Observations About OpenLCB CAN Timing

Bob Jacobsen

May 26, 2024

1 Introduction

There have been some recent discussions of whether the OpenLCB Standards should, or even can, require that the frames of a message be sent sequentially on the CAN bus. This would be particularly important for the proposed Event-with-Payload protocol update.

This note describes measurements of the OpenLCB CAN timing of a TCS CS-105 command station, JMRI PanelPro connected via an LCC-Buffer USB, an RR-Cirkits Tower-LCC, and an SPROG DCC Ltd. SERVOIO-LCC to try to shed some light on current behavior in this area.[1]

2 Measurement Setup

The measurement setup consisted of a single CAN segment using 6" cables connecting, in order:

1. An RR-CirKits terminator.
2. An RR-Cirkits LCC Buffer-USB connected to a 2021 M1 Mac PowerBook Pro running OlcbChecker[2] for stimulating the device being measured.
3. A second RR-Cirkits LCC Buffer-USB connected to that same Powerbook Pro running JMRI PanelPro 5.7.5 to log the bus traffic.
4. An XDS3104E digital storage oscilloscope attached to the CAN+ and CAN- lines. The scope signal ground is isolated from power ground and attached to CAN signal ground.

[1] The original version of this note was dated March 24, 2024. This version includes an update, marked by change bars, to the new version 1.5 of the SPROG SERVO-IO firmware.

[2] Available on GitHub.

5. An RR-CirKits Power Point with a 15V power supply.
6. The device being measured.
7. An RR-CirKits CAN terminator.

All stimuli were sent from a suitably-modified version of OlcbChecker's signal_generator script running on the PowerBook Pro. The Mac was idle except for running JMRI and the OlcbChecker script.

We use the following bit notation when measuring the time between frames:[3]

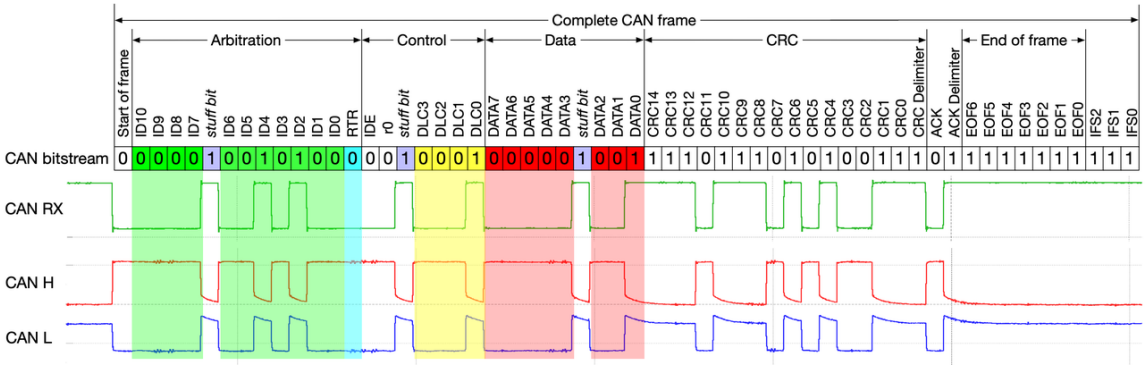

Figure 1: CAN Frame Notation

What we call "the interframe time" is determined by measuring from the trailing edge of an ACK bit to the leading edge of the next Start of Frame bit and then subtracting the CAN protocol minimum of 11 bit times or 88 microseconds. The interframe time will be zero if the frames follow each other sequentially.

2.1 Limitations

The setup described here has some limitations:

1. It's not practical to decode individual packets on the scope. That's done using the JMRI monitor.
2. The JMRI monitor screen's timing display is not sufficiently precise for measuring the time of arrival of CAN frames. It's only used to record the order of arrival of the frames and to decode their contents.
3. The scope has limited dynamic range on the horizontal axis. Measurements of the overall timing of a sequence have to be made in separate shots from the measurement

[3]Figure from Wikipedia.

of e.g. individual CAN frame timing.

3 Devices Being Measured

3.1 TCS CS-105

This self-identifies as hardware version Rev E and software version 1.00

3.2 RR-CirKits Tower-LCC

This self-identifies as hardware version rev-D and software version rev-C7e.

3.3 JMRI PanelPro

JMRI release 5.7.4 was running on the slowest machine I have, a 2017 3GHZ iMac. It was connected to the OpenLCB CAN bus using an LCC Buffer-USB.

3.4 SPROG DCC Ltd. SERVOIO-LCC

This self-identifies as hardware version 1.0 and software version 1.5.

4 Measurements

4.1 Single SNIP Interaction

This measurement sends a single SNIP request and examines the timing of the reply. A typical interaction is shown in Figure 2. Figure 3 shows more detail of the time between the first and second frames within the reply.

Device	Typical Reply Time	Typical Interframe Time
CS-105	10 ms	0μs
JMRI	1.2 ms	0μs
Tower-LCC	0.4 ms	12 - 20 μs
SERVOIO-LCC	0.8-1.2 ms	0μs

To summarize, all four devices have enough delay between receiving a request and sending the response for another packet to be put on the CAN bus. The CS-105, JMRI and SERVIO-LCC reply without inter-frame delays while the Tower-LCC has an additional delay between reply frames that would allow a lower-priority frame to be inserted.

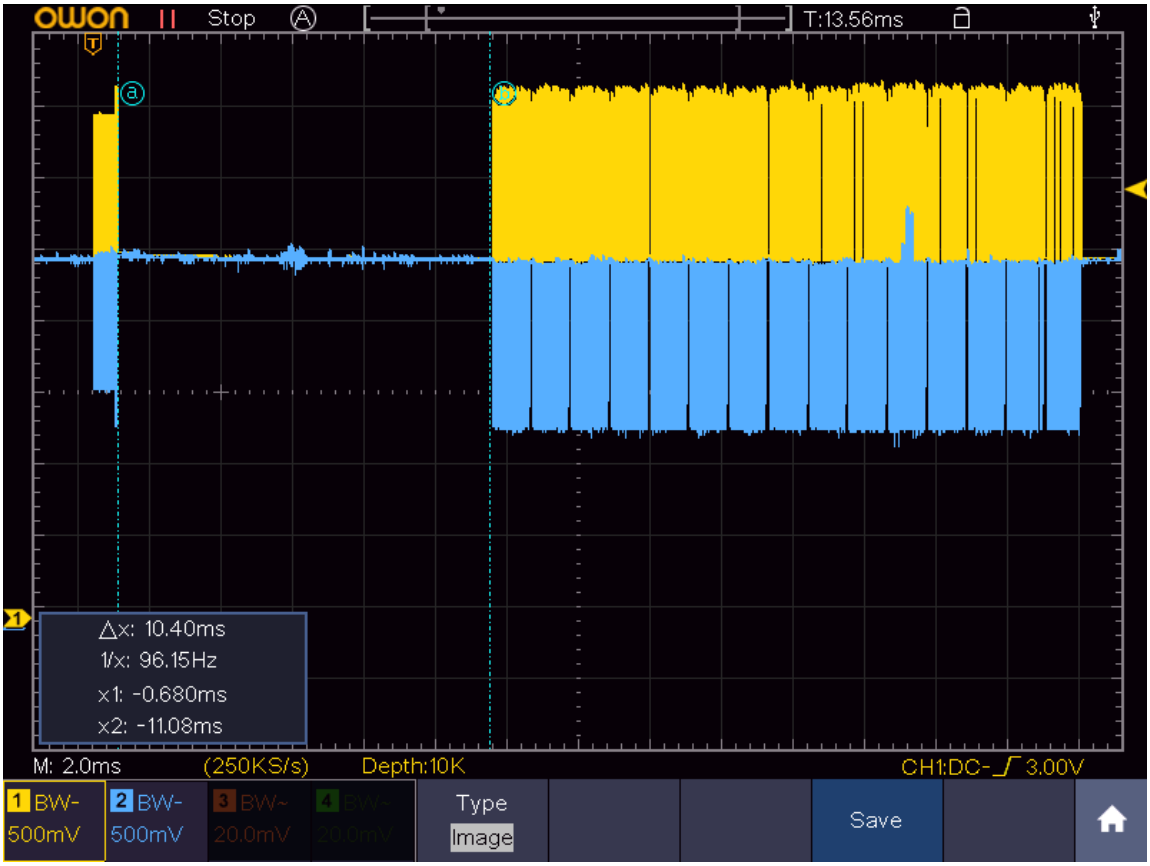

Figure 2: Overview of a single CS105 SNIP interaction. The first frame on the left is the SNIP request message. The SNIP reply message is made up of the 15 frames in the middle.

