# Digital Signal Conversion

**By David Strachan and Randy Conrod**
**Illustrated by Michel Proulx**

In the first article of this series we identified the four basic television signal formats. These are illustrated in Fig. 1. In the second, we looked at many of the different varieties of digital signals that we can expect to encounter in a modern digital studio complex. Today we shall consider the problems involved in the conversion of television signals from one format to another. For simplicity, we shall refer to component 4:2:2 digital television as D-1, and $4f_{sc}$ composite digital television as D-2.

## Interfacing the New with the Old

In a new digital television installation we may, for cost reasons, wish to retain some of our earlier-generation products, but even if all of our equipment is digital, we will still need to interface with analog signals in the outside world. As we have seen before, there are many different types of television signals to deal with, including serial, parallel, component, composite, analog and digital, so the problems of choosing the most cost-effective interfacing solutions can be quite daunting (Fig. 2). A knowledge of how much impairment can be expected from each conversion process and of how much these processes cost is clearly desirable.

## Encoding and Decoding

Television signals originate from the camera as analog red, green, and blue (RGB) components. Therefore, television engineers had to become familiar with encoding techniques, so that TV signals could to be transmitted on one cable instead of three. Unfortunately, the process of encoding three colors into one signal generates aberrations in the picture. The process of decoding causes abberations as well, so encoding and decoding analog pictures (Fig. 3) should be avoided wherever possible. In the digital world, component signals (D-1, D-5, and digital Betacam) can also be converted into composite signals (D-2 and D-3) and vice versa. More on this later.

## Conversions

The conversions from analog to digital (A/D) and back are well proven in much of the equipment available over the last decade. If all signals remain in a component format throughout the conversion process, or alternatively remain in the composite format throughout the conversion process, the impairments are minimal (Fig. 4). The worst-case scenario is to cross the boundaries diagonally from composite analog to component digital. The conversion process is particularly complex and expensive when converting from PAL to component digital (Fig 5).

The highest quality television can be maintained by staying in the component digital domain. Converters should be used only when importing analog material into the digital environment or when releasing finished programs for analog transmission or storage.

### *Analog-to-Digital (A/D) Conversions*

Let's take a closer look at what is involved in the converting processes. With the vast amount of analog Betacam and MII recorded material available in the world, one of the most common needs is to convert from component analog video to D-1. Various devices are available on the market for this purpose and, not surprisingly, the best ones are the most expensive. When converting from analog to digital, it is important to take as many samples of the analog signal as possible. A good compromise is to use 2x over sampling techniques. The quality of the filters used also plays a significant part in the overall quality of the conversion process.

As we have seen, it is easier to convert composite analog signals into composite digital signals, but the component digital environment has many advantages and the world seems to be heading in this direction. We are stuck, therefore, with the need to adopt the most complicated and damaging conversion process at least once, when using PAL or NTSC material. In the area of decoders, there are again many manufacturers incorporating many different levels of sophistication into their machines.

Even simple decoders are quite expensive, and one can pay up to $20,000 for a good decoder using adaptive comb filter techniques. These devices must be capable of storing up to a frame of video so that it may be examined for temporal and spatial content prior to decoding. All this really means is that the decoding process is adjusted "on the fly" to take into account movement and sharp vertical picture transitions. The adaptive filter gives the decoder the ability to temporally look forwards and backwards and choose the most suitable algorithm to adapt to the changing conditions.

### *Digital-to-Analog (D/A) Converters*

Fortunately, the process of digital-to-analog conversion is less complex. But then again a digital television studio probably will not require so many D/A converters as converters to go in the opposite direction. Such is life! Anyway, in the near future the largest requirement for D/A converters will be to get programs on the air in a format compatible with the average television set (Fig. 6). Unlike decoders, D/A encoders should be genlocked to a house reference.

In the digital world, there is a thing called jitter. Jitter, simply put, is move-

This is the third in a series of tutorial articles from these authors. David Strachan, Randy Conrod, and Michel Proulx are with Leitch Video International, Inc., North York, Ont., Canada M3B 3J5. 

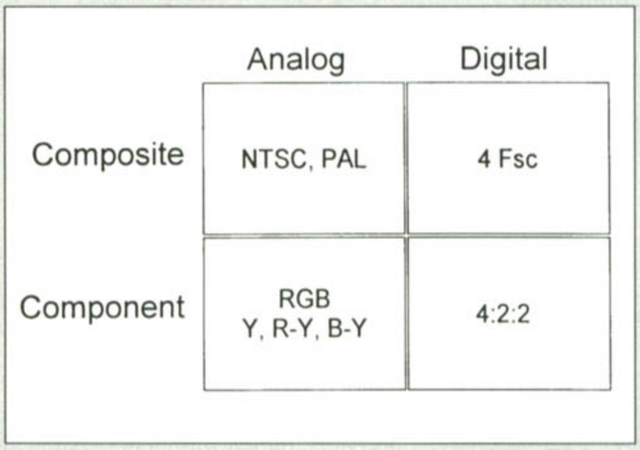


Figure 1. Basic signal formats.

