Designing a Digital Facility: A Case Study

By Michel Proulx and Randy Conrod

Previous tutorial articles in this series have covered the various digital formats and issues involved in serial digital television systems. This one looks more closely at the cost and effects of video format translation, examines several different system architectures, and notes the impact of format translation on each.

Few would question the assertion that a digital facility design is preferable to a traditional analog plant design. Digital systems provide significant operational and signal quality advantages not available with standard analog technology. Digital technology has matured, and the elements required for successfully building digital systems are now well established.

The problem lies in how best to bridge the gap between the analog systems of yesterday and the digital systems of today. Both composite digital and component digital systems offer advantages and disadvantages to facilities upgrading from analog designs. Component digital systems provide significantly better signal quality, particularly where intensive signal processing is involved. However, the historical lack of practical and affordable component recording devices has, until recently, discouraged the use of component digital systems. With the growing popularity of formats such as Digital Betacam, D-5, and DCT, component digital technology is rapidly becoming a more viable solution.

Composite digital systems, on the other hand, offer the advantage of more cost-effective conversion of composite analog signals with less signal impairment than is noted in composite analog-to-component digital conversions. The sheer number of composite analog signals that exist in our facilities today suggests the use of the more NTSC-friendly composite digital format. In some facilities, previous investments in composite recording formats such as D-2 and D-3 also encourage the upgrade to a composite digital plant.

This composite versus component dilemma was recently faced by WTTG, the Fox-owned and operated facility in Washington, D.C. In their design decisions lie a number of lessons that could benefit most of the broadcast stations in North America today. Equipped with limited funding, WTTG sought to upgrade its analog facility to digital technology in an economical fashion without sacrificing signal quality or limiting the facility's future. The key requirement in WTTG's plan was the need to interface with a large

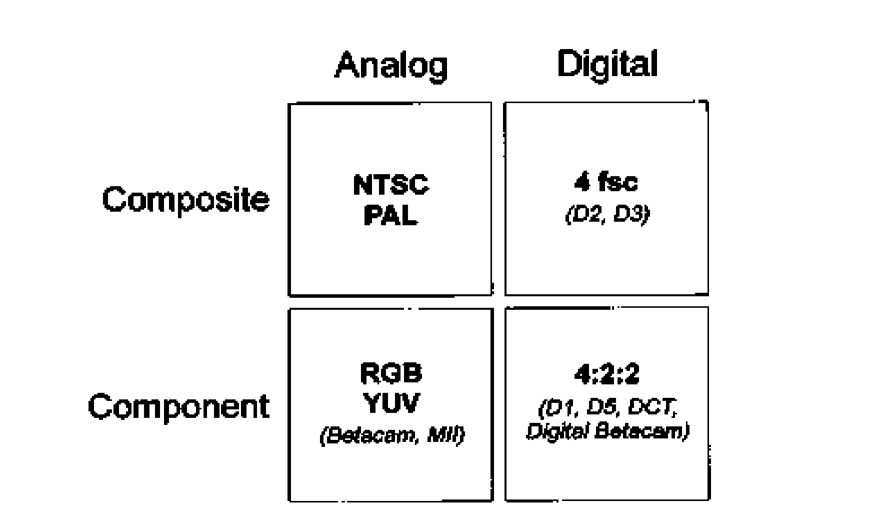

Figure 1. The various video formats.

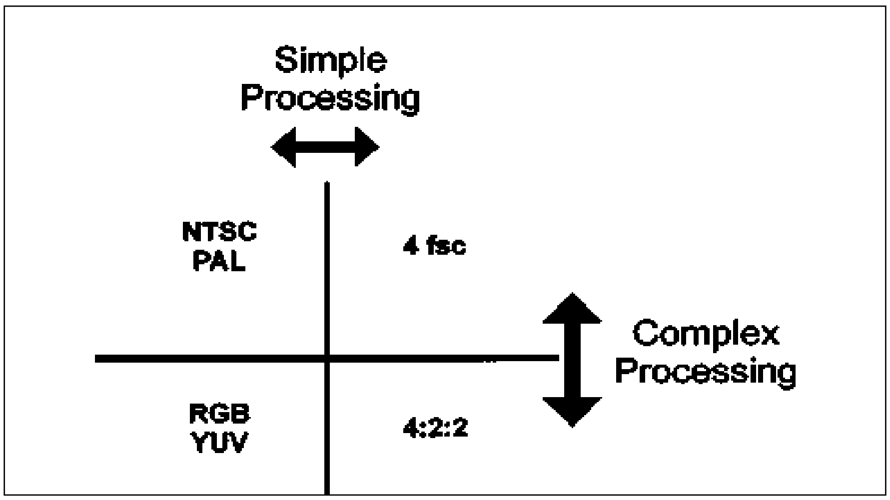

Figure 2. Comparing video format translations.