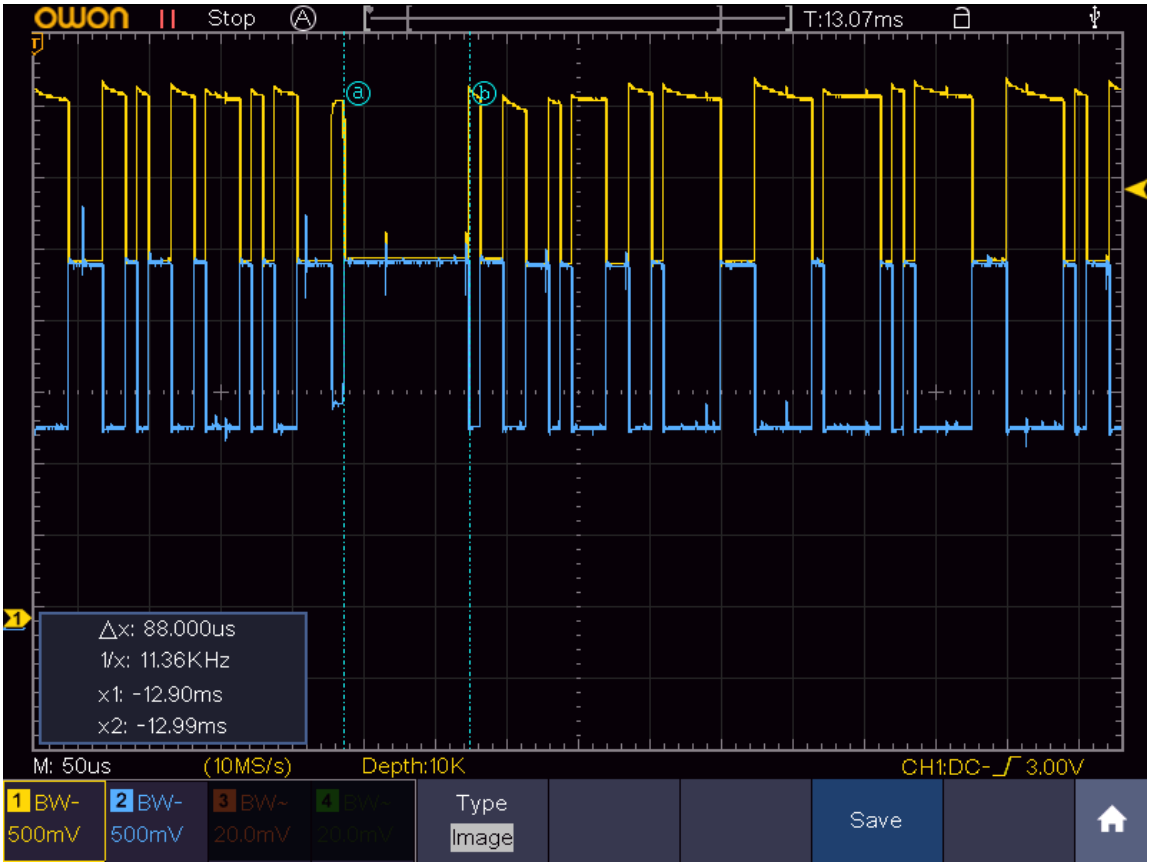

Figure 3: Interframe delay of CS105 SNIP reply. The time cursors are on the trailing edge of the first reply frame's ACK bit and the leading edge of the next Start of Frame bit.

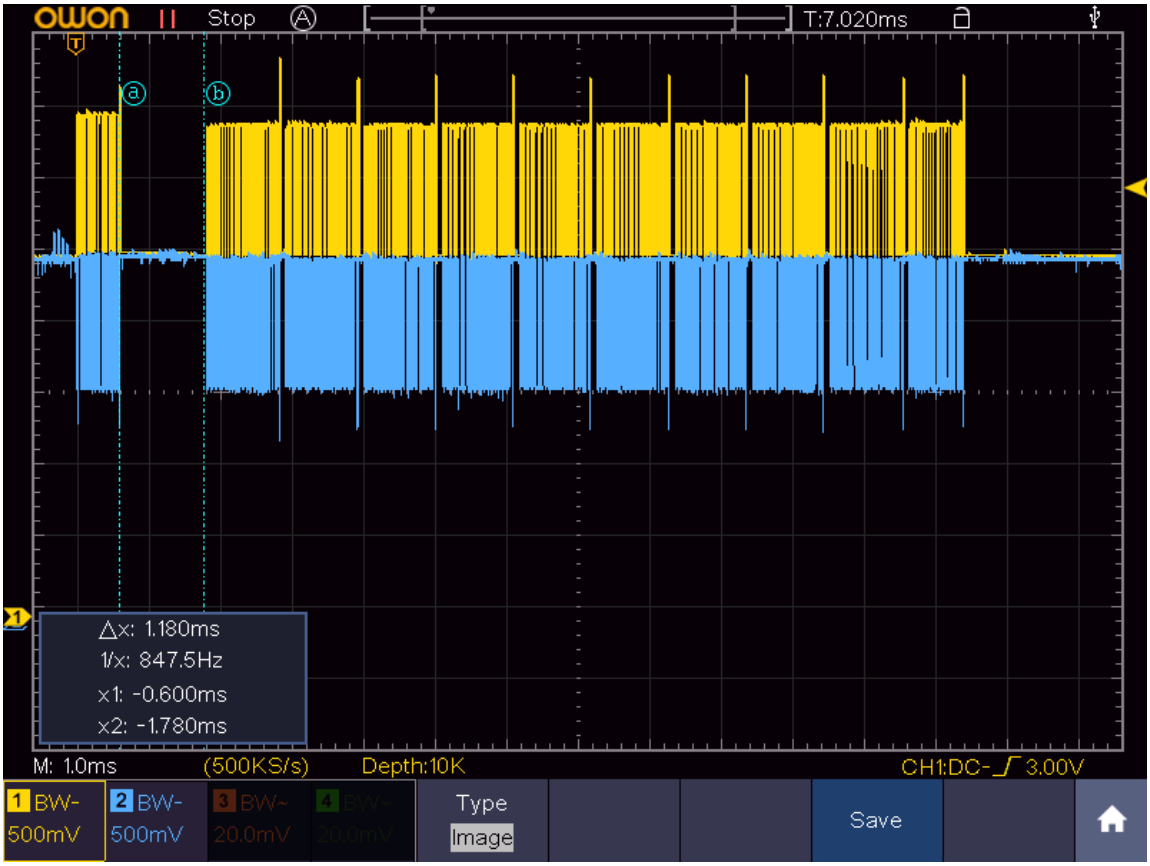

Figure 4: Overview of a single JMRI SNIP interaction.

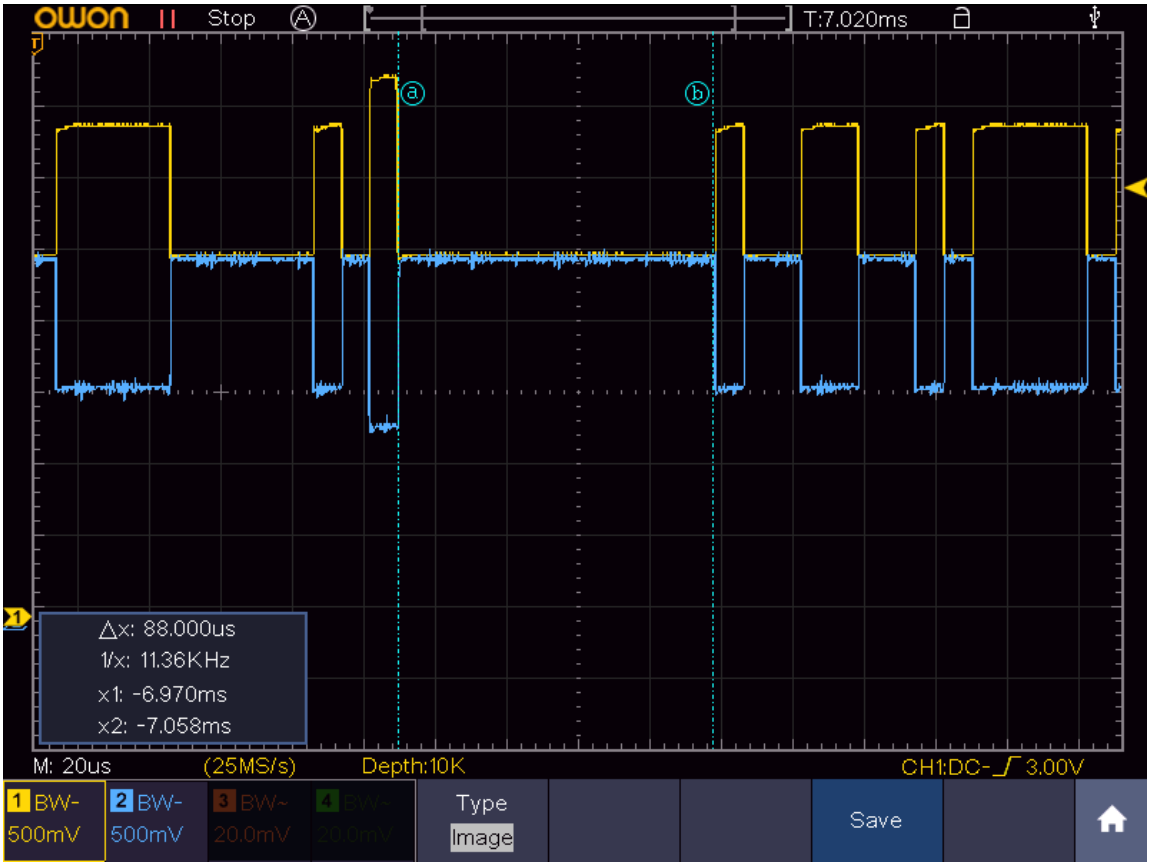

Figure 5: Interframe delay of JMRI SNIP reply.

