IMPROVEMENTS IN SPACEWIRE TEST

Session: Test & Verification

Short Paper

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ABSTRACT

During system test and integration, recordings are made of the interactions between the various subsystems. Both the bandwidth per link and the number of links in a typical SpaceWire system present challenges for such recording. Furthermore, the recordings need to be both time tagged and dated. The time tag is used for analysis of functionality and latencies, and the date for archival purposes so that there is no confusion between different recordings. With the move towards SpaceWire-RT, there is an increased need both for precise SpaceWire Time Codes and for measuring the response of the system to those Time Codes.

The new Multi-link SpaceWire Recorder and Absolute Time Interface meet these challenges and work together to provide recordings of many links stored on different discs on different computers (and even in different countries) and yet all coordinated and dated to remarkable precision. In addition, zero-jitter time codes can be generated.

1 RECORDING TRAFFIC ON SPACEWIRE LINKS

MIL 1553 and CAN are both buses and both operate at 1Mbit/s; recording data at this rate is not a great challenge. SpaceWire [1] link speeds are one or two orders of magnitude faster and, without the constraint of a single bus, system speeds can be more than an order of magnitude greater still. Recording SpaceWire traffic is thus vastly more of a challenge. The new Multi-link SpaceWire Recorder [3] meets this challenge.

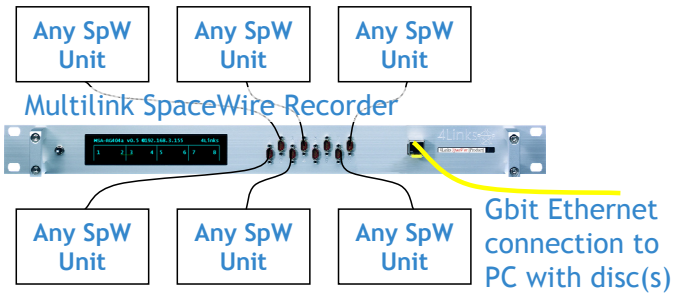

Figure 1: Multi-Link SpaceWire Recorder

The Multi-Link SpaceWire Recorder (MSR) enables passive recording of SpaceWire transfers, on up to four links per MSR unit. It monitors packets in both directions on each link, sending the data to a computer for recording and analysis. Software is provided to help manage and search the recordings. The MSR brings to SpaceWire the comprehensive records that are available from earlier and much slower on-board technologies such as MIL1553.

As well as recording the data flowing over a SpaceWire link, the MSR can optionally be set to trigger a waveform capture of the wire signals on a variety of events, including low-level SpaceWire errors.

When recording both directions of several SpaceWire links, it is useful (or essential) to be able to relate the timing of each packet in each direction on each link to the other packets.

1.1 Time Tagged Recordings

The timing relation between packets is provided by Time Tags on the start and end of each packet. A short example recording is shown in Figure 2. [For the technically minded, notice the level of detail provided by the time tags here. The interval between packets is 840ns, which is 600ns for the three Bytes of each packet at 50Mbits/s plus 80ns for the End of Packet plus a further 160ns for a Null token between packets.]

```
10.079 194 952 0s  1<--2  Data @0000  05 55 30
                   1<--2  EOP at 10.079 195 552 0s (SOP + 0.600us)
10.079 195 792 0s  1<--2  Data @0000  05 55 30
                   1<--2  EOP at 10.079 196 392 0s (SOP + 0.600us)
```

Figure 2: Time tagged record of two short packets

Even on such short packets in one direction of a single link, this time-tagged recording can be extremely useful. Figure 3 shows a slightly later set of packets from the recording of Figure 2. Packets were sent in pairs separated by 100ms, to allow an action to complete before trying to start the next action. The first two packets in Figure 3 are a valid pair, but the third packet immediately follows them rather than waiting for the 100ms, and then the fourth packet is actually 200ms later (the millisecond times of these incorrect arrival times are shown in red in the Figure). The incorrect arrival times resulted in some of the packets being ignored, and explained a system integration failure. Knowing the cause of the failure made it easy to design a workaround to the problem.

```
10.479 772 121 4s  1<--2  Data @0000  05 55 32
                   1<--2  EOP at 10.479 772 721 4s (SOP + 0.600us)
10.479 772 961 4s  1<--2  Data @0000  05 55 37
                   1<--2  EOP at 10.479 773 561 4s (SOP + 0.600us)
10.479 773 800 0s  1<--2  Data @0000  05 55 70
                   1<--2  EOP at 10.479 774 401 4s (SOP + 0.601us)
10.680 351 792 0s  1<--2  Data @0000  05 55 73
                   1<--2  EOP at 10.680 352 392 0s (SOP + 0.600us)
```

