

The Movie-2 Digital Audio/Video Expansion Bus

By Alain Legault and Janet Matey

The use of economical, general-purpose personal computers (PCs) in demanding professional video applications like nonlinear editing, graphics creation, animation recording, three-dimensional (3-D) rendering, video-on-demand, and commercial insertion continues to grow. In these applications, specialized PC adapters are typically used to handle the massive processing requirements for transporting natural data types in real time. Commonly used subsystems include video input/output (I/O), video processing (digital video effects [DVE-mixing]), video compression/decompression (codec), audio I/O, audio processing (equalization [EQ]-mixing), mass storage interface, network interface, and video-in-a-window console display. Although it is possible to accomplish some of these tasks with host central processing unit (CPU) software and a single highly integrated adapter, most professional systems require more than one adapter. How to connect these multiple video adapters together inside a PC is a question that system integrators have been wrestling with for many years. This paper examines the limitations of commercially available buses in these demanding broadcast video applications, proposes the Movie-2 bus as a high-performance open-architecture standard that overcomes these limitations, discusses the Movie-2 bus in detail, and finally, presents a model of a typical nonlinear editing platform as an example of system-level Movie-2 bus implementation.

Through the use of specialized adapters, economical general-purpose PCs can be used in demanding professional video applications like nonlinear editing, graphics creation, animation recording, 3-D rendering, video-on-demand and commercial insertion. Systems designers must provide the system bandwidth to handle the massive processing required for transporting natural data types in real time. The problem is essentially one of data rate considering that:

- A single ITU-R 601 4:2:2 digital video stream = 21 Mbytes/sec (32 Mbytes/sec with key bus 4:2:2:4).
- Eight 48-kHz 16-bit audio tracks = 768 kbytes/sec.
- A motion JPEG compressed digital video stream at Betacam quality = 6 Mbytes/sec.

Commonly used subsystem adapters include video I/O, video processing

(DVE mixing), video compression/decompression (codec), audio I/O, audio processing (EQ mixing), mass storage interface, network interface, and video-in-a-window console display. Although it is possible to accomplish some of these tasks with host CPU software and a single highly integrated adapter, most professional systems require more than one adapter. For example, a nonlinear editing system may require a codec card, a videographics card, a 3-D DVE unit, an audio processor, a console display, and mass storage and network interfaces (Fig. 1).

How to interface these multiple video adapters together inside a PC is a question that system integrators have been wrestling with for many years. Of course, the ideal solution is an open architecture that leads to a wide variety of different price/performance solutions from multiple vendors.

Exploring the Alternatives

There are two ways to deal with digital video data types—through the system host bus and through a dedicated bus architecture.

Host Bus Interfaces

Digital audio and video data can be

communicated through the system host bus, but with this approach the bus bandwidth needed by the video stream(s) must be shared with the other common host-CPU activities such as interfacing with the system hard disk controller (SCSI or integrated drive electronics [IDE]), the graphics display device (graphical user interface [GUI]), and the network interface controller (NIC). Where the bus bandwidth is insufficient to handle the demands placed on it, normal application response time diminishes, and/or the video stream breaks (Fig. 2).

ISA Bus

Industry-standard architecture (ISA) is clearly useless for professional video applications. Bandwidth is insufficient for uncompressed video or even high-quality compressed video data. Products using ISA can only communicate digital audio data over this bus.

Nu Bus, EISA, and MicroChannel

Nu bus, extended industry-standard architecture (EISA), and Micro-Channel (MC) have been used successfully by a number of vendors over the last five years to send compressed video and audio data between adapters. EISA and MC even have enough bandwidth theoretically to accommodate a full, uncompressed digital video stream interface. In practice, unfortunately, there is not enough bandwidth left for the rest of the application, which kills system performance.

The market is now demanding real-time A/B roll systems, lossless 13-Mbyte/sec compressed data streams, multiple audio tracks, powerful mass storage, high-performance graphics controllers, and local area network interfaces. Clearly, these buses aren't good enough anymore.

