HDMI: How a Nerdy Serial Link Became a Household Name

Jano Banks
Consultant, Angel Investor, and HDMI Co-Inventor
September 12, 2023
3 Stories

- Invention Motivation
- Mr. Hollywood
- Let’s Get Physical
Who the heck is Jano Banks?

- Retired from *Big Tech* in 2023!
  - Angel Investor, Recently became a Grandfather!
- Stanford: BS, MS Electrical Engineering
- **Apple**: *Mac Systems, ASIC Designer*
  - DVDO, Inc.
  - **Silicon Image, Designer/Manager, HDMI**
  - Co-Founder, CEO, Radiient Technologies
- **Amazon Lab126**: Sr. Mgr, Principal Engr, FireTV
- **Apple**: HW Director, AppleTV
- **Google**: HW Director, Nest
Who the heck was Silicon Image?

- 1995: David Lee, Co-founded Silicon Image with D.K. Jeong
  - Xerox PARC researchers, Seoul National University/KAIST Ph.D.s
  - TMDS - Transition-minimized differential signaling (!)
    - “PanelLink” goes head-to-head with LVDS

- 1999: DVI introduced for Computer Monitors, Display Working Group
  - Silicon Image goes Public (SIMG)!
- 2000: Silicon Image acquires DVDO, Inc.

- 2002: HDMI introduced for TVs, Consumer Electronics STBs, HDMI, LLC
  - 2015: Silicon Image acquired by Lattice Semiconductor for $600M
HDTV - Greatest Technology held hostage by Engineers!

- 1927 TV invented. 1953 Color TV introduced. 480i, Analog
- 1996 DVD introduced. SD, 480i. Digital format. Analog transport.
- 1998 HDTV introduced. HD, 720p/1080i.
- Consumers: Flat Screens, Digital - Let’s Go!
  - Engineers: CRTs, Analog - Let’s Stay :-(
- David Lee goes on the road
  - DVI: Digital Interface for TVs. Time to Go Digital
    ■ CE companies NOT interested in Computer standard
    ■ And, it MUST have audio, too!
- “I’m sure we can do it. Use the blanking period. Should work ... theoretically.”
Story #1: Invention Motivation

“Invention is a process; you don’t get there overnight.”

Louis Foreman
Sony and Panasonic throw down the gauntlet

- 2001 Worldwide Competition for the New Digital Interface for CE
- Has to do both Video AND AUDIO, and without audible errors
  - BER of TMDS: $< 10^{-14}$. No Problem for Video.
  - BER requirement for Audio: $< 10^{-17}$ or, whatever it takes so it doesn’t pop
- Competitors
  - Panasonic
  - BGT
  - ... and Silicon Image!
- Working Demo in Tokyo set for September 2001
Working(?) Demo

- 2 prototype systems, FPGA-based. 1 for Japan, 1 for Development
- Time to fly to Japan for the Working Demo ... but it’s NOT working!
  - Paul Heninwolf, Technical Marketing, to Japan with **popping** system.
  - Seung Ho Hwang, Jano Banks, Al Scalise keep working in Sunnyvale
  - Evening comes ... still not working! Let’s get some sleep ...
- David calls Seung Ho at home at 11pm ...
  - Seung Ho can’t sleep ... Think, Think, Think
  - Signal Integrity, Long Cables, Electrical Layer ...
  - Japanese are testing with multiple short cables!
  - Use your genius: Mathematician, Signal Processing, Encoding Theory ...
The Next Morning

- 2am Epiphany!
  - 5am Seung Ho calls Jano at home - come to the office
  - It’s the Encoding. Using all 256 codes will never be $< 10^{-17}$ BER
  - Cherry-picked the best 8 codes. I’m sure it’ll work!
- Jano: “Wow, awesome ... but we need 4 bits ...”

- Jano: “What did David say to you last night?”
- Seung Ho: “You need to invent something ... by tomorrow”
- Jano: “I think you did. Let’s Go!”
Race Against Time

- I coded it up
- Al verified it
- Seung Ho found 8 more codes ...

- And it WORKED!
- And we WON!

Invention Motivation:

- An “encouraging” conversation from the CEO at 11pm never hurts!
OK, we won, now what?

- Write a standard
- Get Hollywood to agree
- And design the chips, too!

- Oh, and the Early 2000s Recession is upon us, after the first Internet Boom
  - Silicon Image stock goes from $63.25 in Feb. 2000 to $1.32 in Oct. 2001
  - “Lucky to have a job - let’s get to work!”
Story #2: Mr. Hollywood
It’s the Content, Stupid

- By now, tech working, chips in progress, standard being written …
- … but Hollywood is afraid of Digital!
- Whatever we need to do to get Hollywood to agree …
- MUST PROTECT THEIR CONTENT!

