

An Introduction to Digital Television

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"Another article about digital television! Boy, as if we haven't seen enough of them already!" This was our reaction when we were asked to consider writing a series of articles for the *SMPTE Journal*. But then again, there is so much to tell about digital television and so many levels of understanding to address. If you are already a digital TV expert, then these articles are not for you. But those who have been too busy to keep up with the fast pace of developments, or who perhaps need a refresher course on some aspects of the subject, may find this series of articles both helpful and easy to absorb. Without a doubt, the adoption of digits is the first step towards a revolution in the way human beings are already communicating with each other over long distances. And television is just part of the big picture.

Why Digital?

NTSC and PAL broadcasters have for many years been using digital television techniques for devices such as time base correctors, frame synchronizers, and special effects mixers. The trouble is, the more products using this technology you have in your TV facility, the more often you have to use analog-to-digital and digital-to-analog conversion processes. As we shall see later, these conversions affect signal quality and also add an extra cost factor. As the number of "digital" products increased to include still stores and complex computer-generated graphics, people started to wonder about keeping the whole signal in the digital domain. Today, with the world talking about transmitting 500 digitally compressed television channels by satellite and recording television signals on computer hard drives, it is not surprising that almost all requests that manufacturers are receiving these days

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for new installations specify a fully digital facility. So let's look at our options.

Four Video Systems

Most television systems today fall into one of four categories (Fig. 1):

- NTSC/PAL
- RGB/Y, R-Y, B-Y
- $4 f_{sc}$
- 4:2:2

NTSC and PAL are *composite* analog signals. Everyone knows about them. This is the type of signal we get at home. Luminance and the color information are *encoded* together into the same signal, so composite signals can be distributed on a single piece of coaxial cable.

Unfortunately the process of encoding generates some aberrations in the picture. So let's look at component television, which is the way TV starts out in the camera anyway. RGB (red, green, and blue), or luminance and color difference signals, Y, R-Y, and B-Y, are *component* signals. They have to be carried on *three* separate BNC cables — better pictures but not so convenient.

The trouble with all of these analog signals is that they can pick up interference. And that's where digital TV comes in. Digital technology keeps television pictures clean, even through multigeneration recording. It's like CDs in audio — all the background noise is gone.

Now, of course, you can digitize either *composite* or *component* signals. Let's look again at NTSC, which, of course, is composite.

Digitizing NTSC

As television engineers know, the analog television signal starts at black level and climbs up to 714 mV at peak white. Let's consider a video signal starting at black level on the left of the TV screen and rising to peak white at the right-hand side. The waveform monitor will show a smooth slope.

	Analog	Digital
Composite	NTSC, PAL	4 f_{sc}
Component	RGB Y, R-Y, B-Y	4:2:2 (601)

Figure 1. The four basic video format types.

Now consider taking *ten samples* of the analog level. Each level would represent 71.4 mV, and attempts to reproduce this slope digitally using only ten levels would turn the slope into a staircase! Therefore, it requires many more samples of the analog voltage to digitize a signal for faithful reproduction.

A digital signal with 1 bit has *two* levels, ON and OFF. A 2-bit word represents 2 to the power 2, or *four* levels. A 4-bit signal has 2^4 (16) levels, and so on. A 10-bit digital video word contains samples from 2^{10} levels. That's 1,024 samples of video level! And this has to be done while the signal is constantly changing, so we have to take these samples pretty fast. In fact, for composite digital television, we use a *clocking* frequency of four times the subcarrier frequency (Fig. 2). The color subcarrier frequency in NTSC is 3.58 MHz and in PAL it's 4.43 MHz, but in both cases we take samples at four times the subcarrier frequency. This is where the term $4 f_{sc}$ comes from. So for an NTSC signal, we take samples at 14.3 MHz. (In PAL, $4 f_{sc}$ is 17.7 MHz.)

D-2 and D-3 tape machines record *composite* digital signals. But didn't we say that *component* pictures look better than composite pictures? Yes. And it is in the world of digital *component* television that something amazing happened!

A Digital Television Standard

The Europeans, Americans, and Japanese actually got together and standardized on the same sampling fre-

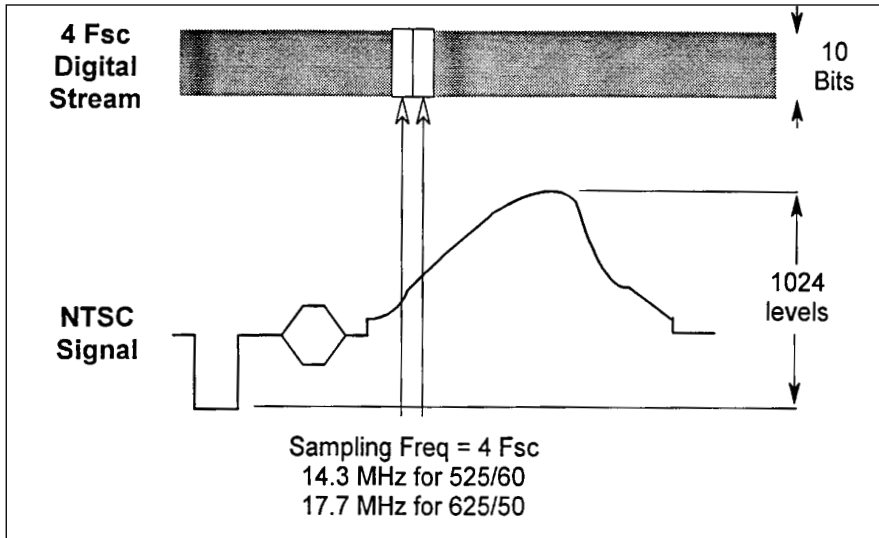


Figure 2. Composite digital structure.