PCI Bus

At first glance, the advent of a peripheral component interconnect (PCI) bus with its 132 Mbyte/sec throughput would seem to be the perfect solution. A number of video chipsets are becoming

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THE MOVIE-2 DIGITAL AUDIO/VIDEO EXPANSION BUS

available that can send uncompressed digital video information over PCI. Rather quickly, however, video equipment manufacturers found PCI's limits. Here's why.

Although the theoretical speed of PCI is 132 Mbytes/sec, the effective bus bandwidth ranges between 40 and 80 Mbytes/sec, depending on the chipset used on the motherboard and various PCI implementation factors. In addition, fast disks, high-resolution desktop displays, and fast network cards require incremental bus bandwidth, leaving less bandwidth available to video adapters.

PCI transfers data by grouping the data into packets. Different agents alternately take control of the bus every 10 to 30 μ sec (depending on their latency times), leaving enough time to transfer only a small data packet (approximately 3,000 bytes) until the next transfer. Because video is synchronous, video data need to be fed continuously; the higher the quality of the video and the more simultaneous streams involved, the more difficult maintaining continuity becomes. This inherent incompatibility creates substantial hurdles for those who want to interface professional-quality video through PCI. To integrate the bus design, manufacturers must devise complicated interfaces that require application specific integrated circuit technology, first in-first out (FIFO) chips, and buffering. The result is longer development cycles, greater expense, and higher risk.

It has become clear that PCI can be used successfully to interface video adapters for some multimedia applications, but it is not ideal for professional video systems.

Expansion Buses

The alternative to commercial general-purpose buses are dedicated, over-the-top expansion buses. A few alternative proposals are available in the marketplace including video graphics array feature connector (VGA FC), Video Electronics Standards Association (VESA) advance feature connector (VAFC), VESA media channel (VMC), and Movie-2 bus (Fig. 3).

VGA FC

VGA FC, the first over-the-top expansion video bus used in PCs, is limited to 256 colors and has only one video bus and no audio support. It is of

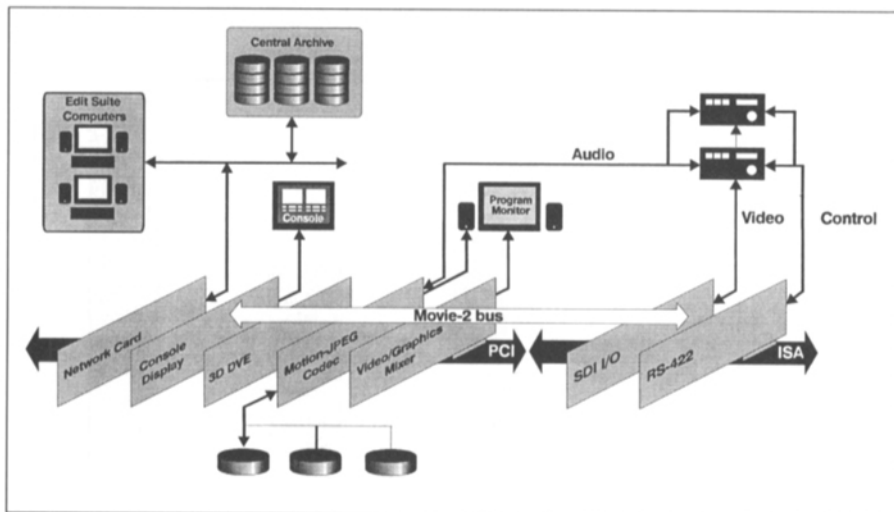


Figure 1. Typical PC-based multi-adapter nonlinear editing system configuration.