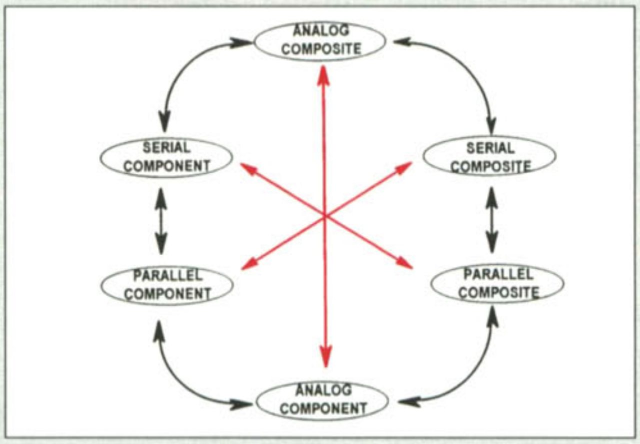


Figure 2. Format conversions.

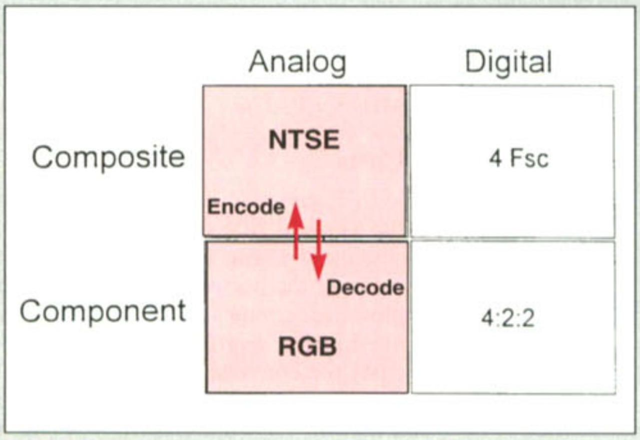


Figure 3. Encoding and decoding.

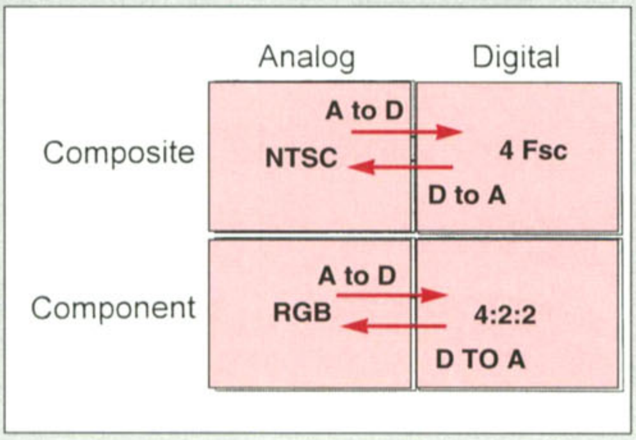


Figure 4. A/D and D/A conversions.

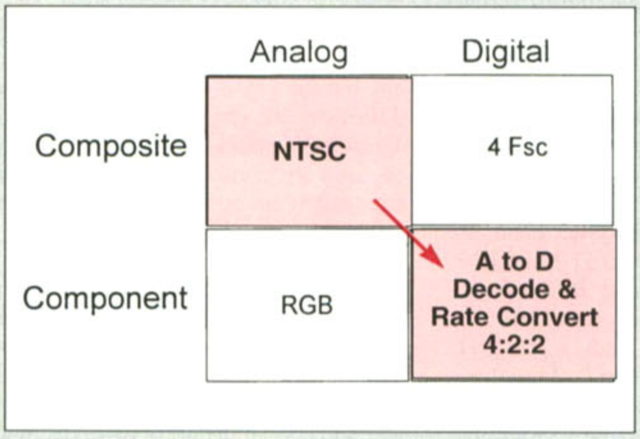


Figure 5. A/D, decode, and rate conversions.

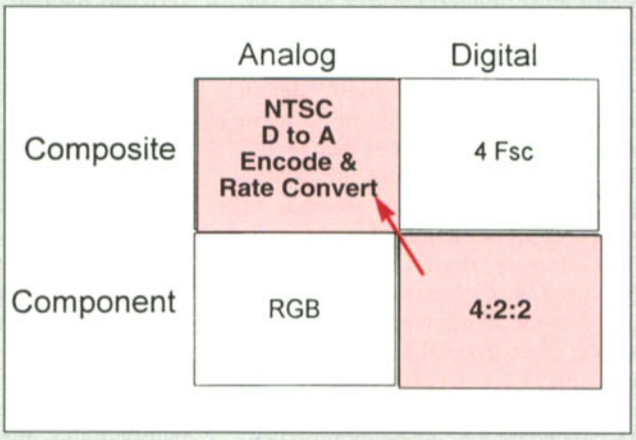


Figure 6. D/A, encode, and rate conversions.

