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CINE-GT 3403
18 October 2018
Assignment 1

SDI: Serial Digital Interface

In "Digital Video: Are You 4:2:2 Compliant?" Extron Electronics VP of Engineering Steve Somers writes: "The Serial Digital Interface simplifies the connection and routing of component digital signals to one coaxial cable."[1] It's an interesting observation because like many production professionals I equate the serial digital interface with a cable, the coaxial cable with a BNC connector. But in actuality, SDI is so much more. Introduced in 1989, and defined by the SMPTE 259M standard, SDI has evolved into a family of digital video interfaces "used for transmission of uncompressed, unencrypted digital video signals."[2] It aids videotape digitization in two significant ways. Essential in understanding these benefits is examining the differences between serial and parallel data communication.

Serial vs Parallel

To appreciate how SDI works requires a general understanding of how serial data communication works and how it differs from parallel communication. Both methods are used and have advantages and disadvantages. In serial transmission, data is sent one bit at a time in sequential order over a single line. In parallel communication, eight bits (one byte) are sent together simultaneously over multiple lines.[3] Serial transmission is simpler; has better signal integrity; uses thinner, more economical cables; and is full duplex, meaning the sender can transmit and receive signals simultaneously. Parallel transmission is more complex; suffers from errors and noise; uses shorter, expensive cables in bundles; and is half duplex, meaning data is either sent or received. Serial bits contain their own clock pulse rate.[4] Parallel

[1]Steve Somers, "Digital Video: Are You 4:2:2 Compliant?" *Extron Resources—Digital Video*, 2018, extron.com/company/article.aspx?id=digvid&tab=tools.
[2] David Aleksandersen, "What is SDI?" *Datacon blog: News & Views*, May 3, 2018, newsandviews.dataton.com/what-is-sdi.
[3]"Difference Between Serial and Parallel Transmission," *TechDifferences*, April 12, 2016, techdifferences.com/difference-between-serial-and-parallel-transmission.html, and "Technology Dictionary," *Technopedia*, 2018, techopedia.com/dictionary.
[4] "Difference Between Serial and Parallel Transmission," *TechDifferences.*

communication utilizes a separate clock line which can sometimes result in clock skew.[5] However, parallel transmission boasts faster data transfer rates because it uses multiple lines simultaneously. As a result, while parallel is used for short distances, serial is considered the best option for long distance communication. And because of its reliability, data integrity, and lower cost, serial is the preferred mode of communication protocol.[6]

A serial interface, therefore, uses serial transmission to exchange digital information between two or more separate components. Again, the data is sent over a single wire and "encodes the bits of a binary number by their temporal location on a wire rather than their spatial location inside a group of wires" as a parallel interface does.[7] Serial interfaces can either be asynchronous—data not synchronized by a clock—or synchronous—the data stream is regulated by a synchronized clock on the receiver and sender ends.[8] Asynchronous interfaces use parity bits to indicate start and stop and alert the receiver about the arrival of new data. This makes the time interval random and unpredictable or variable. Synchronous interfaces transmit data in blocks or packets with control information inserted at the beginning and end of each block to ensure constant timing.[9] Synchronous transmission is therefore faster and more efficient. Serial digital video is synchronous because the receiver, synched with the sender, must be able to extract the sampling clock from data signal transitions in order to decode the video properly.[10]

A Brief History of the SDI Standard

By the late 1970s, the broadcast television sector had begun using some digital equipment, such as graphics generators and time base correctors, in the production workflow. However different manufacturers utilized different digital interfaces eliminating digital interoperability between. Instead

[5] "Technology Dictionary—Serial Communication," *Techopedia*, 2018, techopedia.com/definition/22010/serial-communication.
[6] "Technology Dictionary—Serial Communication," *Techopedia.*
[7] "Technology Dictionary—Serial Interface," *Techopedia*, 2018, techopedia.com/definition/9312/serial-interface.
[8] Guy Lewis and Michael Waidson, *A Guide to Standard and High-Definition Digital Video Measurements*, Tektronix, 2009, pg. 101, 103, tektronix.com/video_audio.
[9] Bathrayyan Rajagopalan, "Is there is difference between synchronous & asynchronous transmission and synchronous & asynchronous communication?" *Quora*, November 16, 2017, quora.com/Is-there-is-difference-between-synchronous-asynchronous-transmission-and-synchronous-asynchronous-communication.
[10] *A Guide to Standard and High-Definition Digital Video Measurements*, Tektronix, pg. 101, 103.

analog connections had to be used, which effectively forfeited the advantages of these digital devices. Recognizing the problem, the Society of Motion Picture and Television Engineers (SMPTE) began work on a digital interface standard. The result was 1979's *Composite Digital Television Standard*, which essentially digitized the NTSC waveform.[11] A sampling rate four times the color subcarrier (4fsc) produced 8-bit samples and specific digital values were assigned to the sync, blank, and white levels.[12] This standard would also resolve the digital interface dilemma.

