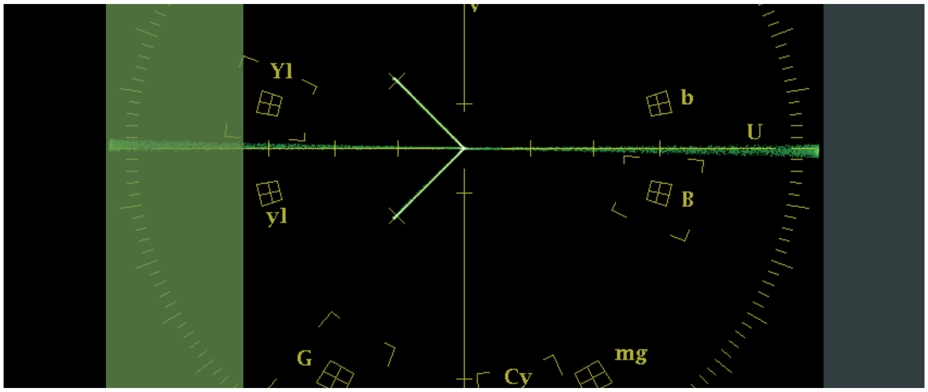

Master Sync and Master Clock Reference Timing within a Facility

Application Note

Introduction

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 SPG8000 and TG8000 are multi-format test signal and master sync generator platforms that can be configured with a variety of options to serve the analog, Standard Definition (SD)-Serial Digital Interface (SDI), High Definition (HD)-SDI and multi-format master synchronization needs of a facility.

Tektronix

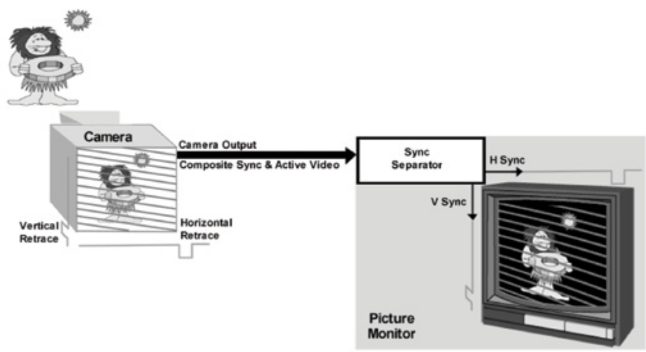

Figure 1. Synchronizing process.

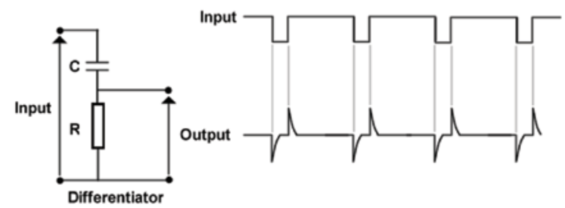

Figure 2. Simple Differentiating circuit to extract sync.

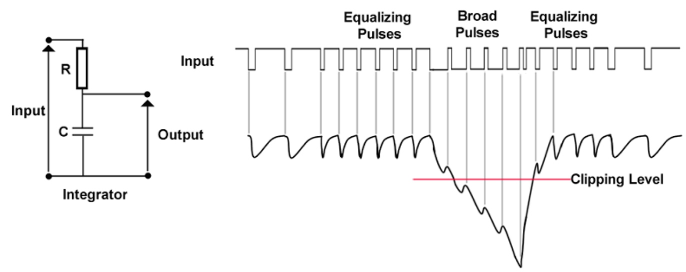

Figure 3. Simple integrating circuit to extract vertical sync pulses.

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 first 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.

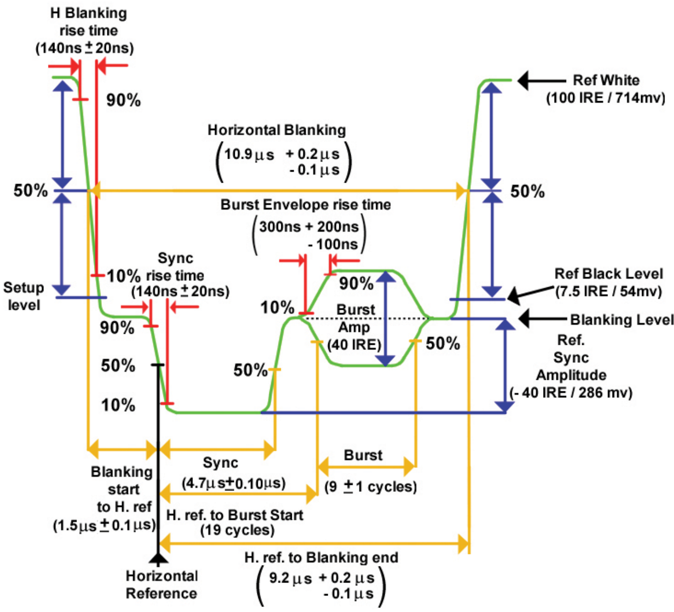

Figure 4. NTSC Horizontal Blanking (from SMPTE 170M).

