

IMPLEMENTATION OF A VERY LOW COST PORTABLE SPACEWIRE MONITOR AND DEBUGGER

Session: SpaceWire test and verification

Short Paper

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ABSTRACT

The advent of a wide range of USB peripherals for personal computers has altered the test and measurement landscape. In particular, easily portable and inexpensive USB logic analyzers, such as the DigiView™ DV1-100, have enabled a host of industry-specific test applications. Such a logic analyzer used in conjunction with the Dynamic Engineering SpaceWire BreakOut (DESWBO, <http://www.dyneng.com/deswbo.html>) and an inexpensive notebook computer allows users to implement a portable and capable SpaceWire troubleshooting tool. Support software included with USB logic analyzers typically provides a myriad of display options, large data capture buffers, specialized trigger functions, and a variety of data export alternatives, including waveform images and ASCII files. A logic analyzer with a suitable sampling rate can be selected depending on the rate of the SpaceWire link of interest. Configuration templates for specific test scenarios are easily stored. The DESWBO fits between two nodes of a SpaceWire link using standard 9-pin MDM connectors. Data, strobe, and recovered clock signals are made available as pin outputs that may be monitored by the logic analyzer. Additionally, pins corresponding to SpaceWire events and conditions allow monitoring and triggering by the logic analyzer. These include the reception of nulls, flow control tokens, normal and error end-of-packets, and timecodes. Signals for monitoring credit, disconnect, escape, and parity errors are provided. Eight data bits and six credit count bits may also be monitored. All components of the system may be stored in a laptop computer bag and deployed at a moment's notice to debug a SpaceWire problem.

INTRODUCTION

One of the common objections raised to the use of SpaceWire is that it is not as widespread in its terrestrial use as other interfaces that have been proposed for space. In particular, MIL-STD 1553, RS-422, IEEE-1394 variants (including FireWire), Ethernet, I2C, and USB have been posed as more palatable alternatives.¹ Though there are many factors that go into interface selection, not the least of which include data transfer capacity, prior spaceflight heritage, power consumption, and development complexity, often price and availability of test equipment are cited as a salient variables to be weighed.

Historically, the costs of interface test equipment are generally dwarfed by other space program cost elements, such as flight hardware procurement and staffing. In some respects this is changing, as the prevalence of high school and university student satellite projects join ranks with small aerospace companies who may be developing only one component or a small experiment. These entities may be severely cost-constrained, and perhaps do not have the millions of dollars in resources often associated with spacecraft development. They frequently depend on uncompensated student labor and donated

launch opportunities, and have very limited if any development budgets. For some, even an additional burden of several thousand dollars may prove insurmountable.

Students will often tend towards tools and technologies with which they are familiar once they enter the workforce. They typically will have spent time developing expertise and experience in specific areas with specialized tools, and will have a penchant towards availing themselves of this knowledge where possible. Students in aerospace will be more likely to employ SpaceWire if they have had an earlier exposure to it, which can be promoted with very low cost debugging tools.

Approximate cost ranges of ground test equipment for various interfaces – prices \$USD				
Interface	Hardware Needed	Software Needed	2008~ cost	Suppliers
MIL-STD-1553 http://www.dyneng.com/ip_1553.html	Interface card	Incl. with hardware	\$500-\$2,000	Dynamic Engineering, SBC, Paravant, others
RS-422	USB or RS232 to 422 conv	Free d/l: Terminal Software	\$100-\$300	Black Box, B&B, others
I2C	USB-I2C converter	Incl. with hardware	\$250-\$750	MCC, total Phase, others
USB	Included with PC	Free d/l: USBET, USBTester	\$0	Usb.org, Jungo, others
IEEE-1394	(Included with many PCs)	Free d/l: libdc 1394, VHPD1394	\$0-\$1500	Sourceforge.net, Thesyscon
Ethernet	(Included with PC)	Free d/l: tcpdump, Wireshark	\$0	Tcpdump.org, wireshark.org
Spacewire http://www.dyneng.com/spacewire.html	Interface card or converter DESWBO and LA	Incl. with hardware Incl. with USB logic analyzer	\$3,500-\$12,000+ \$900+LA*	Dynamic Engineering, Star-Dundee, 4Links, others Dynamic Engineering

*Appropriate USB logic analyzers (LA) range from \$149-\$1500+

-Cost of time to become familiar with hardware and software tools, which is considerable in some cases, is not included.

