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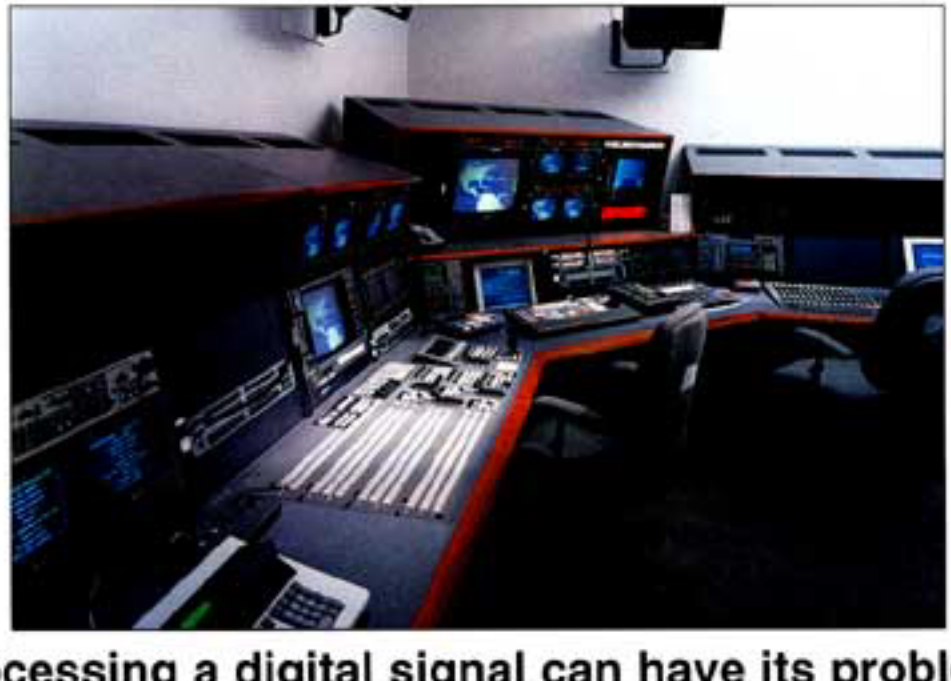

Processing a digital signal can have its problems.

By Jim Boston

THE BOTTOM LINE:
Problems such as noise and distortion do not affect digital signals in the same manner that they affect analog signals. Because of this, many assume that digital will be a "problem-free" solution. Although it has eliminated many problems associated with analog, digital has brought with it a few new problems. Keeping digital signals at the highest possible quality level can be done fairly easily, but not without an understanding of how digital signals can be changed as they move from device to device within a facility. $

It has become common today to refer to digital video as data. There is no doubt that in a video stream defined by SMPTE 259M, a significant portion of the bitstream can be devoted to ancillary data. Although slightly less than 10Mb/s are available in composite bitstreams (barely enough for four channels of embedded audio), more than 55Mb/s are available for ancillary data in a component digital stream. That's approximately 20% of the bitstream. Currently, almost all of this auxiliary data is embedded audio.

Video as data

In the serial digital data interface (SDDI) bitstream, all bits are considered data. SDDI is a serial digital signal conforming to SMPTE 259M (270Mb/s) where the active video portion of the bitstream is replaced with data. This data could be of any type, but it's typically MPEG video and audio data. Because 4:2:2P@ML has a data rate of approximately 18Mb/s, and component digital video has approximately 207Mb/s of capacity, either multiple streams of MPEG data or MPEG data at faster than real time can be sent. The SDDI bitstreams can pass through a serial digital interface (SDI) component video path and can even be displayed on an SDI monitor. Although you won't see recognizable video, you will see the datastream

Photo: Digital technology, like that shown in this production control room at DirecTV, is the key to high-quality video and future HDTV/multichannel operation.

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arrayed on the raster.

The point is that even when "baseband" serial digital component video is the bitstream, it's helpful to think of this stream as all data. In the DSP realm, where video spends more and more of its time, this datastream would often be referred to as a number sequence. Each sample of luminance or chrominance information is just a number representing the original intensity value of a picture in spatial space.

The beauty of digital video is that once the video signal is in the digital domain, these number values should never change, not by one literal "bit." You should be able to send this stream of "numbers" or values on a never-ending journey and not have any change in their value.

Is that really true? Like most sweeping statements, it depends. First, let's describe a scenario that would be a mistake in an analog facility. Take one analog framestore (yes, we all know that internally it's a digital TBC on steroids, but it still has analog ins and outs) as shown in Figure 1:

- First, feed a signal to the frame sync from the output of a router.
- Second, take the framestore's output and run it to the input of an analog router.
- Third, switch the crosspoint feeding the router to the output of the framestore.

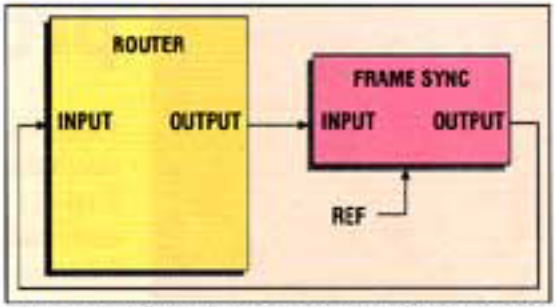

Figure 1. Video feedback occurs when the same signal appears at the input and output of a device, such as a framestore.