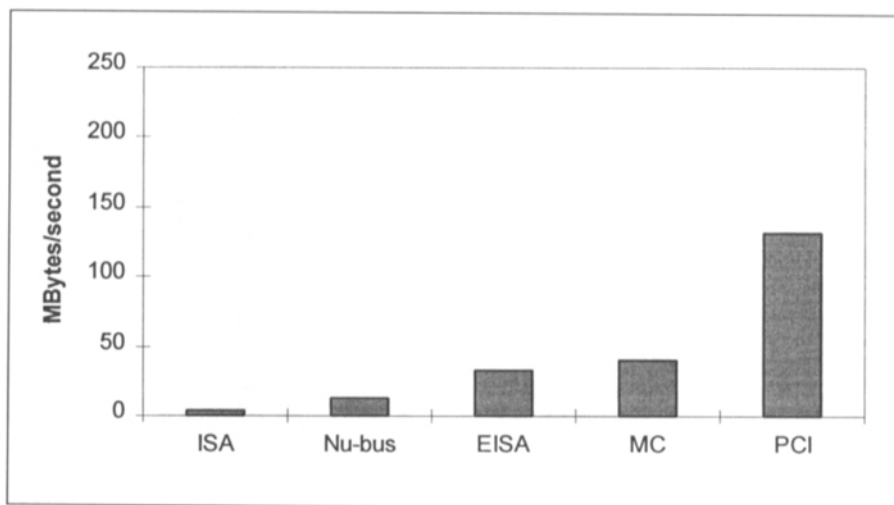


Figure 2. Maximum data throughput of various commercial buses.

no use for professional video applications.

VAFC

VAFC is an enhanced version of the VGA FC. It offers the ability to interface 32-bit RGB with alpha or luminance, chrominance components (YUV) without alpha, but still is limited to a single video channel and provides no audio support. Its primary application is in computer graphics.

VMC

VMC is closer to the needs of the professional video marketplace. It interfaces multiple video streams over a unified bus, similar to PCI. Video can be 32-bit RGB or YUV, and there is enough bandwidth for designers to implement an alpha channel and support for audio.

When it was initially proposed, VMC generated some interest, but it has not garnered many adherents because, like a PCI interface, it is complicated and costly to implement. In addition, since both VMC and PCI exchange data through packets, some of the same problems exist in this area as well. Systems designers ask, "If PCI and VMC accomplish the same task, in much the same way, why design the same solution twice?"

Matrox Movie-2 Bus

The broadcast and professional video industries have standardized on the ITU-R 601 specification. Virtually all video chipsets, board-level products, and systems adhere to the ITU-R 601 standard. This specification defines the video timings, the frequency of operation, and the

THE MOVIE-2 DIGITAL AUDIO/VIDEO EXPANSION BUS

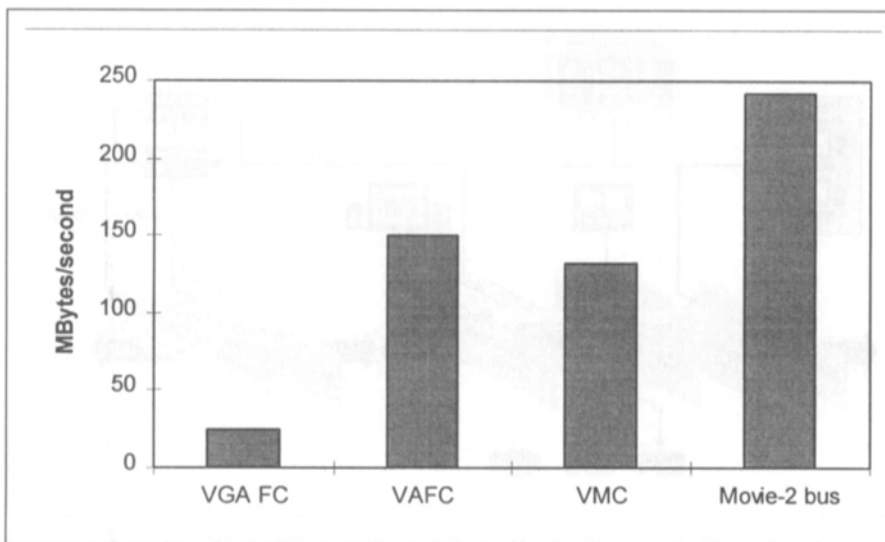


Figure 3. Maximum data throughput of various expansion buses.

