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


Introduction

Successful creation, transmission, and recovery of a video picture depends on each of the devices in the system (e.g. cameras, VTRs, editors, switchers, and other video equipment) operating in synchronization with every other device. Inside a large studio or post-production plant, a master Sync Pulse Generator (SPG) provides synchronization signals. Equipment that is synchronized by a master generator is often referred to as being generator locked, or "genlocked" for short.

Adjusting system timing and achieving synchronization is one of the most fundamental and critical procedures in a facility. With multi-format facilities operating in the analog, digital and standard or high definition environments, synchronization becomes challenging and even more critical. The Tektronix TG700 is a multi-format test signal and sync pulse generator platform that can be configured with a variety of modules to serve the analog, Standard Definition (SD)-Serial Digital Interface (SDI), High Definition (HD)-SDI and multi-format master synchronization needs of the customer.
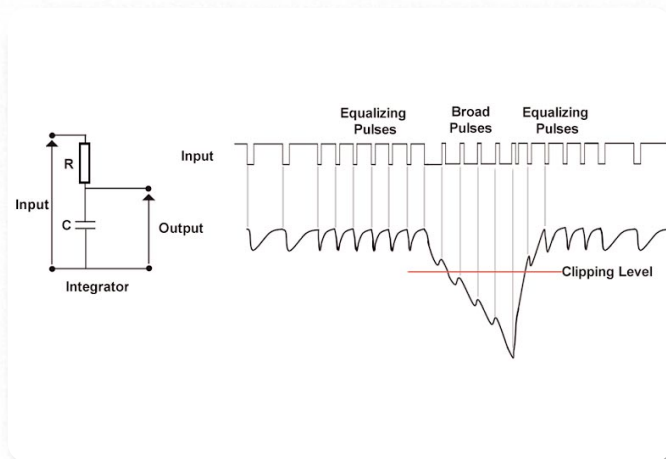
Tektronix

Enabling Innovation

Understanding analog timing
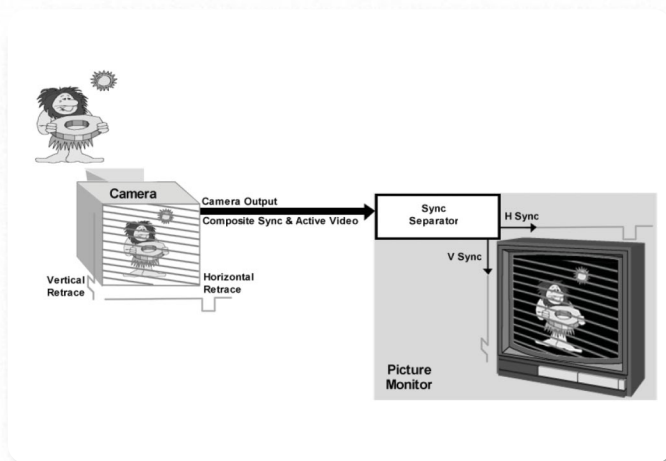
▶ **Figure 1.** *Synchronizing process.*
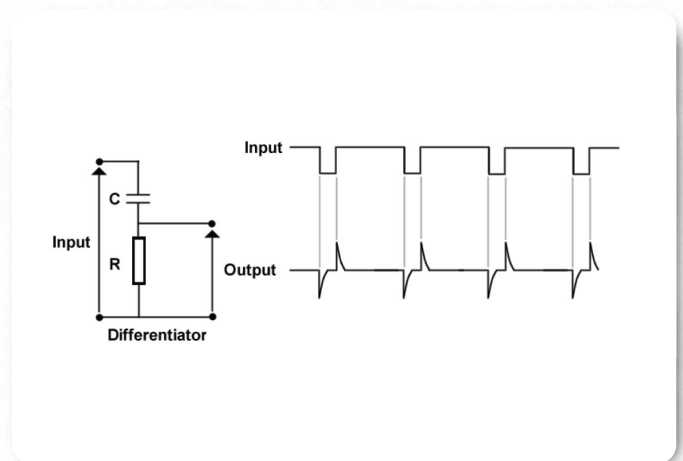
▶ **Figure 2.** *Simple differentiating circuit to extract sync pulses.*

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

To understand how synchronization is achieved, we need to understand the basics of analog timing and how it works (Figure 1). For accurate reproduction of the image, both the camera and the television receiver must be synchronized to scan the same part of the picture at the same time. At the end of each horizontal line, the beam must return to the left side of the picture. This is called **"horizontal retrace"**. The horizontal sync pulse handles coordination of the horizontal retrace. At the bottom of the picture, when the end of active picture is reached, it is time for the beam to return to the top of the picture. The vertical sync pulse, which is different in width than horizontal sync pulses, signals the start of the vertical retrace. Since the vertical retrace takes much longer than the horizontal retrace, a longer vertical synchronizing interval is employed. During the time when horizontal and vertical retrace is taking place, the electron beams to the display are turned off and nothing is written to the screen. This is known as the blanking interval. A composite sync is produced by combining the horizontal and vertical sync pulses in a way that allows for easy extraction of the H and V sync at the receiver. When television signals were being developed, the circuit designs needed to be simple because of the technology available at the time. Therefore, a simple differentiating circuit was used in the sync separator to extract the horizontal drive signal for the receiver. A sharp spiked pulse is produce at the edges of the sync pulse as shown in Figure 2. The synchronizing circuit uses the leading negative edge of sync to ensure lock to the negative pulse and ignores the positive pulses.

To prevent drift of the horizontal drive circuit, the line sync pulse should occur through the entire field interval. In order to distinguish the vertical sync from the horizontal sync pulse, a longer pulse width duration is used. These pulses are known as the broad pulses. Equalizing pulses occur before and after the broad pulses to produce a similar pulse pattern for odd and even fields. A simple integrating circuit can be used to extract the vertical pulse as shown in Figure 3.
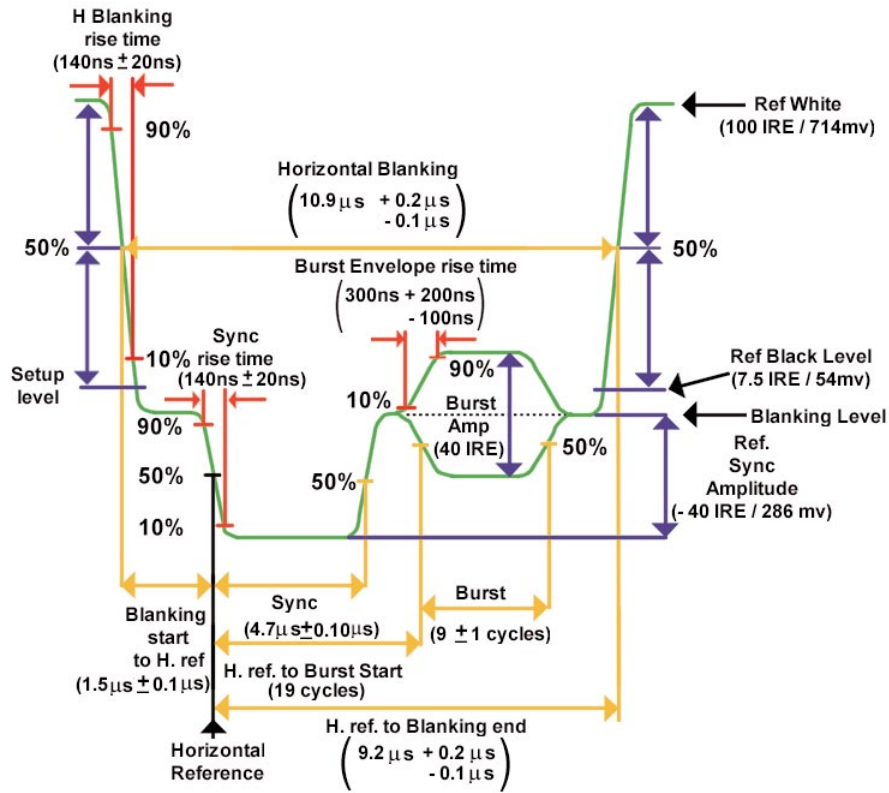
▶ **Figure 4.** *NTSC Horizontal Blanking (from SMPTE 170M).*

