SPACEWIRE STANDARD: LOW SPEED SIGNALLING RATES

Session: SpaceWire Standardisation

Short Paper

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ABSTRACT

The SpaceWire standard defines that the start-up speed of a SpaceWire link shall be 10 Mbit/s +/- 10%. Therefore part of the SpaceWire interface logic and the LVDS drivers and receivers must be capable of operating at a clock speed of 10 MHz and a 10 MHz clock source must be available on the PCB (or 5 MHz for double data rate).

When lower clock speeds are required for lower power applications the 10 Mbit/s start-up speed requirement poses a significant problem for successful link connection. At 10 Mbit/s it takes 800 ns to transmit one NULL character therefore approximately 14 can be transmitted during the minimum Started timeout period of 11.64 µs. This gives enough time to receive and decode the SpaceWire NULLs at the other end of the link. At 2 Mbit/s it takes 4 µs to transmit one NULL character and at most two complete NULL characters can be transmitted during the minimum Started timeout. This does not give enough time for NULLs to be exchanged between SpaceWire interfaces and link start-up cannot occur.

1. INTRODUCTION

The Bepi-Columbo MMO Mission Data Processor SpaceWire Interface Design requirements specify the SpaceWire interface to run at a data rate between 2 and 16 Mbits/s exclusively to save power on the instrument. The current design runs on a 2 Mbit/s link speed with an internal clock speed of 2 MHz. As the interface cannot start up at 10 Mbit/s it is not compliant with ECSS-E-50-12 [1].

This short paper describes a worked example of the University of Dundee/ESA SpaceWire IP core operating at 2 Mbit/s and the exchange level changes required to ensure that a link connection occurs.

2. CONTEXT

The SpaceWire initialisation state machine is shown in Figure 1.

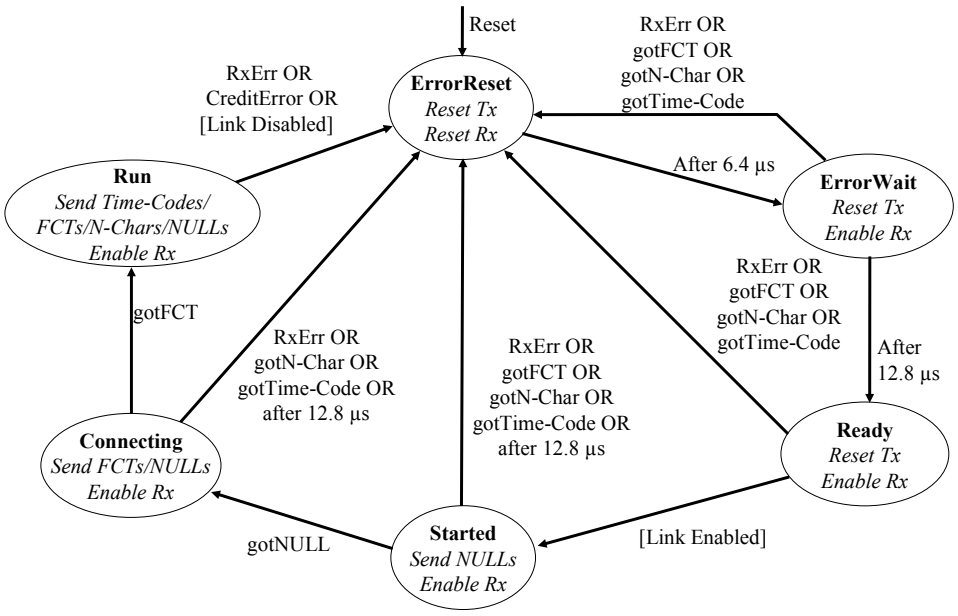

Figure 1 SpaceWire Initialisation State Machine

The state machine timeouts are defined below:

Transition	Nominal Timeout	Lower Limit	Upper Limit
ErrorReset → ErrorWait	6.4 µs	5.82 µs	7.22 µs
ErrorWait → Ready	12.8 µs	11.64 µs	14.33 µs
Started → ErrorReset	12.8 µs	11.64 µs	14.33 µs
Connecting → ErrorReset	12.8 µs	11.64 µs	14.33 µs

Table 2-1 SpaceWire Initialisation State Machine Timeouts

For link initialisation to occur both ends of the SpaceWire link must exchange NULL characters and flow control tokens. NULL characters are exchanged so both state machines can move from Started to Connecting. FCT characters are exchanged so both ends can move from state Connecting to state Run. In state Run all characters can be exchanged and normal operation of the link is performed until an error is detected or the link is disabled.

3. OPERATION AT 2 MBITS

The SpaceWire standard specifies Started and Connecting timeout periods dependent on an initialisation bit period of 10Mbit/s. At 10Mbit/s it takes 800 ns to transmit one NULL character therefore approximately 14 can be transmitted during the minimum Started timeout period of 11.53 µs. This gives enough time to receive and decode the SpaceWire NULLs at the other end of the link.

At 2 Mbit/s it takes 4 µs to transmit one NULL character and at most 2 complete NULL characters can be transmitted during the minimum Started timeout period of

11.53 µs. This does not give enough time for the receiver to decode the First NULL and the state machine to move to state Connecting. The time from receiving the first bit of the first NULL character to entering state Started is shown in Figure 2.