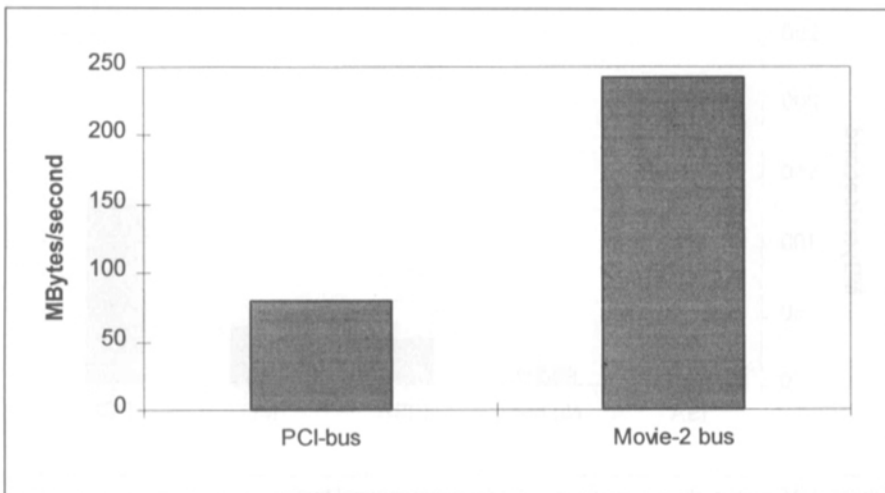


Figure 4. Effective bandwidth comparison.

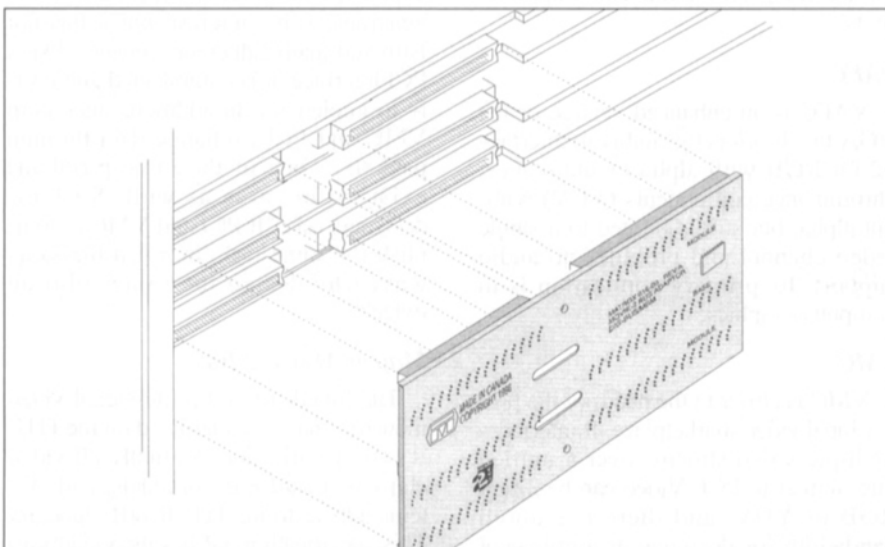


Figure 5. Passive PCB interconnects Movie-2 bus compatible adapters.

video data format needed to communicate digital video information. The Movie-2 bus has been designed around the ITU-R 601 standard. Because the Movie-2 bus was defined for demanding professional video applications, it uses synchronous parallel D-1 as the native video data format. Movie-2 features an uncompressed, 10-bit video bus architecture. These characteristics ensure a simple and inexpensive implementation for board designers.

The Movie-2 bus carries eight digital video buses, six digital key buses, and four serial digital audio buses for a constant data bandwidth above 242 Mbytes/sec, almost three times the effective bandwidth of PCI (Fig. 4).

The Movie-2 Bus Solution

The Movie-2 bus is an over-the-top expansion bus consisting of two high-density, right-angle connectors—CON 1 and CON 2—on the top edge of adapter cards (Fig. 5). CON 1 has 90 pins and CON 2 has 70 pins. Movie-2 bus-compliant audio/video adapters interface to each other through an over-the-top, passive printed circuit board (PCB) that connects to CON 1 and/or CON 2, depending on the adapter's function in the system. PCI, EISA, or ISA video adapters can use the Movie-2 bus.