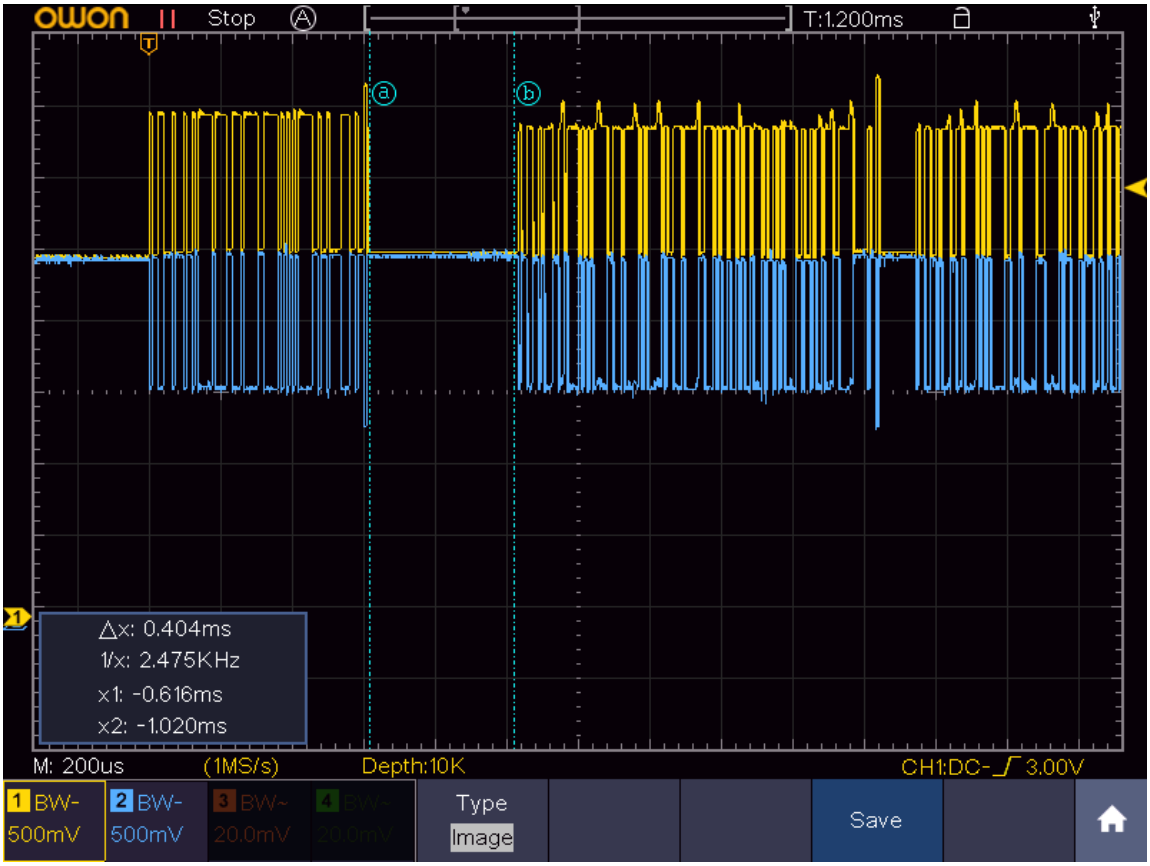

Figure 6: View of a single Tower-LCC SNIP interaction showing the initial reply time. The entire set of reply frames is not shown to get additional precision on the reply time measurement.

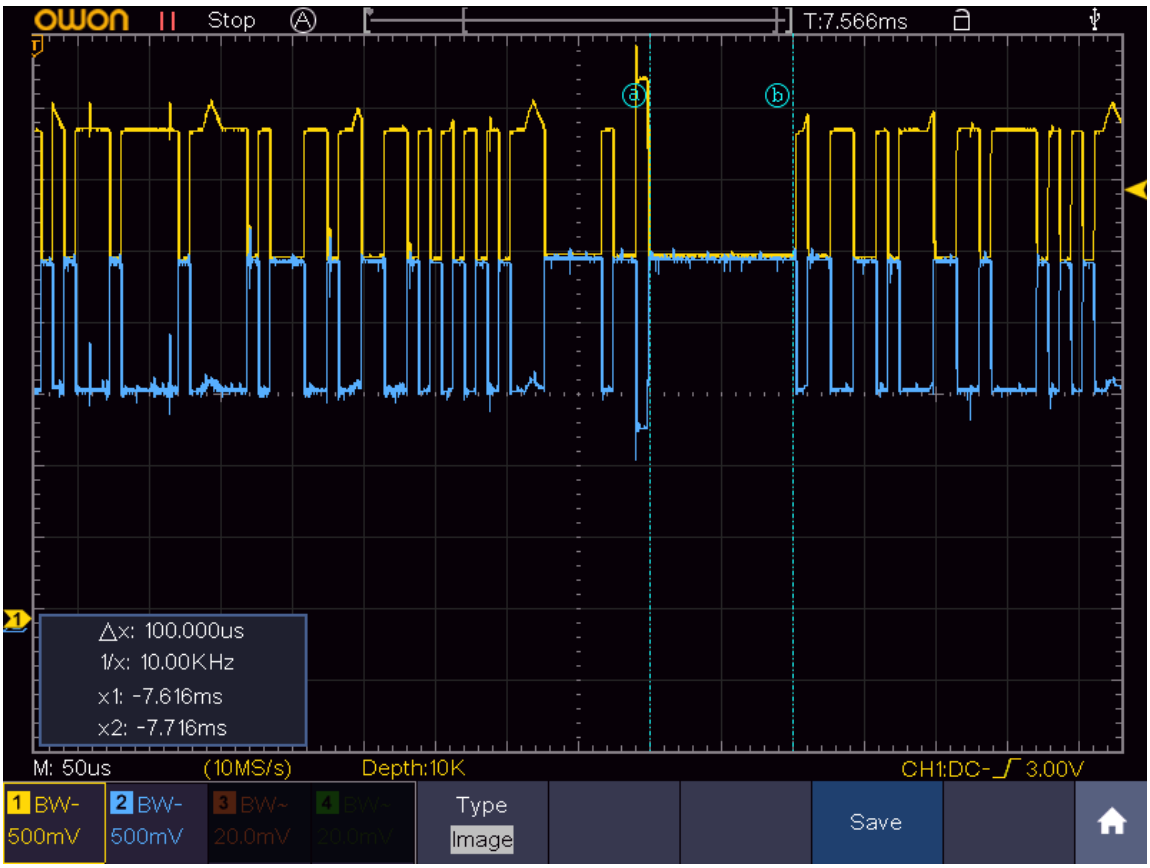

Figure 7: Interframe delay of Tower-LCC SNIP reply. After the required 88 μs, there's an additional 12μsinter-frame delay.

