Timing and Synchronization in a Multi-Standard, Multi-Format Video Facility

Meeting the Challenges of Operating in Mixed Environments

Synchronization is one of the most fundamental and critical procedures in a video facility. Every device in a system must be synchronized in order to successfully create, transmit, and recover video pictures and audio information. The complexities of an analog and digital multi-standard, multi-format environment require flexibility to achieve and maintain synchronization in facilities that operate in a mix of formats.

Synchronization is one of the most fundamental and critical procedures in a video facility. Every device in a system (cameras, VTR's, editors, switchers, etc.) must be synchronized in order to successfully create, transmit, and recover video pictures and audio information. Adjusting system timing to achieve and maintain synchronization has become even more important and challenging in facilities that operate in multiple formats.

The complexities of an analog and digital multi-standard, multi-format environment require flexibility in customizing the synchronizing needs of the facility. Signals from a master sync pulse generator (SPG) are used to synchronize all of the equipment in a system – resulting in a state known as generator locked, or genlocked, for short. In a typical studio or post-production plant, the SPG must provide a variety of timing and synchronization signals to address the needs of multi-format, multi-standard equipment.

This application note consists of two parts. The first part describes the basic timing properties of analog and digital systems. The second part describes the use of the Tektronix TG700, a versatile video signal generator, to meet the many timing and synchronization challenges presented by today's mix of analog and digital systems. The TG700 is a multi-format test signal and sync pulse generator platform that can be configured with a variety of modules to serve the needs of analog, Standard Definition (SD)-Serial Digital Interface (SDI), High Definition (HD)-SDI, and multi-format environments.

Basic Timing Properties of Analog and Digital Systems

Understanding Analog Timing

For accurate reproduction of a video image, both the camera and the television receiver must be synchronized to scan the same part of the picture at the same time (Figure 1). Separate sync pulses are used for horizontal (line) and vertical (field) control of the electron beams that create the picture.

NOTE: The term "beams" is used to describe video monitors throughout this note, even though monochrome monitors use only one.

The beams are scanned from left to right for horizontal lines; at the end of each line, the beams must return to the left side of the picture – a process called **horizontal retrace**. The horizontal sync pulse coordinates the horizontal retrace.

Lines are scanned from top to bottom of the screen to create an active picture. Standard analog systems **interlace** odd and even lines to create a full picture (two alternating fields). Some higher-definition systems use **progressive** scanning of all lines in a single field. When the end of a field is reached at the bottom of the picture, the beams return to the top for the start of the next field – an interval known as **vertical retrace**. The vertical sync pulse signals the start of the vertical retrace.

Because the vertical retrace takes more time than the horizontal retrace, a longer vertical synchronizing interval is required and the vertical sync pulses are wider than horizontal sync pulses. During each horizontal and vertical retrace, the electron beams are turned off and nothing is written to the screen – a period referred to as the **blanking interval**.

The analog video transmission combines the horizontal and vertical sync pulses into a single **composite sync signal** in a way that allows for easy extraction and separation at the receiver. When analog television signals were first developed, the circuit designs needed to be

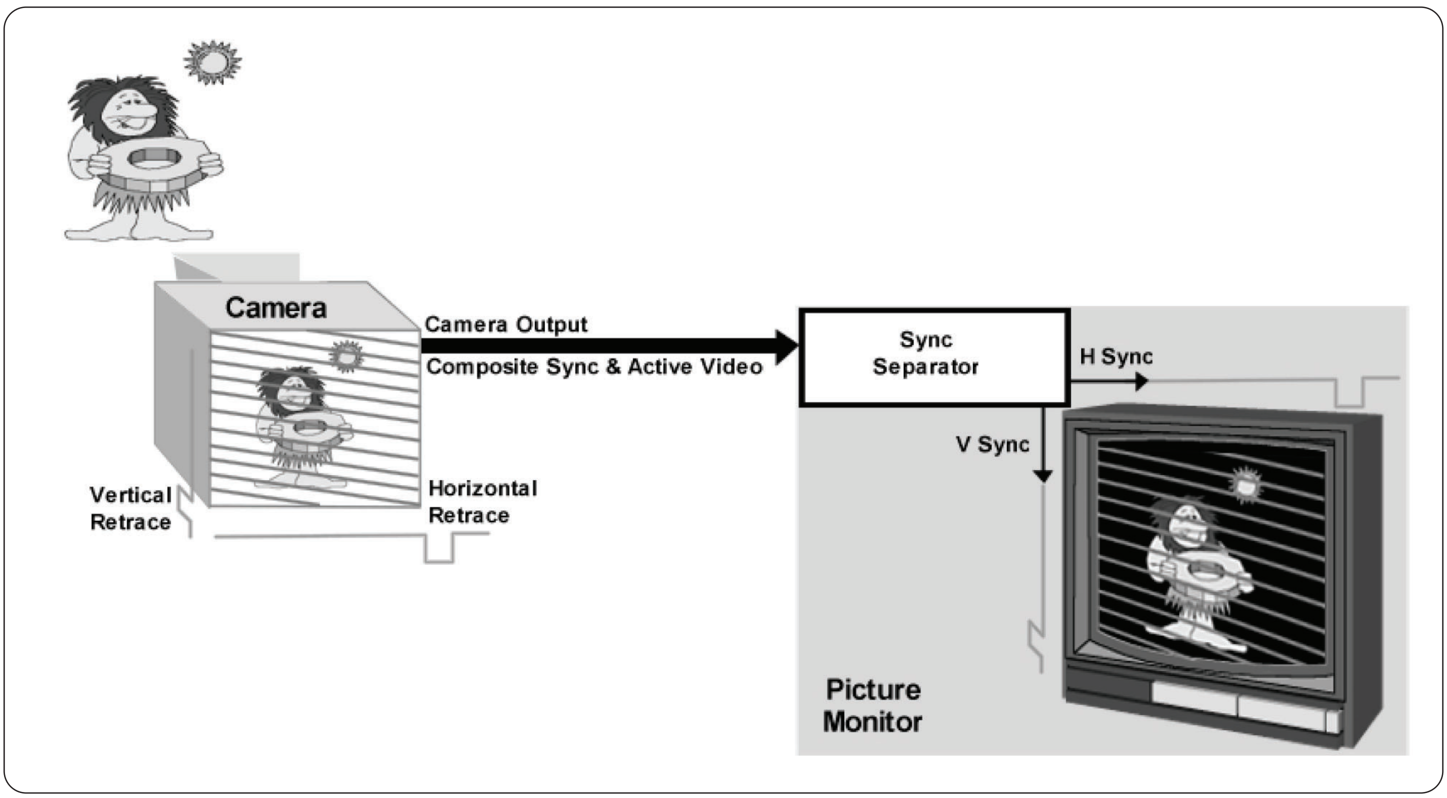


Figure 1. *Synchronizing process for analog video.*

basic because of the limited technology available at the time. As a result, the sync separator that is used to extract the horizontal drive signal in the receiver is a simple differentiating circuit. The differentiator produces sharp spiked pulses at both edges of each horizontal (line) sync pulse, as shown in Figure 2. The synchronizing circuit then uses the leading negative spike to ensure a lock to the negative pulse and ignores the positive spikes. To prevent drift of the horizontal drive circuit, the line sync pulses occur during the entire field interval.

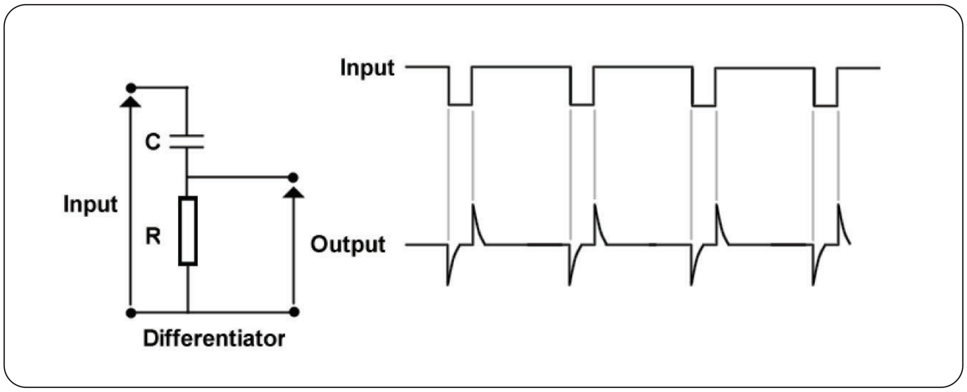


Figure 2. *Simple differentiating circuit to extract line sync pulses.*

Longer pulse widths, known as **broad pulses**, distinguish the vertical sync from the horizontal sync pulses in a composite signal. Equalizing pulses are inserted before and after the broad pulses, which produce a similar pulse pattern for odd and even fields. A simple integrating circuit is used to extract the vertical pulses, as shown in Figure 3.