CON 1 is used to provide video input and video output buses to/from a digital video mixer card, for example. CON 1 also provides master reference synchronization signals. CON 2 is used to interface with an optional video effects card (for example, a 3-D DVE generator). The connector provides the buses to send and return video and key signals from the DVE. CON 2 also provides the same master reference synchronization signals as CON 1.

CON 1 and CON 2 (Fig. 6) carry the following information:

- Eight independent ITU-R 601 8 or 10-bit uncompressed digital video buses in YUV 4:2:2 (parallel D-1).
- Six independent ITU-R 601 8-bit key buses.
- Eight tracks of serial digital audio data (AES/EBU and S/PDIF compatible).
- I²C Philips device control bus and other general purpose control signals.
- Video and audio timing reference signals.

From a video timing point of view, a video adapter on the Movie-2 bus can be

THE MOVIE-2 DIGITAL AUDIO/VIDEO EXPANSION BUS

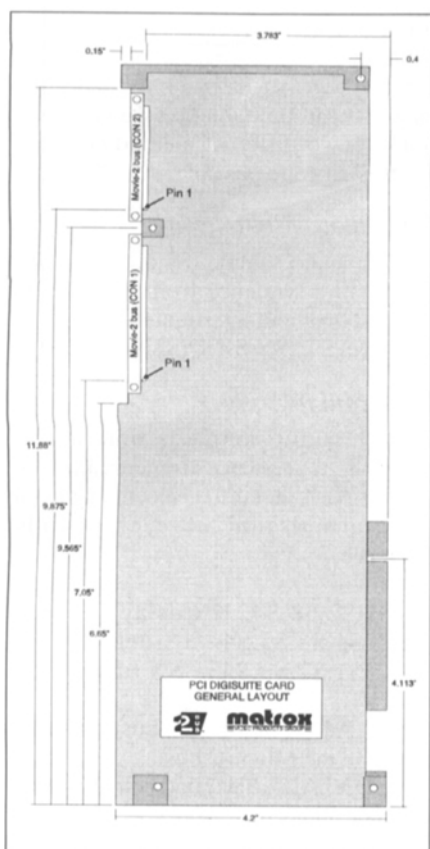


Figure 6. Mechanical positioning of Movie-2 bus connectors CON-1 and CON-2.

either a slave or a master agent. Only one master agent is allowed at a time. Typically, the video I/O board that is genlocked to the studio reference generates the master signals on Movie-2. The other adapters are slaved to the Movie-2 master.

From an audio timing point of view, there is always a master audio reference card, with any other audio devices slaved to it. The maximum number of audio cards is three: one master, one slave input, and one slave output. To allow proper synchronization between audio and video streams, the master audio reference clock must be locked on the video reference. Thus the audio system is slave of the video system.

Movie-2 Bus Functional Specifications

Eight video buses and six key buses carry the uncompressed digital video information between the Movie-2 adapters, in sync with the master video reference signal. The main time base uses the 27-MHz video clock. These buses are bidirectional, under software

control, to ensure flexibility in the bus operation. Probably the best analogy is to picture the bus as a very compact digital D-1 video router.

Video Bus Format

Video buses carry time-multiplexed data with a standard encoding of 4:2:2 in the form:

$$U_0, Y_0, V_0, Y_1, U_2, Y_2, V_2, Y_3 \dots$$

Note that the U_1 and V_1 values are not used in the 4:2:2 coding scheme.

- Y is the luminance signal encoded in 10 or 8 bits. If the data are encoded in 10 bits, then the black level is 64 and the white level is 940, giving 877 discrete values. The corresponding ITU-R 601 8-bit value is derived by using the 8 most significant bits.

- U corresponds to C_b and V to C_r (naming alternatives are $B-Y$ and $R-Y$). If data are encoded in 10 bits, the zero level is 512. The lower level is 64 and the highest level is 960. There are thus 897 levels available. As with Y , using the 8 most significant bits conforms to the ITU-R 601 specification.

The video is conveyed at 27-MHz time multiplexed in the above order. The parameters are as follows:

- Y at 13.5 MHz, U and V at 6.75 MHz
- The first sample of each active line is U

- Number of active luminance samples is 720

- There are 360 color-difference samples per line

The following eight video buses can be found on the Movie-2 bus:

- I0, I1, and I2. Video input/output between video adapters.
- MAIN. Typically the main video output (program).
- PREVIEW. Typically the preview video output of the video mixer.
- LOOPOUT A and B. Typically the front and back face video for 3-D DVE.
- LOOPIN. Typically the processed video output from 3-D DVE.