-The level of capability provided by the options in the table is highly variable.

Figure 1. Cost comparison of interface test equipment

USB LOGIC ANALYZERS (LA)

Logic analyzers have gone from being cumbersome, complex, expensive pieces of equipment that cost tens of thousands of dollars to small, easy-to-use devices available at near commodity pricing. This has been enabled in large part by two advances: the ubiquity of the personal computer and the comparatively recent rise of the USB interface. By 2008, several billion USB interface devices had entered the market², and USB had become the dominant interface in the personal computer realm. At the time of this writing, over a dozen different types of USB logic analyzers were available for less than \$1,000 US, offering amenities such as integrated oscilloscopes, pattern generators, as many as 34 channels per device, and up to oscillator frequencies of 1 GHz.³

For the system described in this paper, a DigiView™ DV1-100 USB logic analyzer was selected, largely because it was on hand, rather than for any specific performance criteria. The logic analyzer features 18 Channels @100 MHz and uses the USB interface for both power and data. Built-in hardware compression reduces resolution vs. collection depth tradeoffs with a compression ratio of up to 256,000:1 depending on signal activity. It can be configured to trigger on rising edges, falling edges, or transition of any channel. Software configuration through a graphical user interface allows for sophisticated pattern triggers employing multiple channels and “don’t care” qualifiers. A wealth of display and export software features allow for storage and analysis of acquired data.⁴ The DV1-100 is available for about \$400 US, and has countless applications beyond use with the DESWBO for SpaceWire debugging.

THE DYNAMIC ENGINEERING SPACEWIRE BREAKOUT (DESWBO)⁵

The DESWBO monitors the signals of a single SpaceWire link and is packaged as a printed circuit board mounted on a compact enclosure with many mounting rail options. The board has two 9-pin MDM connectors to facilitate in-line monitoring of both sides of a SpaceWire link. The DESWBO is designed to detect and decode bit sequences on the SpaceWire link. Signals are issued indicating what types of characters are passing between nodes as well as the contents of data and timecode characters. A running count of flow control credits for each node is calculated by the DESWBO by monitoring FCTs and N-character occurrences.

The low voltage differential signalling (LVDS) signals from each node are buffered to the opposite node and monitored by a field programmable gate array (FPGA). The FPGA contains the equivalent of two SpaceWire receiver modules that decode the SpaceWire signals, and extract the various data and control characters as shown in Figure 2. The DESWBO has been tested with a hardware that has the ability to insert errors under software control. Normal and error conditions are tested on each unit as part of the acceptance test procedure.

The end-of-packet, got-data and got-FCT signals from each node are connected to pulse capture and duration extension circuits to drive three green LEDs. The error-end-of-packet, parity error, escape error, credit error and disconnect error signals for each node drive five red LEDs. These sixteen LEDs give a quick status of link activity and health.

In addition, there are 24 test points for each node that are driven by the real-time signals from the SpaceWire character receivers, two test points for each node that are connected to the DIN and SIN signals from the LVDS receivers, and one test point for each node that is driven by the recovered clock from the SpaceWire bit receivers. The 24 test point signals consist of eight data bits, six credit count bits, Parallel data strobe, NULL received, FCT received, Timecode received, End-of-Packet, Error End-of-Packet, Credit error, Disconnect error, Escape error and Parity error. There are also three ground test points per node to facilitate probe grounding.

The DESWBO is powered by an included external 5-volt supply with on-board regulators for the various operating voltages required.

USE OF THE SYSTEM

The logic analyzer software configuration allows the user to tailor the interface and signal layout to the task at hand. Specific configurations for SpaceWire troubleshooting can be created and saved for

