DESIGNING SPACEWIRE NETWORKS WITH THE LATEST GENERATION OF TEST AND DEVELOPMENT EQUIPMENT

David Gibson(1), Chris McClements(1), Pete Scott(1), Stephen Mudie(1), David Paterson(1), Alan Spark(1), Stuart Mills(1) and Steve Parkes(2)

(1)STAR-Dundee Ltd, STAR House, 166 Nethergate, Dundee, DD1 4EE, Scotland, UK.

Email: david.gibson@star-dundee.com

(2)University of Dundee, Space Technology Centre, Dundee, DD1 4HN, Scotland, UK.

ABSTRACT

During the design and testing of SpaceWire systems, issues can arise that require the use of specialised SpaceWire test and development equipment. Interface devices, link analysers and data recorders can be used to design and prototype systems, investigate emerging issues and identify the underlying causes.

This paper focuses on several key benefits that can be provided by using the latest SpaceWire test and development equipment. Firstly, remote access to SpaceWire systems can be provided using a Gigabit Ethernet (GbE) connected SpaceWire interface device. Secondly, detailed link analysis can be performed using a USB 3.0 connected SpaceWire link analyser. Thirdly, large amounts of recorded SpaceWire traffic can be visualised and navigated using new software tools. Finally, deterministic behaviour within non-real-time environments can be provided using a hybrid software and hardware triggering system.

1 REMOTE SPACEWIRE ACCESS

In order to remotely access a SpaceWire [1] system located within a test chamber, a PC and, for example, a USB 3.0 connected SpaceWire interface device may be placed within the test chamber. An engineer may then remotely connect to the PC to configure and control the interface device.

Alternatively, if the test chamber has an interface to an Ethernet network, a GbE connected SpaceWire interface device may be used, removing the requirement for an additional on-site PC. An engineer may then control the interface device over the Ethernet network directly.

The STAR-Dundee SpaceWire GbE Brick Mk1 [2] provides a GbE interface, two SpaceWire interfaces, and two external trigger interfaces. A photo of the SpaceWire GbE Brick Mk1 is provided in Figure 1-1.

Figure 1-1: SpaceWire GbE Brick Mk1

The SpaceWire GbE Brick Mk1 is functionally equivalent to the SpaceWire-USB Brick Mk3 [3]. The two SpaceWire ports can operate at up to 400 Mbit/s and the device can operate as both an interface or a router. In addition, the GbE Brick is supported by the STAR-System software suite, which is the common software suite used to configure and control all of the latest STAR-Dundee devices. This allows an engineer to write software for one device type and port it to another with minimal changes.

2 LINK ANALYSIS

During the design and testing of a SpaceWire system, a link analyser capable of transparently capturing traffic across a link can aid in the investigation of issues and the validation of the system.

In addition to the link analyser hardware, an efficient and easily usable software tool is required to visualise, navigate and search the captured traffic.

The STAR-Dundee SpaceWire Link Analyser Mk3 provides the capability to transparently capture up to

512 MB of traffic on a link which is then uploaded to a host PC rapidly over a USB 3.0 interface. A photo of the SpaceWire Link Analyser Mk3 is provided in Figure 2-1.

Figure 2-1: SpaceWire Link Analyser Mk3

The SpaceWire Link Analyser Mk3 is the successor to the Mk2 and provides several improvements. The USB 3.0 interface allows for much quicker capture uploading to the host PC. An entirely new software tool provides the capability to display over 60 million samples simultaneously at various levels of detail. The character view displays each individual captured SpaceWire character. The packet view builds packets out of the character stream and displays them. A new network view provides a visualisation of the entire traffic capture and allows for rapid navigation and synchronisation with the other views. Finally, a separate bit-stream level capture is displayed within the bit-stream view.

In addition to the traffic viewing improvements, the search functionality has been improved to provide a Remote Memory Access Protocol (RMAP) [4] search function.

3 TRAFFIC VISUALISATION

As well as the SpaceWire Link Analyser Mk3, STAR-Dundee also provides a SpaceWire Recorder [5] for recording large amounts of traffic on up to four links at a time. When the amount of data reaches this scale, new software tools are required in order to display it efficiently and in a meaningful way. STAR-Dundee has designed and developed a scalable traffic visualisation software tool for this purpose. The same traffic views are used by both the SpaceWire Link Analyser Mk3 and the SpaceWire Recorder, providing a familiar interface between the two devices.

When viewing recorded traffic, a visualisation of the entire recording is displayed in a network view, as shown in Figure 3-1.

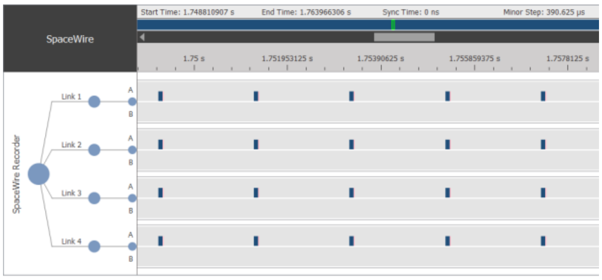
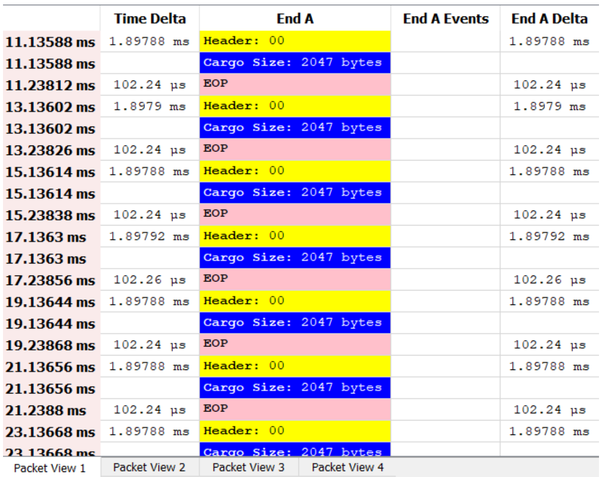


Figure 3-1: Network View

In Figure 3-1, the top section of the view contains the timeline and timing information. In the main section, each link's traffic is displayed in a row, with End A and B displayed in the top and bottom halves of the row, respectively.

