

HDMI: How a Nerdy Serial Link Became a Household Name



Jano Banks

Consultant, Angel Investor, and HDMI Co-Inventor

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HDMI

HIGH-DEFINITION MULTIMEDIA INTERFACE

3 Stories

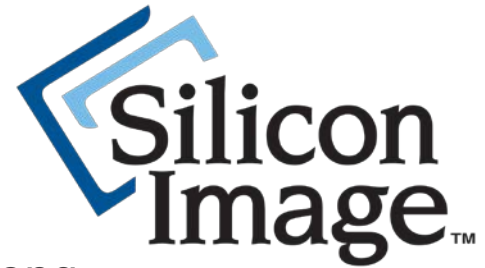
- Invention Motivation
- Mr. Hollywood
- Let's Get Physical

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.
- (2007: FHD, 1080p. 2010: UHD, 4K)
- 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

SONY

Panasonic



BROADCOM



**Silicon
Image**

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
- AI verified it
- Seung Ho found 8 more codes ...

- And it WORKED!
- And we WON!

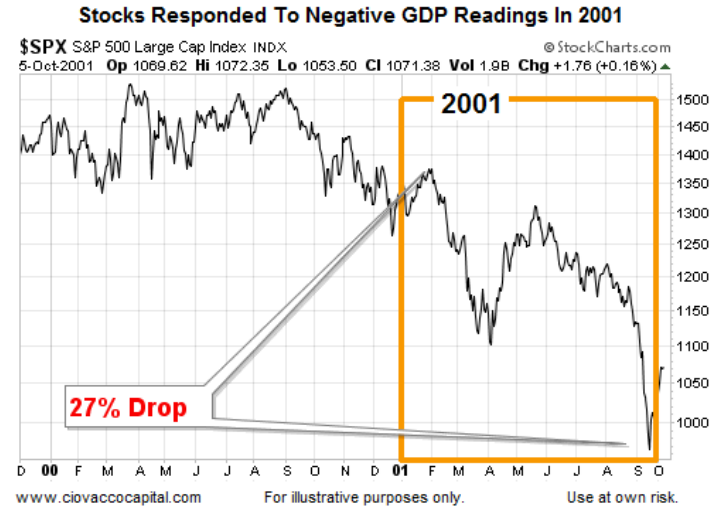
Invention Motivation:

- 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!”

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

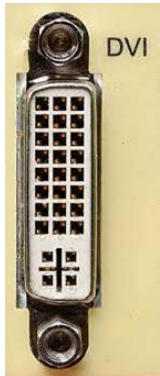
The Deal Maker



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!”*



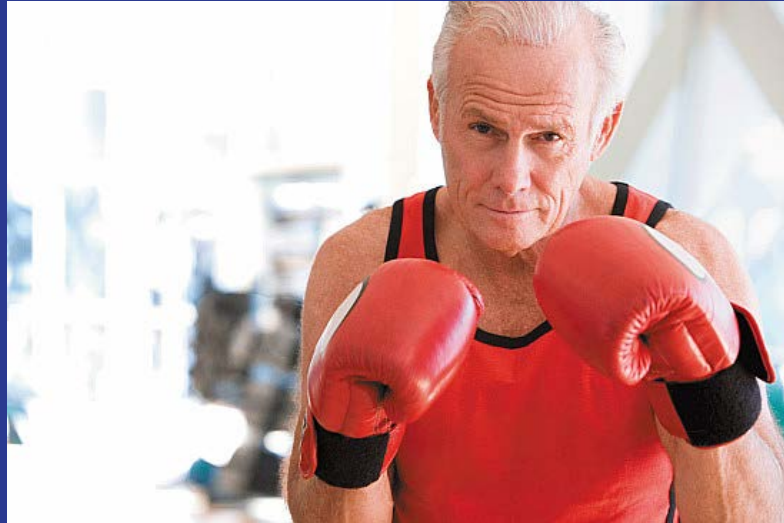
Brett - The Deal Maker



- 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

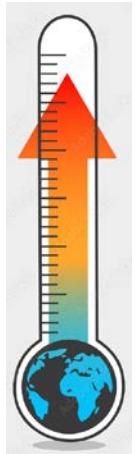
- HDMI Spec Editor, Paul Heninwolf: **“The Father of HDMI”**
- HDMI Technical Working Group (TWG)
 - 7C = 4 from Japan (HMST)
 - 1 US (Thomson/RCA)
 - 1 Europe (Philips)
 - 1 Technology Contributor (Silicon Image)
- Matsushita (Panasonic) rep spoke for the Japanese
- Epic battles over the English Language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



Temperatures Rising

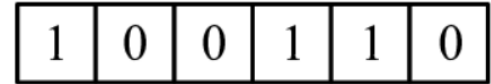
- Paul and Panasonic Rep butted heads, repeatedly
 - Seung Ho dispatched to Japan to explain communications, BER
 - David appealed to Panasonic Management, bring in some help
- The chips, products were getting ready for the launch ...

- 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

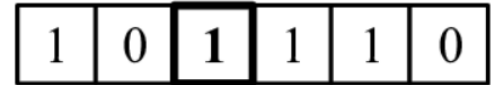


Oops

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



Bit-Flip



- 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 😊”

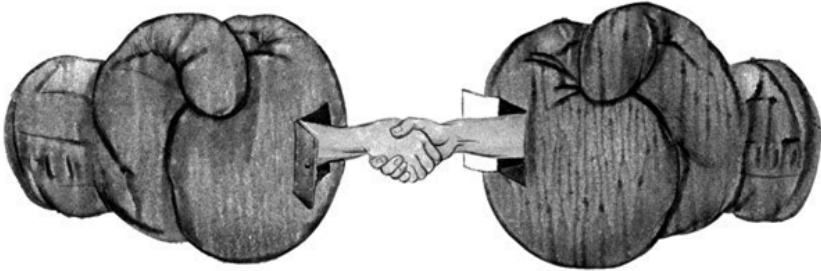
The Last Straw

- 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



Paul Heninwolf



David Lee



Seung Ho Hwang



Brett Gaines

Q & A