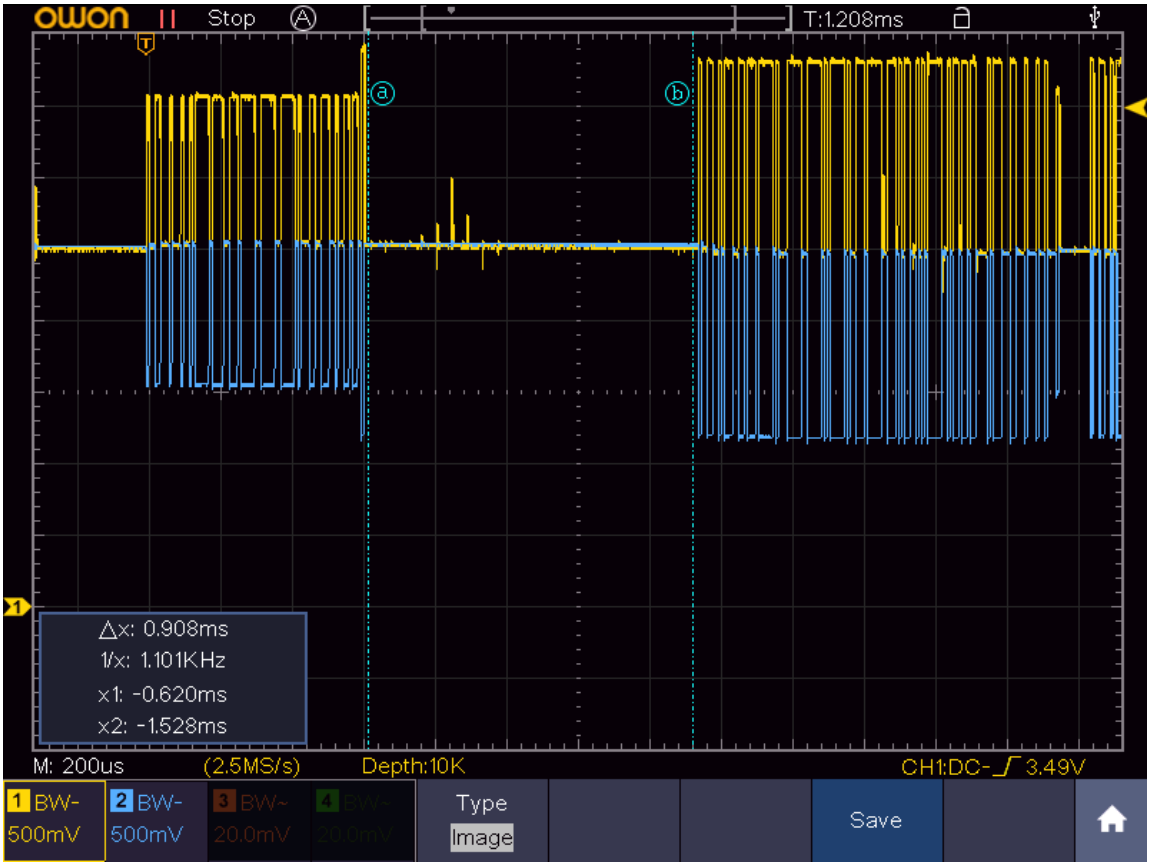

Figure 8: Overview of a single SERVOIO-LCC SNIP interaction. The entire set of reply frames is not shown to get additional precision on the reply time measurement.

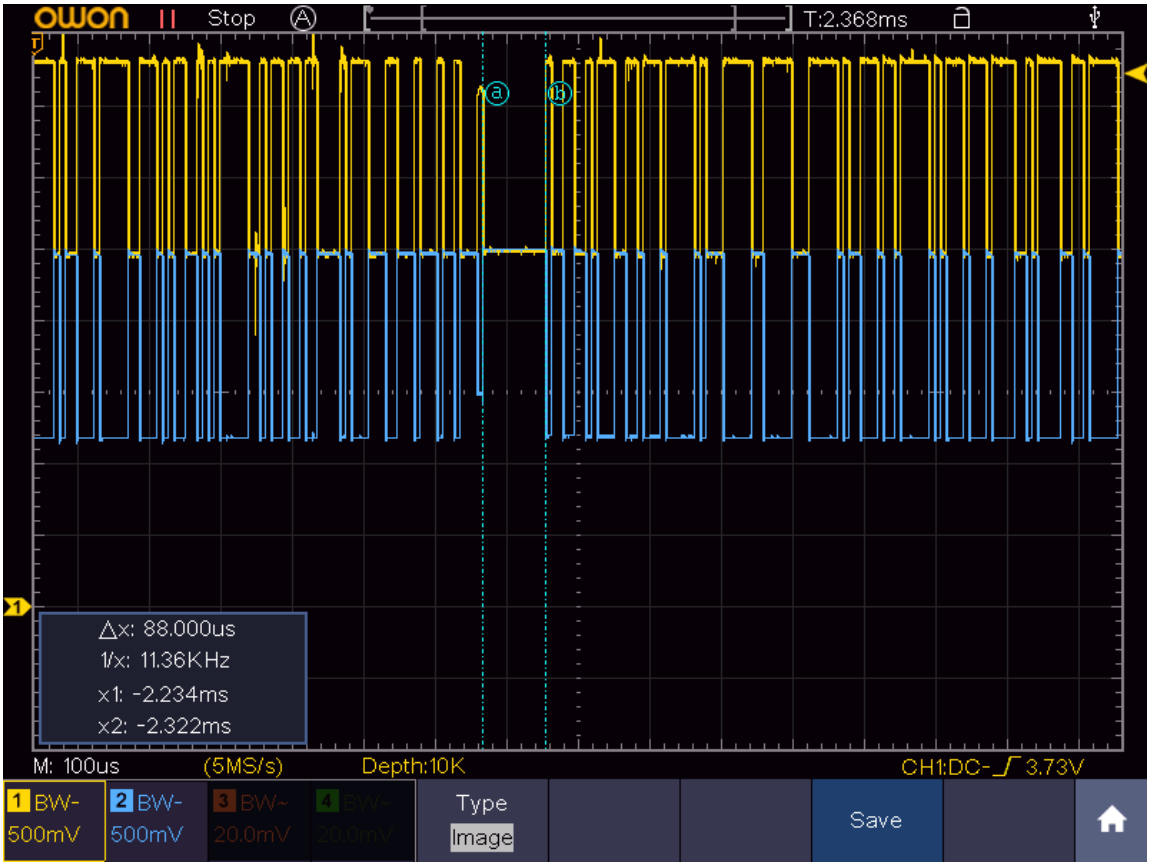

Figure 9: Interframe delay of SERVOIO-LCC reply.

4.2 Double SNIP Interaction

This measurement sends two SNIP requests sequentially and examines the timing of the replies. This is intended to see what happens when a second request occurs before the first reply is sent.

The two request frames are sent at line rate, with no additional interframe time between them.

In all four cases, the two SNIP requests were sent before the device sends the first SNIP reply frame.

The CS-105 and JMRI send their first responses with the delays typical of those seen above, and the second reply immediately after the first.

In the single-SNIP measurement above, the Tower-LCC sent its reply in less than a single frame time after the request was received. Here, the first reply frame follows the request with zero interframe time. The second reply frame, part of the first reply message, followed after an interframe gap of typically 12-16μs. See Figure 10 for more detail on this.

The SERVOIO-LCC sent an OIR frame to temporarily reject the 2nd SNIP request frame. [4] See Figure 11 for more detail on this.

To summarize, all four devices properly handled receiving a second SNIP request message before the reply to the first request has been sent.

[4]The OpenLCB_Java library used by JMRI will normally retransmit the SNIP request on receipt of a OIR addressed to it with a non-permanent error code; what other control programs do is unknown at present.