The entire traffic recording can be navigated rapidly by zooming in and out and panning left and right. As the view is zoomed out, the traffic is merged together to maintain the responsiveness and efficiency of the software. When the view is zoomed in far enough, the detailed traffic for the viewable region is loaded dynamically from disk.

When the network view is clicked, a window of detailed traffic is loaded into the packet views, as shown in Figure 3-2.



	Time Delta	End A	End A Events	End A Delta
11.13588 ms	1.89788 ms	Header: 00		1.89788 ms
11.13588 ms		Cargo Size: 2047 bytes		
11.23812 ms	102.24 µs	EOP		102.24 µs
13.13602 ms	1.8979 ms	Header: 00		1.8979 ms
13.13602 ms		Cargo Size: 2047 bytes		
13.23826 ms	102.24 µs	EOP		102.24 µs
15.13614 ms	1.89788 ms	Header: 00		1.89788 ms
15.13614 ms		Cargo Size: 2047 bytes		
15.23838 ms	102.24 µs	EOP		102.24 µs
17.1363 ms	1.89792 ms	Header: 00		1.89792 ms
17.1363 ms		Cargo Size: 2047 bytes		
17.23856 ms	102.26 µs	EOP		102.26 µs
19.13644 ms	1.89788 ms	Header: 00		1.89788 ms
19.13644 ms		Cargo Size: 2047 bytes		
19.23868 ms	102.24 µs	EOP		102.24 µs
21.13656 ms	1.89788 ms	Header: 00		1.89788 ms
21.13656 ms		Cargo Size: 2047 bytes		
21.2388 ms	102.24 µs	EOP		102.24 µs
23.13668 ms	1.89788 ms	Header: 00		1.89788 ms
23.13668 ms		Cargo Size: 2047 bytes		

Packet View 1 | Packet View 2 | Packet View 3 | Packet View 4

Figure 3-2: Packet Views

In Figure 3-2, the view shows the dynamically loaded traffic for End A of Link 1. The packet views provide the same functionality as the Link Analyser Mk3, and allow packets to be expanded, collapsed, displayed in different formats and decoded into RMAP packets.

4 DETERMINISTIC BEHAVIOUR

When designing and prototyping a SpaceWire system using a general-purpose operating system, it can be challenging to achieve deterministic behaviour due to the inherently non-real-time environment. The most recent STAR-Dundee interface and router devices, such as the Brick Mk3, GbE Brick Mk1, and PXI cards [6], can provide a level of determinism in non-real-time environments using a hybrid software and hardware triggering system.

4.1 Events, Triggers and Actions

The STAR-System Triggering API operates using three main mechanisms: events, triggers and actions. An event, such as a time-code being received or an external trigger pulse, causes a trigger to be set. The trigger can then cause an action, such as a packet transmission or an error injection.

Using these three mechanisms, complex triggering scenarios can be developed rapidly. Once configured in the software, the triggering is coordinated by the hardware, removing the non-deterministic software overheads and latencies. This allows real-time systems to be prototyped whilst still using a general-purpose operating system.

4.2 Triggering Use Cases

A common use case of triggering is to coordinate the transmission of packets based on one or more input events. This use case can be performed by, for example, enabling packet queuing on a port and using a simple input event, trigger and transmission action chain. A subset of the available input events includes time-codes being received, external trigger pulses, or the firing of periodic timers.

For more complex packet transmission, such as groups of packets separated by time intervals, the triggering system provides multiple internal counters and timers that can be used in collaboration with other input events.

Triggering the transmission of pre-queued packets in this manner removes the software overhead and minimises the latency between an event occurring and a packet being transmitted.

Another use case is the injection of errors such as disconnects, parity errors, or the disabling of flow-control. This use case can be performed in a similar manner, with one or more input events that set triggers and cause error injection actions. For example, an external signal generator can be used to send a pulse to one of a device's external trigger inputs. The input event can then set a trigger that causes an error to be injected, or flow-control to be disabled for the duration of the pulse.

5 CONCLUSIONS

This paper has described how the latest generation of SpaceWire test and development equipment can be used to provide key benefits during the design and testing of SpaceWire systems.

Firstly, the SpaceWire GbE Brick Mk1 was described including how it can be used to remotely access a SpaceWire system. Secondly, the SpaceWire Link Analyser Mk3 was described, showing how detailed link analysis can be performed. Thirdly, a new traffic visualisation software tool was introduced which allows large amounts of recorded SpaceWire traffic to be displayed efficiently and meaningfully. Finally, the STAR-System Triggering API was presented, showing how it can be used to provide a level of determinism in non-real-time environments such as general-purpose operating systems.

6 REFERENCES

[1] ECSS Standard ECSS-E-ST-50-12C, "SpaceWire, Links, Nodes, Routers and Networks", Issue 1, European Cooperation for Space Data Standardization, July 2008, available from http://www.ecss.nl.

[2] S. Mills, C. McClements, D. Paterson, P. Scott, S. Parkes, "Testing over Ethernet with the SpaceWire GbE Brick", International SpaceWire Conference, Los Angeles, USA, May 2018.

[3] S. Mills, P. Scott, S. Parkes, "High Speed Test and Development with the SpaceWire Brick Mk3", International SpaceWire Conference, Athens, Greece, September 2014.

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