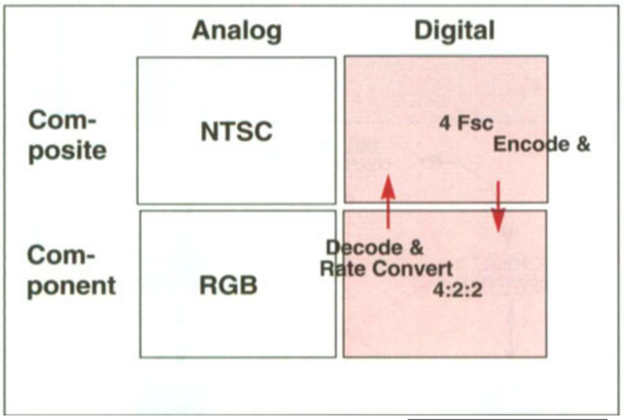


Figure 7. Digital-to-digital conversion.

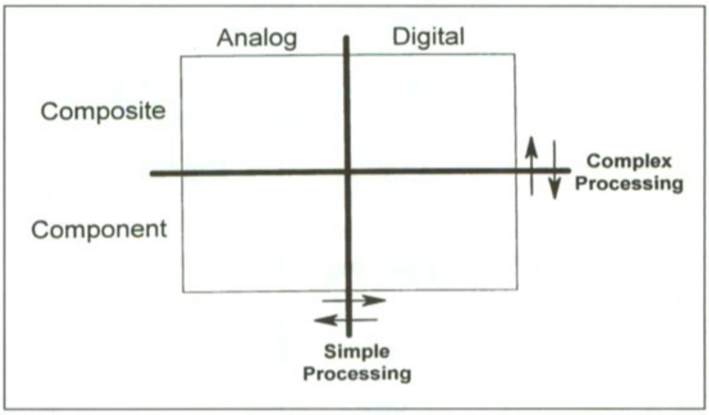


Figure 8. Format conversion.

| Translation Type | Approx. Cost | Relative Impairment |
|---|---|---|
| Ser <-> Par | $ 700 | transparent |
| NTSC <-> 4Fsc | $ 1.5 K | ↓ |
| RGB <-> 4:2:2 | $ 3 K | ↓ |
| 4:2:2 -> NTSC | $ 3 - 8 K | ↓ |
| NTSC -> 4:2:2 | $ 8 - 20 K | worst case |

Figure 9. Comparison summary.

ment backwards and forwards in time with the digital square wave signal; the pulses appear to be unstable, with their leading edges twitching at a high frequency. (Actually, there are both high-frequency and low-frequency jitter, and we shall investigate this topic later in the series.) The serial digital domain can tolerate a lot more jitter than would be acceptable for a composite analog signal so, in the encoding process, we have to get rid of the jitter.

Encoders typically need a digital storage buffer and a stable analog genlocking signal as a reference to provide a stable, jitter-free NTSC or PAL output (and PAL-M for our South American friends). D-1-to-NTSC (or PAL) encoders tend to be more expensive than component D/A converters because there is more processing required.

### *Digital-to-Digital (D/D) Converters*

The simplest form of conversion is serial to parallel and parallel to serial. In fully digital conversion, there should be no loss of quality whatsoever. As the price of serializer and deserializer chips continues to fall, parallel interfaces are becoming less popular. Converters for these signal types are therefore likely in the future to be confined for use with older equipment. On the other hand, as there is a huge number of D-2 and D-3 composite tape machines in the field, there will be a need for some years to come for D-1 to D-2 and D-2 to D-1 format converters. D-1 to D-2 involves an encoding process but, as the signal is purely digital, theoretically it should be possible to eliminate all aberrations. It's only software! The same is true for D-2 to D-1 converters, where the trickier decoder is required (Fig. 7).

As well as digital encoders and decoders, digital format converters also need a rate conversion process. Rate conversion is necessary because component digital signals are sampled at 13.5 MHz and composite signals are sampled at 4x the subcarrier frequency ($4f_{sc}$, or 14.3 MHz for NTSC and 17.7 MHz for PAL).

## Costs

In Fig. 8, we can see that crossing the vertical line requires simple processing and costs are kept down. When crossing the horizontal line more complex processing is required and costs are higher. Figure 9 shows general costs for conversions from transparent processes like serialization and deserialization to processes like NTSC to 4:2:2, which will create impairments in the picture and costs significantly more.

## Into the Digital Future

In the digital world, you are going to need many different types of converters, but the key is to use NTSC or PAL decoders as sparingly as possible. These converters are either expensive or not very good. Your program manager might not appreciate the signatures left by cheap converters!

Component digital television has a great deal to offer for overall picture quality, special-effects generation, multigeneration recording, and now disk-based storage and editing. When your budget allows, jump in with both feet and stay in the 4:2:2 world as much as possible.

Next month we will discuss quality control in a digital facility.