What happens? Video feedback, of course. A coherent picture quickly dissolves into a blur and usually pulsates or undulates at some rate based on the overall resonance of the path. Not useful. Let's try the same thing, but with an entirely digital path. What happens when the router crosspoint feeding the frame sync is switched so that the frame sync sees its output? Nothing. A still-frame occurs. The output of the frame sync circulates through the router/frame sync path forever. In fact, you can add many other digital boxes to this path and have the same result. Why? Because the "number sequence" is faithfully being reproduced by each box in the path. In fact, you can keep this bitstream recursively transversing through the frame sync for many days (in a normal "healthy" path) and not see any errors. How would you know if you picked up an error? If it occurs during the active portion of the video, you'll see a "dot" appear in the picture. Once that error is generated, it will continuously circulate with the

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The actual DCT process isn't lossy in itself, because you can end up with more data than you started with. Hence, the frequency coefficients are scaled to make the small-valued ones go to zero. (For more information, see "Video Compression 101," *BE*, February 1996.)

When the signal is returned to the time domain and then back into the frequency domain of the compressed world, the video data will change some more. If you continually do this, the amount of data change will diminish exponentially, meaning that the fifth or sixth change will be small compared with the first change, with one caveat — if any part of the picture is changed (a key laid on the existing compressed video steam, a wipe added), then the exponential degradation for that area starts over. This is only true if you stay in the digital domain.

If you're going between the analog and digital domains, all bets are off. No D/A or A/D is completely linear or perfectly accurate. Non-linearity breeds unwanted harmonics. Noise is added in each step of the analog domain, followed by quantization noise as you return to the digital domain. Techniques, such as one-bit D/As (used to improve accuracy when converting audio) can't be used for video due to the speeds required.

Compressed video is not the only place where digital video can be changed. It turns out that any domain change introduces video data change. Going from digital component (SMPTE 125M) to digital composite (SMPTE 244M) or vice versa isn't transparent; it has some cost. Just because you're in the digital domain doesn't mean that what Fourier had to say is no longer true. Most approaches to these domain changes involve subsampling, and thus low-pass filtering, and in some cases, interpolation. But it's digital, it shouldn't do that, you say. Yes, DSP techniques, namely when applied to filtering, have made many DVEs/DMEs remarkable when it comes to video quality during complex effects, and DSP has made 28k and now 56k modems possible, but even they can't approximate enough poles when it comes to filtering and making the process completely transparent.

Additionally, if you traverse into the composite domain from the component domain, you no longer have separate luminance and chroma information. Upon re-entering the component realm, you will have some of the luminance in the chroma, and vice versa, traditionally known as cross-modulation. In situations such as this, the analog reference fed to these digital boxes can become important for minimizing artifacts. All boxes should also have the same reference. What should be stressed here is that once you're in a particular domain and stay there, and as long as nothing in the path is broken, your quality shouldn't diminish. Up to now, the main beneficiary of digital operations has been the VTR. The ef-

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fects of multiple recording generations are no longer a factor. Even VTRs that are doing mild compression, say 2:1 or 4:1, can go dozens of generations with no noticeable artifacts.

Also, be aware that there are items in the serial digital stream outside of the actual video data that can impact the handling of the video information. Many pieces of equipment, such as video switchers, strip off timing signals. In digital component video, there are no sync pulses anymore; instead there are timing reference signals (TRSs). There is one at the beginning of the active video for each line called start of active video (SAV) and one at the end of active video called end of active video (EAV). Each is comprised of four words and the first three are unique values, 3FF (all 1s) and two sets of 000. These first two bytes are a big reason some equipment strip these signals off. Once these serial bitstreams are converted to parallel data, which most equipment does for processing, they can play havoc if many video signals arriving in a given box have all their data lines going from all on to all off at once. The fourth word indicates whether the TRS is an EAV or an SAV, which field of the frame you're in, and whether you're in the vertical interval. You want the video to have the same TRS values out of a box that you put in.

Some devices use the video index data on line 14 in the vertical blanking to carry signal legacy information, helping some equipment process the signal (SMPTE RP 186). This data is hard to see on a traditional waveform display, because only the chrominance data is used, and each word represents only one bit of an 89-byte stream. A 0 bit is represented by hex value 200 for the whole word and a 1 by hex value 204. This will show up as a minute change in value in the Cr, Cb signals. This information needs to pass through intact.

Finally, another system can be used to ensure your video data values aren't changing between devices. This is the error detection and handling or EDH (SMPTE RP165). Devices that conform to this recommended standard place active and full-field check words in the horizontal blanking portions of line nine, which is in the vertical blanking. Included are two words that contain active and full-field error flags. These flags indicate whether an error has been discovered at the input of a particular box or upstream from that box. (For more information, see "EDH: Monitoring Networked Video," *BE*, April 1996.)

Because line nine is out of the optional video area described in SMPTE 125M, a box that strips and re-inserts TRS data and doesn't support EDH will remove the history or errors that the EDH datastream contained.

Digital video has proved to be robust. Once placed in a particular domain, it will retain the state and quality it had when it got there. Each successive domain change introduces some, although often small, degradation. These degradations can be kept to a minimum by reducing the number of domain changes a signal must undergo as it makes its way through your facility. ■

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