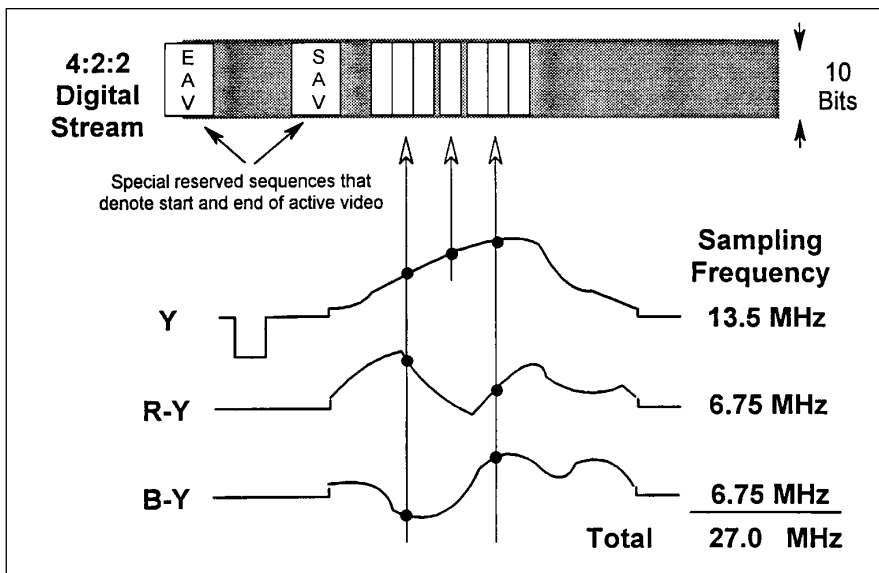


Figure 3. Component digital structure.

quency for the D-1 component digital tape recording format! It became known as the CCIR 601 component digital standard. (Of course, SMPTE was influential in facilitating the adoption of this standard.)

In component television there is no subcarrier, and a sampling (or clocking) frequency of 13.5 MHz was chosen as a useful frequency that “works” in both the 525 and 625-line worlds (Fig. 3); the luminance channel is sampled at 13.5 MHz, and each of the two color-difference channels (where there is less detail) are sampled at 6.75 MHz. If 13.5 MHz is four times the frequency of some imaginary subcarrier, then 6.75 would be two times the same fre-

quency. This ratio of 13.5 to the two chrominance sampling frequencies of 6.75 became known as 4:2:2 digital component television, and if you add these three frequencies together you get 27 MHz — a very important number, as the majority of digital work is currently based on 27 MHz.

With this international standardization, the only significant difference between NTSC and PAL that remains in the component digital world is the number of TV lines — 525 versus 625.

D-1, D-5, DCT, and digital Betacam machines all record component digital signals. Now, how do we send these digital signals down cables? We could send all the 10 bits down 10 pairs of

wires in a *parallel* cable in much the same way as a home computer talks to the printer. As there are 10 parallel paths, communication is fast, but imagine the complications of routing and distributing these signals throughout a TV complex. Anyone who’s tried will know that soldering a D25 connector onto the cable isn’t much fun either. And then there’s the real estate problem on the back of the equipment. A 2-RU distribution amplifier frame can have up to 80 outputs. Where do you put 80 D25 connectors?

The Digital Sergeant

Fortunately, serializer chip sets came to the rescue. Serializers are the sergeant majors of the digital world. The digital sergeant makes all the dig-its line up neatly behind each other and march in single file down a single piece of coax! But doesn’t this slow the process down? Well, it would, except that we increase the clock frequency — actually by 10 times. The NTSC serial bit rate becomes 10 x 14.3 or 143 Mbits/sec (177 Mbits/sec in PAL), and for 4:2:2 component it is 270 Mbits/sec!

The bit rate is very high, but now you have a really useful signal. It is defined in SMPTE document 259M and described as Serial Digital Interface (SDI). (The SMPTE 259M document actually covers both 4:2:2 and 4 *f_{sc}*, but the term SDI is commonly becoming associated with *component* serial digital interface. We shall use SDI to refer to component serial digital interface.) The SDI (component) signal carries clean video and it’s much easier to route around the TV studio.

And we can use our same old coaxial cable once again, this time for *component* television. Not only that but, as you’ll see later, the SDI signal can carry up to 16 channels of audio along with the video!

Digital TV in More Detail

Next month we will explore the basics of digital television in more detail, and in subsequent issues of the *SMPTE Journal* we will look at digital signal testing, embedded audio, widescreen, and most of the other digital television topics you might want to learn about in this rapidly evolving technology.