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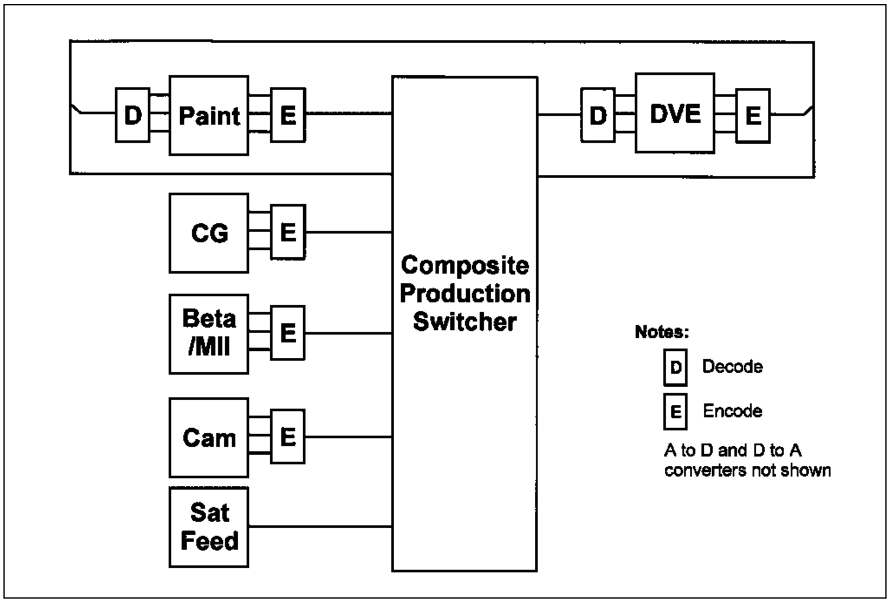

Figure 3. Typical composite production studio.

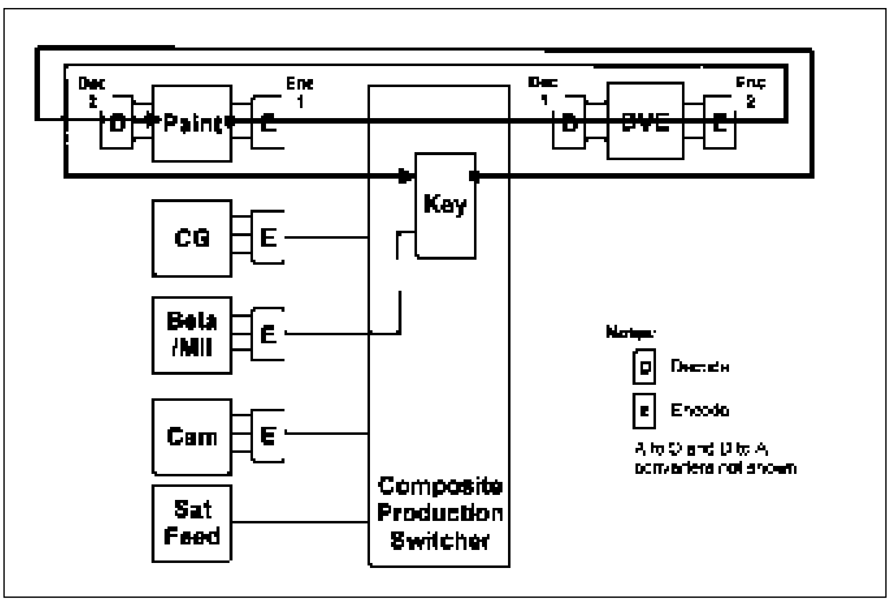

Figure 4. Excessive transcoding in a composite architecture limits multigeneration capability.