Analog Timing Parameters

In analog video timing, three basic parameters need to be synchronized in order to establish a reference and ensure picture quality:

- Horizontal sync for line timing
- Vertical sync for field timing
- Subcarrier for color synchronization

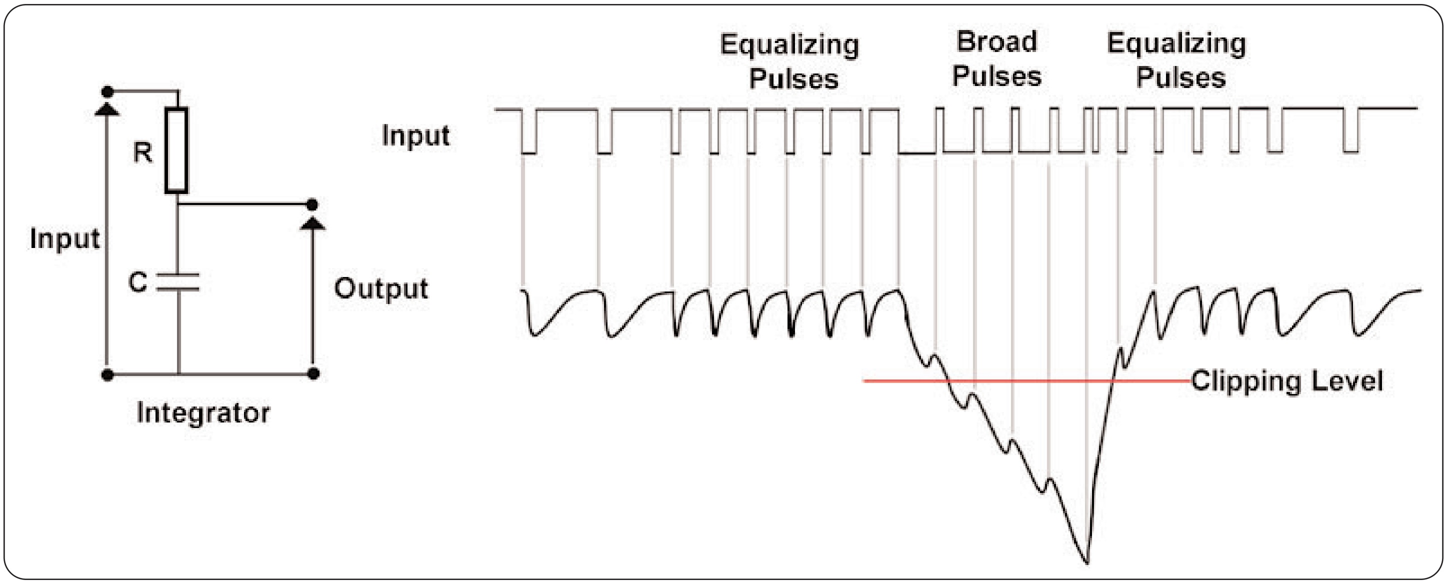


Figure 3. *Simple integrating circuit to extract vertical sync pulses.*

Horizontal sync for line timing

The **horizontal blanking interval** occurs once per line of video information and is composed of a horizontal sync, front porch, and back porch. The horizontal front porch defines a time for the video to settle to zero and prevents the video signal from interfering with sync extraction. The horizontal blanking interval allows enough time for the beams to return to the left side of the display (flyback) and settle before the start of the video signal. During the flyback period the beams are blanked to prevent the scan lines from appearing on the display. Figures 4 and 5 illustrate the relative timing of NTSC and PAL horizontal-blanking intervals. The color burst can also be seen on the back porch of each horizontal interval.

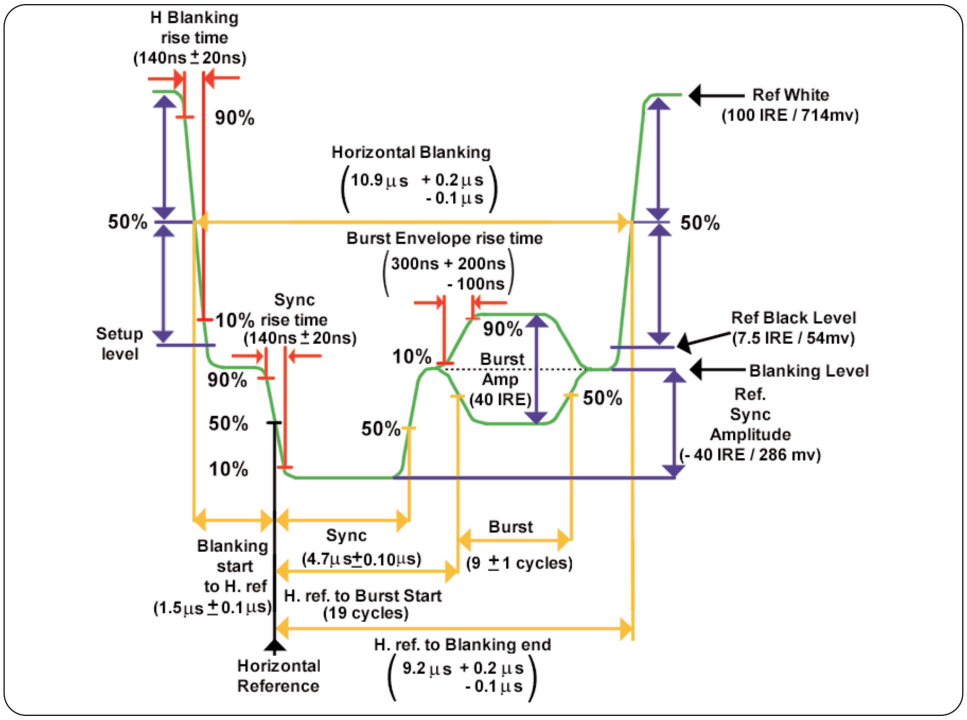


Figure 4. NTSC horizontal blanking interval (from SMPTE 170M).

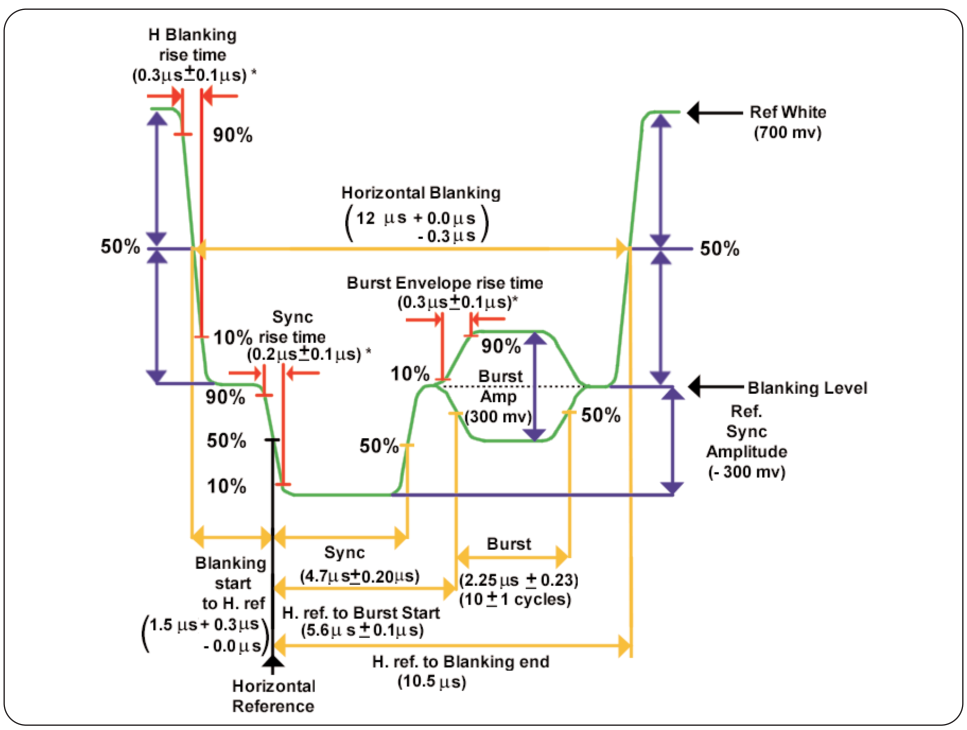


Figure 5. PAL horizontal blanking interval (from ITU-R.BT.470-6). Note that PAL-I systems use rise/fall times of (0.25 µs + 0.05 µs).