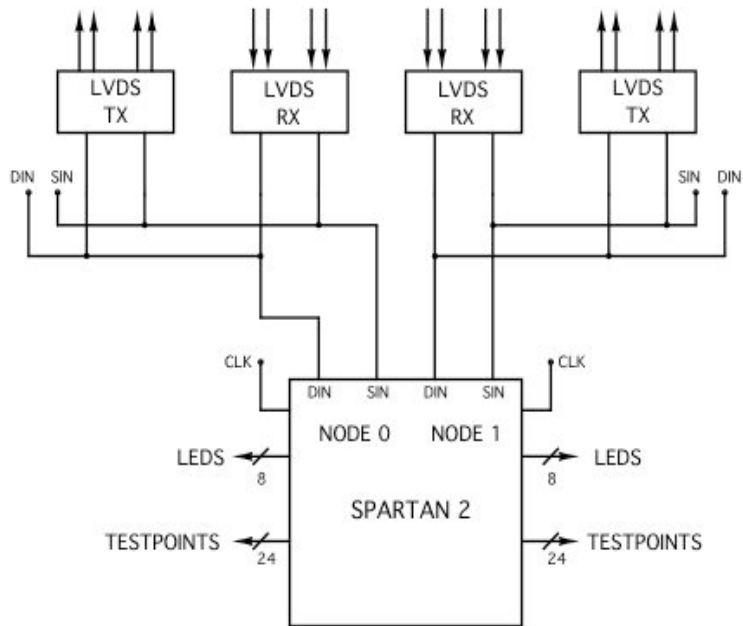


Figure 1. DESWBO Block Diagram

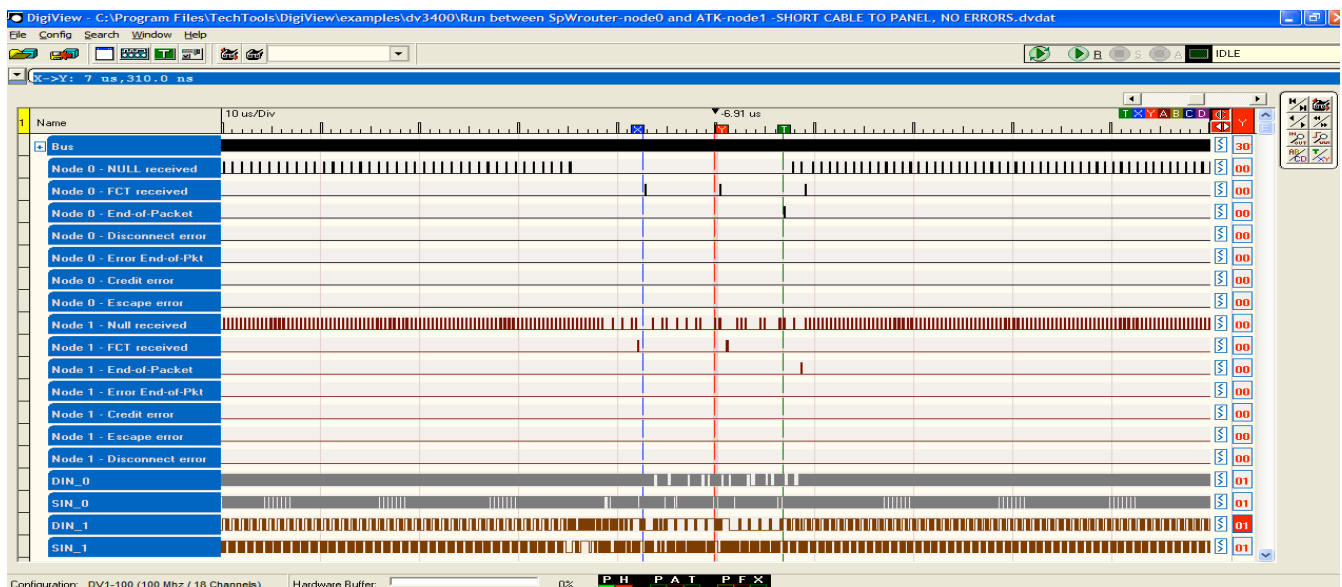


Figure 1. Large time scale capture

ongoing use. An array of cursors and zoom levels allows for fast discernment of what is happening on a given SpaceWire link. At larger timescales, flag signals like NULL-received and FCT received give a good overall picture of link activity as in Figure 3. For inspecting activity on the actual data and strobe signals, smaller timescales can be used as in Figure 4.

This combination was used successfully to debug and gain insight into SpaceWire links on TacSat-4, PnPSat, Herschel II, and other satellite programs. Its portability proved a boon and provoked positive feedback from many colleagues.