Table 1 — Comparison of Video Format Translations

Conversion	Process Required	Approximate Cost	Relative Impairment
NTSC to 4fsc	A to D	$1,500-2,000	1
CAV to 4:2:2	A to D	$3,000-3,500	1
NTSC to 4:2:2	A to D, Decode	$7,000-14,000	4
4:2:2 to NTSC	D to A, Encode	$3,000-5,000	2
4fsc to 4:2:2	Sample Rate Convert, Decode	$7,000-14,000	4
4:2:2 to 4fsc	Sample Rate Convert, Encode	$4,000-7,000	2

portion of the existing NTSC plant while moving gradually (over a period of 4 to 5 years) toward an all-digital facility.

This article discusses the effects of transcoding, presents a number of facility architectures, and examines the transcoding issues in each case. It also studies the architecture selected by WTTG and discusses the advantages such an architecture offers.

Transcoding Issues

At the heart of the composite versus component digital issue are the costs and signal impairment effects of the format translations required to bring the various television facility signals into the digital domain. Figure 1 illustrates the four categories in which video signals are classified.

As discussed in a previous tutorial article, the key to understanding the impact of format translation lies in the fact that not all format translations have the same cost or the same impact on signal quality. Table 1 describes the various translations, providing approximate cost and a signal impairment rating for each. Costs are based on a survey of devices available in 1994. Prices vary widely depending on signal quality, features, and packaging. The signal impairment rating is based on a relative scale from 0 to 4, in which 0 indicates no impairment and 4 indicates the worst possible impairment.

To summarize the contents of Table 1, converting the signal from analog to digital while maintaining the composite or component structure of the signal is less costly and better for signal quality than traversing the boundary between composite and component. Figure 2 illustrates how the implications of the cost and quality create a stronger barrier between composite and component than exists between analog and digital.

Implications of Format Translations on Facility Design

Based on this analysis of the cost and signal-quality impact of the various format translations, it is clear that the primary goal of a facility design should be to minimize the number of times the signal will cross the component-to-composite line. The decision to use a composite or component digital facility core depends on the equipment and the signals that must be interfaced with the new digital facility.

Composite System Architecture

For example, consider the use of a composite production switcher in a production environment. Traditional production equipment such as cameras, paint systems, character generators, DVEs, and 1/2-in. Beta/MII tape machines are internally based on component signal processing. In the past, we have utilized the composite inputs and outputs provided by these devices. As illustrated in Fig. 3, the devices utilize built-in encoders and decoders (symbolized by boxes with the letter E for "encode" and D for "decode") to provide the composite outputs and inputs.

As signals travel from device to device through the production switcher they must undergo repeated encode and decode processes. These conversions cause the signal to cross the composite-to-component line, affecting signal quality and limiting the multigeneration capability of the production studio. It is important to note that the encode and decode conversions play a larger role in limiting the multigeneration capability than do the analog-to-digital (A/D) and digital-to-analog (D/A) conversions. In the case illustrated in Fig. 4, a paint image passes through the production switcher's auxiliary bus on its way to the DVE, returns to the production switcher to be keyed, and is recaptured by the paint system. In this common example, the signal has undergone two encode and two decode steps in a single generation.

Component Analog System Architecture

The generation-limiting effects demonstrated in the example just cited were the primary reason that production and post-production facilities in the pre-digital era used component analog for multigeneration production suites. As illustrated in Fig. 5, the use of component analog signals eliminated transcoding, but added expense and complexity in