Key Bus Format

Key buses carry data with a standard encoding of 4:0:0 in the form:

$$Y_0, Y_1, Y_2, Y_3 \dots$$

Only luminance data are carried on this bus. The parameters are as follows:

- 256 quantization levels are available
 - Code 0 is the black level and code 255 is the peak white level
 - Number of active samples per line is 720
 - Sampling frequency is 13.5 MHz
- The following six key buses can be found on the Movie-2 bus:
- I0KEY, I1KEY, and I2KEY. Key buses associated with I0, I1, and I2 video buses.

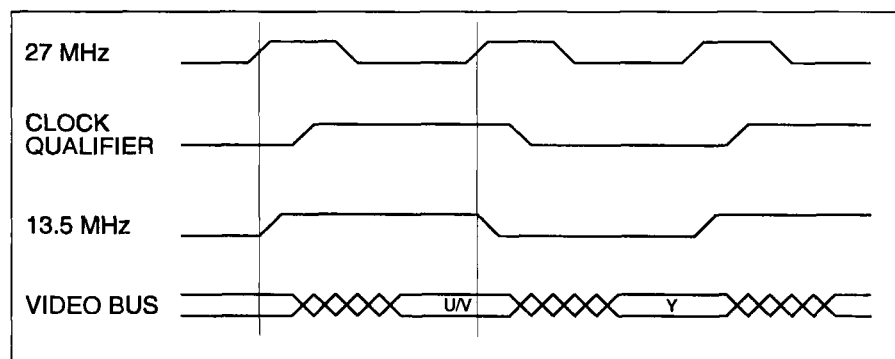


Figure 7. Horizontal line video timing.

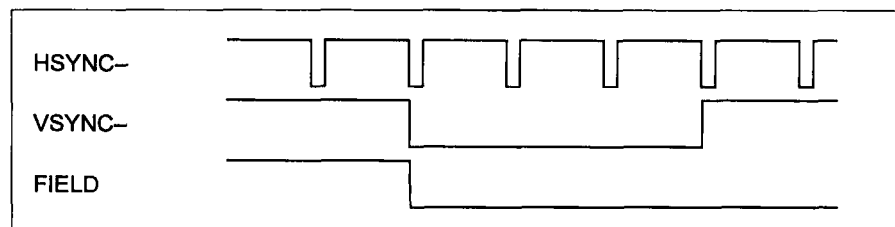


Figure 8. Vertical line video timing.

THE MOVIE-2 DIGITAL AUDIO/VIDEO EXPANSION BUS

- **KEYIN.** Key bus associated with the LOOPIN video bus.
- **KEYOUT.** KEYOUT time-multiplexes the key bus associated with the LOOPOUT buses and the main video output (two key buses).

Audio Bus Format

Audio buses serially carry digital audio samples coded using standard two's complement binary integers. The serial word length must be 16 or 32 bits. Data samples are transferred using the

most significant bit (MSB) first. Multiple audio streams can be time multiplexed together on one bus. One serial data line can time multiplex eight audio tracks. Two different methods of time multiplexing are possible.

Continuous Multiplexing

Each audio sample (S) is time multiplexed in a sequence from stream 1 to stream N without interruption.
 $S_1, S_2, S_3, S_4 \dots S_N, S_1, S_2, S_3, S_4 \dots S_N \dots$

Burst Multiplexing

Each audio sample is time multiplexed in a sequence from stream 1 to stream N. A delay can occur between the transmission of each sample sequence,

$S_1, S_2, S_3, S_4 \dots S_N$ (delay)
 $S_1, S_2, S_3, S_4 \dots S_N$ (delay)
 $S_1, S_2, S_3, S_4 \dots S_N$ (delay)...

The following audio buses can be found on the Movie-2 bus:

- **SDATAIN.** Two audio input buses transmit audio data from the input card to the master card.
- **SDATAOUT** Two audio output buses transmit audio data to the output card from the master card.