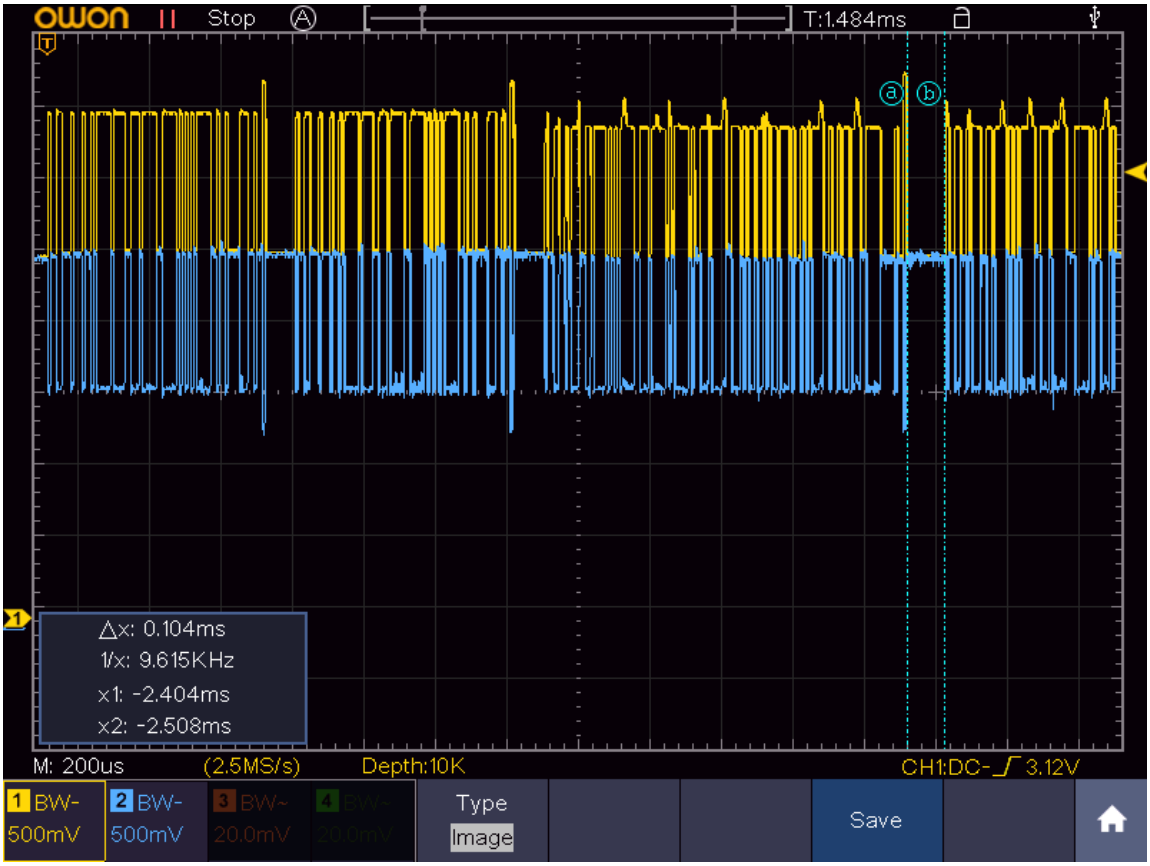

Figure 10: Interframe delay of Tower-LCC SNIP reply with two requests. The first two frames on the left are the SNIP requests sent to initiate the measurement. The second two frames on the right are the SNIP reply from the Tower-LCC. The interframe time between the first and second reply frame is measured at 16μs here.

```
03.662: [[19de8031] 08 1C                 ]  R: 03.00.00.00.00.01 - 02.01.2C.01.09.00
                SimpleNodeIdentInfoRequest with no payload
03.663: [[19de8031] 08 1C                 ]  R: 03.00.00.00.00.01 - 02.01.2C.01.09.00
                SimpleNodeIdentInfoRequest with no payload
03.664: [[19a0881c] 10 31 04 53 50 52 4F 47]  R: SNIP Reply 1st frame
03.666: [[1906881c] 00 31 20 00 0D E8      ]  R: 02.01.2C.01.09.00 - 03.00.00.00.00.01
                OptionalInteractionRejected with payload 20 00 0D E8
                Optional Interaction Rejected for MTI 0xDE8 code 0x2000
03.666: [[19a0881c] 30 31 20 44 43 43 20 4C]  R: SNIP Reply middle frame
03.668: [[19a0881c] 30 31 74 64 00 53 45 52]  R: SNIP Reply middle frame
03.669: [[19a0881c] 30 31 56 4F 49 4F 2D 4C]  R: SNIP Reply middle frame
03.670: [[19a0881c] 30 31 43 43 00 31 2E 30]  R: SNIP Reply middle frame
03.671: [[19a0881c] 30 31 00 31 2E 35 00 02]  R: SNIP Reply middle frame
03.672: [[19a0881c] 20 31 00 00            ]  R: 02.01.2C.01.09.00 - 03.00.00.00.00.01
                Simple Node Ident Info
                with content '4,SPROG DCC Ltd,SERVOIO-LCC,1.0,1.5,2,,,'
```

Figure 11: SERVOIO-LCC double-SNIP sequence. The SERVOIO-LCC starts to reply to the 1st SNIP request, then sends a higher-priority OIR message to reject the 2nd request.

4.3 SNIP, PIP interaction

This measurement sends a SNIP request followed by a higher-priority PIP request and examines the timing of the replies. This is intended to see what happens when a second request with higher CAN priority occurs before the first reply can be sent.

The two request frames are sent at line rate, with no additional interframe time between them.

The CS-105 replied to the PIP request before replying to the SNIP request. There were no additional delays between the replies.

JMRI replied to first the SNIP request, then the PIP request with no additional delays between the reply frames.

The Tower-LCC started its SNIP reply by sending the first frame, then replied to the PIP request, then sent the rest of the SNIP replies. The interframe delays were typically 16μs.

The SERVOIO-LCC starts the SNIP reply with its first frame, then sends the higher-priority PIP reply frame, followed by the rest of the SNIP reply frames.

```
50.187: [[19de8031] 03 00                  ]  R: 03.00.00.00.00.01 - 09.00.99.03.00.35
    SimpleNodeIdentInfoRequest with no payload
50.187: [[19828031] 03 00                  ]  R: 03.00.00.00.00.01 - 09.00.99.03.00.35
    ProtocolSupportInquiry with no payload
50.198: [[19668300] 00 31 54 58 00 00 00 00]  R: 09.00.99.03.00.35 - 03.00.00.00.00.01
    ProtocolSupportReply with payload 54 58 00 00 00 00
50.199: [[19a08300] 10 31 04 54 72 61 69 6E]  R: SNIP Reply 1st frame
50.200: [[19a08300] 30 31 20 43 6F 6E 74 72]  R: SNIP Reply middle frame
50.201: [[19a08300] 30 31 6F 6C 20 53 79 73]  R: SNIP Reply middle frame
50.202: [[19a08300] 30 31 74 65 6D 73 20 28]  R: SNIP Reply middle frame
50.203: [[19a08300] 30 31 54 43 53 29 00 43]  R: SNIP Reply middle frame
50.204: [[19a08300] 30 31 53 2D 31 30 35 00]  R: SNIP Reply middle frame
50.206: [[19a08300] 30 31 52 65 76 20 45 00]  R: SNIP Reply middle frame
50.207: [[19a08300] 30 31 31 2E 30 30 00 02]  R: SNIP Reply middle frame
50.208: [[19a08300] 30 31 54 43 53 20 43 53]  R: SNIP Reply middle frame
50.209: [[19a08300] 30 31 2D 31 30 35 2C 20]  R: SNIP Reply middle frame
50.210: [[19a08300] 30 31 53 2F 4E 20 30 30]  R: SNIP Reply middle frame
50.211: [[19a08300] 30 31 33 35 00 54 43 53]  R: SNIP Reply middle frame
50.212: [[19a08300] 30 31 20 43 6F 6D 6D 61]  R: SNIP Reply middle frame
50.213: [[19a08300] 30 31 6E 64 20 53 74 61]  R: SNIP Reply middle frame
50.214: [[19a08300] 20 31 74 69 6F 6E 00   ]  R: 09.00.99.03.00.35 - 03.00.00.00.00.01
    Simple Node Ident Info
    with content '4,Train Control Systems (TCS),CS-105,Rev E,1.00,2,TCS CS-105, S/N 0035,TC
```

Figure 12: CS-105 SNIP, PIP reply packet sequence

```
06.610: [[19de8031] 05 41                  ]  R: 03.00.00.00.00.01 - 02.01.57.00.04.9D
    SimpleNodeIdentInfoRequest with no payload
06.611: [[19828031] 05 41                  ]  R: 03.00.00.00.00.01 - 02.01.57.00.04.9D
    ProtocolSupportInquiry with no payload
06.612: [[19a08541] 10 31 04 52 52 2D 43 69]  R: SNIP Reply 1st frame
06.613: [[19668541] 00 31 D4 18 20 00 00 00]  R: 02.01.57.00.04.9D - 03.00.00.00.00.01
    ProtocolSupportReply with payload D4 18 20 00 00 00
06.614: [[19a08541] 30 31 72 4B 69 74 73 2C]  R: SNIP Reply middle frame
06.615: [[19a08541] 30 31 20 49 6E 63 2E 00]  R: SNIP Reply middle frame
06.616: [[19a08541] 30 31 54 6F 77 65 72 2D]  R: SNIP Reply middle frame
06.617: [[19a08541] 30 31 4C 43 43 00 72 65]  R: SNIP Reply middle frame
06.618: [[19a08541] 30 31 76 2D 44 00 72 65]  R: SNIP Reply middle frame
06.619: [[19a08541] 30 31 76 2D 43 37 65 00]  R: SNIP Reply middle frame
06.620: [[19a08541] 30 31 02 5A 69 6F 6E 45]  R: SNIP Reply middle frame
06.621: [[19a08541] 30 31 20 74 75 72 6E 6F]  R: SNIP Reply middle frame
06.623: [[19a08541] 30 31 75 74 73 20 31 73]  R: SNIP Reply middle frame
06.624: [[19a08541] 30 31 74 20 32 34 2D 30]  R: SNIP Reply middle frame
06.625: [[19a08541] 30 31 31 2D 30 34 00 54]  R: SNIP Reply middle frame
06.626: [[19a08541] 30 31 75 72 6E 6F 75 74]  R: SNIP Reply middle frame
06.627: [[19a08541] 30 31 20 6F 77 6E 65 72]  R: SNIP Reply middle frame
06.628: [[19a08541] 20 31 2E 20 54 57 52 00]  R: 02.01.57.00.04.9D - 03.00.00.00.00.01
    Simple Node Ident Info
    with content '4,RR-CirKits, Inc.,Tower-LCC,rev-D,rev-C7e,2,ZionE turnouts 1st 24-01-04,
```

Figure 13: TowerLCC SNIP, PIP reply packet sequence

```
21.065: [[19de8031] 08 1C                 ]  R: 03.00.00.00.00.01 - 02.01.2C.01.09.00
               SimpleNodeIdentInfoRequest with no payload
21.066: [[19828031] 08 1C                 ]  R: 03.00.00.00.00.01 - 02.01.2C.01.09.00
               ProtocolSupportInquiry with no payload
21.067: [[19a0881c] 10 31 04 53 50 52 4F 47]  R: SNIP Reply 1st frame
21.069: [[1966881c] 00 31 54 58 20 00 00 00]  R: 02.01.2C.01.09.00 - 03.00.00.00.00.01
               ProtocolSupportReply with payload 54 58 20 00 00 00
21.071: [[19a0881c] 30 31 20 44 43 43 20 4C]  R: SNIP Reply middle frame
21.071: [[19a0881c] 30 31 74 64 00 53 45 52]  R: SNIP Reply middle frame
21.072: [[19a0881c] 30 31 56 4F 49 4F 2D 4C]  R: SNIP Reply middle frame
21.073: [[19a0881c] 30 31 43 43 00 31 2E 30]  R: SNIP Reply middle frame
21.074: [[19a0881c] 30 31 00 31 2E 35 00 02]  R: SNIP Reply middle frame
21.075: [[19a0881c] 20 31 00 00           ]  R: 02.01.2C.01.09.00 - 03.00.00.00.00.01
               Simple Node Ident Info
               with content '4,SPROG DCC Ltd,SERVOIO-LCC,1.0,1.5,2,,,'
```

Figure 14: SERVOIO-LCC SNIP, PIP reply packet sequence

4.4 Triple SNIP Interaction

This measurement sends three SNIP requests sequentially and examines the timing of the replies.

