EVALUATING SPACEWIRE SYSTEMS

Session: SpaceWire Test and Verification

Short Paper

Dr Barry M Cook, C Paul H Walker

4Links Limited

E-mail: barry@4Links.co.uk, paul@4Links.co.uk

ABSTRACT

The 4Links family of SpaceWire test equipment has been built over many years, and this paper will consolidate and update what has been presented at past ISC conferences and at SpaceWire Working Group meetings. The family consists of interfaces, monitors, and instrumented simulators, and a synchronization interface to absolute time. Versions are available with or without extensive instrumentation for measuring time and performance, and with or without synchronization across a complete SpaceWire test set. The equipment has been used for a wide variety of applications and some of these user scenarios will be described.

1 INTRODUCTION: THE 4LINKS FAMILY OF SPACEWIRE TEST EQUIPMENT

The 4Links family of SpaceWire test equipment started with the PCI-1355 board in 1997, which was used by ESA and several of the companies with early interest in the technology that evolved to SpaceWire. PCI-1355 was built with Inmos C101 chips, and the SpaceWire-PCI followed in 2000 using the ESA-sponsored SMCS chips. The SpaceWire-PCI board was widely used, by ESA, by NASA, and by many companies.

1.1 BENEFITS OF INTERFACING VIA ETHERNET AND TCP/IP

4Links introduced the first Ethernet/TCP/IP-based SpaceWire test product in 2004, and has built a comprehensive family that is regularly acclaimed by its users for its quality and usefulness.

Ethernet and TCP/IP are provided with every main-stream operating system and the user has no need to install, and keep updated, any other driver software. Users are able to work remotely, with the benefit of running the tests from the office instead of the clean room. Remote working can even extend to other countries and continents, and 4Links equipment has been used in this way to help users to diagnose problems.

The Ethernet/TCP/IP based test equipment family consists of interfaces, monitors, instrumented simulators, and a synchronization interface to absolute time. The products are accurate, reliable, use a uniquely mature synchronous SpaceWire Codec, and include failsafe measures to protect flight equipment from faults.

2 INTERFACES FROM A COMPUTER TO SPACEWIRE

A range of products offer a choice from a simple interface with one SpaceWire port to a full diagnostic interface with up to eight ports, and a new Wireless interface.

The **EtherSpaceLink** provides a single active SpaceWire port. This can be in a single port unit, or can be software selectable from up to eight physical SpaceWire ports.

The EtherSpaceLink proved its worth immediately. A test with one of the agencies, just before silicon tape-out, exposed a lost byte under certain conditions. Another early user needed the PC to run Real-Time Linux, and problems with a USB interface caused delays. The EtherSpaceLink ran immediately and progress was resumed.

The EtherSpaceLink has recently been upgraded to generate a Time Code from an external pulse or, as originally, from its internal clock.

The **Diagnostic SpaceWire Interface** is able to drive up to eight SpaceWire ports simultaneously and, as its name implies, includes comprehensive diagnostics.

One device tested by the Diagnostic SpaceWire interface was ESA's SMCS-SpW, unfortunately too late to prevent errors in the silicon. One of the errors seen could result in deadlock from a lack of flow-control credit, another was the delivery of a packet to the user despite there being a parity error in the packet and another was occasional failure to detect disconnection timeout as defined in the SpaceWire standard [1].

The Diagnostic SpaceWire interface is widely used for many purposes, including simulating, testing, debugging and validating both hardware and software of SpaceWire devices, boards, and subsystems.

The use of Ethernet and TCP/IP allow 4Links equipment to be in the clean room while the engineers testing the satellite are outside the clean room. For planetary landers or rovers, the need for cleanliness is particularly acute. Having a **SpaceWire WiFi Interface** built into the satellite could avoid the need for any other test equipment to be in the clean room. Under an ESA project with SEA, 4Links built a concept demonstrator for such an interface, housing the SpaceWire interface within a COTS Access Point. This will be re-engineered as a commercial product.

3 MONITORING, ANALYZING, TIME-TAGGING AND RECORDING SPACEWIRE

Active interfaces, and the software supplied with them, permit extensive analysis of equipment under test. But when equipments are connected together, there is also a need for passive monitoring. Monitors include an Analyzer that gathers statistics of the traffic, and a Recorder that records the traffic.

The **Multi-link SpaceWire Analyzer** accumulates statistics of the SpaceWire characters flowing in each direction of the SpaceWire links. It is an "honest broker" between flight units, or between a flight unit and test software under development. It has quickly enabled the solution of problems that had been delaying projects.