- Enter Brett Gaines, a.k.a. …
  
  Mr. Hollywood
  
  The Deal Maker
Why was Hollywood afraid of Digital?

- Petrified HD content copied, digitally, perfectly. $$$$$
- Content Protection Technical Working Group (CPTWG) created
  - Hollywood Studios, Intel Architecture Labs
  - Use FireWire (IEEE-1394) with DTCP
    - Compressed
- Interim solution: DVI with HDCP
  - Hollywood: Uncompressed - if encryption compromised, hard to store
  - Typical Computer solution - DVI kitchen sink - dual link, analog, large/ugly connector
  - Hollywood didn’t want analog because it’s recordable, not encryptable
    - Compromise: Hollywood content ONLY over DVI (Digital) with HDCP, not analog
Enter Japan, with Hollywood wanted CE Solution

- To date, VCR (VHS) and DVD - SD (4:3, SD, 480i)
- Hitachi leader: VCR was big, HD even bigger!
- Transition to HD = Sell new TVs, Big Screens - HD (16:9, HD, 720p/1080i)
- Hollywood more compelling content - HD, advanced Audio
- HD-DVD, Blu-Ray - HD and Audio digitally to the TV over a cable
- Needs
  - Smaller, easy-to-use, attractive connector
  - YUV, not RGB (OK, both)
  - **AND IT MUST ALSO CARRY AUDIO!!!**
  - And be content protected
- Solution: HDMI with HDCP
But it wasn’t easy gaining agreement ...

- Back to CPTWG …
- Andy Setos, Fox rep, thought leader for studios
- Conference Call: Brett, Andy, Brendan Traw, Intel DCP
- One (small) technical policy point
  - If HDCP couldn’t authenticate, channel left open
  - Allows “helpful” user messaging
- Andy flipped out
  - “What the F were you guys thinking?!!! This breaks everything!”
Brett - The Deal Maker

- Silicon Image non-threatening, between Hollywood, Japan, Intel
- HDCP out in the wild, already on DVI
- Go beyond tech spec - licensing model, legal deterrents
  - Enforcement at the Display. If authentication failed, block Source signal
  - Revocation of keys - public shaming
  - Compliance, Compatibility, HDMI Logo badge
- After a few extra months, Andy on board, the rest followed
- Later, HDCP criticized, not the greatest encryption, but didn’t matter
  - Legal deterrents in licensing agreement had teeth
Story #3: Let’s Get Physical
The TWG

- HDMI Spec Editor, Paul Heninwolf: “The Father of HDMI”
- HDMI Technical Working Group (TWG)
  - 7C = 4 from Japan (HMST)
  - 1 US (Thomson/RCA)
  - 1 Europe (Philips)
  - 1 Technology Contributor (Silicon Image)
- Matsushita (Panasonic) rep spoke for the Japanese
- Epic battles over the English Language
- Who made the proposal mattered
- Backroom strategizing needed, even for seemingly trivial items
Temperatures Rising

- Paul and Panasonic Rep butted heads, repeatedly
  - Seung Ho dispatched to Japan to explain communications, BER
  - David appealed to Panasonic Management, bring in some help
- The chips, products were getting ready for the launch ...

- But the Spec wasn’t resolving!
  - Every word, every comma, every bug fix ... epic battle
- When Paul pre-conditioned other 3 Japanese reps ...
  - ... they would side with Panasonic at the meeting
Oops

- We found a bug in the chips, both Tx and Rx
- 1 control bit, polarity flipped vs. the Spec

- Jano: “Tell them it’s all my fault. Change the spec, not the chips.”

- Paul: “Yeah, they like you … but I have to sell this to the Panasonic rep!”
- Jano: “Good luck. I know you can pull it off 😁”
The Last Straw

- Paul had trashed his knee skiing
- Walking with a cane, flies to England, final(?) Spec meeting
- 2nd floor, conference room, huge plate of shrimp
- Pre-conditioned others, but did not with Panasonic
- Paul makes light of the “trivial” change, Jano’s fault.
- Heads nodding yes. Panasonic rep shakes his head no.
- Launch is at risk, future of HDMI as well ...

- What will Paul do?
Any way to get agreement!
Introductions

David Lee

Paul Heninwolf

Seung Ho Hwang

Brett Gaines
Q & A