well below the ration level, with an almost 50% usage reduction below the 1976 consumption. Also, the dollar savings still accrue, despite a 40% rate increase in July of 1977 (Fig. 8).

Our water-conservation program is continuing. Process specifications are under constant review, and in some cases further reductions in water use seem possible. We are fine-tuning the lawn system to find survival level. Our employees are aware and concerned and continue to bring in water-saving suggestions. We are studying "gray water" from the sand-filter back wash and from the cooling tower bleed-down, which amounts to over 3000 gal/day, and are using this water for irrigation. The ration level set by Palo Alto is 28% less than the 1976 consumption, but we expect to continue at nearly 50% less than that base rate.

Our program was not startling. It was based on sensible housekeeping and conservation rather than on "big technology" that might or might not have been economical. Our program has shown that where incentive, concern, and motivation come together to solve an immediate problem a great deal may be accomplished in a short time.

Television Studio Design — Signal Routing and Measurement

By DONALD ROURKE

Conventional methods for routing signals in a television plant, with their associated limitations, may include patch panels, passive switching, and electronic routing switchers. The production-quality color television routing and measurement system concept discussed here utilizes a modern, standard production, video/audio routing switcher as the central system element. This system eliminates the need for testing through the production switcher (the conventional method) by providing facilities for accurate testing of all sources at the engineering area during full operation. This is of particular significance where unattended switchers are in operation. Other precision timing benefits become possible and practical, further reducing the number of chances for errors. The "path length accuracy" principle is demonstrated in a practical operational model.

Introduction

Routing signals in a color television plant while attempting to maintain path length accuracies to prevent color errors is an age-old problem for the television engineer. As an example, one foot of coaxial cable is capable of producing a visible flesh-tone error of 2° when introduced incorrectly or accidentally into a video line. A modern production facility may utilize more than 20 video/audio sources, providing many possibilities for errors. These sources will generally consist of recording/playback and processing equipment or input/output devices.

From a studio design and operational standpoint, the primary objective is to achieve conditions where signals from all of these sources arrive at the input of the production switcher (where mixing and effects with the sources are to be accomplished) with precisely the same timing. Timing must be considered in two components: synchronizing information (sometimes referred to as monochrome timing) and color timing. These components are interrelated but are generally treated separately.*

Monochrome errors are easily detected by horizontal shifts between consecutively switched signals. The tolerance for monochrome timing in a high quality, post production studio is as tight as possible for initial editing purposes because program material may be re-edited and any position shifts may not be acceptable. A minus B methods providing high accuracy will be shown for this purpose.

Generally, the color timing error is the greater problem encountered with production switching and signal routing systems. As stated earlier, 2° (1.5 ns) color errors during program assembly are visible and therefore unacceptable. The degree of accuracy required would appear to be something less than 1° (less than 0.77 ns). It is this type of accuracy on an overall system basis that one should expect to achieve.

Another equally important aspect of plant (studio) design is signal routing and distribution to and from all equipment. In order to accommodate real situations, it is required that source signals must change position from time to time, and in order to function efficiently and effectively, a television plant must be flexible in terms of inputs and outputs. As we shall see, the production switcher and the routing switching systems must be considered together in the overall plant design.

Types of Routing

There are several methods available to the television engineer to accomplish signal routing. The oldest and most obvious method is the patch panel. With great care to detail, adequate accuracy within limitations is obtainable. An additional panel will be required for audio signals. Some disadvantages of video and audio patch panel switching include: excessive rack space; slow, nonsynchronous switching; no possibility for remote or computer control; greater chance for operator errors; the necessity for large numbers of distribution amplifiers; the increased probability of mechanical failure; and the unsightly cabling.

Another method of signal routing is passive switching. Passive switching is not recommended at video frequencies unless coaxial switches are used. In this case, the hardware limitations are prohibitive unless the systems are very simple. A separate audio panel will also be required.

The third and currently most popular method is electronic routing where all video and audio inputs can be electronically routed to any or all outputs. There are numerous standard production configurations available ranging from 5 × 1 to greater than

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*A good source of additional information is the pamphlet "Timing Fundamentals in Color and Monochrome Television Systems," RCA Form 3J5689, available from RCA Broadcast Systems, Marketing, Bldg. 2-2, Camden, NJ 08102.

