Jitter, Wander, and Time Lock of ST 2110 Video Streams

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Introduction
Who I am

- **Koji Oyama**
  - Working for Business Development over 10+ yrs, Used to be an LSI design engineer for 10 yrs

- **M3L Inc.** (株式会社メディアリンクスエルエスアイラボ)
  - [http://www.m3l.co.jp/en/](http://www.m3l.co.jp/en/)
  - Found : April 1997
  - President : Kenji Fukuda
  - Office : Kawasaki, Japan
  - Employees : 10
  - SMPTE and VSF member

  - **Independent IP-Core Design Company**
    - IP Core: Reusable logic design blocks ([See Wiki](https://en.wikipedia.org/wiki/Independent_IP-Core_Design_Company))
    - Mission: Speedy & High Quality, Vision: Pursue ideal IP cores

  - **Value: 15+ years Experience** with Professional Video Over IP technology

This Presentation Helps You

- know what happens inside your ST 2110 and ST 2059 function cores
- understand your ST 2110 and ST 2059 features, characteristics, and performance
- know what the difference between SDI and ST 2110 + ST 2059 IP-based technology
You can know them w/videos and numbers

1. Jitter / Wander
   Sender
   Receiver
   Parameters
   What happens?
   Recovering Clock
   ST 2110 ST 2059

2. Time Lock
   Receiver
   Connect
   ST 2110 ST 2059
   Recovering Clock

SDI and ST 2110 + ST 2059

SDI-based Network
- Shorter distance because of coax cables
- Peer to peer connection
- Timing Jitter Requirement
  3G-SDI/12G-SDI: < 2UI

UI := minimum time interval between condition changes of a data transmission signal
UI = 0.333 ns / baud @ 3Gb/s (3G-SDI)
UI = 0.083 ns / baud @ 12Gb/s (12G-SDI)

IP-based Network
- Longer distance because of optical cables
- n to n connection
- Lock-time Requirement
  5 sec @1 μS PTP offset

Low Latency
↓↑ tradeoff
Buffer Size
(overflow/underflow)

GPS
Clock
PTP (ST 2059)
Clock Recovery

Curated by Video Services Forum vsf.tv
Advance Information

• So that you don’t get confused

• The jitter and wander I mention are NOT PTP jitter and wander
  – But timing jitter and phase shift of a reproduced video and SDI signals

• These jitter and wander depend on each implementation
  – Numbers in this presentation are just an example of our implementation
  – ST 2110 and ST 2059 standards have no numbers regarding jitter, wander, and lock time

• Such numbers may be criteria for network system reliability
Jitter / Wander

What Jitter and Wander are

• What’s Jitter?
  – the short-term (<1sec) variations of the significant instants of a digital signal from their ideal positions in time

• What’s Wander?
  – the long-term (>=1sec) variations of the significant instants of a digital signal from their ideal positions in time

Quoted from http://users.rcn.com/wpacino/jitwtutr/jitwtutr.htm
What is ST 2059 PTP synchronization for?

- To achieve less data buffering ➔ **Low Latency**
  - Reasonable adjustment by feedback control
    ➔ Some jitter and wander are good to prevent resonance
    ➔ Basically, lower jitter and wander, better quality of reproduction on a receiver

Quoted from [http://users.rcn.com/wpacino/jitwtutr/jitwtutr.htm](http://users.rcn.com/wpacino/jitwtutr/jitwtutr.htm)

Video: 4K/UHD ST-2110 over 25GbE transmission
Timing Jitter for 12G-SDI over 25GbE

Timing Jitter for 3G-SDI over 10GbE
Timing Jitter Comparison

12G-SDI/25GbE vs 3G-SDI/10GbE w/L2 Switches

12G-SDI over 25GbE

3G-SDI over 10GbE

Wander for 12G-SDI over 25GbE
Wander for 3G-SDI over 10GbE

![Graph showing wander for 3G-SDI over 10GbE](image)

Wander Comparison

![Graph comparing 12G-SDI/25GbE vs 3G-SDI/10GbE with L2 switches](image)
Jitter and Wander Results

- Too few PTP interval could make jitter and wander worse
- The default value of PTP interval $2^{-3}$ (8Hz) in ST 2059 would be good
  - Most vendors would adjust the default value to be optimal
- It has 15-sec period of phase shift btw sending SDI and received SDI signal