Analog Video Timing

In analog video timing, there are three basic parameters that need to be synchronized to match a program signal to a reference. These three basic parameters are:
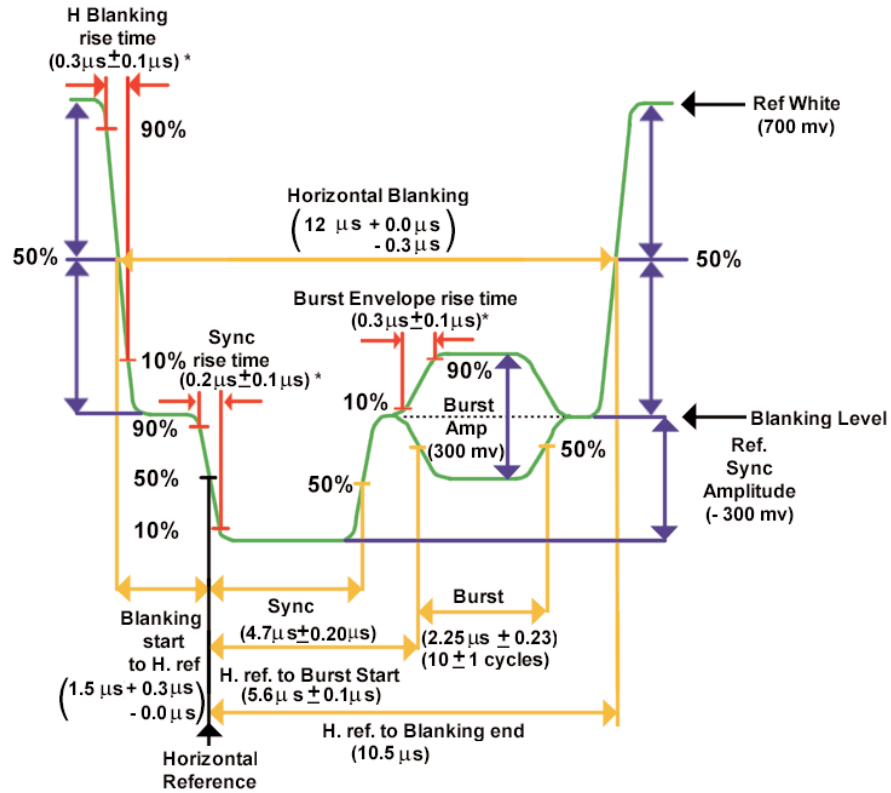
▶ Horizontal sync for line timing

▶ Vertical sync for field timing

▶ Subcarrier for color synchronization

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 prevent the video from interfering with sync extraction. The horizontal blanking period allows enough time for the flyback of the beam to go back to the left-hand side of the display and settle before the start of the video signal. During the flyback time, the beam is blanked to prevent the scan lines from being observed on the display. Figure 4 and 5 show the relative timings of a NTSC and PAL horizontal-blanking intervals. The color burst is added to the back porch of the horizontal interval.
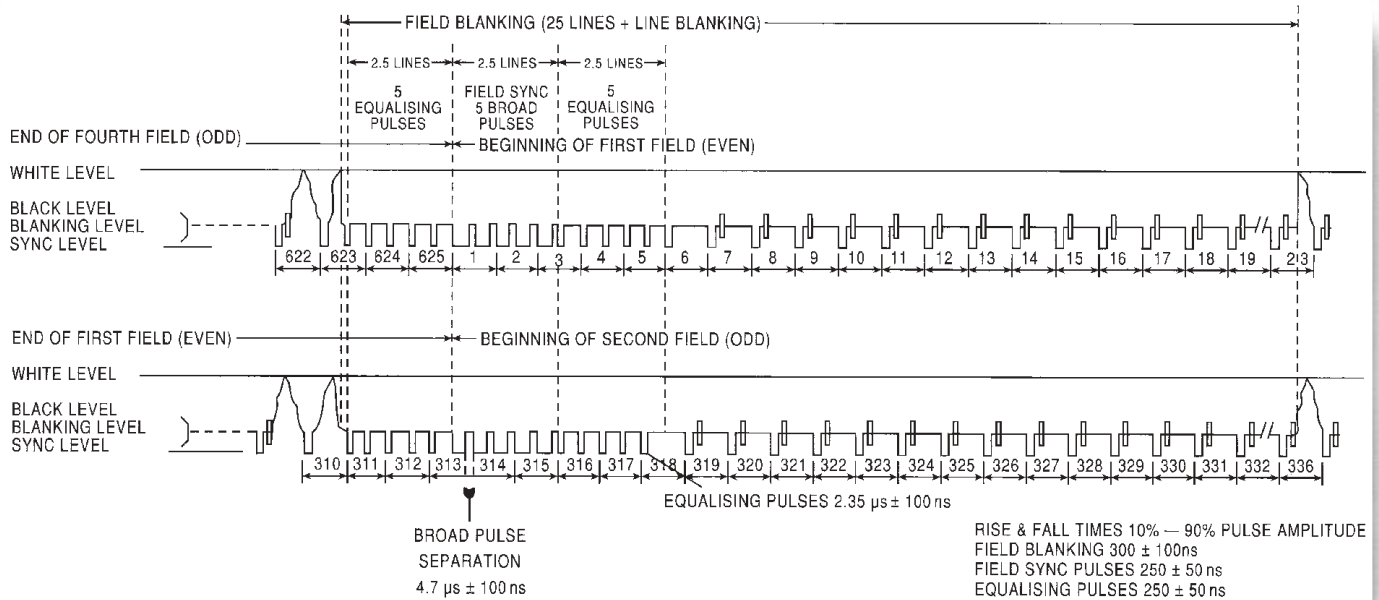
▶ **Figure 5.** *PAL Horizontal Blanking (from ITU-R.BT.470-6) * PAL-I system uses rise/fall time of (0.25ms + 0.05ms)*
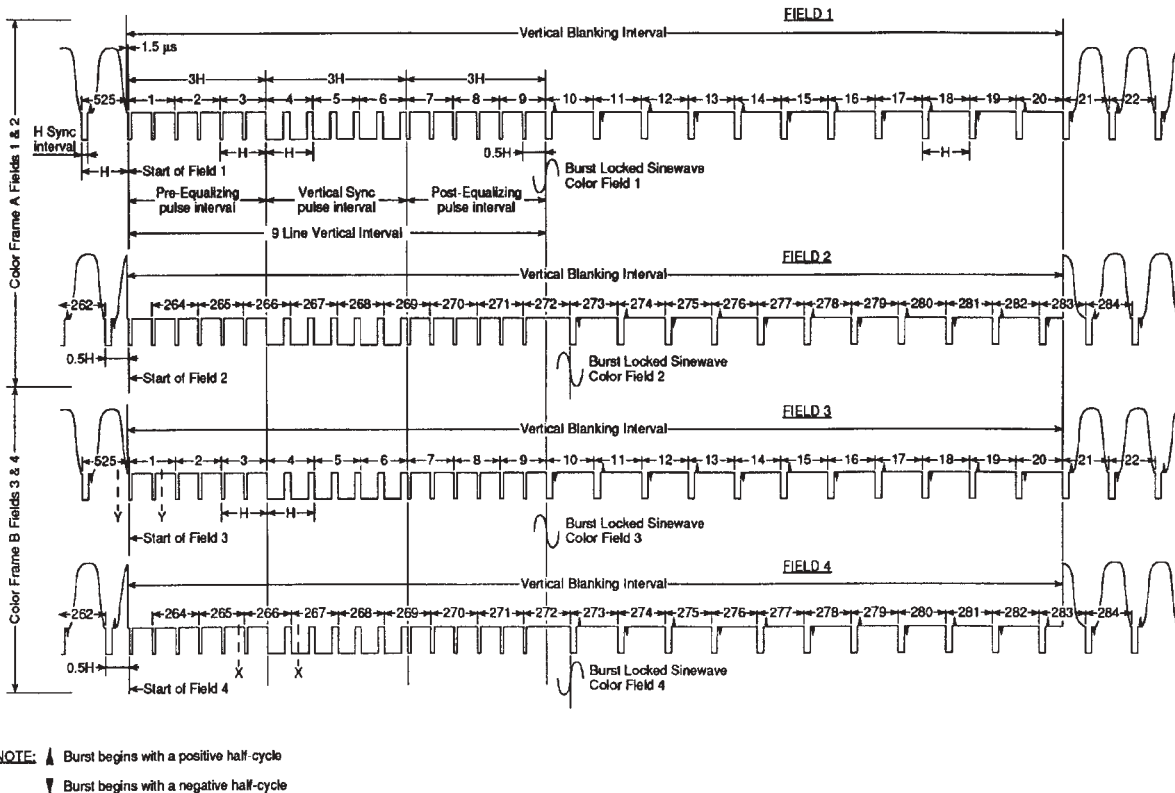
▶ **Figure 6.** *NTSC Vertical Blanking Interval.*