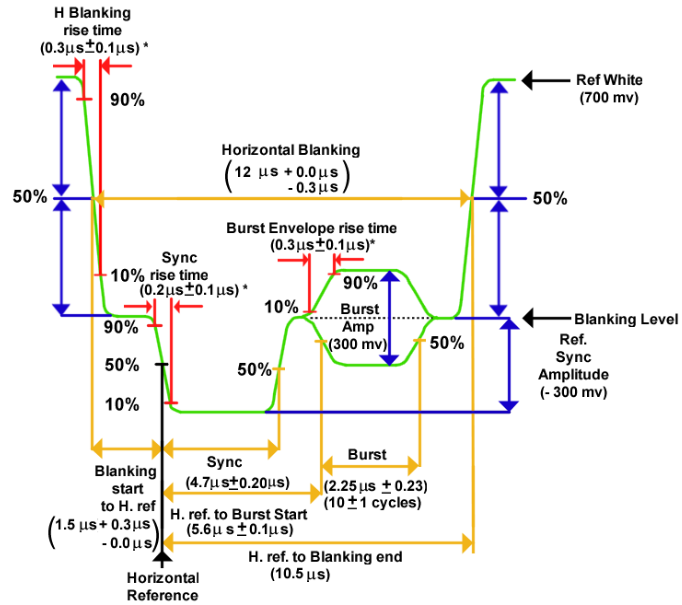

Figure 5. PAL Horizontal Blanking (from ITU-R.BT.470-6) * PAL-I system uses rise/fall time of (0.25ms + 0.05ms).

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.

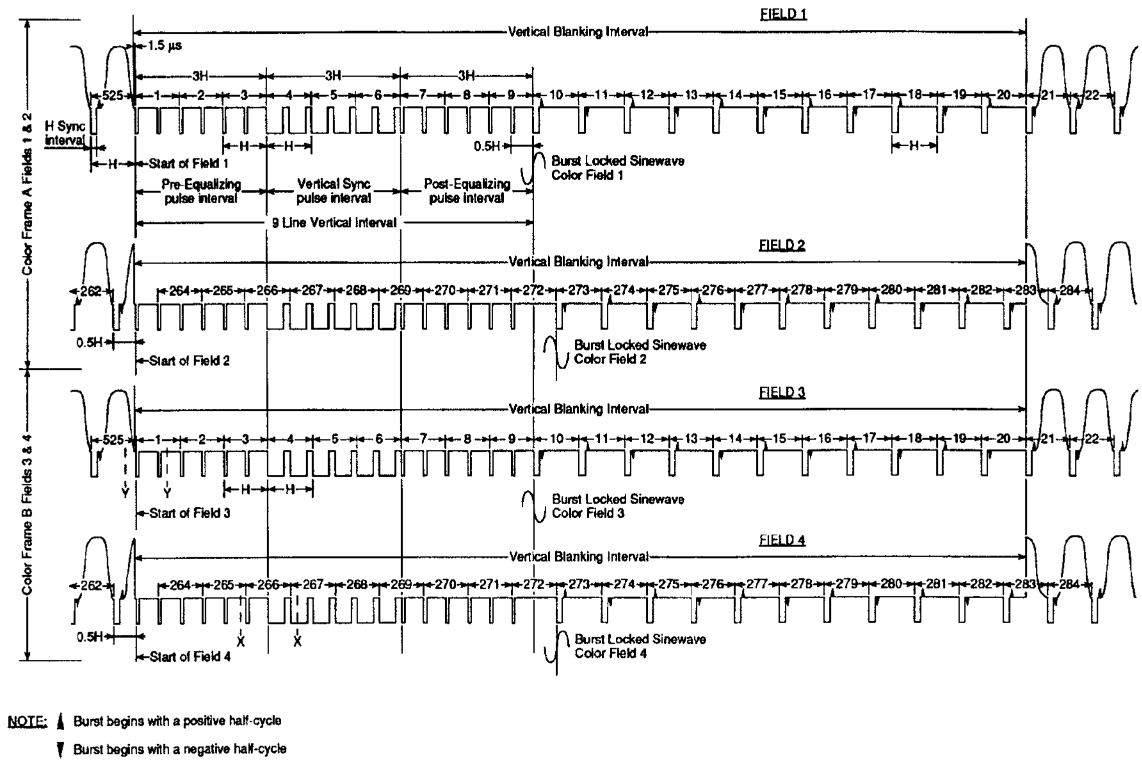

Figure 6. NTSC Vertical Blanking Interval.