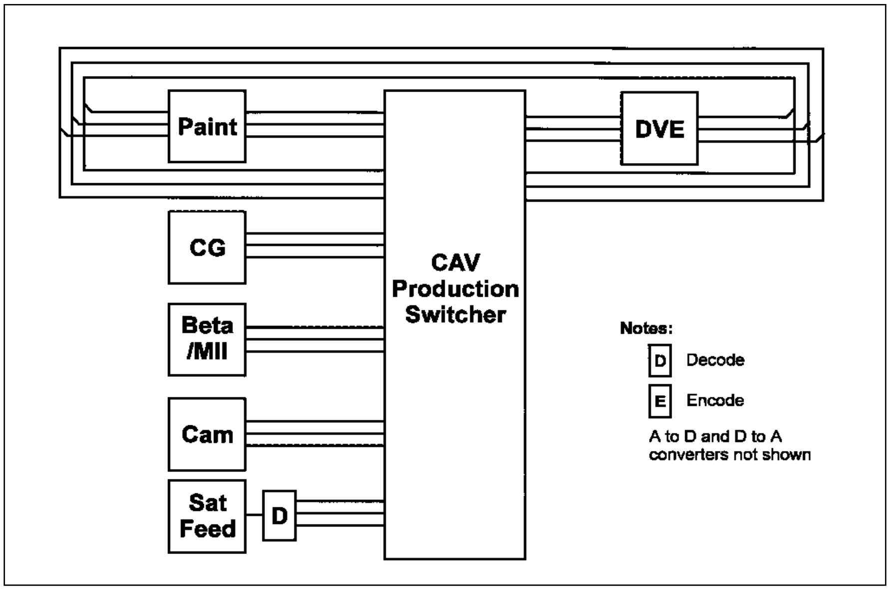

Figure 5. Component analog production studio.

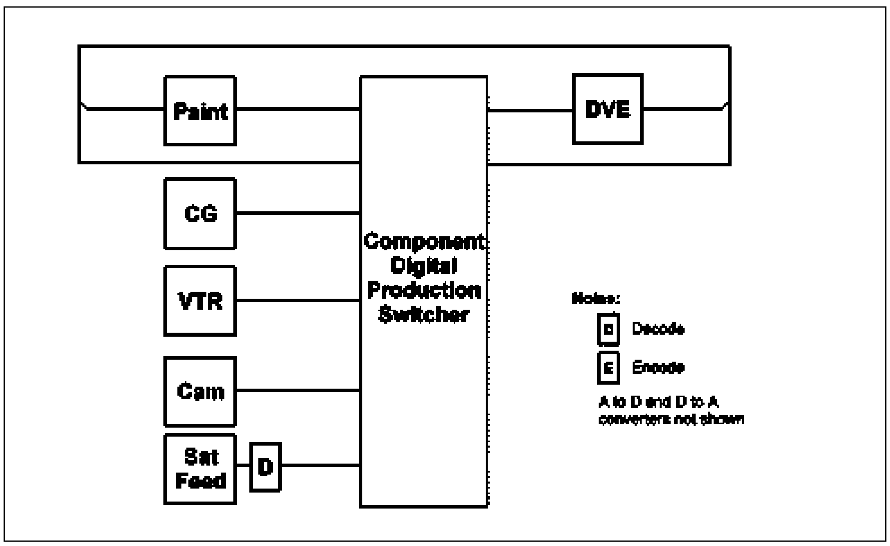

Figure 6. Typical component digital (4:2:2) production studio.

Table 2 — Internal Format of Popular Devices and Processes

Device or Process	Typical Internal Format
Camera	Component
DVE	Component
Paint	Component
Character Generator	Component
Still Store	Component or Composite
Analog Satellite Transmission	Composite
Compressed Satellite Transmission	Component
VTR (Type C, D-2, D-3,...)	Composite
VTR (Betacam, MII, D-1, D-5, DCT, DigBeta)	Component
Disk Servers	Component
Production Switcher	Component or Composite
Routing and Distribution	Component or Composite

routing, distribution, and processing. The three-wire system is necessarily more complex and expensive due to the tripling of signals that must be handled.

The A/D and D/A conversions remain at the inputs and outputs of devices that feature digital internal processing. Despite the conversions, this is a vastly superior system because no encoding or decoding is required. This system has a far greater multigeneration capability than the system illustrated in Fig. 4, which utilized a composite production switcher.