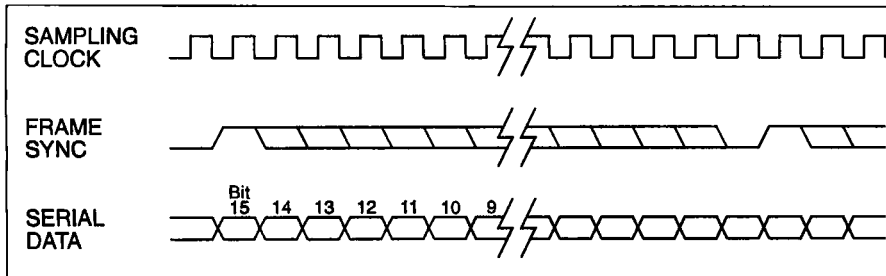


Figure 9. Timing of the transfer of one audio sample (S1).

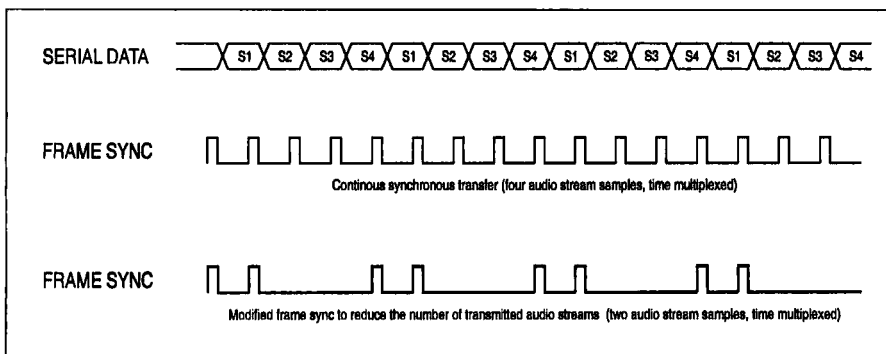


Figure 10. Timing of the transfer of a complete audio stream sequence.

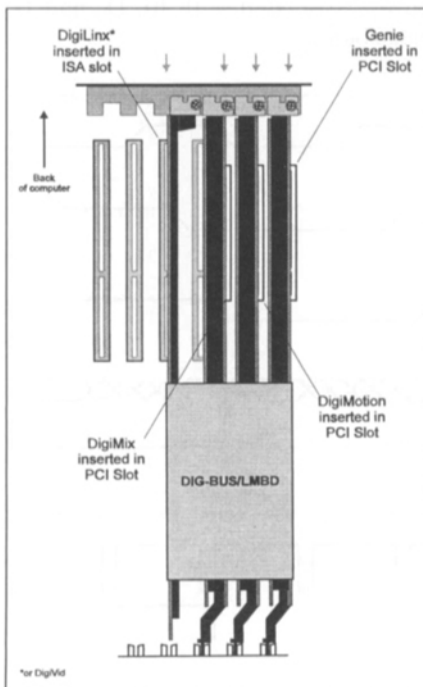


Figure 11. Top view of Movie-2 bus in a four-card nonlinear editing (NLE) configuration inside a PC.