▶ **Figure 7.** *PAL Vertical Blanking Interval.*

## Vertical sync for field timing:

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

Detection of color timing within the picture is achieved by using the subcarrier burst added to the back porch in the horizontal interval for sub-carrier timing. Synchronization of two signals relies on their subcarrier bursts being in phase. The color burst is a frequency of 3.579545 MHz for NTSC and a frequency of 4.43361875 MHz for PAL. These frequencies were chosen to increase separation of the color and luma signals and prevent interference with the

black and white television signal. 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 relationship between the PAL sync and subcarrier takes eight fields for everything to come to the original phase. The phase relationship between the PAL or NTSC vertical sync pattern identifying the correct field, and the color subcarrier phase, are both important when one source of video signal joins or is suddenly replaced by another source, as when the video is edited or switched or combined by special effects equipment. This important relationship is referred to Sub Carrier to- Horizontal phase (SCH phase). (Refer to SCH Phase application note. 20W-5613-2 NTSC and 20W-5614-1 PAL).
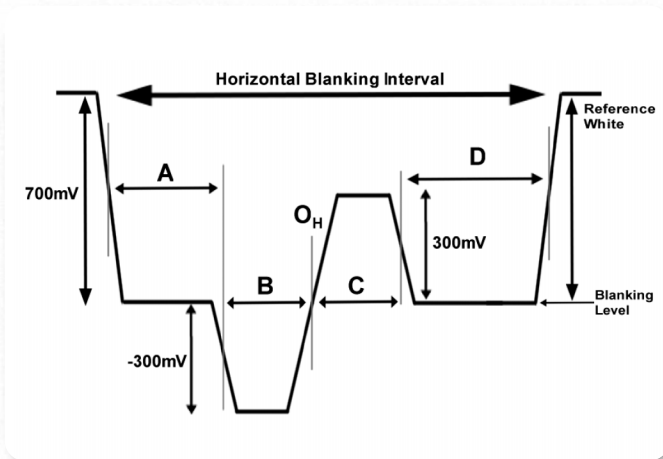
▶ **Figure 8.** *High Definition Tri-Level Sync Signal.*

HD analog Horizontal timing:

In HD analog horizontal timing, the HD Tri-level sync is used instead of the Bi-level composite sync pulse. The reference point is at blanking on the rising edge, but is still at the half height of the tri-level sync. The Tri-level signal has fast rise time edges because of the increased bandwidth of HD providing accurate timing edges. These factors improve jitter performance and sync separation. Figure 8 shows a typical Tri-Level sync signal. Because of the wide variety of HD formats, timing intervals can be different. Table 1 gives appropriate timing intervals for the wide array of different HDTV formats.

Genlock Reference:

The black burst signal is often used for system timing (genlocking) equipment. It is a composite signal with a 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 - 0mV for PAL, 7.5 IRE (black) for NTSC (America) and 0 IRE for "NTSC no-setup" (Japan). The color burst provides a synchronizing reference for color framing. In some cases a Continuous Wave (CW) signal can be used to lock an SPG. A continuous wave signal is a clock signal of sinusoidal shape usually selectable in frequencies of 1, 5 or 10 MHz depending on the device. This sine wave signal has no positional information of H and V since it is just 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 to the unit.

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

▶ **Table 1.** *HDTV Horizontal Blanking.*

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) always 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
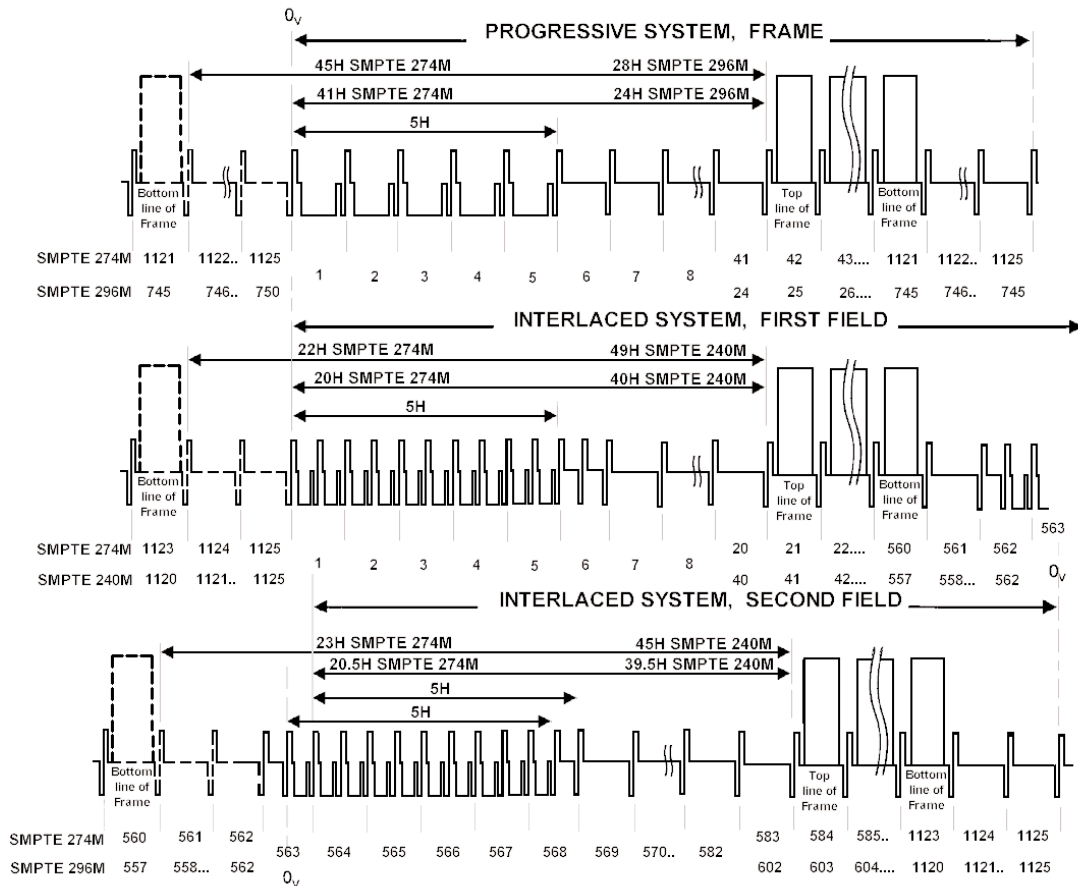
Bit 7 – (V-bit) 1 in vertical blanking interval; 0 during active video lines

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

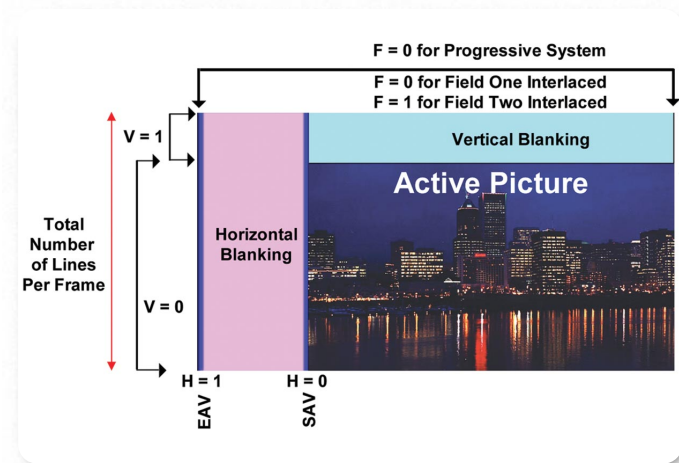▶ **Table 2.** *Format of EAV/SAV "XYZ" Word.*

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

HD analog vertical timing:

The analog vertical blanking interval within HD, which is simpler than standard definition, is shown in Figure 9. As seen in Table 1, there are a variety of different formats, both interlaced and progressive.