However, around the same time, the European Broadcasting Union (EBU) decided to pursue a component digital video standard to resolve its PAL/SECAM issue (a component signal can be encoded as a composite signal of either).[13] This meant that equipment manufacturers would begin development of component digital video products. Recognizing that agreeing and adopting a worldwide digital interface standard served all concerned, SMPTE hit the pause button on composite digital coding while awaiting the results of the EBU's research. By 1981 consensus was reached amongst the SMPTE, the EBU, and NHK in Japan to adopt a new standard called SMPTE 125. Titled *Television ---- Component Video Signal 4:2:2 ---- Bit-Parallel Digital Interface*, SMPTE 125 outlined an 8-bit, 13.5 MHz system with 4:2:2 color sampling. The EBU generated its own similar standard and the two were combined to create ITU-R BT.601-2 in 1982. This document defined the 4:2:2 YCbCr component digital video interface standard for use in either a 525-line/60 Hz or 625-line/50 Hz system.[14] The actual physical parallel and serial interconnect specs are defined in ITU-R BT.656, which incorporates definitions from SMPTE 125M (parallel 525) and SMPTE 259M (serial 525).[15]

In 1981 engineers developed 601 component digital video around existing technological parameters, namely 8-bit samples transmitted on parallel interfaces. But even then, they recognized that

[11] Stanley Baron and David Wood, "Rec. 601—The Origins of the 4:2:2 DTV Standard," *EBU Technical Review,* October 2005, tech.ebu.ch/docs/techreview/trev_304-rec601_wood.pdf.
[12] "Extron Glossary of Terms." *Extron Resources—Library*, 2018, extron.com/technology/glossary.aspx.
[13] *EBU Technical Review,* October 2005.
[14] *EBU Technical Review,* October 2005.
[15] *A Guide to Standard and High-Definition Digital Video Measurements*, Tektronix, pg. 104.

10-bit sampling using serial transmission was optimal. In 1989, SD-SDI was introduced with SMPTE 259M. Titled *SDTV Digital Signal/Data - Serial Digital Interface,* the document's original intent was "to provide a serial digital connection between equipment replacing the parallel interface."[16] Specifically it describes a 10-bit serial digital interface that could carry uncompressed standard definition TV signals (480i and 576i) with four possible bitrates—143,177, 270, and 360Mbps. The standard "evolved to also carry formatted data within the defined payload areas."[17] The 270 Mbps rate is the NTSC/PAL standard and therefore the most widely used. HD-SDI (high-definition serial digital interface) was defined in 1998 by SMPTE 292M.[18] It defines two bitrates 1.485 Gbps and 1.485/1.001 Gbps for 720p and 1080i formats. The 1/1.001 factor allows HD-SI to support NTSC-compatible frame rates of 59.94, 29.97, and 23.98.[19] In total the SDI family currently encompasses eight standards up to 12G-SDI for 4K and 8K resolutions. The standard continues to evolve to support higher bitrates and frame rates and greater color fidelity.

Technical Makeup of SDI

The serial digital face defined by SMPTE 259M transmits standard definition video at 270 Mbps with video pixels "characterized with a 10-bit depth and 4:2:2 color quantization." HD-SDI defined in SMPTE-292M transits high-definition video at a 1.485 Gbps with 10-bit depth and 4:2:2 color sampling.[20] That means that the serial data format is 10-bits wide for SD and 20-bits wide for HD. The data-stream pattern for SD is Cb Y Cr Y', where Y is luminance, Y' is gamma-corrected luminance, and Cb and Cr are the color difference channels. The HD pattern is split into two parallel 10-bit streams, one of Y Y' and one of Cb Cr.[21] In SD, Y is encoded at 13.5 Mhz and chroma is subsampled horizontally and encoded at half bandwidth of 6.75 Mhz. In HD, Y is 75 MHz and chroma half that at 37.5 MHz.

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[16] *SDTV DigitalSignal/Data - Serial Digital Interface: SMPTE 259M*, White Plains, NY: The Society of Motion Picture and Television Engineers, 2002.
[17] *SMPTE 259M.*
[18] David Aleksandersen, "What is SDI?" *Datacon blog: News & Views*, May 3, 2018, newsandviews.dataton.com/what-is-sdi, and "Serial digital interface," *Wikipedia*, June 11, 2018 (last edited), en.wikipedia.org/wiki/Serial_digital_interface.
[19] ibids
[20] "Extron Glossary of Terms." *Extron Resources—Library*, 2018, extron.com/technology/glossary.aspx.
[21] "Serial digital interface," *Wikipedia*.