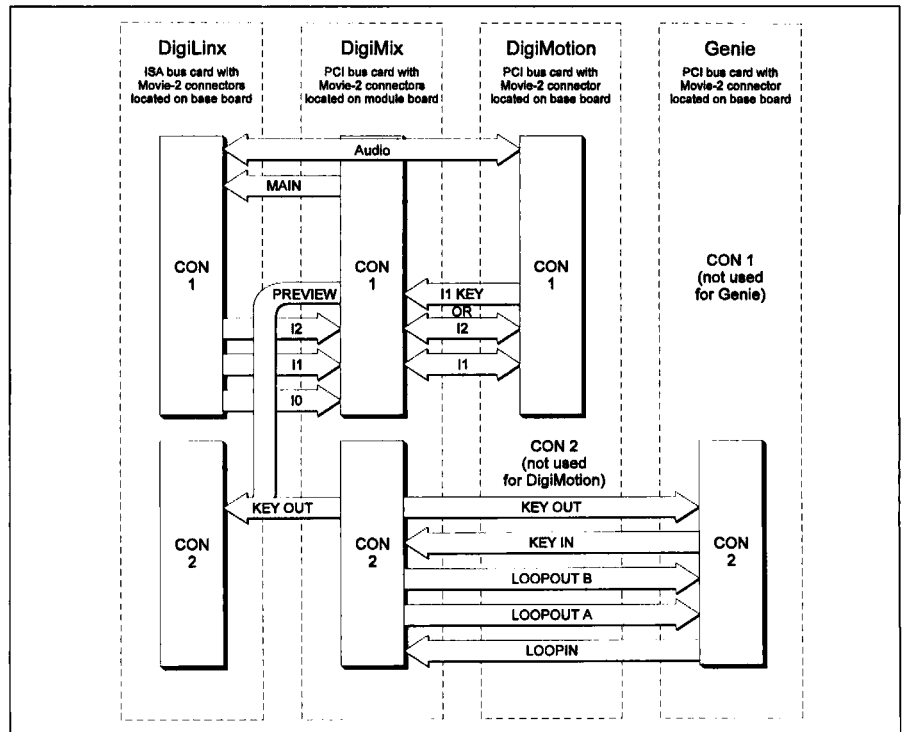


Figure 12. Data flow over the Movie-2 bus in a four-card NLE configuration.

Movie-2 Bus Synchronization Signals

The master adapter on the Movie-2 bus generates the video and audio signals (Figs. 7 and 8).

Video Signals

- 27-MHz clock
- 13.5-MHz clock
- Clock qualifier to identify U/V samples from Y samples
- Horizontal sync
- Vertical sync
- Field signal

Audio Signals (Figs. 9 and 10)

- Audio sampling clock
- In 48-kHz audio applications, the audio sampling clock will have a frequency of 12.288 MHz
- Frame sync to define each sample's MSB position

Typical Movie-2 Bus Nonlinear Editing System Implementation

The modularity of Movie-2 bus makes it easy to combine different vendors' products to create system-level digital video solutions like nonlinear editing systems, virtual videotape recorders, MPEG-2 video-on-demand servers, live video switchers, commercial insertion systems, community antenna TV (CATV) barker channels, animation/paint/CG workstations, and compositing systems. For example, products from Matrox Video Products Group, Pinnacle Systems, and Miranda Technologies—all built around the Movie-2 bus—can be used to build a hardware platform for third-party nonlinear editing applications. Such a system would include a Matrox DigiMix—digital video/graphics mixer with 2-D DVE, a Matrox DigiMotion—motion JPEG codec/digital audio mixer/Fast-20 SCSI controller, a Pinnacle Genie—3-D DVE unit, and a Miranda DigiLinX—serial digital (SDI) I/O board (Fig. 11).

Data flow over the Movie-2 bus in such a system is as follows (Fig. 12):

- Three video inputs are sent from the DigiLinX SDI I/O board to the DigiMix video mixer using I0, I1, and I2.
- The program and preview outputs from DigiMix are sent to DigiLinX using MAIN and PREVIEW.
- DigiMix interfaces with the dual codec DigiMotion over I1 and I2. These

bidirectional buses allow two streams to be sent back and forth for record and playback.

- A key signal can also be played back using the I1KEY bus on DigiMotion.

- The Genie 3D DVE board interfaces with the DigiMix through five video buses.

- LOOPOUT A and LOOPOUT B transmit front and back face video layers to be processed along with a key fill using KEYOUT.

- The transformed video image is sent back to the DigiMix through LOOPIN and KEYIN.

Conclusion

Movie-2 bus is the only open-standard, high-speed PC adapter interconnect that meets the needs of the professional video industry. Movie-2 bus overcomes bandwidth problems experienced by designers of broadcast-quality digital video systems who must use multiple adapters in a PC. It is a simple, inexpensive bus to implement and provides the high performance and modularity that system integrators need. Its widespread adoption in the video industry provides a way to quickly incorporate different digital video building blocks from many different vendors into a complete system.

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