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

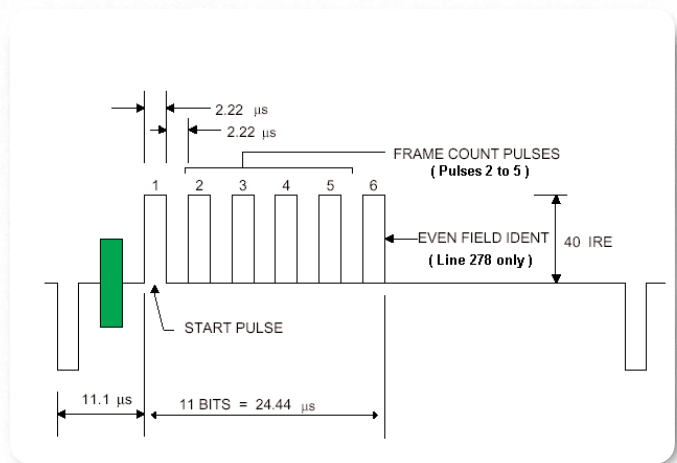► **Figure 11.** *SMPTE318M Timing Reference synchronizing line.*

Digital Horizontal Timing:

The analog sync signal is not replicated within the digital environment. Synchronization is achieved by the use of specific codeword sequences representing the start of active video (SAV) and ending with a codeword sequence representing the End of Active Video (EAV). The codeword is indicated by reserved values starting with a data packet of 3FF followed by codewords of 000, 000, and then an XYZ value which contains information on F, V and H as shown in Table 2. This data is then used to synchronize the timing within the digital video signal. For HD, separate codewords sequences are used for the luma and color difference signal and interleaved to form the sequence 3FF(C), 3FF(Y), 000(C), 000(Y), 000(C), 000(Y), XYZ(C), XYZ(Y).

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

Digital Audio:

The transition to digital introduces the need to synchronize digital audio signals within the facility. 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 together so that clock rate drift does not occur between equipment. If this happens, clicks can occur within the audio because of misalignment in recognizing the data correctly between devices. It is therefore important to provide a digital audio reference to all digital audio equipment. This reference is usually an AES/EBU signal or, in some cases, a 48 kHz word clock. The Tektronix TG700 Audio Generator module AG7 provides AES Silence and word clock outputs, 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 1920 audio samples per video frame. There are 192 frames within AES/EBU digital audio structure, which produces exactly 10 audio interface frames per video frame. However, for NTSC, because of the frame rate of 29.97 Hz (30/1.001), there is a non-integer number of samples per frame. Therefore, it takes five NTSC frames in order to have an integer number of audio samples – a total of 8008.

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

The SMPTE 318 Timing Reference, shown in Figure 11, 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 ten-field identification sequence. Pulses (2-6) are defined in Table 3 and represent the ten-field sequence count. The end pulse (6) is always absent on line 15 and always present on line 278. The Tektronix 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 CB color bar option.

Ten Field Sequence	Pulse Position						Line Position	
	(1)	(2)	(3)	(4)	(5)	(6)		
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

▶ **Table 3.** *SMPTE318M Ten-Field Timing Sequence.*

TG700 Solution:

The complexity of an analog and digital multi-standard, multi-format environment requires flexibility in customizing the synchronizing needs of the facility. The Tektronix TG700 test and sync pulse generator platform, with its range of available modules, can be configured accordingly to provide an array of test signals and sync signals that can be generated and synchronized simultaneously per the needs of the customer's operating environment. A maximum of four signal generation modules can be contained within the TG700 mainframe.

Within an analog facility, the TG700 has three different appropriate modules - AGL7, BG7 and ATG7. The AGL7 Analog Genlock module accepts PAL, NTSC, or Tri-level sync as an external genlock reference and also allows lock to Continuous Wave (CW) signals. The AGL7 module provides 3 selectable outputs - NTSC/PAL Black Burst or Tri-level sync. The ATG7 Analog Test Generator module provides 4 independent output channels that can generate NTSC and PAL outputs, including Analog test signals, Bars with ID text, and two black signals. Black outputs can generate timing pulses, sub-carrier or black burst signals. All outputs have independent timing adjustment with Full Color Frame range. If more blacks are required, the BG7 module can be added to the configuration to add an additional 4 independently timeable Black Burst or Trilevel sync signals.

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	

▶ **Table 4.**

Within a "mixed" standard definition digital facility, the TG700 could be configured with four of the five different modules (AGL7, BG7, ATG7, AG7 and DVG7) to suit the customer's requirements. The AG7 provides 4 pairs of AES/EBU digital audio signal outputs along with AES/EBU Silence output and 48 kHz Word Clock. The AG7 can be synchronized to a video reference or can free-run. The AES/EBU Silence output can be used to provide a reference to other digital audio equipment. The DVG7 can provide an array of test signals for the facility and, with the option BK, provides SDI Black to specific digital equipment.

For customers making the transition to High Definition, they require additional sync signals of Tri-Level sync and HD SDI. The BG7 can have any of its outputs configured for Tri-Level Sync in any of the HD formats supported, while the AGL7 can have the third black output (Black 3) configured for Tri-level sync. The HDVG7 module can provide an array of test signals for the facility and, with the option BK, provides HD-SDI Black to specific digital equipment.

The TG700 offers automatic selection of three frame resets to support simultaneous synchronized generation of different video formats. This is very useful for post-production facilities that need to support multiple formats e.g. 525 / 625 / HD standards. It offers three frame resets to output simultaneous different video formats and synchronization of multiple frame rates. For example 525/59.94, 625/50 and 1080p/24 can be generated and synchronized simultaneously. Frame reset automatically changes to a common frequency multiple to provide appropriate frame lock for the formats when the same group of formats is selected. For example: NTSC + 1080i/59.94 + 1080/23.98sF is 2.997 Hz. The TG700 selects the best frame reset frequency for a specific video format combination. This information is available on the front panel of the mainframe menu - TG700: Frame Reset Status.

The three frame resets that the TG700 supports are as follows:

▶ Frame Reset 1 independently supports the 1/1.001 system signal. It is used for NTSC and HDTV formats with (74.25/1.001)1 MHz clock.

▶ Frame Reset 2 supports the integer signal system and is used for PAL and HDTV formats with 74.25 MHz clock.

▶ Frame Reset 3 supports either 1080/24p or /24sF when Frame Reset 2 is already being used for other formats.