Note that the SNIP request is lower priority than the SNIP reply. If a SNIP reply has already started by the time the third SNIP request is ready to send, that request should be deferred from transmission until that reply has been completely sent.

For the CS-150 and JMRI PanelPro, there's enough delay before the first reply is sent that all three requests can go out. For these two devices, a delay has been added to schedule sending that 3rd SNIP request in the middle of the first SNIP reply.

In the case of the CS-105 and JMRI, the third SNIP request frame is delayed by CAN arbitration until after the second SNIP reply message has been completely sent.

In the case of the Tower-LCC, the third SNIP request successfully arbitrates after the first reply frame has been sent. This is consistent with the Tower-LCC queuing the first frame of the reply while the second request is being sent so that it immediately follows that second request, and then the third request successfully arbitrating during the extra time that the Tower-LCC inserts between reply frames.

Note that the third SNIP request to the Tower-LCC is apparently being lost, as there are only two SNIP replies.

In the case of the SERVOIO-LCC, the 2nd and 3rd SNIP requests get an OIR temporarily rejecting them.

```
35.218: [[19de8031] 03 00                  ]  R: 03.00.00.00.00.01 - 09.00.99.03.00.35
    SimpleNodeIdentInfoRequest with no payload
35.223: [[19de8031] 03 00                  ]  R: 03.00.00.00.00.01 - 09.00.99.03.00.35
    SimpleNodeIdentInfoRequest with no payload
35.230: [[19a08300] 10 31 04 54 72 61 69 6E]  R: SNIP Reply 1st frame
35.238: [[19a08300] 30 31 20 43 6F 6E 74 72]  R: SNIP Reply middle frame
35.238: [[19a08300] 30 31 6F 6C 20 53 79 73]  R: SNIP Reply middle frame
35.238: [[19a08300] 30 31 74 65 6D 73 20 28]  R: SNIP Reply middle frame
35.238: [[19a08300] 30 31 54 43 53 29 00 43]  R: SNIP Reply middle frame
35.238: [[19a08300] 30 31 53 2D 31 30 35 00]  R: SNIP Reply middle frame
35.238: [[19a08300] 30 31 52 65 76 20 45 00]  R: SNIP Reply middle frame
35.238: [[19a08300] 30 31 31 2E 30 30 00 02]  R: SNIP Reply middle frame
35.239: [[19a08300] 30 31 54 43 53 20 43 53]  R: SNIP Reply middle frame
35.242: [[19a08300] 30 31 2D 31 30 35 2C 20]  R: SNIP Reply middle frame
35.242: [[19a08300] 30 31 53 2F 4E 20 30 30]  R: SNIP Reply middle frame
35.242: [[19a08300] 30 31 33 35 00 54 43 53]  R: SNIP Reply middle frame
35.255: [[19a08300] 30 31 20 43 6F 6D 6D 61]  R: SNIP Reply middle frame
35.255: [[19a08300] 30 31 6E 64 20 53 74 61]  R: SNIP Reply middle frame
35.255: [[19a08300] 20 31 74 69 6F 6E 00   ]  R: 09.00.99.03.00.35 - 03.00.00.00.00.01
    Simple Node Ident Info with content '4,Train Control Systems (TCS),CS-105,Rev E,1.00,2,
35.255: [[19a08300] 10 31 04 54 72 61 69 6E]  R: SNIP Reply 1st frame
35.255: [[19a08300] 30 31 20 43 6F 6E 74 72]  R: SNIP Reply middle frame
35.255: [[19a08300] 30 31 6F 6C 20 53 79 73]  R: SNIP Reply middle frame
35.255: [[19a08300] 30 31 74 65 6D 73 20 28]  R: SNIP Reply middle frame
...
35.271: [[19a08300] 30 31 20 43 6F 6D 6D 61]  R: SNIP Reply middle frame
35.271: [[19a08300] 30 31 6E 64 20 53 74 61]  R: SNIP Reply middle frame
35.271: [[19a08300] 20 31 74 69 6F 6E 00   ]  R: 09.00.99.03.00.35 - 03.00.00.00.00.01
    Simple Node Ident Info with content '4,Train Control Systems (TCS),CS-105,Rev E,1.00,2,
35.271: [[19de8031] 03 00                  ]  R: 03.00.00.00.00.01 - 09.00.99.03.00.35
    SimpleNodeIdentInfoRequest with no payload
35.274: [[19a08300] 10 31 04 54 72 61 69 6E]  R: SNIP Reply 1st frame
35.286: [[19a08300] 30 31 20 43 6F 6E 74 72]  R: SNIP Reply middle frame
35.286: [[19a08300] 30 31 6F 6C 20 53 79 73]  R: SNIP Reply middle frame
...
35.290: [[19a08300] 30 31 20 43 6F 6D 6D 61]  R: SNIP Reply middle frame
35.290: [[19a08300] 30 31 6E 64 20 53 74 61]  R: SNIP Reply middle frame
35.290: [[19a08300] 20 31 74 69 6F 6E 00   ]  R: 09.00.99.03.00.35 - 03.00.00.00.00.01
    Simple Node Ident Info with content '4,Train Control Systems (TCS),CS-105,Rev E,1.00,2,
```

Figure 15: CS-105 triple SNIP reply packet sequence. Note: Some SNIP Reply middle frames elided to save space.

```
18.722: [[19de8031] 05 41                  ]  R: 03.00.00.00.00.01 - 02.01.57.00.04.9D
    SimpleNodeIdentInfoRequest with no payload
18.723: [[19de8031] 05 41                  ]  R: 03.00.00.00.00.01 - 02.01.57.00.04.9D
    SimpleNodeIdentInfoRequest with no payload
18.724: [[19a08541] 10 31 04 52 52 2D 43 69]  R: SNIP Reply 1st frame
18.725: [[19de8031] 05 41                  ]  R: 03.00.00.00.00.01 - 02.01.57.00.04.9D
    SimpleNodeIdentInfoRequest with no payload
18.726: [[19a08541] 30 31 72 4B 69 74 73 2C]  R: SNIP Reply middle frame
18.727: [[19a08541] 30 31 20 49 6E 63 2E 00]  R: SNIP Reply middle frame
18.728: [[19a08541] 30 31 54 6F 77 65 72 2D]  R: SNIP Reply middle frame
18.729: [[19a08541] 30 31 4C 43 43 00 72 65]  R: SNIP Reply middle frame
18.730: [[19a08541] 30 31 76 2D 44 00 72 65]  R: SNIP Reply middle frame
18.731: [[19a08541] 30 31 76 2D 43 37 65 00]  R: SNIP Reply middle frame
18.733: [[19a08541] 30 31 02 5A 69 6F 6E 45]  R: SNIP Reply middle frame
18.734: [[19a08541] 30 31 20 74 75 72 6E 6F]  R: SNIP Reply middle frame
18.735: [[19a08541] 30 31 75 74 73 20 31 73]  R: SNIP Reply middle frame
18.736: [[19a08541] 30 31 74 20 32 34 2D 30]  R: SNIP Reply middle frame
18.737: [[19a08541] 30 31 31 2D 30 34 00 54]  R: SNIP Reply middle frame
18.738: [[19a08541] 30 31 75 72 6E 6F 75 74]  R: SNIP Reply middle frame
18.739: [[19a08541] 30 31 20 6F 77 6E 65 72]  R: SNIP Reply middle frame
18.740: [[19a08541] 20 31 2E 20 54 57 52 00]  R: 02.01.57.00.04.9D - 03.00.00.00.00.01
    Simple Node Ident Info with content '4,RR-CirKits, Inc.,Tower-LCC,rev-D,rev-C7e,2,ZionE
18.742: [[19a08541] 10 31 04 52 52 2D 43 69]  R: SNIP Reply 1st frame
18.743: [[19a08541] 30 31 72 4B 69 74 73 2C]  R: SNIP Reply middle frame
18.744: [[19a08541] 30 31 20 49 6E 63 2E 00]  R: SNIP Reply middle frame
18.745: [[19a08541] 30 31 54 6F 77 65 72 2D]  R: SNIP Reply middle frame
18.746: [[19a08541] 30 31 4C 43 43 00 72 65]  R: SNIP Reply middle frame
18.747: [[19a08541] 30 31 76 2D 44 00 72 65]  R: SNIP Reply middle frame
18.748: [[19a08541] 30 31 76 2D 43 37 65 00]  R: SNIP Reply middle frame
18.749: [[19a08541] 30 31 02 5A 69 6F 6E 45]  R: SNIP Reply middle frame
18.750: [[19a08541] 30 31 20 74 75 72 6E 6F]  R: SNIP Reply middle frame
18.751: [[19a08541] 30 31 75 74 73 20 31 73]  R: SNIP Reply middle frame
18.752: [[19a08541] 30 31 74 20 32 34 2D 30]  R: SNIP Reply middle frame
18.754: [[19a08541] 30 31 31 2D 30 34 00 54]  R: SNIP Reply middle frame
18.755: [[19a08541] 30 31 75 72 6E 6F 75 74]  R: SNIP Reply middle frame
18.756: [[19a08541] 30 31 20 6F 77 6E 65 72]  R: SNIP Reply middle frame
18.757: [[19a08541] 20 31 2E 20 54 57 52 00]  R: 02.01.57.00.04.9D - 03.00.00.00.00.01
    Simple Node Ident Info with content '4,RR-CirKits, Inc.,Tower-LCC,rev-D,rev-C7e,2,ZionE
```