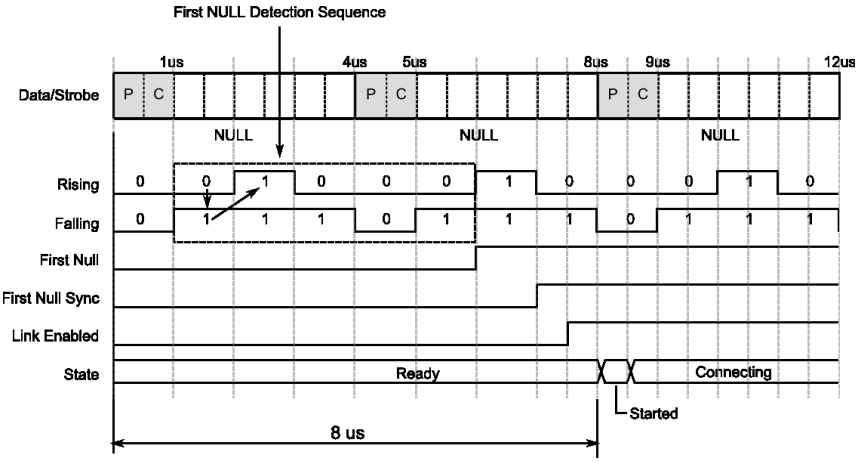

Figure 2 Receive first NULL to Started/Connecting time

The Input bit stream is decoded on the rising and falling edges of the recovered receive clock. The complete first NULL plus the parity and control bit of the rising/falling edge data are shifted into the receiver and checked before the first null signal is set. Another two system clock cycles are required to synchronise the first null signal and an extra cycle is used up by setting link enabled. Once link enabled is set the state machine moves to state started and then immediately to Connecting.

The time from moving to state started to the sending the first NULL character is defined in Figure 3.

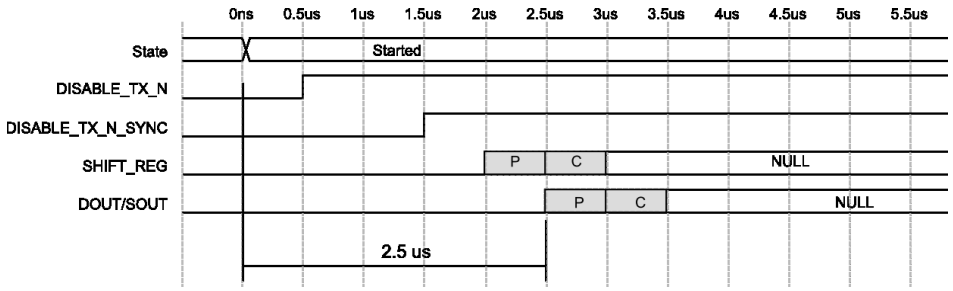

Figure 3 Started to sending first NULL time

One cycle after started is entered DISABLE_TX_N is set low. In the transmitter DISABLE_TX_N is passed through a two stage synchroniser. DISABLE_TX_N is asynchronously reset therefore it must be synchronised. When DISABLE_TX_N_SYNC is set high the shift register is enabled and one cycle later the data strobe pattern is present on DOUT/SOUT. The time to send the first bit of the NULL character is therefore 2.5 µs.

Therefore the basic time to receive and decode the first NULL and instruct the transmitter to reply with a NULL character almost violates the minimum 11.53 us Started timeout and the link cannot start.

4. RESULTS

By increasing the state machine Started and Connecting timeouts for a 2 Mbit/s bit period the First NULL/FCT encoding and decoding can be performed successfully. The proposed state machine time-out changes are listed in Table 2.

Transition	Normal Minimum Timeout	Adjusted Minimum Timeout
ErrorReset → ErrorWait	5.82 µs	5.82 µs
ErrorWait → Ready	11.64 µs	11.64 µs
Started → ErrorReset	11.64 µs	21 µs
Connecting → ErrorReset	11.64 µs	19 µs

Table 2 Normal and adjusted state machine timeouts

The SpaceWire standard defines the minimum bit period before a disconnect can be detected and the maximum bit period where a disconnect is always detected as 727 ns and 1 µs respectively. With a bit rate of 2 Mbit/s a special disconnect detection timer using both edges of the clock is used to provide a disconnect detection period between the upper and lower limits. A better approach would be to increase the timeout period or adjust the tolerance so low speed clocks can be used.

5. CONCLUSION

The SpaceWire standard 10 Mbit/s start-up speed requirement, SpaceWire state machine timeouts and the SpaceWire disconnect period prohibit a SpaceWire link from running at 2 Mbit/s. By extending the Started and Connecting timeout periods without changing the error recovery time of the SpaceWire link (ErrorReset and ErrorWait timeouts) the link can operate successfully at lower clock speeds.

6. REFERENCES

1. ECSS, “SpaceWire: Links, nodes, routers and networks”, ECSS-E50-12A, January 2003.

2. Chris McClements, “SpaceWire CODEC IP - Application Note: 2Mbit/s Operation”, ESA Micro-electronics, 28th May 2008.