Within an HD facility, the follow table shows how the Frame Reset will lock each of the output formats within the generator. Frame Reset 1 is used for odd multiple field rates of 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.
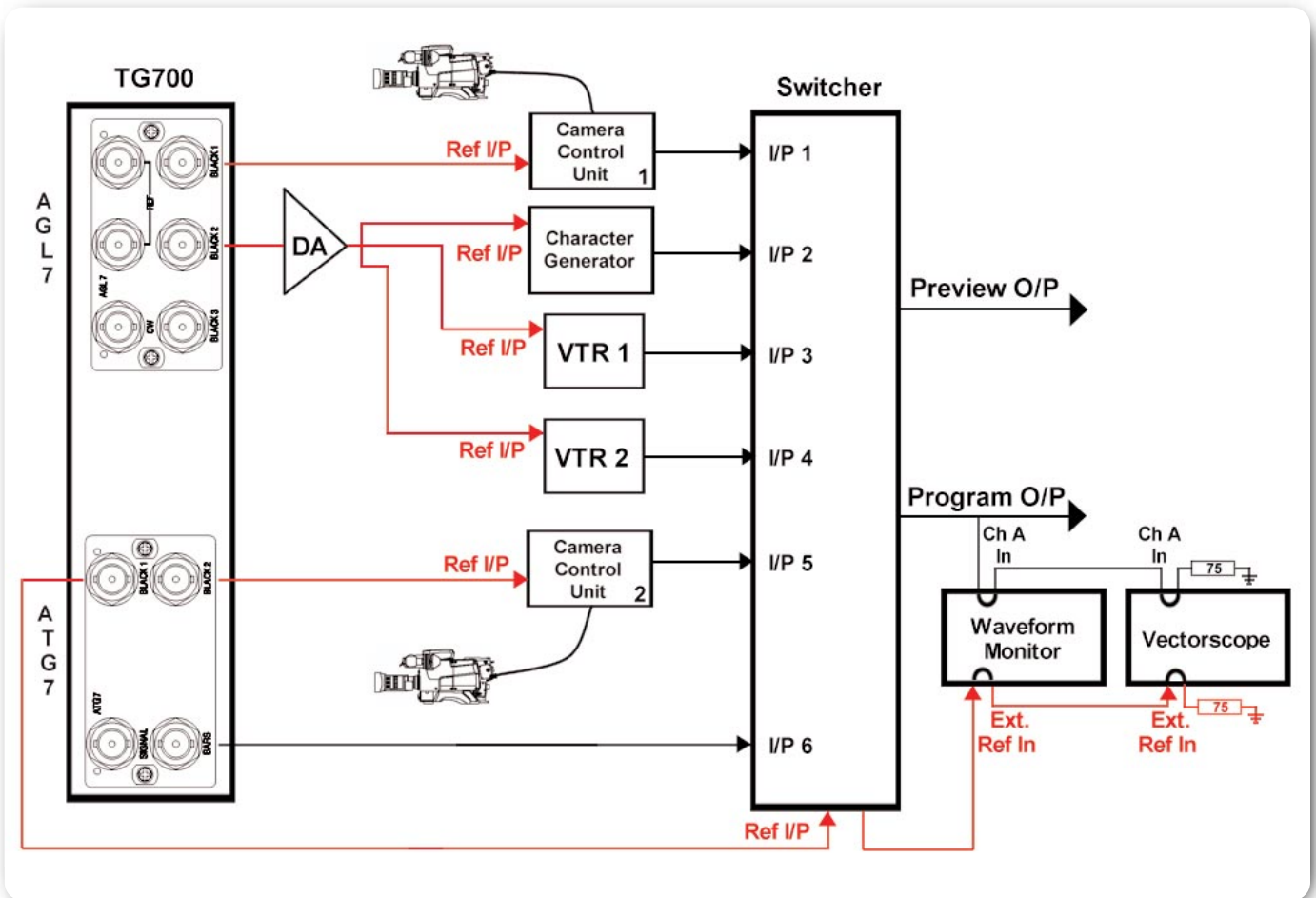
▶ **Figure 12.** *Basic Analog Video System.*

System Timing:

When combining various video sources together, it is necessary that the signals be timed together. Otherwise, the picture will roll, jump, tear or have incorrect colors. Careful system design is necessary to ensure synchronization between all signals within the facility. This is achieved by using a precision reference from a sync pulse generator (SPG) such as the TG700. This reference is then applied appropriately to each device and genlocked so that the output of the equipment is synchronized with the timing of the reference. In planning the system timing of the facility, it is necessary to know the processing delay of the equipment and the propagation delay of the lengths of cable needed to connect the equipment. Typically, the propagation delay through 1 foot of cable is approximately 1.5ns (1 meter @ 5ns) dependent on the type of cable used. This propagation delay can become significant in long lengths of cable.

A basic system diagram (Figure 12) shows some of the basic factors to take into account when designing a system. First, it is important to know the cable run lengths connecting the equipment, the processing delay of the equipment and how timing adjustments can be made on the equipment. In this scenario, the video tape recorders (VTR) have Time Base Correctors and allow output timing adjustment, the character generator has output timing adjustments via software and the Camera Control Units require delay adjustment in order to guarantee system timing.
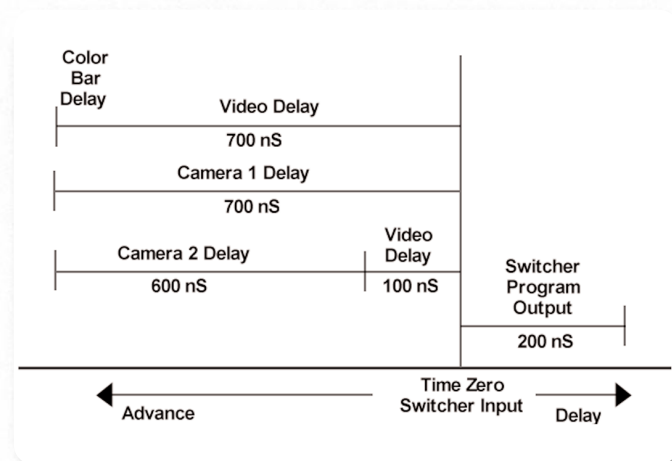
▶ **Figure 13.** *System Timing through the studio.*

Figure 13 shows the calculated delays through the system. It is important to document the timing of each piece of equipment in order to know the longest delay through the system. Every signal should arrive at the switcher at the same time and we can define this as Time Zero. The processing delay and cable delay is greatest through the signal path for camera 1. We use this as the basis to time every other signal to. We therefore need to insert appropriate delay into the other circuits so that everything is synchronized at the input to the switcher. This is achieved by using the timing adjustments of the SPG for each black output to create the delay for each signal path. In this case, a separate black output is used for each camera control unit to adjust the delay appropriately to ensure correct synchronization at the input to the switcher. The character generator and VTRs each have timing adjustments so a Distribution Amplifier (DA) can be used to provide the same reference to each piece of equipment, or if the equipment was in close proximity to each other, the reference signal could be looped through each piece of equipment. Note that by using a DA in the system, this will also introduce a small processing delay. 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.
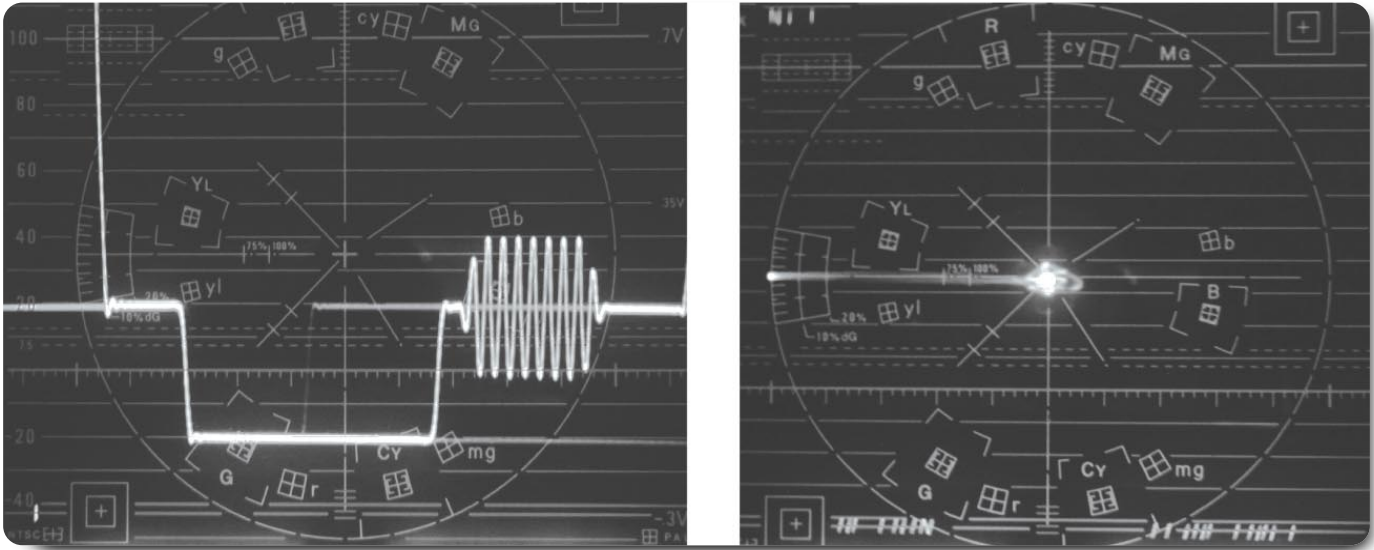
▶ **Figure 14.** *NTSC Waveform and Vector display.*
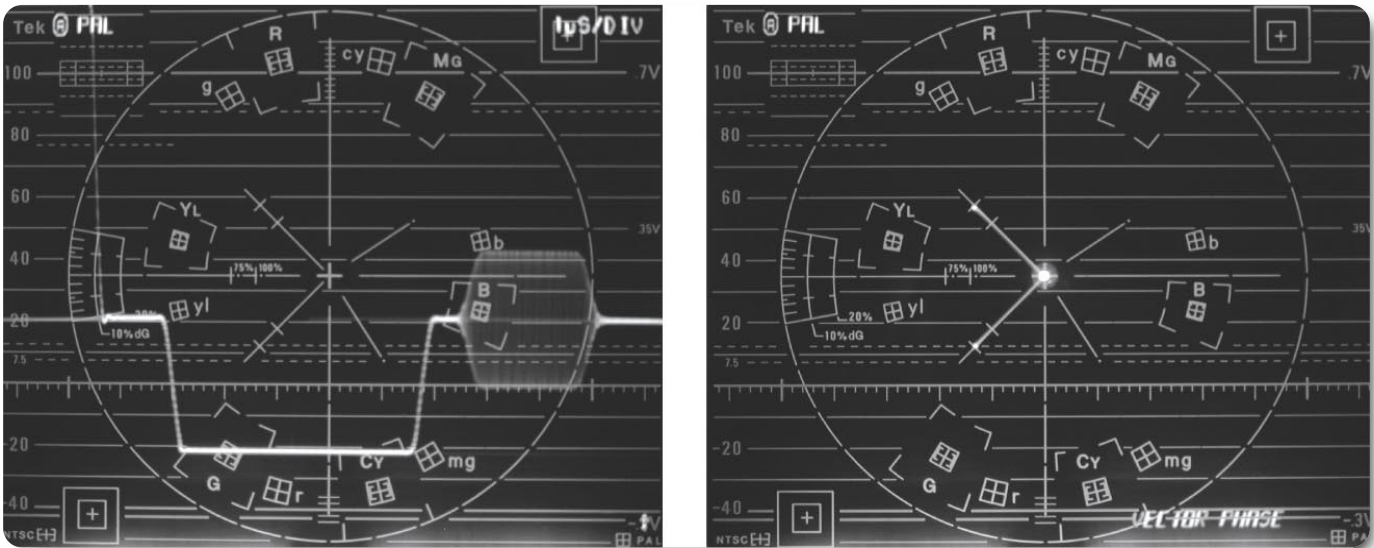
▶ **Figure 15.** *PAL Waveform and Vector display.*