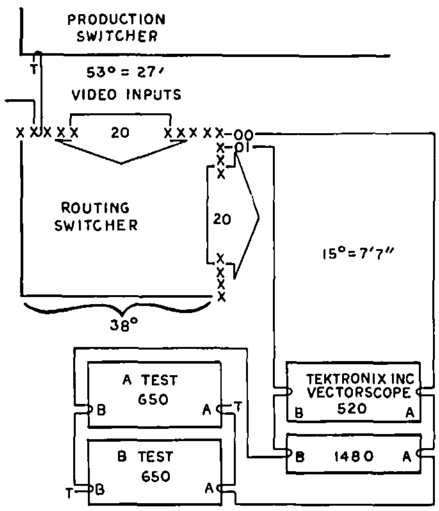

Fig. 1. Block diagram of the "ideal" signal routing and measurement system. The 20 × 20 routing switcher is a TeleMation TVS/TAS video/audio routing system. Besides the vectorscope, two picture monitors and a waveform monitor are used.

100 × 100. Most of these electronic routing switchers provide reasonable technical specifications in terms of television distortions; some of the newer ones provide vertical interval switching, numerous convenient control methods, and differential inputs with high common-mode rejection. Most drive multiple lines and some provide selective audio (any audio to any video or vice versa). Options may include features such as single coaxial party controllers; a computer and dataphone control interface which translates RS-232 control data from a computer or dataphone mode to party line data at the 300-baud rate; power line drop-out protection for the memories for up to 3 h; and a mnemonic four-character status display on video monitors. All of these options are available on the sytem to be described.

Electronic signal routing has gained wide acceptance and is generally preferred to patch panels and cables. However, with all of the aforementioned benefits and conveniences, there is a major limitation inherent in most currently produced electronic routing switchers. The "path length accuracy" from any input to an output varies in accordance with the internal propagation delay from each input selected. The variation from inputs is related to the switchers. Remembering that a 2° fleshtone error is quite visible, particularly during editing, it can be determined that most routing switchers cannot be used as sources for inputs or auxiliary inputs at the production switcher or for any equipment that derives its color reference elsewhere (external subcarrier), such as color television test equipment and specialized processing equipment. For some applications this may not pose much of a problem, but for the modern production facility this can be a serious and expensive problem. Dedication and duplication of equipments are created, thus providing far less flexibility than that which might be afforded by systems designed with "path length accuracy" as a primary characteristic.

System Design

The basic building block for this color television signal routing and measurement system is the TeleMation (of Salt Lake City) TVS/TAS 1000 Video/Audio Routing System. At the time of writing we believe this is the only routing system that can provide the required technical specifications and facilities. This system contains no patch panels; all video switching during the vertical interval and audio switching are accomplished electronically.

Referring to Fig. 1, the routing switcher is shown by Xs representing cross points. A 20 × 20 array will have 400 video cross points and 400 audio cross points. The Xs in the vertical line represent outputs and those in the horizontal line represent inputs. Input sources (VTRs, film, etc.) may be located at any distance, with regard to normal considerations: the synchronizing timing must accommodate the longest propagation delay because all video inputs must be coincident at the inputs of both the production switcher and the routing switcher. This applies to both monochrome and color timing.

The routing switcher may be located a convenient distance from the production switcher electronics, such as in the engineering area where other control and measurement equipment is usually located. Location will also be governed by the location of the vectorscope. This distance must include the internal propagation delay of the routing switcher so the inputs to the vectorscope are precisely equal to the inputs of the production switcher. This is the basis for the precision measurement system.

Referring to Fig. 1, the propagation delay for the routing switcher is shown as 38° at the subcarrier frequency. This data is furnished accurately by the manufacturer in a computer printout form obtained by automatic testing methods. The shortest, longest, difference, and mean data are given, along with a great deal of other pertinent test data. The maximum tolerance or specification for worst-case delay is ±1° between all inputs to an output, which is a primary requirement for this system. The overall propagation delay varies according to the size of the system. Systems presently available range from a 10 × 10 switcher to one that is 100 × 100. The system described here is a typical 20 × 20 switcher.

The distance or delay between the outputs of the routing switcher measurement system (shown in Fig. 1 as channels 00 and 01) and the inputs of the vectorscope may be of any reasonable length; in this case it is 7 ft 7 in (2.31 m). This distance adds directly to all cables connecting the production switcher and routing switcher, which are shown in Fig. 1 as 27 ft each (8.23 m or 53°).

This brings us to another very important point. Looping inputs are not standard with the TVS/TAS 1000. The manufacturer will furnish looping inputs as an option at the time of purchase or else parts may be purchased to retrofit existing switchers. Looping inputs will reduce all cables looping to the production switcher by 1 ft (30 cm) or 2°. This is included with the original data to produce the total of 38° as shown in Fig. 1. For systems larger than 20 × 20 this delay may increase. It is important to stipulate to the manufacturer at the time of system design that these looping inputs are to be perfectly matched. Looping inputs will add two constraints. All electronics must stack vertically. This requires 8¾ in (22 cm) of rack space per 10 × 10 plus a 1¾-in (4.5-cm) ventilation unit for every two-card frame or each set of 20 channels.