The computer, DESWBO, logic analyzer, and necessary cables easily fit in a laptop computer bag. This allows quick deployment of a useful test capability on the other side of the laboratory or the other side of the world.

CONCLUSION

There is a clear need for very inexpensive SpaceWire test and debugging equipment. Though not as fully featured as other alternatives, the combination of a notebook computer, USB logic analyzer, and Dynamic Engineering's DESWBO provides an easily portable and highly effective troubleshooting capability.

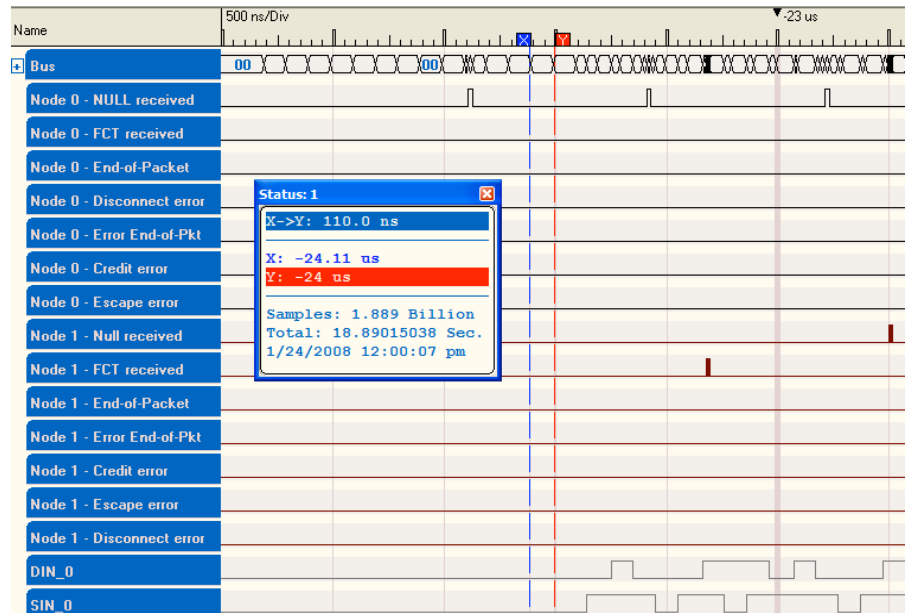


Figure 4. Small time scale capture

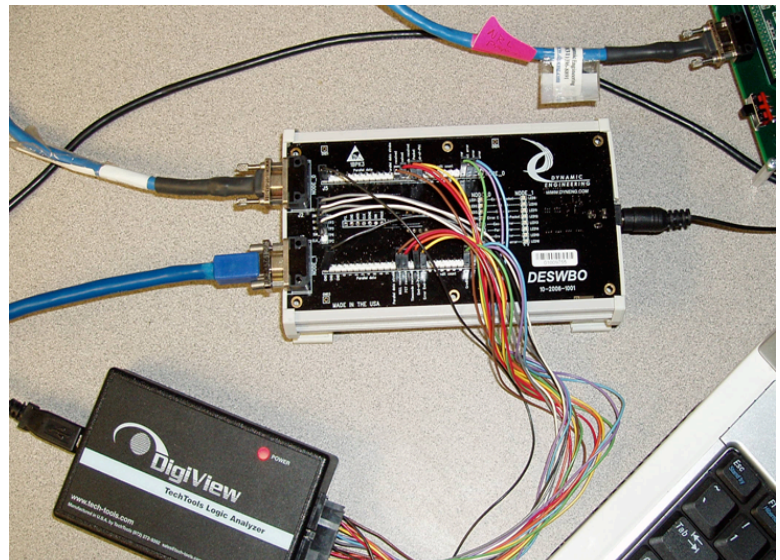


Figure 5. Logic analyzer and DESWBO

¹ Jaffe, P., Clifford, G., Summers, J., "SpaceWire for Operationally Responsive Space as part of TacSat-4", International SpaceWire Conference, Dundee, Scotland, September, 2007.

² http://www.jungo.com/st/usb_market.html, retrieved 2008-09-27

³ <http://www.techtravels.org/tech/logicanalyzer.html>, retrieved 2008-09-27

⁴ "DigiView User's Guide", TechTools 2007.

⁵ <http://www.dyneng.com/deswbo.html>, retrieved 2008-09-27