Figure 16: TowerLCC triple SNIP reply packet sequence. Note that there is no reply to the third SNIP request.

```
02.120: [[19de8031] 08 1C                ]  R: 03.00.00.00.00.01 - 02.01.2C.01.09.00
                SimpleNodeIdentInfoRequest with no payload
02.120: [[19de8031] 08 1C                ]  R: 03.00.00.00.00.01 - 02.01.2C.01.09.00
                SimpleNodeIdentInfoRequest with no payload
02.121: [[19de8031] 08 1C                ]  R: 03.00.00.00.00.01 - 02.01.2C.01.09.00
                SimpleNodeIdentInfoRequest with no payload
02.123: [[19a0881c] 10 31 04 53 50 52 4F 47]  R: SNIP Reply 1st frame
02.123: [[1906881c] 00 31 20 00 0D E8     ]  R: 02.01.2C.01.09.00 - 03.00.00.00.00.01
                OptionalInteractionRejected with payload 20 00 0D E8
                Optional Interaction Rejected for MTI 0xDE8 code 0x2000
02.125: [[19a0881c] 30 31 20 44 43 43 20 4C]  R: SNIP Reply middle frame
02.126: [[1906881c] 00 31 20 00 0D E8     ]  R: 02.01.2C.01.09.00 - 03.00.00.00.00.01
                OptionalInteractionRejected with payload 20 00 0D E8
                Optional Interaction Rejected for MTI 0xDE8 code 0x2000
02.126: [[19a0881c] 30 31 74 64 00 53 45 52]  R: SNIP Reply middle frame
02.128: [[19a0881c] 30 31 56 4F 49 4F 2D 4C]  R: SNIP Reply middle frame
02.129: [[19a0881c] 30 31 43 43 00 31 2E 30]  R: SNIP Reply middle frame
02.130: [[19a0881c] 30 31 00 31 2E 35 00 02]  R: SNIP Reply middle frame
02.131: [[19a0881c] 20 31 00 00           ]  R: 02.01.2C.01.09.00 - 03.00.00.00.00.01
                Simple Node Ident Info with content '4,SPROG DCC Ltd,SERVOIO-LCC,1.0,1.5,2,
```

Figure 17: SERVOIO-LCC triple SNIP reply packet sequence. Note that the 2nd two requests receive OIR replies

4.5 SNIP, SNIP, PIP Interaction

This measurement sequentially sends two SNIP requests followed by a higher-priority PIP request and examines the timing of the replies.

This is similar to the Triple SNIP interaction examined above, except that the third request is of higher CAN priority than the first two.

For the CS-150 and JMRI PanelPro, there's enough delay before the first reply is sent that all three requests can go out. For these two devices, a delay has been added to schedule sending that request in the middle of the first SNIP reply.

For all four devices, the PIP request successfully arbitrates immediately, appearing during the SNIP reply sequence.

For the CS-105 and JMRI, the PIP reply is delayed until after the two SNIP replies are complete.

Note that the 2nd SNIP request to the Tower-LCC is apparently being lost, as there is only one SNIP reply.

The SERVOIO-LCC interleaves its OIR reply to the 2nd SNIP request with the start of the 1st SNIP reply, followed by the PIP reply a frame later. See Figure 21 for more detail on this.

```
37.595: [[19de8031] 03 00                  ]  R: 03.00.00.00.00.01 - 09.00.99.03.00.35
    SimpleNodeIdentInfoRequest with no payload
37.596: [[19de8031] 03 00                  ]  R: 03.00.00.00.00.01 - 09.00.99.03.00.35
    SimpleNodeIdentInfoRequest with no payload
37.607: [[19a08300] 10 31 04 54 72 61 69 6E]  R: SNIP Reply 1st frame
37.608: [[19a08300] 30 31 20 43 6F 6E 74 72]  R: SNIP Reply middle frame
37.609: [[19a08300] 30 31 6F 6C 20 53 79 73]  R: SNIP Reply middle frame
37.610: [[19a08300] 30 31 74 65 6D 73 20 28]  R: SNIP Reply middle frame
37.611: [[19a08300] 30 31 54 43 53 29 00 43]  R: SNIP Reply middle frame
37.613: [[19a08300] 30 31 53 2D 31 30 35 00]  R: SNIP Reply middle frame
37.614: [[19a08300] 30 31 52 65 76 20 45 00]  R: SNIP Reply middle frame
37.614: [[19828031] 03 00                  ]  R: 03.00.00.00.00.01 - 09.00.99.03.00.35
    ProtocolSupportInquiry with no payload
37.615: [[19a08300] 30 31 31 2E 30 30 00 02]  R: SNIP Reply middle frame
37.617: [[19a08300] 30 31 54 43 53 20 43 53]  R: SNIP Reply middle frame
37.618: [[19a08300] 30 31 2D 31 30 35 2C 20]  R: SNIP Reply middle frame
37.619: [[19a08300] 30 31 53 2F 4E 20 30 30]  R: SNIP Reply middle frame
37.621: [[19a08300] 30 31 33 35 00 54 43 53]  R: SNIP Reply middle frame
37.621: [[19a08300] 30 31 20 43 6F 6D 6D 61]  R: SNIP Reply middle frame
37.623: [[19a08300] 30 31 6E 64 20 53 74 61]  R: SNIP Reply middle frame
37.624: [[19a08300] 20 31 74 69 6F 6E 00   ]  R: 09.00.99.03.00.35 - 03.00.00.00.00.01
    Simple Node Ident Info with content '4,Train Control Systems (TCS),CS-105,Rev E,1.00,2,
37.625: [[19a08300] 10 31 04 54 72 61 69 6E]  R: SNIP Reply 1st frame
37.626: [[19a08300] 30 31 20 43 6F 6E 74 72]  R: SNIP Reply middle frame
37.627: [[19a08300] 30 31 6F 6C 20 53 79 73]  R: SNIP Reply middle frame
37.628: [[19a08300] 30 31 74 65 6D 73 20 28]  R: SNIP Reply middle frame
37.630: [[19a08300] 30 31 54 43 53 29 00 43]  R: SNIP Reply middle frame
37.631: [[19a08300] 30 31 53 2D 31 30 35 00]  R: SNIP Reply middle frame
37.632: [[19a08300] 30 31 52 65 76 20 45 00]  R: SNIP Reply middle frame
37.634: [[19a08300] 30 31 31 2E 30 30 00 02]  R: SNIP Reply middle frame
37.634: [[19a08300] 30 31 54 43 53 20 43 53]  R: SNIP Reply middle frame
37.635: [[19a08300] 30 31 2D 31 30 35 2C 20]  R: SNIP Reply middle frame
37.636: [[19a08300] 30 31 53 2F 4E 20 30 30]  R: SNIP Reply middle frame
37.637: [[19a08300] 30 31 33 35 00 54 43 53]  R: SNIP Reply middle frame
37.638: [[19a08300] 30 31 20 43 6F 6D 6D 61]  R: SNIP Reply middle frame
37.639: [[19a08300] 30 31 6E 64 20 53 74 61]  R: SNIP Reply middle frame
37.640: [[19a08300] 20 31 74 69 6F 6E 00   ]  R: 09.00.99.03.00.35 - 03.00.00.00.00.01
    Simple Node Ident Info with content '4,Train Control Systems (TCS),CS-105,Rev E,1.00,2,
37.641: [[19668300] 00 31 54 58 00 00 00 00]  R: 09.00.99.03.00.35 - 03.00.00.00.00.01
    ProtocolSupportReply with payload 54 58 00 00 00 00
```