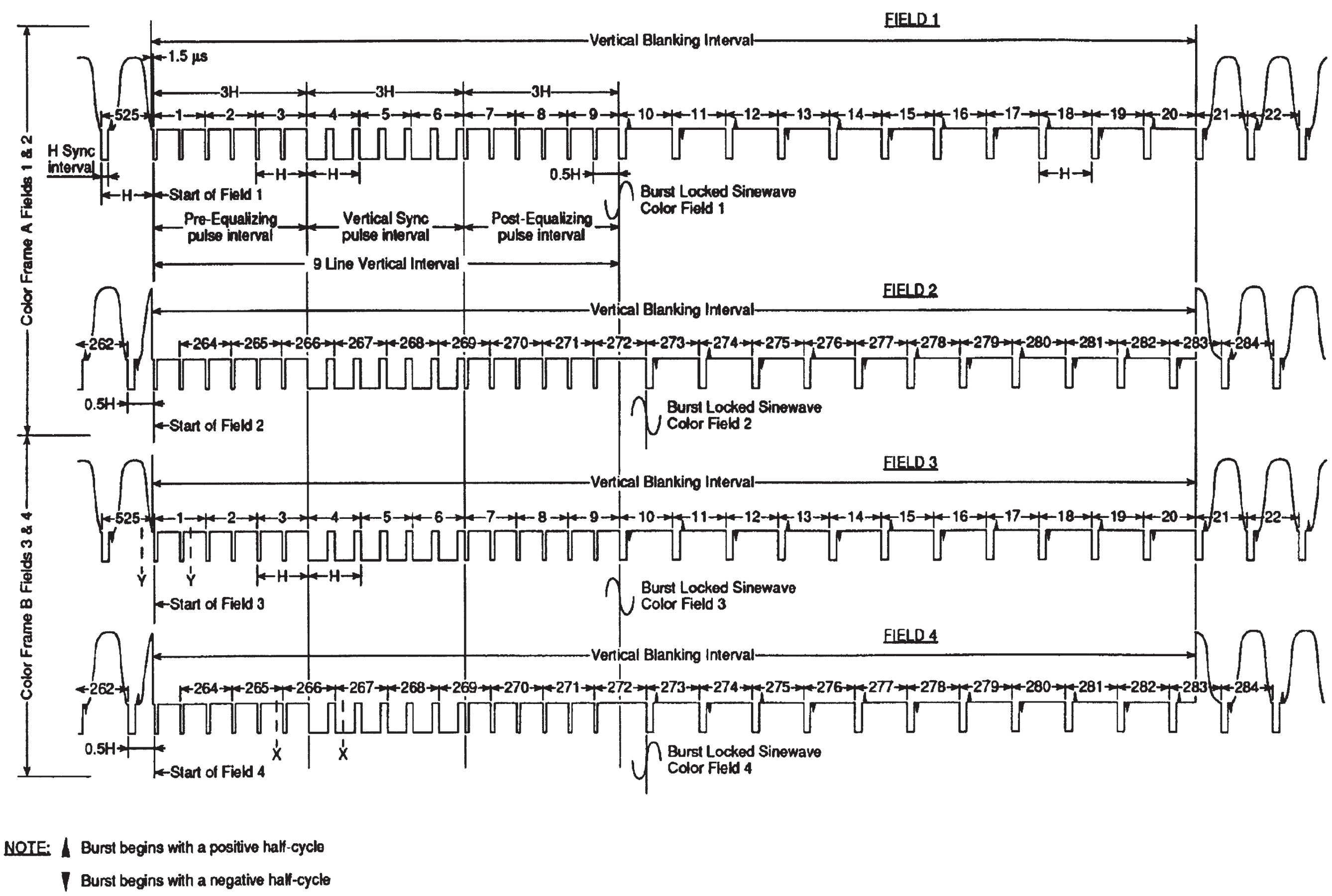


Figure 6. *NTSC vertical blanking interval.*

Vertical sync for field timing:

Vertical sync is extracted from the equalizing pulses and broad pulses during the vertical timing interval. The vertical interval allows the identification of the odd and even fields in an interlace system, and the longer vertical blanking time allows the picture tube electron beams to return to the top of the screen. The **vertical blanking interval** signals the end of the active picture and the start of the next picture, as shown in Figure 6 for NTSC and Figure 7 for PAL.

Subcarrier for color synchronization:

For the detection of color in the picture, a subcarrier burst is added to the back porch in the horizontal interval and is used for subcarrier timing. Synchronization of transmitted and received signals relies on their subcarrier bursts being in phase.

The color burst frequency is 3.579545 MHz for NTSC and 4.43361875 MHz for PAL. These frequencies were chosen to increase the separation of color and luma signals and to prevent interference with monochrome television signals. Figure 6 shows the alternating fields, and the four-field NTSC color frame sequence. The color subcarrier comes back into the same relationship with the vertical sync after four fields in NTSC. The PAL sync and subcarrier take eight fields to return to the original relationship because of the horizontal sync to subcarrier relationship.

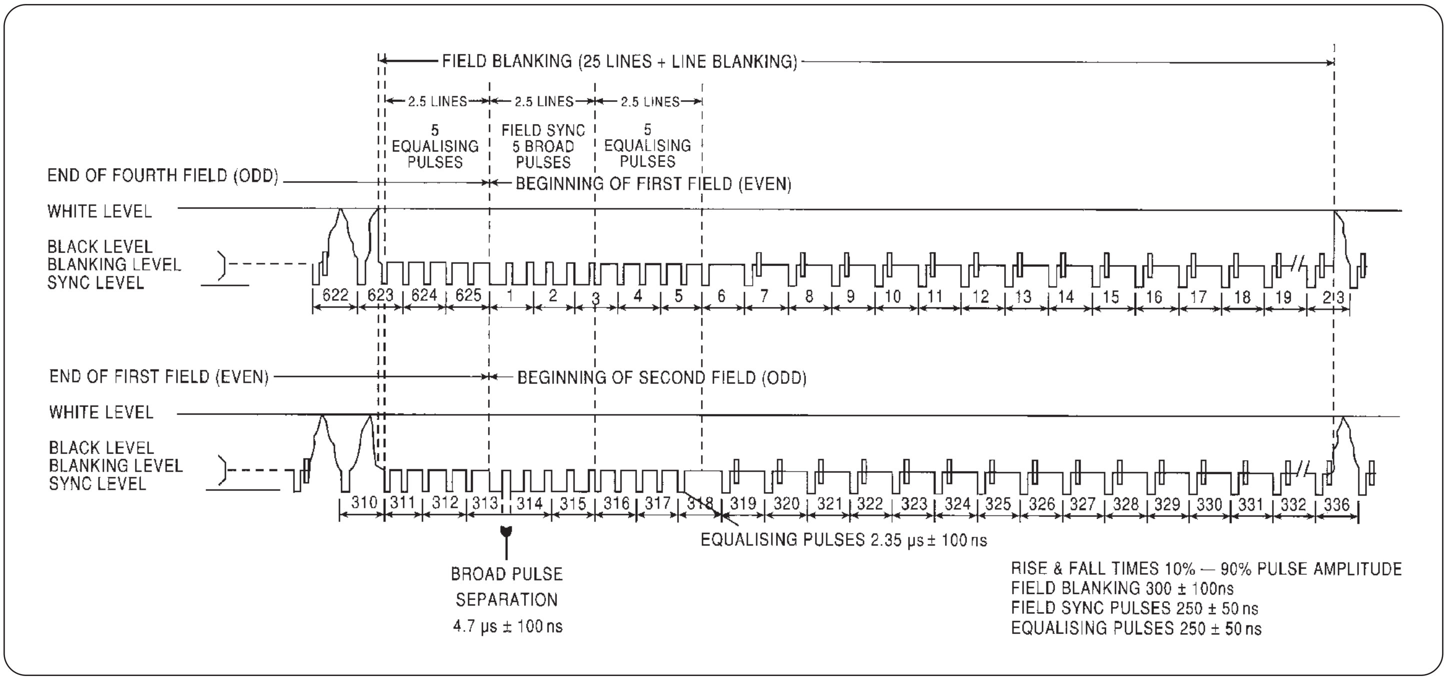


Figure 7. *PAL vertical blanking interval.*

The phase relationship between the PAL and NTSC vertical sync patterns is important when one source of video signal joins or is suddenly replaced by another source, as when the video is edited, switched or combined by special effects equipment. The critical process of identifying the correct field and color subcarrier phase is referred to as **Subcarrier-to-Horizontal Phase** (SCH phase). (Refer to SCH Phase application note 20W-5613-2 NTSC and 20W-5614-1 PAL.)

Genlock reference for analog video:

The **black burst** signal is often used to genlock equipment. It is a composite signal that contains horizontal and vertical syncs and a small packet of NTSC or PAL color subcarrier (color burst). The term black burst arises from the fact that the active picture portion of the signal is at black level (0 mV for PAL, 7.5 IRE (black) for NTSC (America) and 0 IRE for NTSC no-setup (Japan)). The black burst is used for system timing, the sync is used for genlock and drive signals and the color burst is used for color framing reference.

In some cases, a **Continuous Wave** (CW) signal is used to genlock a sync pulse generator (SPG). The CW signal is a clock signal of sinusoidal shape, usually selectable in frequency at 1, 5 or 10 MHz, depending on the device. This sine wave signal has no positional information of H and V because it is only a clock. Therefore, the timing output of the SPG cannot be guaranteed if the CW signal is removed from the SPG and then re-applied.

High-definition (HDTV) analog horizontal timing:

For high-definition analog horizontal timing, the **HD Tri-Level sync** is used instead of the bi-level sync pulse. Figure 8 shows a typical Tri-Level sync signal. The reference point is at the blanking level on the rising edge, at the half height of the tri-level sync. The tri-level sync signal has faster rise times because of the increased bandwidth of HD, which results in more accurate timing edges. These factors also improve jitter performance and sync separation.

Table 1 lists appropriate timing intervals for a wide array of HDTV formats.