Time Lock
Lock-time Evaluation Scenarios

**Scenario A**
- **Media Node (Receiver) Connection**
- **Fiber Cable Connected**
- **Video Out (Ether PHY Linked)**
- **Start PTP Locking**
- **PTP Locked**
- **Jitter Stable**

**Scenario B**
- **GM Lost & Reconnection**
- **12G-SDI(2160/59.94p)**
- **3G-SDI(1080/59.94p)**
- **FPGA Eva Board**
- **Xilinx FPGA**
- **M3L 2110**
  - **Egress Core**
  - **SFP28 / SFP+**
  - **Xilinx KCU116**
- **M3L 2059**
  - **Slave Core**
  - **SFP28 / SFP+**

**Analysis / Monitor**
- **Phabrix Qx12G**
- **12G-SDI / 3G-SDI**
- **BB**
- **Arista 7280SE-68 (10G)**
- **Mellanox SN2010 (25G)**

**Video: Lock-time Scenario A example**

**Fiber Cable**
- **Connected**
- **Video Out**
  - (Ether PHY Linked)
- **Start PTP Locking**
- **PTP Locked**
- **Jitter Stable**

**Video Timing & System Reference**
- **SDI A vs System Reference**
- **SDI A Co-Timing**
- **Initial LLDE**
- **Locked SDI A**
- **A100kHz / 10kHz**
- **A725mV / 40ps**
- **A1725mV / 10ps**
Lock-time for 12G-SDI over 25GbE w/8Hz PTP

PTP offset
= slave clock time – master clock time
= Receiver current time – GM time

PTP-is-locked does not mean that jitter of video/audio clock is stable

Scenario A Comparison: 25GbE vs 10GbE

• Similar results
  • except for Ether-PHY-Linked and Start-PTP-Locking
  • It depends on switches
Scenario A Comparison: PTP Sync Interval

- Less PTP sync interval needs longer PTP lock and jitter stable time

Option 1: 26s PTP sync interval
- Fiber Connected
- Ether PHY Linked
- Start PTP Locking
- PTP Locked
- Jitter Stable
- Time: 21.5s
- Time to PTP Locked: 23.0s
- Time to Jitter Stable: 26.0s

Option 2: 22.9s PTP sync interval
- Fiber Connected
- Ether PHY Linked
- Start PTP Locking
- PTP Locked
- Jitter Stable
- Time: 22.9s
- Time to PTP Locked: 7.0s
- Time to Jitter Stable: 11.5s

Video: Lock-time Scenario B example #1
Lock-time Scenario B result #1

- No Error
- 0.333μS/49 pixels
- PTP Relocked
- Jitter Stable
- 4s
- 5s

GM Lost
GM Reconnected
Start PTP Locking
PTP Relocked
Jitter Stable

Video: Lock-time Scenario B example #2

- GM Lost
- GM Reconnected
- Start PTP Locking
- PTP Relocked
- Jitter Stable
Lock-time Scenario B result #2

- **Jitter Errors**
- **GM Lost**
- **GM Reconnected**
- **Start PTP Locking**
- **Jitter Stable**
- **PTP Locked**
- **0.496μS/73 pixels**
- **4s**
- **2s**
- **10.0s**

Lock-time Scenario B result #3

- **Jitter Errors**
- **PTP Errors**
- **GM Lost**
- **GM Reconnected**
- **Start PTP Locking**
- **Jitter Stable**
- **1.035μS/153 pixels**
- **4s**
- **3s**
- **2s**
- **13.5s**
Time Lock Results

• Scenario A: New Media-Node Connection:
  – PTP-is-locked does not mean that jitter of video/audio clock is stable
  – Jitter-stable times for 10GbE and 25GbE are similar
  – Less PTP sync interval needs longer PTP-lock and Jitter-stable time

• Scenario B: GM-lost & Reconnection:
  – There are 3 types of recovery for GM-lost & Reconnection
    1. Recover without an error
    2. Reconnect with jitter errors
    3. Reconnect with PTP and jitter errors

Conclusion

• You saw some examples for jitter/wander and time lock
• You understood more of ST 2110 and ST 2059 features

• I highly recommend measuring the actual number of your own products because it depends on their implementations
• Knowing the actual number of signal qualities will be better knowledge for controlling the reliability of your IP-based networks
• Hope this presentation helps your work
Thank you

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