Component Digital System Architecture

The next logical step is to convert the production studio to digital component, as shown in Fig. 6. The use of digital equipment simplifies wiring, distribution, and routing by eliminating most of

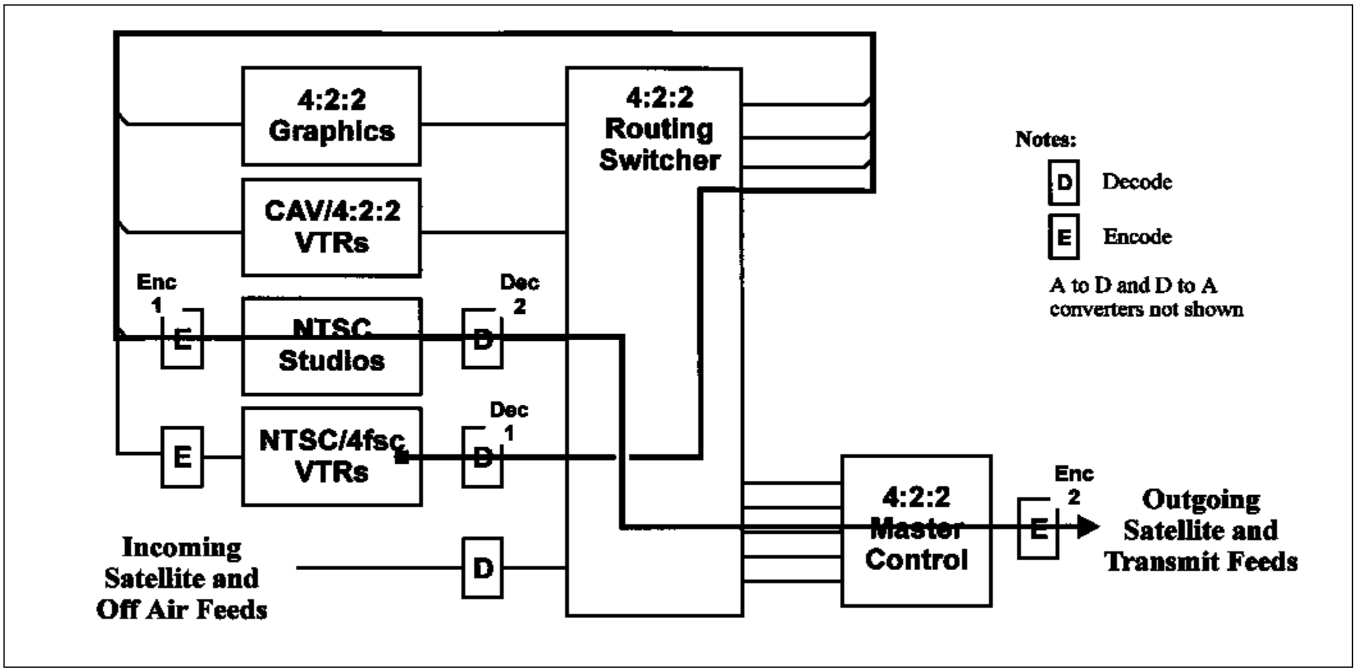

Figure 7. Component digital (4:2:2) routing in a largely NTSC facility.