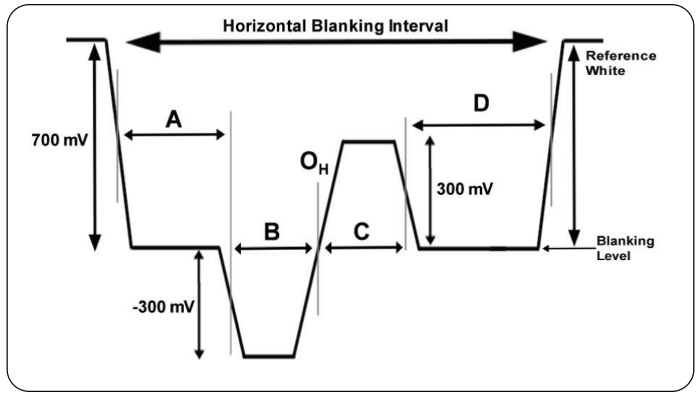


Figure 8. *High-definition tri-level sync signal.*

Table 1. HDTV Horizontal Blanking

Format	A (pixels)	B (pixels)	C (pixels)	D (pixels)	Digital Horizontal Blanking (pixels)	Digital Horizontal Blanking (µs)
1920x1080/60/1:1	44	44	44	148	280	1.886
1920x1080/59.94/1:1	44	44	44	148	280	1.887
1920x1080/50/1:1	484	44	44	148	720	4.848
1920x1080/60/2:1	44	44	44	148	280	3.771
1920x1080/59.94/2:1	44	44	44	148	280	3.775
1920x1080/50/2:1	484	44	44	148	720	9.697
1920x1080/30/1:1	44	44	44	148	280	3.771
1920x1080/29.97/1:1	44	44	44	148	280	3.775
1920x1080/25/1:1	484	44	44	148	720	9.697
1920x1080/24/1:1	594	44	44	148	830	11.178
1920x1080/23.98/1:1	594	44	44	148	830	11.190
1280/720/60/1:1	70	40	40	220	370	4.983
1280/720/59.94/1:1	70	40	40	220	370	4.988
1280/720/50/1:1	400	40	40	220	700	9.428
1280/720/30/1:1	1720	40	40	220	2020	27.205
1280/720/29.97/1:1	1720	40	40	220	2020	27.233
1280/720/25/1:1	2380	40	40	220	2680	36.094
1280/720/24/1:1	2545	40	40	220	2845	38.316
1280/720/23.98/1:1	2545	40	40	220	2845	38.355

High-definition analog vertical timing:

The analog vertical blanking interval is simpler in HD than in standard definition (Figure 9). However, there are a variety of different interlaced and progressive HD formats to be managed.

Understanding Timing for Digital Video and Audio Signals

There are no analog sync signals in digital video. Synchronization in the digital environment is achieved by the use of specific codeword sequences that represent the **Start of Active Video (SAV)** and the **End of Active Video (EAV)**. Each codeword is composed of values starting with a data packet of 3FF followed by the words 000, 000, and then a value of XYZ that contains information on the field (F), vertical blanking (V), and horizontal (H), as shown in Table 2. This data is used to synchronize the timing in the digital video signal. For digital HD, separate codeword sequences are used for the luma and color difference signals, which are then interleaved to form the sequence 3FF(C), 3FF(Y), 000(C), 000(Y), 000(C), 000(Y), XYZ(C), XYZ(Y).

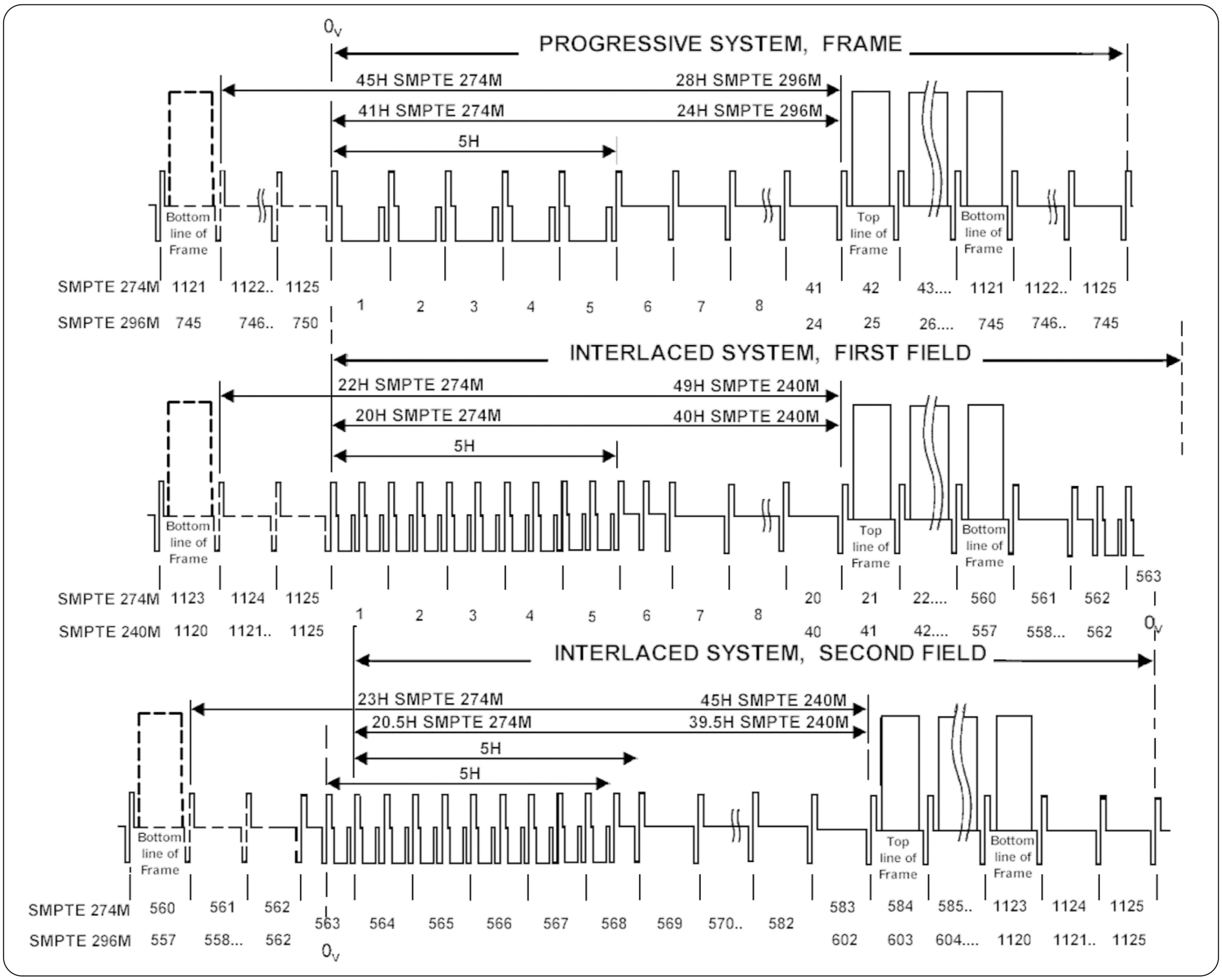


Figure 9. *Analog HD vertical interval for SMPTE 240M, 274M and 296M.*

Table 2. Format of EAV/SAV "XYZ" Word

Bit Number	9 (MSB)	8	7	6	5	4	3	2	1	0 (LSB)
Function	Fixed (1)	F	V	H	P3	P2	P1	P0	Fixed (0)	Fixed (0)

- Bit 9 – (Fixed bit) fixed at 1
- Bit 8 – (F-bit) always 0 in a progressive scan system; 0 for field one and 1 for field two of an interlaced system
- Bit 7 – (V-bit) 1 during vertical blanking interval; 0 during active video lines
- Bit 6 – (H-bit) 1 indicates the EAV sequence; 0 indicates the SAV sequence
- Bits 5, 4, 3, 2 – (Protection bits) provide a limited error correction of the data in the F, V, and H bits
- Bits 1, 0 – (Fixed bits) set to zero to have identical word value in 10 or 8 bit systems

Figure 10 shows how the F, V and H bits are used in the video signal. The vertical count begins at line 1, field 1 of the video signal.

Digital systems include audio equipment in the facility, as well. Most professional digital audio systems use a 48 kHz sample rate, conforming to the AES/EBU standards. It is important to ensure that digital audio equipment is synchronized to eliminate clock rate drift that would cause clicks in the audio because of misalignment in recognizing the data between devices. Therefore, a digital audio reference should be applied to all digital audio equipment. This reference is usually an AES/EBU signal or, in some cases, a 48-kHz word clock.

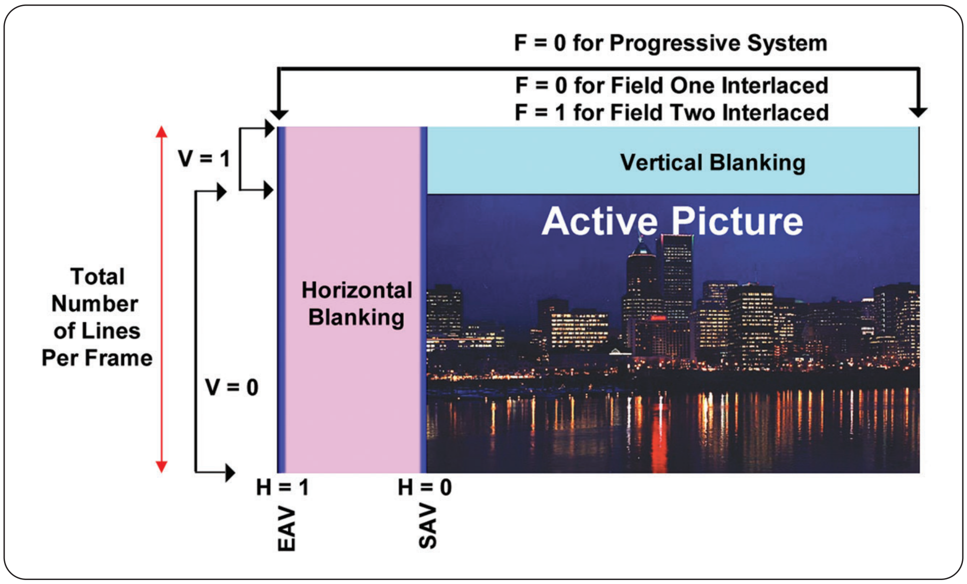


Figure 10. *Spatial layout of the digital frame with V, F, and H-bit values.*

Timing and Synchronization Solutions

Configuring the TG700 for Analog and Digital Environments

The Tektronix TG700 test and sync pulse generator platform, with its range of available modules, can be configured to provide an array of simultaneous test signals and sync signals to test and synchronize a mix of equipment based on the needs of the operating environment. A maximum of four modules can be installed in a TG700 mainframe.