Figure 18: CS-105 SNIP, SNIP, PIP reply packet sequence.

```
05.502: [[19de8031] 0A 20                  ]  R: 03.00.00.00.00.01 - 02.01.12.FE.E6.6D
    SimpleNodeIdentInfoRequest with no payload
05.503: [[19de8031] 0A 20                  ]  R: 03.00.00.00.00.01 - 02.01.12.FE.E6.6D
    SimpleNodeIdentInfoRequest with no payload
05.504: [[19a08a20] 10 31 04 4A 4D 52 49 00]  R: SNIP Reply 1st frame
05.505: [[19a08a20] 30 31 50 61 6E 65 6C 50]  R: SNIP Reply middle frame
05.506: [[19a08a20] 30 31 72 6F 00 4D 79 20]  R: SNIP Reply middle frame
05.507: [[19a08a20] 30 31 4A 4D 52 49 20 52]  R: SNIP Reply middle frame
05.508: [[19a08a20] 30 31 61 69 6C 72 6F 61]  R: SNIP Reply middle frame
05.509: [[19828031] 0A 20                  ]  R: 03.00.00.00.00.01 - 02.01.12.FE.E6.6D
    ProtocolSupportInquiry with no payload
05.510: [[19a08a20] 30 31 64 00 35 2E 37 2E]  R: SNIP Reply middle frame
05.511: [[19a08a20] 30 31 34 70 6C 75 73 2B]  R: SNIP Reply middle frame
05.512: [[19a08a20] 30 31 6A 61 6B 65 2B 32]  R: SNIP Reply middle frame
05.513: [[19a08a20] 30 31 30 32 34 30 00 02]  R: SNIP Reply middle frame
05.514: [[19a08a20] 20 31 00 00            ]  R: 02.01.12.FE.E6.6D - 03.00.00.00.00.01
    Simple Node Ident Info with content '4,JMRI,PanelPro,My JMRI Railroad,5.7.4plus+jake+20
05.515: [[19a08a20] 10 31 04 4A 4D 52 49 00]  R: SNIP Reply 1st frame
05.516: [[19a08a20] 30 31 50 61 6E 65 6C 50]  R: SNIP Reply middle frame
05.517: [[19a08a20] 30 31 72 6F 00 4D 79 20]  R: SNIP Reply middle frame
05.518: [[19a08a20] 30 31 4A 4D 52 49 20 52]  R: SNIP Reply middle frame
05.519: [[19a08a20] 30 31 61 69 6C 72 6F 61]  R: SNIP Reply middle frame
05.520: [[19a08a20] 30 31 64 00 35 2E 37 2E]  R: SNIP Reply middle frame
05.521: [[19a08a20] 30 31 34 70 6C 75 73 2B]  R: SNIP Reply middle frame
05.523: [[19a08a20] 30 31 6A 61 6B 65 2B 32]  R: SNIP Reply middle frame
05.524: [[19a08a20] 30 31 30 32 34 30 00 02]  R: SNIP Reply middle frame
05.524: [[19a08a20] 20 31 00 00            ]  R: 02.01.12.FE.E6.6D - 03.00.00.00.00.01
    Simple Node Ident Info with content '4,JMRI,PanelPro,My JMRI Railroad,5.7.4plus+jake+20
05.526: [[19668a20] 00 31 04 10 00 00 00 00]  R: 02.01.12.FE.E6.6D - 03.00.00.00.00.01
    ProtocolSupportReply with payload 04 10 00 00 00 00
```

Figure 19: JMRI SNIP, SNIP, PIP reply packet sequence.

```
45.836: [[19de8031] 05 41                  ]  R: 03.00.00.00.00.01 - 02.01.57.00.04.9D
    SimpleNodeIdentInfoRequest with no payload
45.837: [[19de8031] 05 41                  ]  R: 03.00.00.00.00.01 - 02.01.57.00.04.9D
    SimpleNodeIdentInfoRequest with no payload
45.838: [[19828031] 05 41                  ]  R: 03.00.00.00.00.01 - 02.01.57.00.04.9D
    ProtocolSupportInquiry with no payload
45.839: [[19a08541] 10 31 04 52 52 2D 43 69]  R: SNIP Reply 1st frame
45.840: [[19668541] 00 31 D4 18 20 00 00 00]  R: 02.01.57.00.04.9D - 03.00.00.00.00.01
    ProtocolSupportReply with payload D4 18 20 00 00 00
45.841: [[19a08541] 30 31 72 4B 69 74 73 2C]  R: SNIP Reply middle frame
45.842: [[19a08541] 30 31 20 49 6E 63 2E 00]  R: SNIP Reply middle frame
45.843: [[19a08541] 30 31 54 6F 77 65 72 2D]  R: SNIP Reply middle frame
45.844: [[19a08541] 30 31 4C 43 43 00 72 65]  R: SNIP Reply middle frame
45.846: [[19a08541] 30 31 76 2D 44 00 72 65]  R: SNIP Reply middle frame
45.847: [[19a08541] 30 31 76 2D 43 37 65 00]  R: SNIP Reply middle frame
45.848: [[19a08541] 30 31 02 5A 69 6F 6E 45]  R: SNIP Reply middle frame
45.849: [[19a08541] 30 31 20 74 75 72 6E 6F]  R: SNIP Reply middle frame
45.850: [[19a08541] 30 31 75 74 73 20 31 73]  R: SNIP Reply middle frame
45.851: [[19a08541] 30 31 74 20 32 34 2D 30]  R: SNIP Reply middle frame
45.852: [[19a08541] 30 31 31 2D 30 34 00 54]  R: SNIP Reply middle frame
45.853: [[19a08541] 30 31 75 72 6E 6F 75 74]  R: SNIP Reply middle frame
45.854: [[19a08541] 30 31 20 6F 77 6E 65 72]  R: SNIP Reply middle frame
45.856: [[19a08541] 20 31 2E 20 54 57 52 00]  R: 02.01.57.00.04.9D - 03.00.00.00.00.01
    Simple Node Ident Info with content '4,RR-CirKits, Inc.,Tower-LCC,rev-D,rev-C7e,2,ZionE
```

Figure 20: TowerLCC SNIP, SNIP, PIP reply packet sequence.

```
37.712: [[19de8031] 08 1C                  ]  R: 03.00.00.00.00.01 - 02.01.2C.01.09.00
               SimpleNodeIdentInfoRequest with no payload
37.713: [[19de8031] 08 1C                  ]  R: 03.00.00.00.00.01 - 02.01.2C.01.09.00
               SimpleNodeIdentInfoRequest with no payload
37.714: [[19828031] 08 1C                  ]  R: 03.00.00.00.00.01 - 02.01.2C.01.09.00
               ProtocolSupportInquiry with no payload
37.715: [[19a0881c] 10 31 04 53 50 52 4F 47]  R: SNIP Reply 1st frame
37.716: [[1906881c] 00 31 20 00 0D E8      ]  R: 02.01.2C.01.09.00 - 03.00.00.00.00.01
               OptionalInteractionRejected with payload 20 00 0D E8
               Optional Interaction Rejected for MTI 0xDE8 code 0x2000
37.717: [[19a0881c] 30 31 20 44 43 43 20 4C]  R: SNIP Reply middle frame
37.718: [[1966881c] 00 31 54 58 20 00 00 00]  R: 02.01.2C.01.09.00 - 03.00.00.00.00.01
               ProtocolSupportReply with payload 54 58 20 00 00 00
37.719: [[19a0881c] 30 31 74 64 00 53 45 52]  R: SNIP Reply middle frame
37.720: [[19a0881c] 30 31 56 4F 49 4F 2D 4C]  R: SNIP Reply middle frame
37.721: [[19a0881c] 30 31 43 43 00 31 2E 30]  R: SNIP Reply middle frame
37.722: [[19a0881c] 30 31 00 31 2E 35 00 02]  R: SNIP Reply middle frame
37.723: [[19a0881c] 20 31 00 00            ]  R: 02.01.2C.01.09.00 - 03.00.00.00.00.01
               Simple Node Ident Info
               with content '4,SPROG DCC Ltd,SERVOIO-LCC,1.0,1.5,2,,,'
```

Figure 21: SERVOIO-LCC SNIP, SNIP, PIP reply packet sequence.

5 Summary

The TCS CS-105 and JMRI PanelPro with LCC Buffer-USB have millisecond-scale delays between receipt of a request and the start of a reply, which can allow additional requests to arrive before the first reply is sent. Both of these rely on deep buffers to handle this. They both send the frames of an individual reply at line speed, preventing a lower-priority request from arriving during the reply.

The RR-CirKits Tower-LCC replies in less than one frame time, allowing only one additional request to arrive before the reply starts. It has short additional delays between the frames of the response, which can allow lower priority requests to arrive and need buffer space during the reply. In the extremely unlikely case of three requests arriving within a few milliseconds, one of them would be lost.

The SPROG DCC Ltd. SERVOIO-LCC replies about a millisecond after receipt of a request. It sends the frames of an individual reply at line speed, preventing a lower-priority request from arriving during the reply. Instead of buffering multiple SNIP requests, the SERVOIO-LCC rejects additional overlapping SNIP requests with an Optional Interaction Rejected (OIR) message that should trigger a retry of the interaction.

The implications of this for the Events-with-Payload protocol update need to be examined carefully.