Measuring and Adjusting System Timing

Analog system timing adjustments are made with a waveform monitor and vectorscope connected to the switcher output as shown in Figure 12. 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% point of the 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. Start by ensuring vertical tim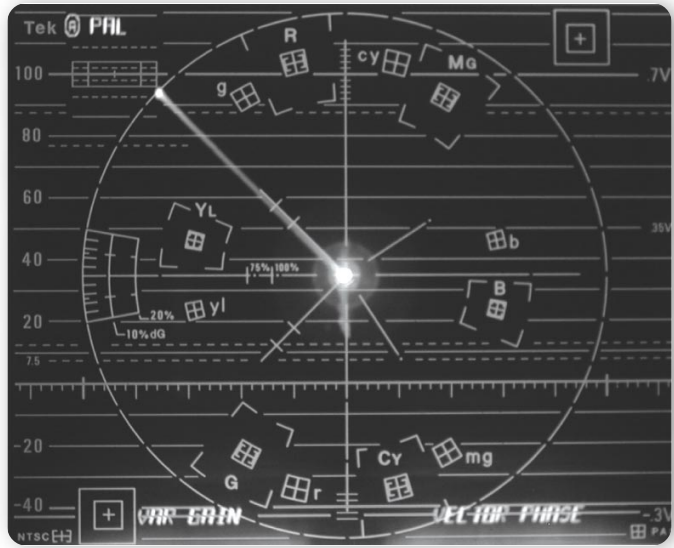ing between inputs. On the waveform monitor select the A input and set-up the waveform display in an H MAG 1 field sweep mode to show the vertical interval of the waveform positioned so that line 1 field 1 is placed at a major tick mark on the waveform monitor. All the other inputs to the switcher can 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 switchers output and select a 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.
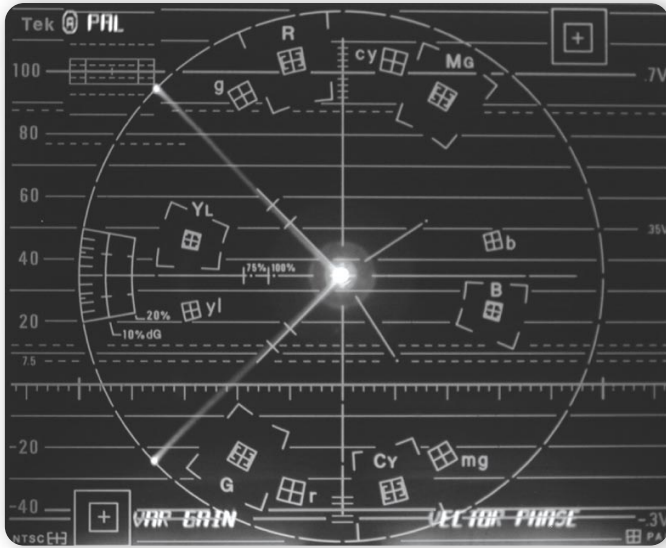
▶ **Figure 16.** *PAL Vectorscope MAG display.*

▶ **Figure 17.** *PAL Vectorscope with V axis switched.*

A similar procedure can be performed on the vectorscope to ensure color burst subcarrier phase. In NTSC, position the color burst to the 9 o'clock position and MAG the display so that the burst amplitude lies on the outer edge of the compass rose as shown in Figure 14. This should be set with the black reference and then the phasing may be adjusted for all other inputs to the switcher. In PAL systems a similar approach is taken, but the phase of the burst is switched on alternate lines and lies at the +135° and +225° as shown in Figure 15. The PAL burst can be magnified as shown in Figure 16 so that it lies along the 135° axis to the outer edge of the compass rose, the V axis switched can be selected on the vectorscope to simplify the display as shown in Figure 17.

The sync and burst are now referenced to zero time and the various input 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 to measure S/CH phase this should also be measured between the reference signal and the other inputs of the switcher. This is particularly important in the editing process to prevent disturbances in the picture and color flashes from occurring when the signal is switched. Once this task is completed, you will now be able to switch smoothly between video sources and make clean edits without picture roll, horizontal jumps or color flashes.

Component Video:

To avoid composite artifacts and improve processing of the signal, edit suites and studios started to use component analog video (CAV). This requires timing of the horizontal and vertical signals and does not require timing of the color subcarrier, allowing the editing process to be simplified. However, this system requires appropriate inter-channel timing of three video signals (Y', P'b, P'r) or (R', G', B') per distribution path. Component serial digital interface (SDI) offered a means to distribute the signal on a single cable and maintain video quality throughout the video facility. However, it offers new challenges and techniques for timing a multi-format facility.

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, provided that the signal is within a specified timing range (30-150ms, depending on the equipment). These switchers can self-compensate for the timing error. However, care still has to be taken when ensuring vertical timing because of the large processing delays of some of the digital equipment. Analog black burst is still the predominant reference signal, although a SDI Black signal can be used on some digital equipment.
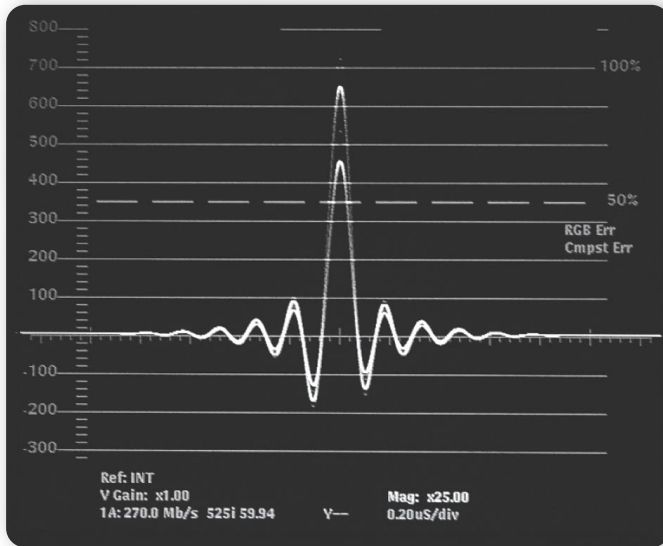
▶ **Figure 18.** *XYZ pulse of Y channel with pass through selected on WFM700.*

## Timing within the Digital Domain

A digital waveform monitor such as the Tektronix WFM1125, WFM601 or the WFM700 can be used to measure digital timing of a signal. The following is a simple procedure for timing two digital signals using a digital waveform monitor. Apply the SDI signals to Channel A and Channel B of the monitor and externally reference the waveform monitor to black burst or Tri-level sync as appropriate. Care needs to be taken to terminate all signals correctly. In the configuration menu of the waveform monitor, select pass EAV and SAV mode. This will allow the 3FF, 000, 000, XYZ values to be displayed on the waveform monitor as shown in Figure 18. 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 when positioned on a major tick mark of the waveform display. Using this timing reference point, comparison can then be made to the other SDI signals to ensure the position of the pulse remains in the same location.