The TG700 offers three modules for analog applications. The **AGL7** Analog Genlock module provides three selectable outputs: NTSC/PAL, Black Burst, and Tri-level sync; it accepts PAL/NTSC/Tri-level sync as an external genlock reference and it allows lock to CW signals. The **ATG7** Analog Test Generator module generates NTSC and PAL outputs in four independent channels, including analog test signal output, bars with ID text and two black signals; all outputs have independent timing adjustment with full color frame range – black outputs contain timing pulses, sub-carrier, or black burst signals. The **BG7** module provides an additional four independently timed Black Burst or Tri-level sync signals for situations where more black outputs are needed.

Two other modules, the **DVG7** and **AG7**, are available for standard definition digital video and audio applications, respectively. The AG7 provides four pairs of AES/EBU digital-audio signal outputs along with an AES/EBU Silence output and 48 kHz Word Clock. The AG7 can be synchronized to a video reference or free-run, and the AES/EBU Silence output can be used to provide a reference to other digital audio equipment. The DVG7 provides an array of test signals for the digital video facility; its option BK provides SDI Black to specific digital equipment.

Facilities working with HD also need Tri-Level sync and HD SDI sync signals. The BG7 module can configure any of its outputs for Tri-Level Syncs in any of the HD formats, while the AGL7 can configure the third black output (Black 3) for Tri-level sync. The **HDVG7** module provides an array of test signals for the HDTV facility; its option BK provides HD-SDI Black to specific digital equipment.

Using multiple frame resets

The TG700 offers automatic selection of frame resets to simultaneously generate and synchronize multiple video formats and frame rates. The TG700 selects the best frame reset frequency for a given video format combination, automatically changing to a common multiple frequency to provide appropriate frame lock for all of the formats as they are selected. For example, the frame reset frequency is set to 2.997 Hz for the combination of NTSC, 1080i/59.94 and 1080/23.98sF.

The TG700 supports the following three frame resets:

- Frame Reset 1 independently supports the 1/1.001 system signal. It is used for NTSC and HDTV formats with a (74.25/1.001) MHz clock.
- Frame Reset 2 supports the integer signal system and is used for PAL and HDTV formats with a 74.25 MHz clock.
- Frame Reset 3 supports either 1080/24p or /24sF when Frame Reset 2 is already being used for other formats.

Table 3 shows how the Frame Reset will lock each of the output formats in the generator. Frame Reset 1 is used for odd multiple field rates 1/1.001. Frame Reset 2 is used for even multiple field rates. Frame Reset 3 is used to support 24p when Frame Reset 2 is being used for 50 Hz.

Table 3. Frame Reset Table for HD Standards

HD Format	Analog	Digital
Frame Reset 1	1080i/59.94, 720p/59.94 1080p/29.97, 23.98, 1080/23.98sF	1035i/59.94,1080i/59.94 1080p/23.98, 29.97, 1080sF/23.98, 720p/59.94
Frame Reset 2	1080i/60, 50, 1080p/30, 25, 24, 1080/24sF, 720/60	1035i/60, 1080i/50, 60 1080p/24, 25, 30, 1080sF/24, 720p/60
Frame Reset 3	If Frame Reset 2 used for PAL and 24p is selected. 24p is assigned to Frame Reset 3.	

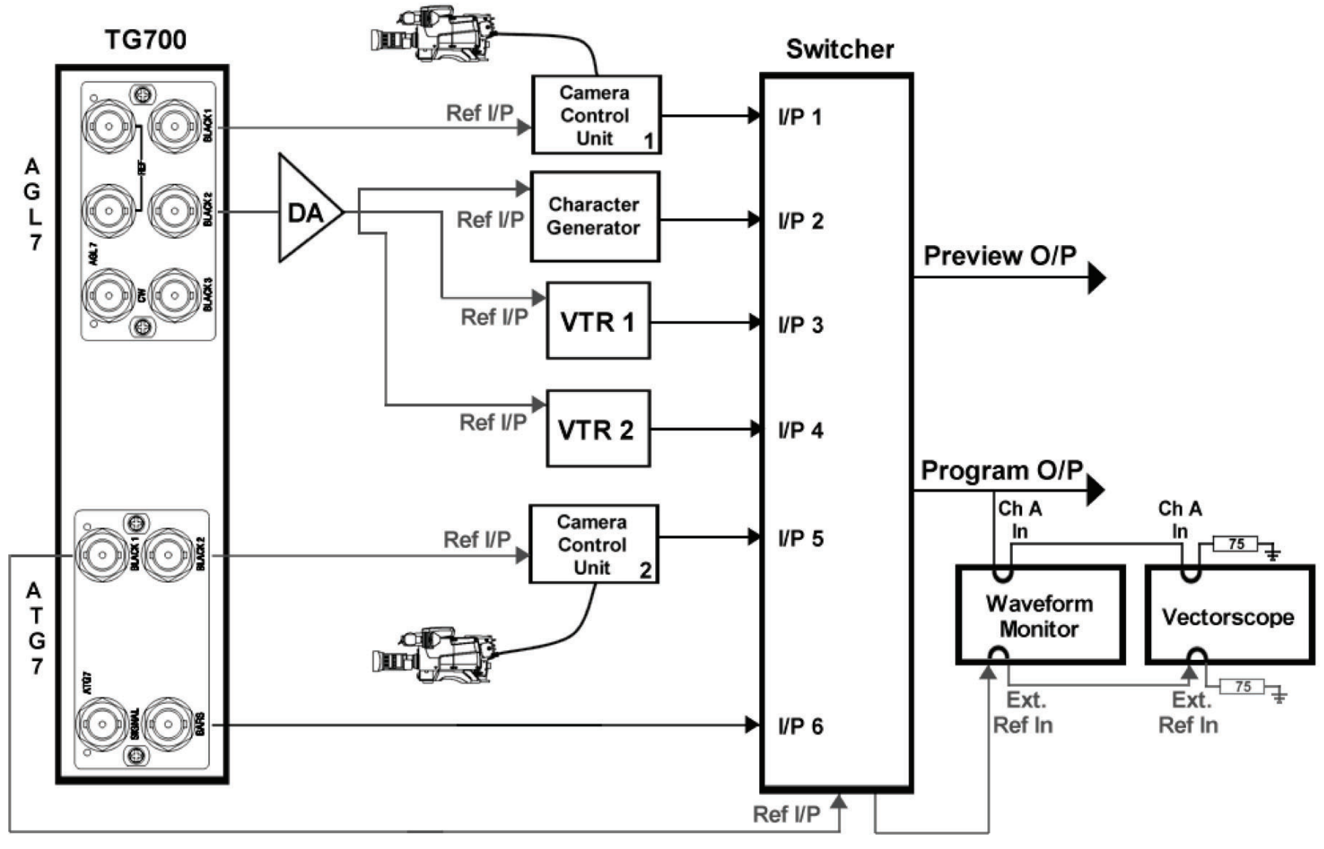


Figure 11. *Basic analog video system.*

Measuring and Adjusting Analog System Timing

When various video sources are combined, their signals must be timed together or the picture will roll, jump, tear or have incorrect colors. A precision reference signal from an SPG, such as the TG700, is applied appropriately to each device and genlocked so that the output of the equipment is synchronized with the timing of the reference.

Careful system design is necessary to ensure synchronization between all signals in the facility. In planning the system timing of a facility, the processing delay of the equipment and the propagation delay of the length of cable needed to connect the equipment must be taken into account. Typically the propagation delay through one foot of cable is approximately 1.5 ns (1 meter equals approximately 5 ns) depending on the type of cable used – a significant factor in long lengths of cable.

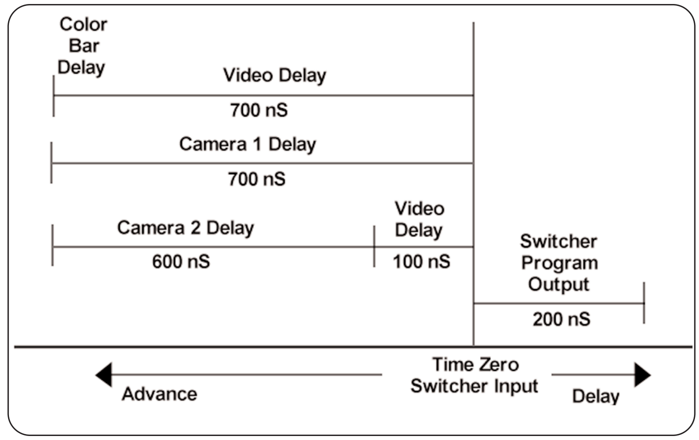
Figure 11 shows a typical basic analog video system. It is important to know the cable lengths, the processing delays of the equipment, and how timing adjustments can be made to correct for them. In this scenario, the video tape recorders (VTRs) have Time Base Correctors and allow output timing adjustment; the character generator allows output timing adjustments via software and the Camera Control Units require external delay adjustments in order to guarantee system timing.