Figure 3: Time tagged records showing incorrect intervals between packets

1.2 Absolute Time, Datation, and SpaceWire-RT

Recordings such as are described here are often made during system integration, both to provide information in the event of a failure and to record the actual behaviour when the system is behaving correctly. So it is useful to tag the recordings not only with relative time but with an absolute date and time.

Furthermore, with the move towards SpaceWire Real-Time, there comes a need for test equipment both to generate a variety of Time Codes and to measure their arrival times (as well as packet arrival times) precisely.

2 ABSOLUTE TIME INTERFACE (ATI)

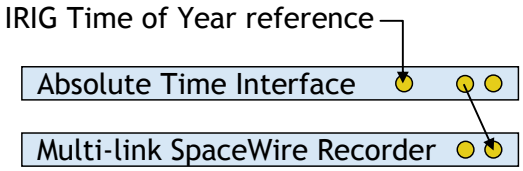

Figure 4: Absolute Time Interface and Multi-Link SpaceWire Recorder

The 4Links Absolute Time Interface (ATI) [4] enables one or more 4Links test units in a test system to be synchronized to an accurate "Time of Year". The Time of Year reference is input to the ATI by a signal conforming to the IRIG B002 standard [2] for signalling Time of Year. Products to this standard are available from many suppliers, and the time signals can be derived from sources such as GPS, Loran, or from an on-board satellite time reference.

The recordings are presented almost identically to the undated recordings, except there are fields for the day of the year as well as hours, minutes and seconds (to ten decimal places). Figure 5 shows a sequence of two packets presented in this format.

```
Day:hh:mm:ss  ms  us  ns     Flow   Activity
288:15:25:10.263 728 870 1s  1<--2  Data @0000  01 02 03 04  05 06 07 08
                             1<--2  Data @0008  09 0A 0B 0C  0D 0E 0F 10
                             1<--2  Data @0010  11 12 13 14  15 16 17 18
                             1<--2  Data @0018  19 1A 1B 1C  1D 1E 1F 20
                             1<--2  Data @0020  21 22 23 24  25 26 27 28
                             1<--2  Data @0028  29 2A 2B 2C  2D 2E 2F 30
                             1<--2  Data @0030  31 32
                             1<--2  EOP at 288:15:25:10.263 731 370 1s (SOP + 2.500us)

288:15:25:15.249 072 811 5s  1<--2  Data @0000  01 02 03 04  05 06 07 08
                             1<--2  Data @0008  09 0A 0B 0C  0D 0E 0F 10
                             1<--2  Data @0010  11 12 13 14  15 16 17 18
                             1<--2  Data @0018  19 1A 1B 1C  1D 1E 1F 20
                             1<--2  Data @0020  21 22 23 24  25 26 27 28
                             1<--2  Data @0028  29 2A 2B 2C  2D 2E 2F 30
                             1<--2  Data @0030  31 32
                             1<--2  EOP at 288:15:25:15.249 075 311 5s (SOP + 2.500us)
```

Figure 5:Recorded packets, time tagged to Time of Year, from synchronizing to ATI

This synchronization can be used with any number of Multi-link SpaceWire Recorders, each connected to a different computer (and discs), to record SpaceWire traffic at a far higher bandwidth than is possible on a single computer or disc. The common date and time reference means that all the recordings can be coordinated.

The units synchronized to the ATI can include bridges such as the EtherSpaceLink, Diagnostic SpaceWire interface or SpaceWire Packet Generator, as shown, for example, in Figure 6. The reconfigurability of the test units means that the same hardware can be used for active test stimuli from the bridge units and passive recording from the MSR, often without needing to unplug cables to the flight equipment.