A line of digital video is divided between the Digital Active Line and Digital Line Blanking. Since the digital video payload is simply a series of binary numbers, or 10-bit words, a code can be assigned to denote both the Start of Active Video (SAV) and the End of Active Video (EAV). The space between EAV and SAV is the horizontal blanking interval. The space at the top of a field/frame and the active picture is the vertical blanking interval. Timing reference signals (TRS) are synch packets that contain flag bits H, V, and F that indicate the start of horizontal blanking, the start of vertical blanking, and an interlace or progressive format.[22]

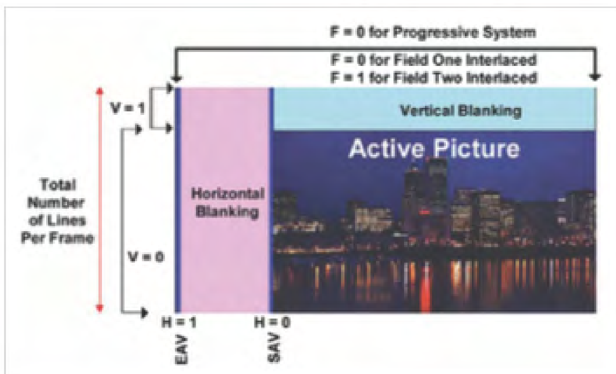

Image from Tektronix "Guide to Standard HD Digital Video Measurements," pg. 16.

The beauty is in the efficiency. Code space does not have to be used to replicate a repetitive event— blanking—as occurs with an analog signal. Instead the receiving system decodes the TRS information to reconstruct blanking and sync and the blanking intervals can be used for ancillary data, including audio, timecode, closed captions, line numbering, error checking data, and other metadata like VPID (video payload identifier) which describes the format.[23]

The transmission system employed by SDI involves multiple steps. A parallel stream of 4:2:2 digital component data is serialized into a single stream and sped up to move 10 bits per sample. The data stream is then scrambled and encoded using the NRZI (non-return to zero inverted) method. All of this

[22] *A Guide to Standard and High-Definition Digital Video Measurements*, Tektronix, pg. 11, and "Serial digital interface," *Wikipedia*.
[23] Steve Somers, "Digital Video: Are You 4:2:2 Compliant?" *Extron Resources—Digital Video*, 2018, extron.com/company/article.aspx?id=digvid&tab=tools.

helps to reduce the DC component on the signal and to facilitate recovery of the clock from the actual data transmission. The serial signal is sent over a coaxial cable with a BNC connector to the receiver where the process is reversed.[24]

Cables and Connectors

It should be noted that SMPTE 259M specifically denotes use of 75-ohm coaxial cables with BNC connectors. Coaxial cable is a type of shielded and insulated copper cable that employs two conductors in which one wraps around the other. The core wire is the primary channel and is surrounded by a plastic insulator, which in turn is covered by a braided copper/aluminum conducting shield. That layer is enclosed by an outer plastic or Teflon insulating jacket. The design prevents EM leakage outside the cable and protects the cable from external EM interference. As a result, the coax cable is excellent for carrying weak signals over great distances and was widely used in computer networks and for transmitting radio frequency (RF) signals.[25] The BNC (Bayonet Neill-Concelman) connector is a coaxial RF connector that replaces the standard one. The name is derived from its two inventors and its bayonet mount locking device, which locks into place. This close-fitting design reduces signal loss and makes it an ideal signal connector for SDI.[26]

SDI's Significance in Digitizing Videotapes

SDI factors into digitization in two significant ways. First, it simplifies the digitization process because one coaxial cable carries all the AV information plus metadata—video, audio, timecode, closed-captioning, format etc—which preservationists can then extract and document. Because of the accuracy

[24] Steve Somers, "HD-SDI: More Possibilities than Just Television," Extron Resources—Digital Video, 2018, extron.com/company/article.aspx?id=hdsdi_ts&tab=tools, and *A Guide to Standard and High-Definition Digital Video Measurements*, Tektronix, pg. 13.
[25] "Technology Dictionary—Coaxial Cable," *Techopedia*, 2018, techopedia.com/definition/15981/coaxial-cable, and "Coaxial Cable," *Wikipedia*, October 9, 2018 (last edited), en.wikipedia.org/wiki/Coaxial_cable.
[26] "Technology Dictionary—Bayonet Neill-Concelman Connector (BNC Connector)," *Techopedia*, 2018, techopedia.com/definition/727/bayonet-neill-concelman-connector-bncconnector.

and high fidelity of the serial interface, there is little to no generation loss or signal degradation during digitization. This also applies to analog signals that are transmitted via SD-SDI to a computer workstation. Whether using a deck with SDI output or an analog-to-SDI converter, the original quality of the analog signal is maintained better than using analog connections.[27] Taking advantage of a single direct connection, the signal-to-noise-ratio is reduced because there are less components in the signal chain. In addition, use of a precision digital video cables with their “tight tolerances” designed for SDI “makes them superb for analog applications.”[28] Lastly, because SDI is an industry standard that continues to be updated, it is not in danger of becoming an obsolete technology. Video production equipment is still being designed around the serial interface, and coax cables with BNC connectors are still in use and available.

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