Again, delays are specified to be "plus or minus one degree between all inputs to an output." A subtle but correct implication of this specification is that all outputs will not necessarily be within 1° of each other. In practice, differences from as little as 0.5° to as much as 7° have been measured. This represents no real problem, but is a condition that the designer should take into consideration.

Channel Assignment

Channel assignments require careful consideration; this is again related to equipment architecture. If a video source is to be switched with several of its audio sources, the sequence should not end a 10-, 20-, or other card frame start number. Consider for example a situation where to satisfy production requirements three audio channels are required to be independently selectable for each VTR video channel. This may be accomplished by assigning three inputs to the VTR and bussing the video inputs internally on the routing switcher mother board. The desired audio sources are cabled to the assigned channels.

In making channel assignments, it is good to establish 00 for test A, 01 for test B, 02 for program line, 03 for preview, etc. Wherever possible, inputs and outputs of equipment should have the same channel number so that the operator can remember them easily. All system inputs and outputs should be defined in advance to be sure that the system will be large enough.

Measurement System Performance

With the switcher card frames in place, cabling to the production switcher may be fabricated. This cable run may be precisely prefabricated, which generally produces a very neat installation. Belden 9231 or equivalent cable is recommended and is applicable to the timing information given.

The next item is the selection of the plant reference. It is convenient to start at a film chain, but this may not be the longest delay or farthest source in the system. Because all inputs must arrive simultaneously all other sources must be delayed sufficiently to accommodate the farthest source, in time, by whatever method was selected by the system designer. Once the reference is selected and connected, it may be color timed to agree with the color background generator of the production switcher. (It is assumed that the production switcher is properly timed throughout in accordance with the manufacturer's specifications and is properly timed for the reference. Reference verification may be measured at the preview output where initial timing errors are more easily seen.)

In order to establish a precise reference for the measurement channels, the cable connecting the reference source at the production switcher position is moved to the "A" input of the vectorscope (terminated). With the vectorscope reference set to external, the "A" phase is selected and the phase control is adjusted for exactly 180°, as indicated on the graticule. The reference source may be temporarily reconnected to the appropriate production switcher input. The phase reference now established on the vectorscope must not be altered after this point, and the rest of the matching procedure should be gone through expeditiously and, if possible, without interruptions. Briefly, the procedure is as follows: The plant reference set to color bars may now be switched to the test A and test B outputs. Connect the calculated test A and B cables (terminated) to the vectorscope A and B inputs. Display A channel. If the data and calculations are correct, the error will be less than 1°. If this is not the case, the simplest solution is to recalculate the test cable length using the displayed information. Thus for every 2° of clockwise rotation, the cable is 1 ft (30 cm) too long, and for every 2° of counterclockwise rotation, the cable is a foot short. When the procedure for 00 channel A is completed, repeat it for 01 channel B. The A and B cables may not be exactly the same length when they are completed because — as noted — there may be a small difference in output timing. Once this is established, no further change will occur unless the equipment is defective.

When this match is complete, the remainder of the test measurement system may be connected as shown in Fig. 1. To permit accurate A minus B measurements at the Tektronix 520 vectorscope, the 1480 waveform monitor, and the 650 picture monitors, it is required that the cables between these devices be kept to exactly the same lengths. The prefabricated (matched) cables connecting the routing switcher and the production switcher may then be permanently installed.

The remainder of the system's inputs may be connected, timing each against A, the plant reference. Each may be verified at the output of the production switcher. There will be small quadrature errors distinguishable even among the best color bar generators and encoders. These will be precisely the same, barring switcher errors, both at the measurement system and at the production switcher output. These errors should not exceed 1°.

It will no longer be necessary to process signals through the production switcher to verify their setup and quality unless, of course, one is testing the switcher itself.

The precision measurement system is just one benefit of this system. It is practical to accurately color-time inputs of all equipment in the studio and to expect them to remain within 1° of any other source. The same principle that is utilized in the measurement system applies to all outputs. This is particularly significant for processing equipment that references to an external subcarrier. Another application is with some VTRs in the edit mode where the color error range is limited. All plant-referenced equipment will benefit from a known stable input.

Summary

The foregoing is a description of what we regard as an ideal functional 20 × 20 system. It has been in operation 24 hours a day for more than three years at the Veteran's Administration Center for Endoscopic Programs of the V. A. Medical Center in Lake City, Florida. It has not been necessary to process source signals through the production switcher, unless the production switcher itself was to be tested. Comprehensive testing for basic timing, color phase, and other color television signal parameters are easily and reliably accomplished while the production switcher is in full operation. The production switcher is mostly unattended and under computer control. Reliability and long-term accuracy have been most satisfactory.

The principle of "path length accuracy" greatly simplifies color television plant design and substantially improves operational reliability and convenience.