Figure 12 shows the calculated delays throughout the system. The first step is to document the timing of each piece of equipment in order to determine the longest delay through the system. The objective is to have every signal arrive at the switcher at the same time, defined as **Time Zero**, by introducing compensating delays.

In this example, the combined processing delay and cable delay is greatest through the signal path for Camera 1, so it will be used as the basis for timing every other signal. Appropriate delays must be inserted into the other signal paths to match that delay and synchronize them at the input to the switcher.

Delays are inserted by using the timing adjustments of the TG700 for each black output. In this example, a separate black output is used for each camera control unit to adjust the delay appropriately. The character generator and VTRs each have built-in timing adjustments, so a **Distribution Amplifier (DA)** can be used to route the TG700 reference signal to each of them. Note that using a DA in the system will also introduce a small processing delay. If the equipment is in close proximity, the reference signal can be looped through them. The internal adjustments of each piece of equipment can then be used to ensure synchronization to the switcher's input. The color bars input timing to the switcher can be adjusted by the TG700.

Analog system timing adjustments are made with a waveform monitor and vectorscope connected to the switcher output, as shown in Figure 11. The external reference is selected on both the waveform monitor and vectorscope so that the units are synchronized to the black burst reference. Care should be taken to ensure that the measurements are made at the 50% levels, which is standard practice for analog signals; otherwise errors can occur in the measurement. Select the black reference signal to the output of the switcher, which will be the zero time reference to compare the other signals applied to the switcher's inputs.



▶ ***Figure 12.*** *System timing through the studio.*

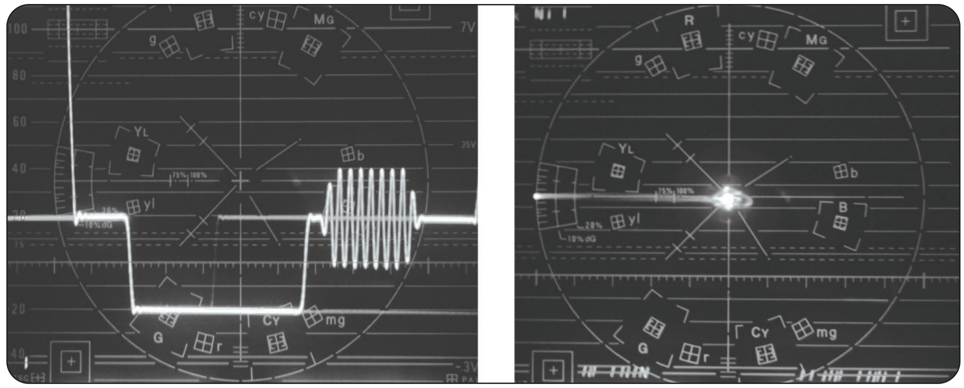
Start by ensuring that vertical timing exists between inputs. On the waveform monitor, select the A input and set-up the waveform display in a horizontal magnification *(H MAG) 1 field sweep* mode to show the vertical interval of the waveform. Position the waveform so that line 1, field 1 is placed at a major tick mark on the waveform monitor. All the other inputs to the switcher can then be compared with the zero black reference and adjusted vertically so that the signals are in the exact same position as the reference.

The next step is to adjust the horizontal timing of the signals. Select the black reference signal at the switcher's output and select an *H MAG one-line sweep* mode on the waveform display so that a horizontal sync pulse is displayed. Position the waveform so that the 50% point of the leading edge of sync is at one of the major tick marks.

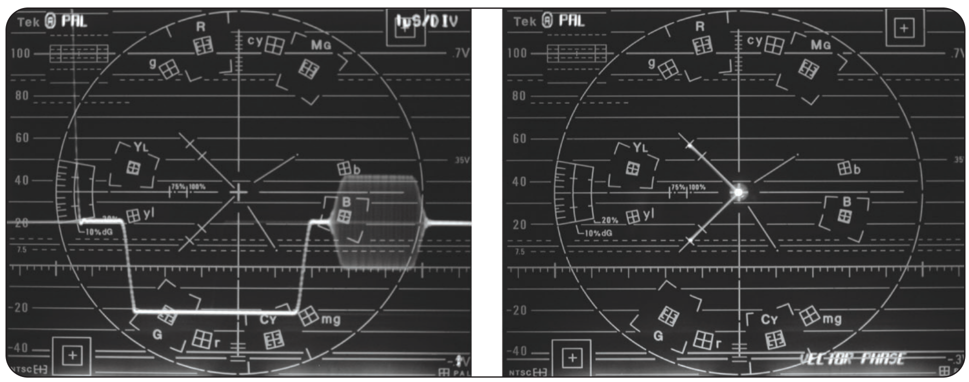
A similar procedure can be performed with the vectorscope to ensure color burst subcarrier phase. For NTSC, position the color burst to the 9 o'clock position and magnify (MAG) the display so that the burst amplitude lies on the outer edge of the compass rose, as shown in Figure 13. Set this up with the black reference and then adjust the phasing for all other inputs to the switcher. A similar approach is used in PAL systems, but the phase of the burst is switched on alternate lines and lies at +135° and +225°, as shown in Figure 14. The PAL burst can be magnified as shown in Figure 15, so that it lies along the 135° axis to the outer edge of the compass rose. The *V axis switched* setting can be selected on the vectorscope to simplify the display, as shown in Figure 16.

Sync and burst signals are now referenced to Time Zero and the various inputs to the switcher can be selected to ensure they are positioned at the appropriate places on the waveform monitor and vectorscope. If the vectorscope has the capability, S/CH phase should be measured between the reference signal and other inputs of the switcher. This is particularly important in the editing process to prevent disturbances when the signal is switched. Once this task is completed, you will be able to switch smoothly between video sources and make clean edits without picture roll, horizontal jumps or color flashes.

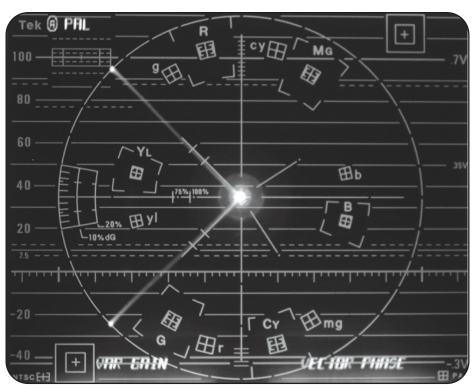
Editing suites and studios have used **Component Analog Video (CAV)** to avoid composite artifacts and improve the management of signals. This is a simpler approach since the process requires the timing of the horizontal and vertical signals, but does not require the timing of the color subcarrier. However, the CAV system does require appropriate inter-channel timing of the three video signals (Y', P'b, P'r) or (R', G', B') per distribution path.



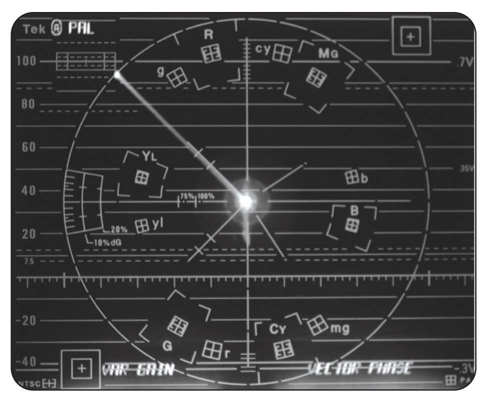
▶ ***Figure 13.*** *NTSC waveform in H Mag with two lines selected (left); Vector display in variable gain mode (right).*



▶ ***Figure 14.*** *PAL Waveform in H Mag with two lines selected (left); Pal Vector Display (right).*



▶ ***Figure 15.*** *PAL Vectorscope MAG display.*



▶ ***Figure 16.*** *PAL Vectorscope MAG display with V axis switched.*

Component Serial Digital Interface (SDI) offers a means to distribute the signal on a single cable and maintain video quality throughout the video facility. However, it brings other new challenges and techniques for timing in a multi-format facility.

Measuring and Adjusting Digital System Timing

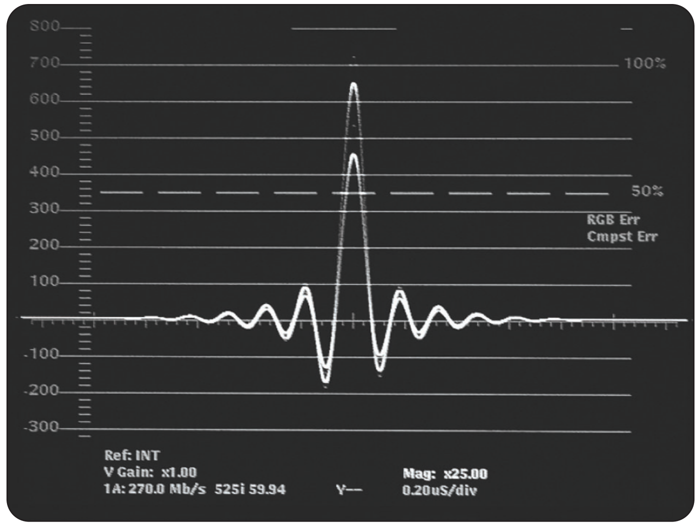
Digital equipment has some advantages over analog and is a little more forgiving when dealing with timing. A digital switcher usually has partial automatic timing of the inputs and it can compensate for timing errors, provided the signal is within a specified range of 30 to 150 µs, depending on the equipment. However, care is still needed to ensure vertical timing because of the large processing delays in some digital equipment. Analog black burst is still the predominant reference signal, although a SDI Black signal can be used on some digital equipment.