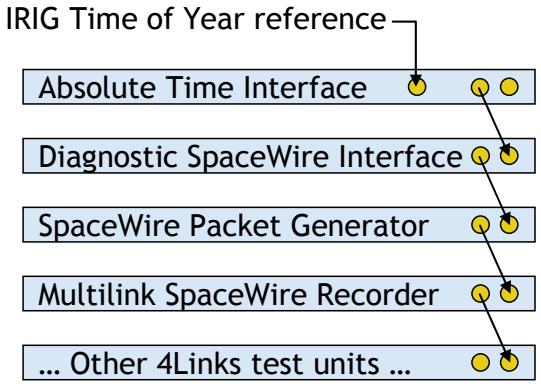

Figure 6: Synchronizing different test units

2.1 ISSUING AND RECORDING PRECISE TIME CODES

The ATI also has a single SpaceWire port which outputs a 1 pulse per second SpaceWire Time Code synchronized to Time of Year. With the Time-code Generator option (TG), the ATI outputs up to four independent and configurable Time Codes, all synchronized to Time of Year. Time codes are generated with zero jitter.

With the evolution of SpaceWire towards SpaceWire-RT, there is increased need for Time Codes and for instrumenting their distribution. By generating precise Time Codes and by synchronizing test units to measure arrival times of packets and Time Codes, the ATI enables precise measurement of Time Code arrival times and Jitter. Figure 7 shows a short example recorded by the MSR of Time Code arrival.

```
Day:hh:mm:ss  ms  us  ns     Flow   Activity
288:15:19:31.000 000 000 5s  1-->2  Time Code 00
288:15:19:32.000 000 000 5s  1-->2  Time Code 01
288:15:19:33.000 000 000 5s  1-->2  Time Code 02
288:15:19:34.000 000 000 5s  1-->2  Time Code 03
288:15:19:35.000 000 000 5s  1-->2  Time Code 04
288:15:19:36.000 000 000 5s  1-->2  Time Code 05
288:15:19:37.000 000 000 5s  1-->2  Time Code 06
288:15:19:38.000 000 000 5s  1-->2  Time Code 07
288:15:19:38.869 933 928 8s  1<--2  Data @0000  01 02 03 04  05 06 07 08
                             1<--2  Data @0008  09 0A 0B 0C  0D 0E 0F 10
                             1<--2  Data @0010  11 12 13 14  15 16 17 18
                             1<--2  Data @0018  19 1A 1B 1C  1D 1E 1F 20
                             1<--2  Data @0020  21 22 23 24  25 26 27 28
                             1<--2  Data @0028  29 2A 2B 2C  2D 2E 2F 30
                             1<--2  Data @0030  31 32
                             1<--2  EOP at 288:15:19:38.869 936 428 8s (SOP + 2.500us)
288:15:19:39.000 000 000 5s  1-->2  Time Code 08
288:15:19:40.000 000 000 5s  1-->2  Time Code 09
```

Figure 7: Recording of Time Code together with a data packet

3 CONCLUSIONS

The Multi-link SpaceWire Recorder can record time tagged traffic over many links, at many hundreds of aggregate Mbits/s, with recordings being made on several different computers. Synchronizing these recordings with the Absolute Time Interface makes it possible to inter-relate the different recordings as if they were a single recording.

This powerful logging and datation, together with precise, zero jitter, issue of Time Codes, creates a powerful tool for accurately recording the temporal behaviour of a complete SpaceWire system or any part of it. Synchronizing with a global time reference such as GPS extends this capability to remote testing and virtual satellite integration between multiple sites.

4 REFERENCES

1. The ECSS-E-50-12 Working Group, “ECSS-E-50-12A 24 January 2003, SpaceWire - Links, nodes, routers and networks”, published by the ECSS Secretariat, ESA-ESTEC, Requirements & Standards Division, Noordwijk, The Netherlands
2. Range Commanders’ Council, Telecommunications and Timing Group, IRIG Standard 200-4 “IRIG Serial Time Code Formats”
3. 4Links Limited, “Multi-link SpaceWire Recorder: product outline”
4. 4Links Limited, “Absolute Time Interface: product outline”