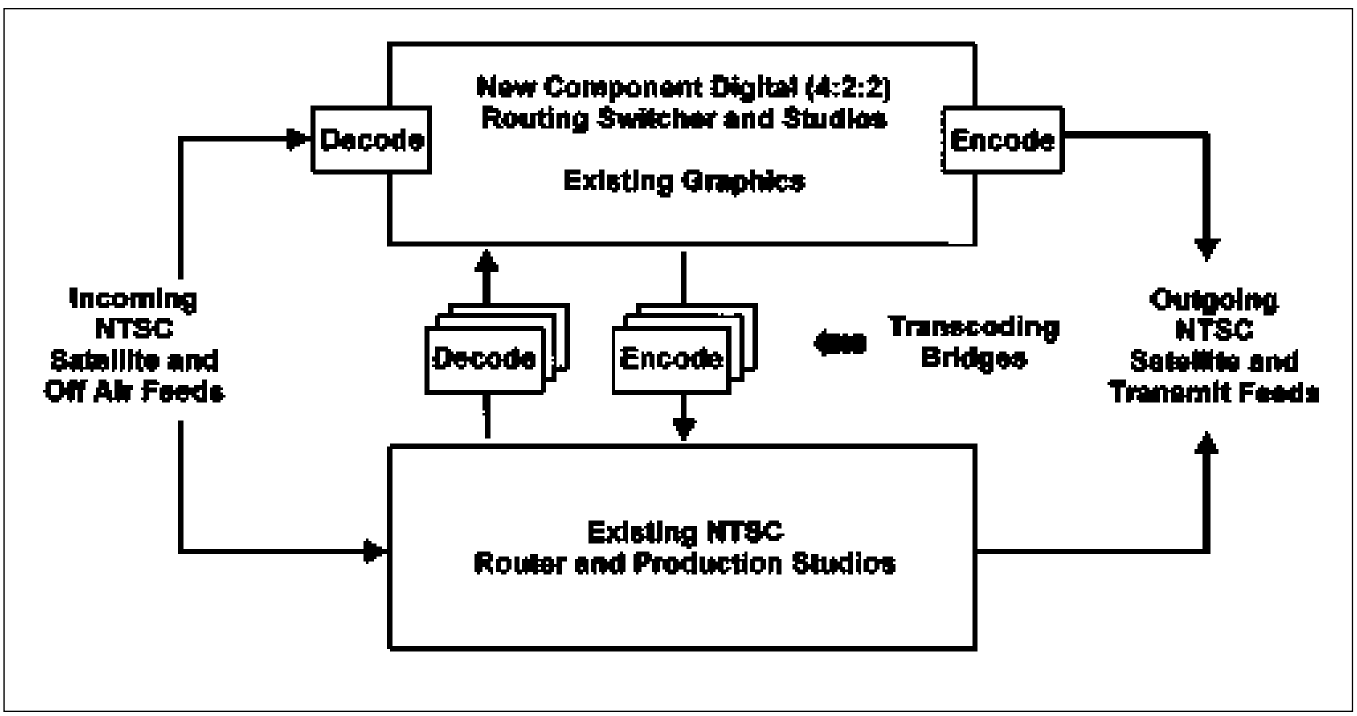

Figure 8. WTTG's hybrid system architecture.

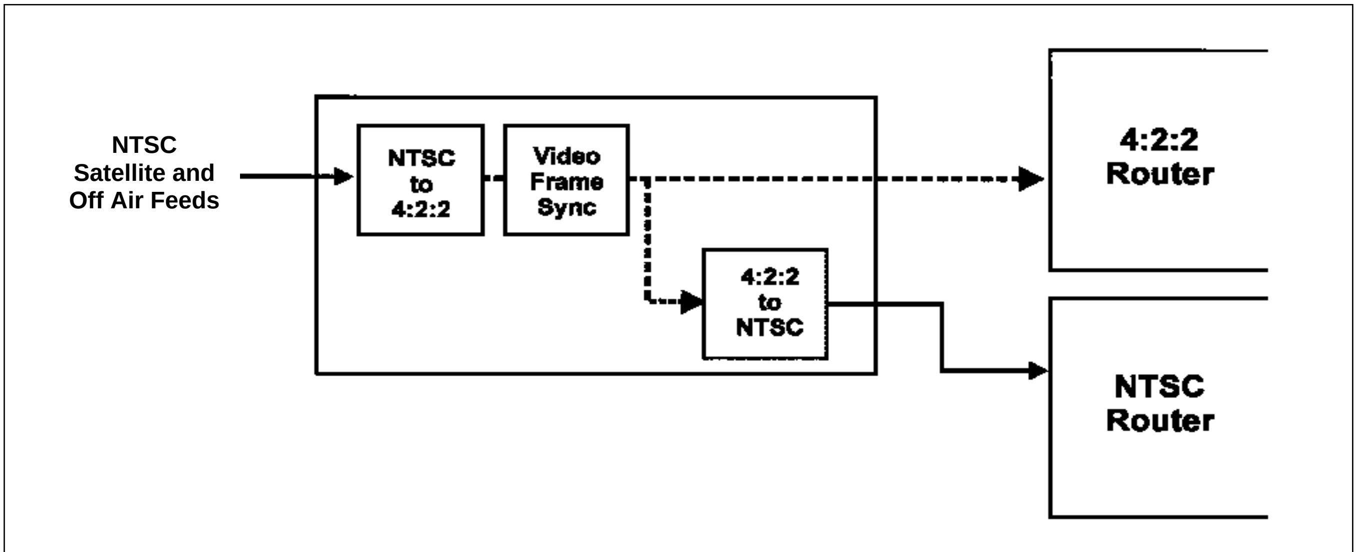

Figure 9. Handling incoming satellite feeds.

the A/D and D/A conversions and reducing the interface to a single cable.