Within the digital domain, there are no vertical pulses and digital systems are expected to calculate their video position based on the values of F, V and H. Therefore, in order to measure vertical timing we need to define a reference point. For simplicity, the first line of active video can be used as the reference, since the vertical blanking lines are normally blank.

To accomplish vertical timing a user should set Line Select and sweep for a 2-line mode. Then, select Field 1 and line select as follows to 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, line 41 for 1080 progressive formats, 25 for 720 progressive, 19 for 525 interlace, or 22 for 625 interlace. If not displayed properly, adjust the vertical timing of the source until correctly displayed. Next, select channel B and make sure the last vertical and first active lines are displayed. Adjust vertical timing if needed 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 then they are in the same field. Different amplitudes of the second pulse indicate the two signals are in opposite fields and timing adjustments should be made to match fields between the sources.

Switching to channel A and setting the waveform monitor to sweep one line, we can start to measure digital horizontal timing. Using 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. Comparison of timing to the other digital channel B input is achieved by selecting the channel and adjusting the fine timing controls to match the timing position of channel A.
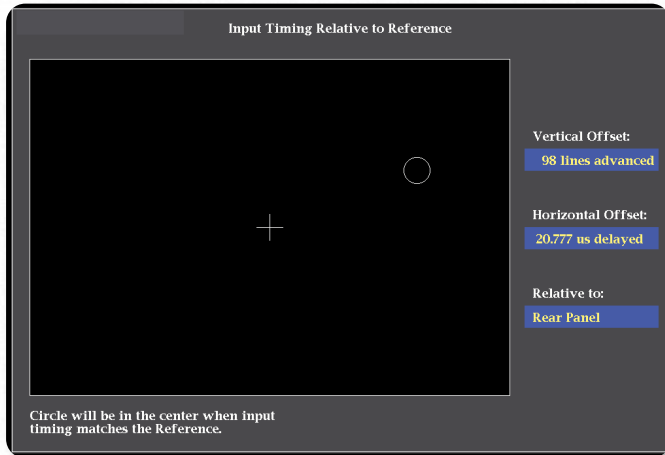
▶ **Figure 19.** *WVR600 Series timing display.*
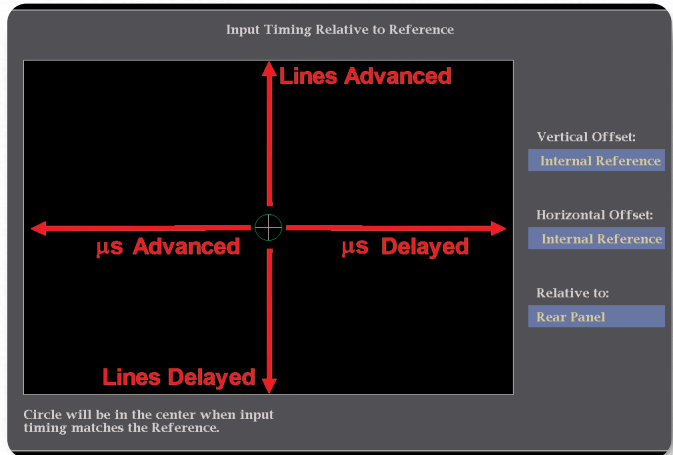
▶ **Figure 20.** *Interpretation of Timing Display.*

Tektronix has developed a simple proprietary method for timing of an analog and digital facility with the WVR Series of waveform rasterizers. The Timing display provides a simple graphical rectangle window, which shows the relative timing between the external reference and input signal. Measurement readouts, in line and microseconds (μs) of the difference between the two signals, are also provided as shown in Figure 19. For the WVR7100 the input signal can be an HD-SDI, SD-SDI or an analog composite input. An external reference signal of black burst or tri-level sync can be used. In the WVR600 and WVR6100 Series the input can be SD-SDI or analog composite.

The rectangle display represents one frame for SD-SDI inputs, or a color frame for composite inputs. The crosshair at the center is zero offset and the circle represents the timing of the input signal. Field timing errors, advanced or delayed, are shown as vertical displacement of the circle, while line timing errors (H timing) of less than a line are shown as horizontal displacement of the circle. See figure 20. If the input is at the same time as the reference, the circle will be centered on the cross hair and it will change color to green.

The "Relative to" box indicates the chosen zero point reference for the timing display. The default is the selected reference at the rear panel. In this mode, the offset is zero when the input and reference are at the same timing at the rear

panel of the instrument. The other choice is to use the Saved offset. In this mode, you can save the timing from one of the input signals and then display the timing relative to this "saved" offset. This is especially useful in timing the inputs to a router. Select one of the inputs to the router as the master relative reference and apply this signal to the input of the WVR Series, along with the external reference signal being used by the router. Press and hold the MEAS button to display the timing configuration menu. Select the Saved Offset menu item and press the Select button on the front panel of the instrument this will now save the offset between the input signal and the external reference. In the timing configuration menu, select the "Relative to:" selection and change the selection from Rear Panel to Saved Offset. The circle will now move to the center of the crosshair and change to a green color. Now, by routing each of the other router inputs to the WVR600, WVR6100 or WVR7100 Series, the measurement will show the relative offset between the master relative reference and the other video inputs. Simply adjust the horizontal and vertical timing controls of each input signal until the circle and the crosshair are overlaid and the circle turns green. Fine timing adjustment can be done directly from the number readouts of the right hand side of the display. Once this process has been completed, each of the inputs to the router is timed relative to the master input signal. This intuitive display can save considerable effort in the timing of video systems.
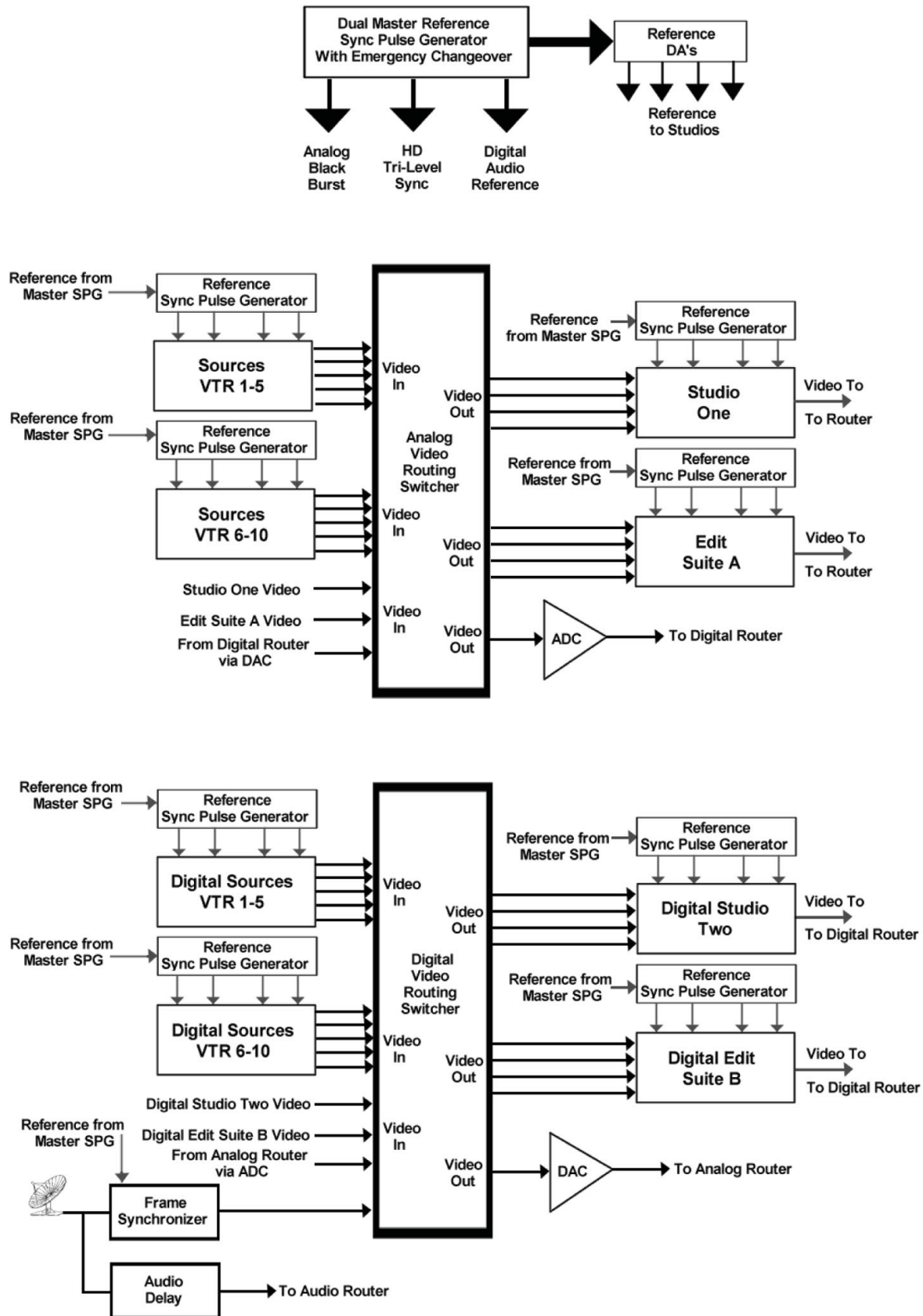
▶ **Figure 21.** *Multi-Format Hybrid Facility.*