Measuring the timing of two digital signals is a simple procedure using a digital waveform monitor such as the Tektronix WFM1125, WFM601, or the WFM700. The SDI signals are connected to Channel A and Channel B and the waveform monitor is externally referenced to the black burst or tri-level sync (as appropriate). Care must be taken to terminate all signals correctly.

In the configuration menu of the waveform monitor, select *pass EAV and SAV* mode and the 3FF, 000, 000, XYZ values will be displayed on the waveform monitor, as shown in Figure 17. The transition from 3FF to 000 and 000 to XYZ produces ringing on the display when passed through the appropriate SD or HD filter. The SAV or EAV pulse can be used as a timing reference by positioning it on a major tick mark of the waveform display and comparing it to the other SDI signals – ensuring that they are positioned at the same mark.

There are no vertical pulses in the digital domain – digital systems calculate their video position based on the values of F, V, and H. Therefore, a reference point must be defined in order to measure vertical timing. For simplicity, the first line of active video can be used as the reference, because the vertical blanking lines are normally blank.

To measure vertical timing, set *Line Select and Sweep* for two-line mode, select *Field 1* and line select at the setting that will display the last line in the vertical interval and the first line of active signal. This setting should be line 20 for 1080 Interlaced HDTV, 41 for 1080 progressive formats, 25 for 720 progressive, 19 for 525 interlace, or 22 for 625 interlace. If necessary, adjust the vertical timing of the source until the display is correct.



▶ ***Figure 17.*** *XYZ pulse of Y channel with pass through selected on WFM700.*

Next, select channel B and make sure the last vertical and first active lines are displayed. If necessary, adjust the vertical timing to align both vertical positions to the start of active video. Lastly, switch back to channel A and set *MAG* to ON, noting the amplitude of the SAV pulses. If the amplitudes of both pulses are identical, they are in the same field. If not, the two signals are in opposite fields and timing adjustments should be made to align the sources to the same starting point.

To measure horizontal timing, switch to channel A and set the waveform monitor to sweep one line. Use the horizontal position knob to set the SAV pulse to a major graticule tick mark, or use cursor mode and set a cursor on the SAV pulse. Compare the timing to the signal on channel B by selecting the channel and adjusting the fine timing controls to match the timing position of channel A.

Synchronizing Digital Audio

The Tektronix TG700 Audio Generator module AG7 provides silence and word clock output as well as four other AES/EBU outputs which can provide a range of test tones or silence. The AG7 can also be locked to the video reference for synchronization between audio and video equipment.

For 625/50 line systems, there is a direct relationship between the 25 Hz video and 48 kHz audio of a 1920 samples per video frame – there are 192 frames in the AES/EBU digital audio structure that produce exactly ten audio interface frames per video frame. For NTSC, there is a non-integer number of samples per frame because of the frame rate of 29.97 Hz (30/1.001), and it takes five NTSC frames to reach an integer number of audio samples (8008).

An optional ten-field identification sequence can be used as specified in SMPTE 318M to enable the synchronizing of digital audio to an NTSC black burst reference with a field frequency of 59.94 Hz. The sequence can also be used in multi-format environments to synchronize equipment operating at 23.976 Hz (24/1.001). For example, a 1080 progressive system at 23.976 Hz provides a means for a direct transfer of film frames to digital files.

The ten-field timing reference is shown in Figure 18 and is inserted on line 15 and 278 of a NTSC 525/59.94 Hz signal. The first pulse (1) is always present at the start of the identification sequence, as defined in Table 4. Pulses 2 through 6 represent the ten-field sequence count. Additionally, the end pulse (6) is always absent on line 15 and always present on line 278. The TG700 signal generator platform provides the ability to genlock to SMPTE 318M with the AGL7 analog genlock module and provides SMPTE 318M output references with the BG7 black burst generator with color bar option (CB).

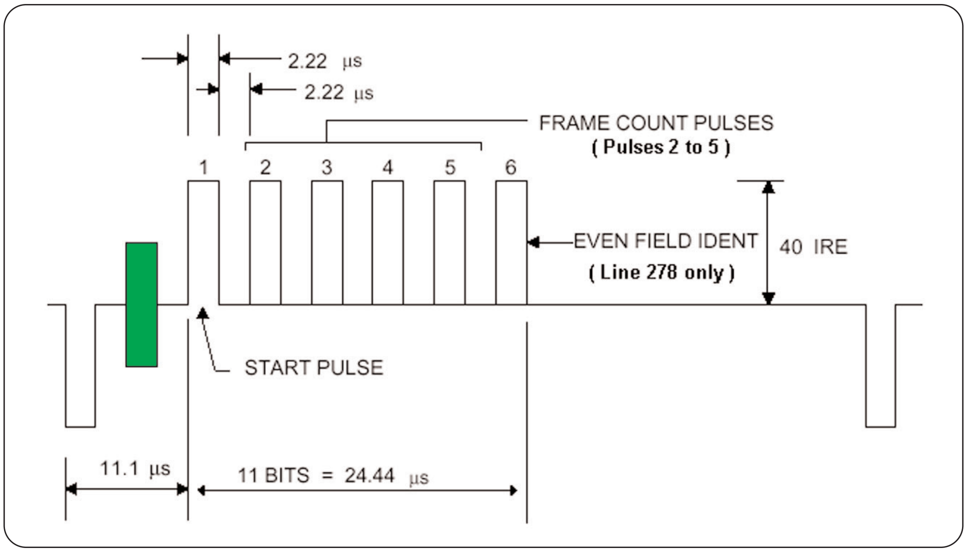


Figure 18. *SMPTE318M timing reference synchronizing line.*

Table 4. SMPTE318M Ten-Field Timing Sequence

Ten Field Sequence	Pulse Position 1	2	3	4	5	6	Line Position	
0	1	0	0	0	0	0	Line 15	Field 1
1	1	0	0	0	0	1	Line 278	Field 2
2	1	1	0	0	0	0	Line 15	Field 1
3	1	1	0	0	0	1	Line 278	Field 2
4	1	1	1	0	0	0	Line 15	Field 1
5	1	1	1	0	0	1	Line 278	Field 2
6	1	1	1	1	0	0	Line 15	Field 1
7	1	1	1	1	0	1	Line 278	Field 2
8	1	1	1	1	1	0	Line 15	Field 1
9	1	1	1	1	1	1	Line 278	Field 2

Timing Across a Multi-Format Hybrid Facility

The basic principles which have been applied to the timing requirements of separate analog and digital systems can be used across a multi-format facility.

To guarantee the quality of the program, the changes between various formats should be minimized. Typically, format islands are created to keep signals in a single format while they are being processed in a specific production area. Timing and synchronization allow the most flexible use of the equipment between the format islands in the hybrid facility.

Figure 19 illustrates the basic components of a typical multi-format hybrid facility. A dual master reference SPG is used in conjunction with an emergency change-over unit to ensure a precisely timed reference throughout the facility.