The **Multi-link SpaceWire Recorder** passively records traffic in each direction on each link. All the recordings are time tagged, and multiple recorders can be synchronized so that recordings on different computers and different discs all have consistent time tags. The recorder is used for debugging higher level system behaviour, and for archiving the results of extensive tests. Recordings can be of any size, limited only by the disc capacity.

4 INSTRUMENTED SIMULATORS

The **Flexible SpaceWire Router** can be used as a packet routing switch, but also as a static routing switch, a mux/demux (concentrator/deconcentrator), as multiple small switches or one large switch comprising several units. It is also instrumented to provide analysis of traffic through the switch.

The **SpaceWire RMAP Responder** simulates instruments and memories that respond to RMAP commands. The memory accessed by the RMAP commands on each port is managed by the user from a PC. Response is exceptionally low latency (single-digit micro-seconds). Other protocols such as CCSDS packets, interleaved between RMAP packets, are passed transparently to and from the PC.

The **Absolute Time Interface** synchronizes a test system to the IRIG time standard, and provides a source of low-jitter Time Codes. Synchronization to IRIG is accurate to within far less than one microsecond, and synchronization between 4Links test units is of the order of ten nanoseconds. With synchronization to IRIG, time tags include both the date (day of year) and an indication of the accuracy of the time.

5 CAPABILITIES AVAILABLE ACROSS THE PRODUCT FAMILY

Versions of the products are available with or without extensive instrumentation for measuring time and performance, and with or without synchronization across a complete SpaceWire test set. These capabilities include:

- Error Injection, for testing the correct response to such errors
- Error Reporting, included in most products, but not always needed
- Event/Error Waveforms, invaluable for hardware debug
- Packet Statistics, simple, accurate, information independent of user software
- Synchronized Outputs, necessary for testing arbiters in routing switches
- Time Tagging, necessary for any time-dependent activity
- Time Code generators, autonomous, accurate, low jitter
- Hardware synchronization between units, essential for real-time system analysis

6 USE SCENARIOS

4Links test equipment addresses a wide range of user scenarios including testing and validating new designs, measuring performance under varied operating conditions, simulating units controlled by an OBC, and archiving the results of a long series of tests. These scenarios exist both with individual test units for a single subsystem and with many synchronized units for a complete mission. Examples are testing a routing switch, testing real-time protocols, and re-use of equipment for different tests.

6.1 Testing a routing switch

Routing switch tests need to include synchronized packets with controllable offsets arriving at the routing switch, testing with several patterns such as all ports accessing the same port, each port accessing a different port, and random addressing, data, and packet lengths.

Such tests can be performed by a set of synchronized Diagnostic SpaceWire Interfaces, all driven by a single computer or each by a separate computer. Test unit synchronization enables the headers of all the packets to be aligned within a few nanoseconds, and time tags are matched so that records of the tests made on different computers can all be correlated with respect to time.

6.2 Real-Time protocols

Real-time protocols need an accurate source of Time Codes. Such Time Codes can be generated either by the Absolute Time Interface from IRIG, or by the EtherSpaceLink interface.

The actual times of the real-time protocol packets, and of real-time events generated by them, can be recorded by one or more Multi-link SpaceWire Recorders, synchronized to the Time Code source and to each other.

6.3 Re-use and Spares

During a project, the needs for test can change from needing active interfaces for test to using monitors for integration. The family of 4Links test equipment is based on a small set of hardware platforms which are customized to a particular product function by an exchangeable memory card. A hardware platform can be used with a variety of different memory cards. This can be useful, for example, to turn an interface used for testing early in a project into a monitoring recorder when the flight equipment is being integrated. It can also be useful to have a spare hardware platform — with memory cards for all the functions used in a test bench — as a standby unit, greatly reducing the cost of spares.

7 Conclusions

A wide range of SpaceWire interfaces, monitors, and instrumented simulators has been described. Users have found these interfaces highly effective in exposing previously undetected design anomalies, of quickly diagnosing and fixing such anomalies, and hence overcoming obstacles to progress. The range includes functions that can be used at all the stages of development through to integration. The hardware platform can often be re-used to minimize cost over the mission life-cycle. The quality and effectiveness of the equipment encourages feedback from users on potential improvements. Many of the capabilities described have resulted from such feedback, and the authors acknowledge and thank those who have provided it.

8 References

1. "ECSS-E-ST-50-12C 31 July 2008, SpaceWire - Links, nodes, routers and networks", published by the ECSS Secretariat, ESA-ESTEC, Requirements & Standards Division, Noordwijk, The Netherlands