This example seems to make a clear and simple case for component digital processing. In most broadcast facilities, however, the issue is not quite as straightforward. In a typical facility, today, NTSC and devices that process that format are commonly used. Installing component digital equipment in a largely composite analog system can produce effects as undesirable as those produced by a composite production switcher in an environment characterized by component-based devices.

For example, consider the result of adopting component digital (4:2:2) central routing in a facility consisting mainly of NTSC sources and destinations. As illustrated in Fig. 7, a signal will undergo as many as four encode/decode steps during routing from the VTR area into a production studio and then out to the transmit area through master control. Given this equipment, the use of component central routing would not be a wise choice.

Plotting the Landscape

Having determined that the key to a successful facility design is based entirely on limiting the number of encode and decode processes, it is appropriate to identify the internal formats of popular devices to establish which format (composite or component) will be dominant. Table 2 lists popular devices or processes and their typical internal formats.

Most emerging disk-based video server systems, particularly those that provide compression, are based on an internal component architecture. Compressed transmission and HDTV are both based on component signal paths, and new product introductions are also predominantly component-based. Based on this list, then, and looking ahead to the future, it seems clear that component digital is a desirable choice.

Considering the benefits of component digital today and in the future, the key to successful upgrade of an analog system is to devise a system architecture that takes advantage of component processing in interfacing with existing NTSC signals without compromising signal quality and budget.

WTTG's Hybrid Architecture

When WTTG began investigating the conversion of its plant to serial digital in 1992, the factors described previously were foremost on their minds. WTTG was aware of both the benefits and the future of component processing. Practicality, however, necessitated a gradual move toward a digital facility while continuing to utilize large portions of WTTG's existing NTSC plant.

After careful consideration, a clever hybrid architecture was devised. This hybrid architecture allows composite signals and studios to continue to interact in composite, while new component digital studios interact in component digital. As illustrated in Fig. 8, the hybrid architecture featured two routers: the existing NTSC router that interfaced existing NTSC studios and equipment, and a new component digital router that interfaces new component digital production studios and devices. Linking the two routers is a set of A/D + Decode and D/A + Encode bridges.

Operationally, the concept was to keep the signals in either the composite analog domain or the component digital domain for as long as possible, crossing the bridges only once for final output. Unlike the earlier examples, in which transcoding was involved in every signal pass, this architecture allowed multigeneration work to be completed entirely in either composite or component, thus avoiding excessive transcoding. A sure indication that WTTG achieved this operational goal is evident in the fact that there are only eight A/D and five D/A bridges, a relatively low number of bridges between an analog router that is 80 x 70 and a digital router that is currently 64 x 64.

Handling Incoming and Outgoing Satellite Feeds

As a Fox network owned and operated station, WTTG makes extensive use of incoming satellite feeds. As an originator of locally produced pro-