Timing Across a Multi-Format Hybrid Facility

The basic principles, which have been applied to an analog studio and the timing requirements of a digital system, can be used across a multi-format facility. To guarantee the quality of the program the change between various formats should be minimized. Normally, format islands are created to allow signals to remain in a single format while being processed in a specific production area. Timing is critical within the hybrid facility to allow the most flexible use of the equipment between each area. A dual master reference SPG is used in conjunction with an emergency change-over unit to ensure a timed referenced signal throughout the facility. Figure 19 outlines the basic principle behind a multi-format hybrid facility. An appropriate analog or digital DA distributes each of the reference outputs throughout the facility. There are two types of digital distribution amplifiers:

a) Fan-out - providing a loop through input and multiple non-reclocked outputs.

b) Equalizing/Re-clocking - which has additional circuitry to recover and equalize a digital signal over a long cable run (200m). The signal will then be re-clocked to produce a completely regenerated digital signal and provide multiple outputs.

The Master references are sent to appropriate areas such as studios or edits suites where they are genlocked by a slave SPG used within that area. The slave references are then used to time equipment within that area as discussed previously.

The same basic principle can be applied to the digital areas. In some cases, digital equipment can use a digital reference, although the majority of systems still use analog black burst as shown in Figure 21. On occasions when signals need to be converted from analog to digital, an Analog to Digital Converter (ADC) is used. This signal can then be supplied to the digital router to be distributed within the digital islands. Similarly, Digital to Analog Converters (DAC) allow digital signals to be converted to analog and applied to the analog router for distribution. Care should be taken in choosing suitable ADC and DAC for the application to ensure the minimum number of format conversions to guarantee quality throughout the signal path.

In some cases, Frame Synchronizers will be used within the facility for synchronizing external sources such as satellite feeds. A reference is applied to allow timing of these external sources within the facility. However care should be taken as these devices can introduce several fields of processing delay within the video path. The audio associated with these video signals has simpler processing and takes significantly less time to process than the video. Therefore audio delay has to be added in order to compensate for this video processing delay. Various types of digital equipment may suffer from large video processing delays and an audio delay may need to be inserted to avoid lip-sync problems.
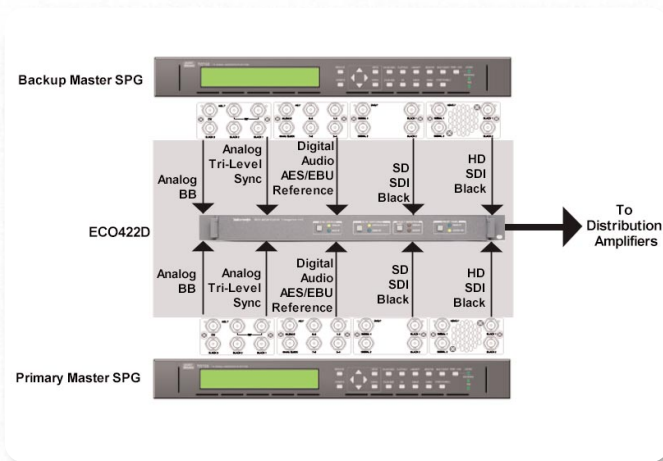
▶ **Figure 22.** *Dual SPGs with Emergency Change-Over unit.*

Redundant synchronization

Dual master reference SPGs are used with an emergency changeover unit (ECO) as shown in Figure 22. The ECO is able to detect a loss of sync signal at its master input and automatically switch to the back-up input. Maintaining the sync signal at the output of the ECO prevents a loss of a critical sync signal from affecting timing within the plant. Synchronization throughout a facility is a critical operation for guaranteed system performance, which is why designing a facility with redundant synchronization provides a complete fault-tolerant, flexible, and robust system. In many broadcast and post-production facilities, Emergency Change-Over 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 within a facility. The TG700 can be used in combination with another TG700 unit to provide a back-up in case of failure of one of the components within the timing system. The ECO422D has eleven user-configurable channels and can be configured to support analog Black Burst (PAL or NTSC), HD tri-level sync, AES/EBU digital audio, SD-SDI and HD-SDI.

After completing the timing set-up of the whole facility it is important to save the settings of the Master and Slave SPG. 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. This can be used to ensure the Slave SPG is an exact duplicate of the Master SPG. TGBackup allows for back-up of the configurations of the TG700 to a computer and TGRestore allows for this saved information to be loaded into a TG700.

To alleviate further concerns for loss of house timing reference signals, an uninterruptible power supply (UPS) should be incorporated into the system. This prevents power surges or brief loss of power from interrupting the output configurations of the SPG and interfering with the timing settings for the system. This configuration of a UPS, ECO422D and SPGs ensure peace of mind and could prevent problems if a power failure occurs.

Conclusion

Since the introduction of television, timing has been a critical part of any analog video facility using Black Burst as the reference. The transition to digital and high definition has introduced the need for synchronizations of a wide variety of formats both analog and digital. Video production equipment may now need other types of reference signals such as HD tri-level sync or (HD/SD) SDI black. In addition to the transition of video, the audio conversion, which never required synchronization in analog, now requires the use of a digital audio reference to synchronize digital audio equipment. The basic familiar techniques used in the analog environment can be applied to a multi-format, multi standard facility. The Tektronix range of analog and digital equipment enables the user to apply the basic techniques of analog to the requirements of these new video formats.

TG700 Multiformat Video Generator

The TG700 is a multiformat analog and digital precision signal generation platform offers sync pulse generation and test signal generation for a wide array of analog, serial digital audio video SD and HD formats.

WVR7100/WVR6100 Waveform Rasterizers

These products offer digital SD/HD and composite video, as well as audio (including analog, Digital AES and embedded, Dolby Digital and Dolby E) —all in one tool. The customized presets allow quick recall of commonly used configurations. The WVR7100/WVR6100 offer fully digital processing which provides accuracy, stability and repeatability.

WFM700 Series Family of SDI Waveform Monitors

These products monitor and measure HD and SD signals in a single unit. They have a modular architecture with up to four input channels of digital video These monitors have HD and SD eye pattern measurements and jitter displays.

1700 Series Family of Waveform Monitors and Vectorscopes

The 1700 Series products are available in a board range of models to address different analog video needs. With up to eight composite or two component input channels these models are available in PAL and or NTSC.

For Further Information
Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit **www.tektronix.com**

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