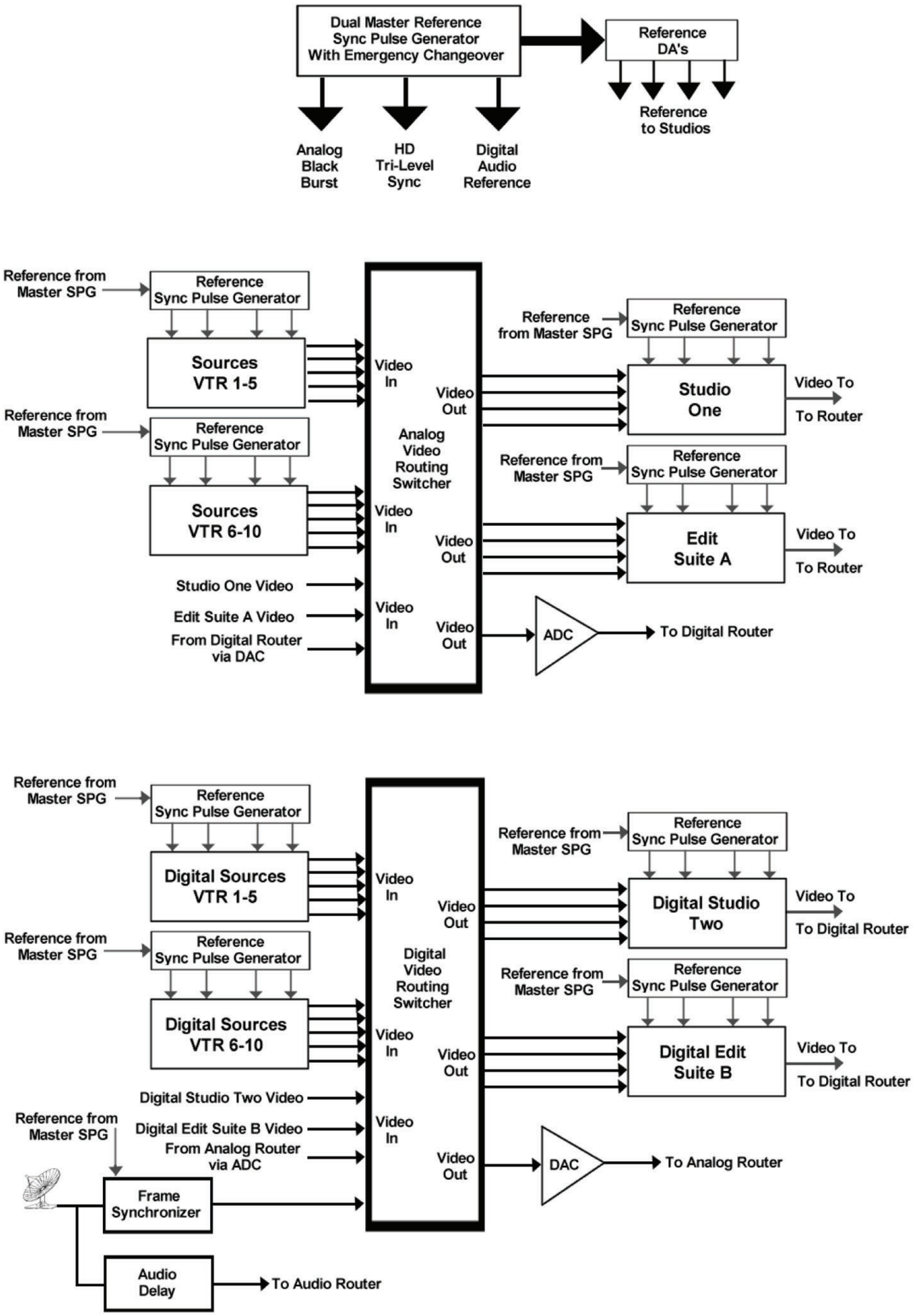


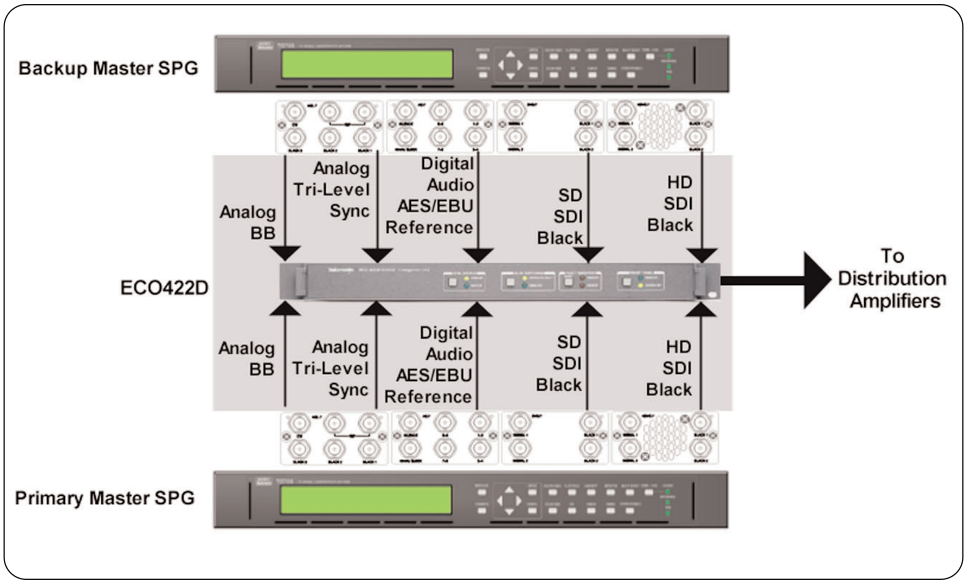
Figure 19. Multi-format hybrid facility.

An appropriate analog or digital distribution amplifier (DA) distributes each of the reference outputs throughout the facility. There are two types of digital distribution amplifiers:

- Fan-out providing a loop-through input and multiple non-reclocked outputs.
- Equalizing/Reclocking which has additional circuitry to recover and equalize a digital signal over a long cable run (200 m). The signal is re-clocked to produce a completely regenerated digital signal and provide multiple outputs.

The Master references are distributed to individual areas, such as studios or editing suites, where they are genlocked to slave SPGs. The slave SPGs produce the references that are used to time equipment in each area, as described above. Although the majority of systems still use analog black burst references, as shown in Figure 19, some digital equipment uses a digital reference. A digital black reference signal can be used in these applications. When signals need to be converted from analog to digital or digital to analog, an Analog-to-Digital Converter (ADC) or Digital-to-Analog Converter (DAC) provides signals to the digital and/or analog router to be distributed to the islands.

In some cases, Frame Synchronizers are used to synchronize external sources such as satellite feeds. A reference is applied to allow the timing of these external sources in the facility; however, these devices can introduce several fields of processing delay in the video path. The audio associated with these external video signals uses simpler processing that takes significantly less time than the video, so audio delay must be added to compensate for the video processing delay. Audio delay may also be needed to compensate for large video processing delays in other digital equipment, in order to avoid lip-sync problems.



▶ ***Figure 20.*** *Dual SPGs with emergency change-over unit.*

Redundant Synchronization

Synchronization throughout the facility is a critical operation for guaranteed system performance. Designing a facility with redundant synchronization provides a complete fault-tolerant, flexible, and robust system. Emergency Change-Over (ECO) units, such as the Tektronix ECO422D, are used to automatically switch from one sync source to another upon fault detection in any active source without loss of service in a facility. The TG700 can be used in combination with a second TG700 to provide a backup in case of failure of one of the components in the timing system (shown in Figure 20). The ECO is able to detect a loss of sync signal at its master input and automatically switch to the back-up master slave input. The ECO422D has eleven user-configurable channels and can be configured to support any of the following formats: Analog Black Burst (PAL or NTSC), HD tri-level sync, AES/EBU digital audio, SD-SDI, or HD-SDI.

After completing the timing set-up of the whole facility, it is important to save the settings of the Master and Slave SPGs. The TG700 has several software applications that can assist in this process. TGDuplicate allows the complete copying of firmware and software settings from one TG700 to another, ensuring that the Slave SPG is an exact duplicate of the Master. TGBackup allows for the configurations of the TG700 to be backed-up to an external computer, and TGRestore allows the backup information to be reloaded into a TG700.

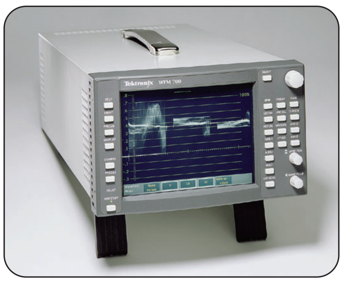
An uninterruptible power supply (UPS) should also be incorporated into the system to alleviate further concern for loss of signals. The UPS prevents power surges or loss of power from disrupting the output configurations of the SPG and interfering with the timing settings.

Conclusion

Television timing using Black Burst as the reference has been a critical part of any analog video facility. The transition to digital and high definition has introduced the need to synchronize a wide variety of analog and digital formats, often simultaneously. Video production equipment may now need other types of reference signals such as HD tri-level sync or (HD/SD) SDI black. In addition, audio conversion, which never required synchronization in analog formats, now requires the use of a digital audio reference to synchronize digital audio equipment. The flexibility of the TG700 allows for simplification of system timing design because it supports a wide range of formats. The Tektronix family of analog and digital equipment enables you to meet the many challenges of these new video formats and operating conditions.

TG700 Multiformat Video Generator

- Multiformat analog and digital test signal generation
- Modular expandable platform
- Ideal channel configuration and performance to support reference generator needs



WFM700 Multiformat Waveform Monitor

- Monitors and measures HD and SD signals in a single unit
- Configurable/modular architecture
- HD and SD eye pattern measurements and jitter displays

1700 Family of Waveform Monitors and Vectorscopes

- Available in PAL and/or NTSC
- Broad range of models address different needs
- Up to eight composite or two component input channels

WFM601 Standard Definition Waveform Monitor

- Two input channels
- SD eye pattern measurements and jitter displays
- Three models tailored for specific applications

Contact Tektronix:

ASEAN Countries & Pakistan (65) 6356 3900

Australia & New Zealand (65) 6356 3900

Austria +43 2236 8092 262

Belgium +32 (2) 715 89 70

Brazil & South America 55 (11) 3741-8360

Canada 1 (800) 661-5625

Central Europe & Greece +43 2236 8092 301

Denmark +45 44 850 700

Finland +358 (9) 4783 400

France & North Africa +33 (0) 1 69 86 80 34

Germany +49 (221) 94 77 400

Hong Kong (852) 2585-6688

India (91) 80-2275577

Italy +39 (02) 25086 1

Japan (Sony/Tektronix Corporation) 81 (3) 3448-3111

Mexico, Central America & Caribbean 52 (55) 56666-333

The Netherlands +31 (0) 23 569 5555

Norway +47 22 07 07 00

People's Republic of China 86 (10) 6235 1230

Poland +48 (0) 22 521 53 40

Republic of Korea 82 (2) 528-5299

Russia, CIS & The Baltics +358 (9) 4783 400

South Africa +27 11 254 8360

Spain +34 (91) 372 6055

Sweden +46 8 477 6503/4

Taiwan 886 (2) 2722-9622

United Kingdom & Eire +44 (0) 1344 392400

USA 1 (800) 426-2200

For other areas contact Tektronix, Inc. at: 1 (503) 627-7111

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