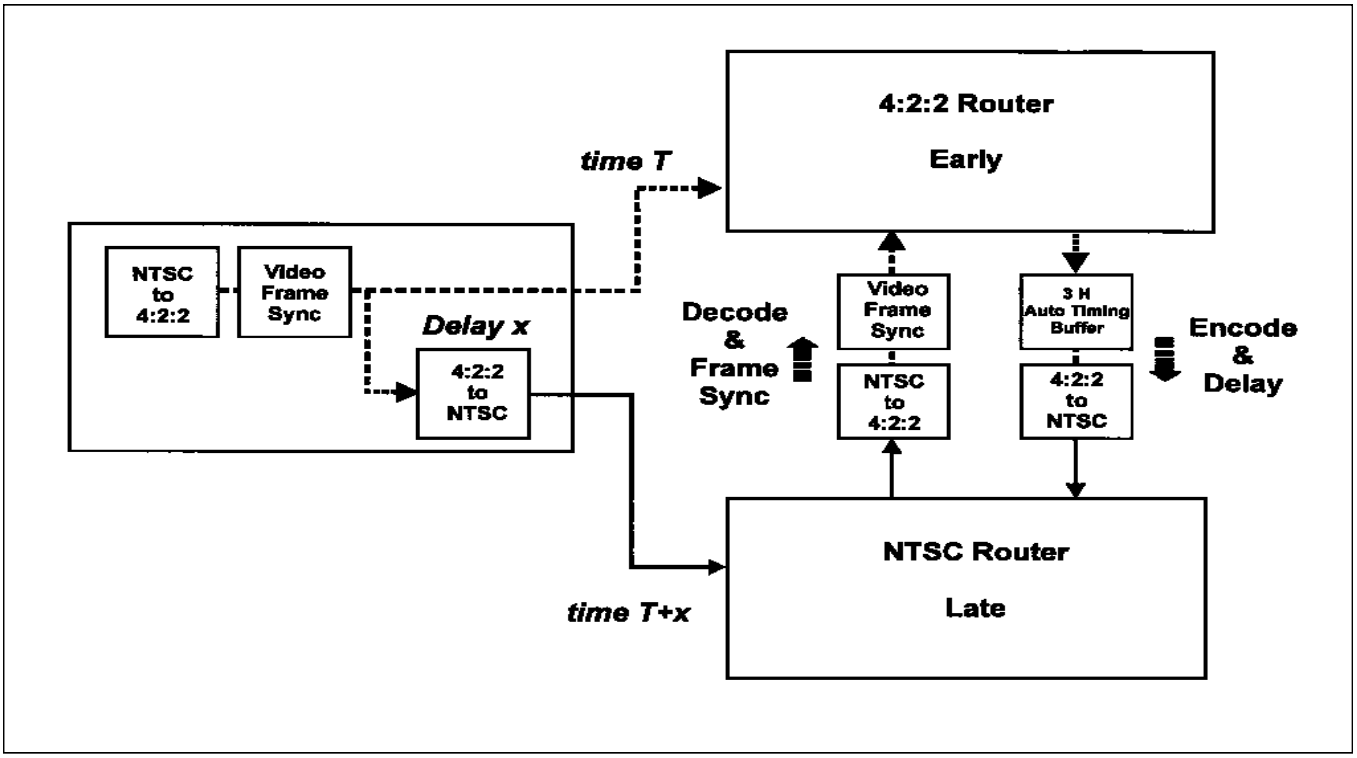

Figure 10. Timing considerations in hybrid system architecture.

grams, WTTG also provides several outgoing feeds, all of which are composite. The decision was made to convert all NTSC feeds to the component digital domain immediately, as they entered the plant prior to frame synchronization. As shown in Fig. 9, a copy of the synchronized signal is converted back to NTSC and fed to the NTSC router. This extra transcoding step was required in order to avoid dual synchronizers and simplify system timing. Because the extra conversion is not in a multigeneration path, it impacts the signal only once as the signal enters the plant.

Timing Considerations

The biggest challenge in designing the dual-format, hybrid architecture was establishing system timing. Digital timing considerations are radically different from analog. Many digital devices offer automatic input timing, which simplifies system timing. However, digital devices tend to add more delay than their analog counterparts. Format converters themselves can add significant delays that must be accounted for, especially when these devices feed the analog portion of the plant.

WTTG's overall strategy was to time the digital portion of the plant ahead of the analog portion. The D/A bridges included a small amount of automatic timing, which allowed the digital signal to be delayed before it entered the analog router. The A/D bridges included frame synchronizers to bring the analog signals "forward" in time to meet the advanced digital portion of the plant. A simplified block diagram of the WTTG plant is shown in Fig. 10. Timing considerations are included.

In WTTG's installation, a three-line timing buffer in the D/A encode bridges provided the jitter removal and the necessary delay to bring the inherently early digital signal into time with the analog plant.

The disadvantage of using frame synchronizers is that they add a significant delay (up to 1 frame) to the video signal. Frame delays soon cause the video and audio to become unmatched, causing undesirable lip-sync problems. Because of the widespread use of frame synchronizers, WTTG elected to use audio delays wherever the video signal was undergoing a lengthy format conversion or frame synchronization.

Conclusion

Both the cost and effects of format translation must be carefully considered when designing a digital facility. The system architecture must take into account the complement of equipment and signals that will be used. A component architecture offers significant benefits, particularly in production environments or when considering the long-term future.

If a new facility is being built from the ground up, then an all-component digital architecture is likely a good solid choice. If, however, a facility is being gradually upgraded to digital and will have to coexist for a time with NTSC, then a hybrid architecture including both composite and component may be the solution to avoiding the effects of excessive transcoding.

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