support a new embedded instrumentation standard, the preliminary IEEE P1687 Internal JTAG (IJTAG) standard, which is defining an open methodology for accessing, managing and controlling instruments that have been embedded in core silicon. The development of the IJTAG standard has progressed to the point where we believe that our commitment as the leading tools vendor will hasten the standard's completion and its inevitable adoption by the industry.

From these past announcements you can surmise that we are evolving ScanWorks into an open platform for embedded instrumentation technology, including non-intrusive structural test, CPU-emulation functional test, in-system device programming, design and signal integrity validation based on embedded instrumentation and much more.

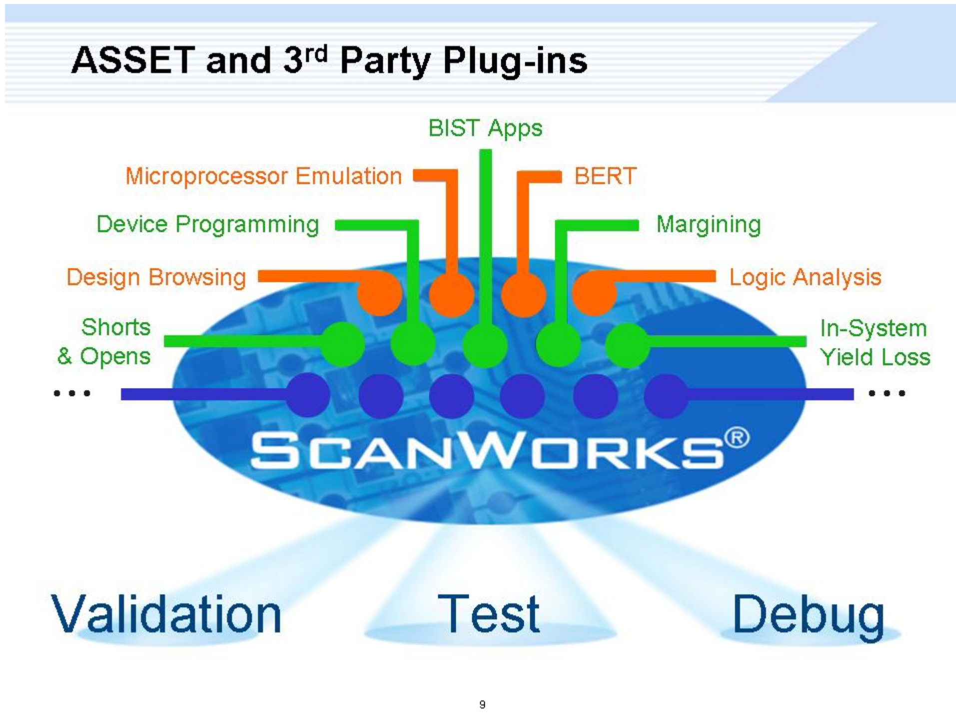

Figure 3: ScanWorks – The Embedded Instrumentation Platform

A New Look to Match Our Bright Outlook

We believe that the outlook for embedded instrumentation is bright. Indeed, we would not set our sights on being the leading open tools provider for embedded instrumentation if we believed otherwise. As a way to formally recognize the significance of this juncture in our history, we have developed a new corporate graphic identity. Below is our new logo with our tagline, "Driving Embedded Instrumentation." The new ASSET logo represents the company's efforts to drive embedded instrumentation on circuit boards, into advanced packages like SiPs and into chips. By doing so, ASSET "brings many diverse pieces together" for its customers. The years ahead will be exciting. As we traverse this new path, you'll hear much more from us as we show the industry how ASSET InterTech is driving open tools for embedded instrumentation.