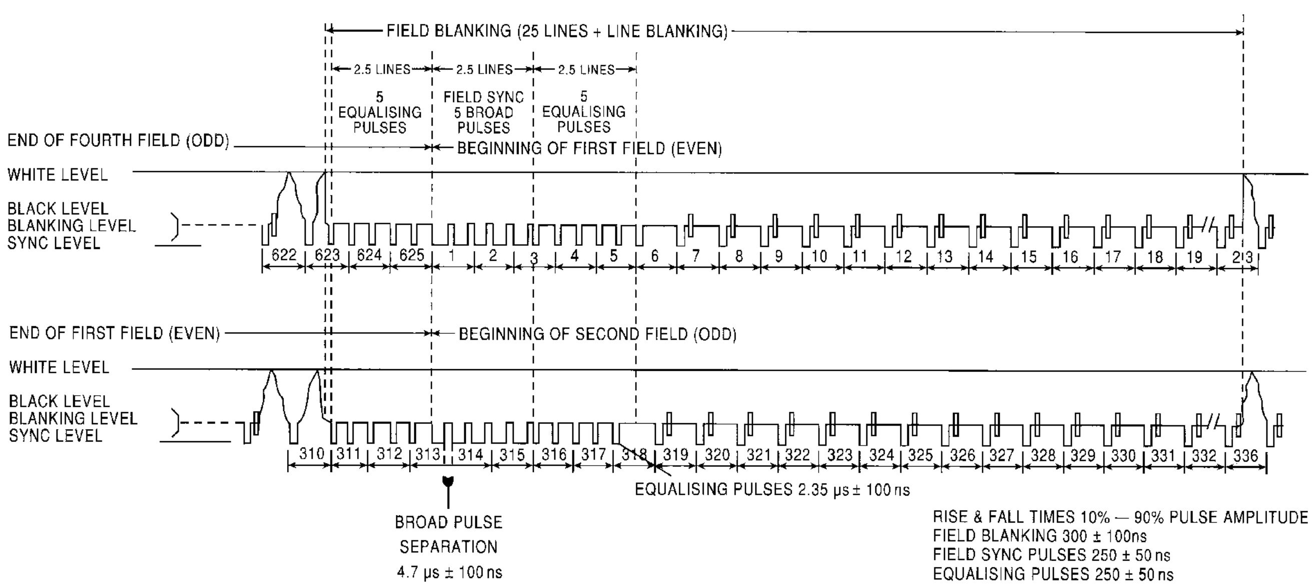

Figure 7. PAL Vertical Blanking Interval.

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).

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.

GPS Global Positioning System

The GPS system can be used for synchronization by obtaining timing information from a number of satellites orbiting the earth. The initial GPS system used 24 orbiting satellites and typical four or more of these satellite signals should be available in order for a GPS receiver to calculate position and time information. Each satellite transmits messages that provide a time the message was sent and the satellites position at the time of message transmission. The GPS receiver uses these messages from each of the satellites to determine the transit time of each message from which the receiver can compute the distance to each satellite. Hence the GPS receiver can determine positional information and the time difference between internal time of the receiver and the time of day provided by the satellites. The internal GPS receiver within the SPG8000 or the GPS7 module of the TG8000 provides a 10MHz clock along with a pulse once per second and time of day information that is used within generator to lock the system timing and provide time of day information. In this way multiple locations around the world can all be locked to the same reference. For more information on the GPS module see appendix A.

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	11.19
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.

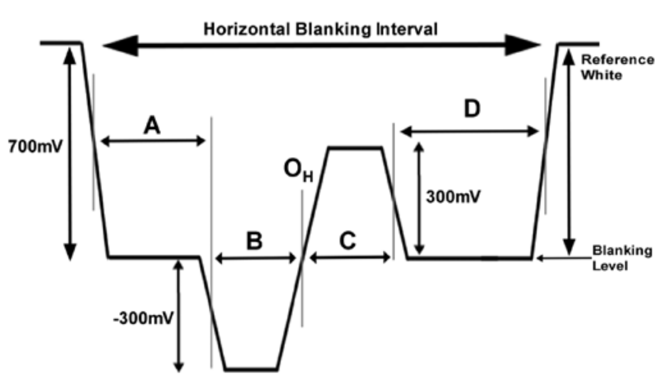

Figure 8. High Definition Tri-Level Sync Signal.

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 (High Definition Television) formats.

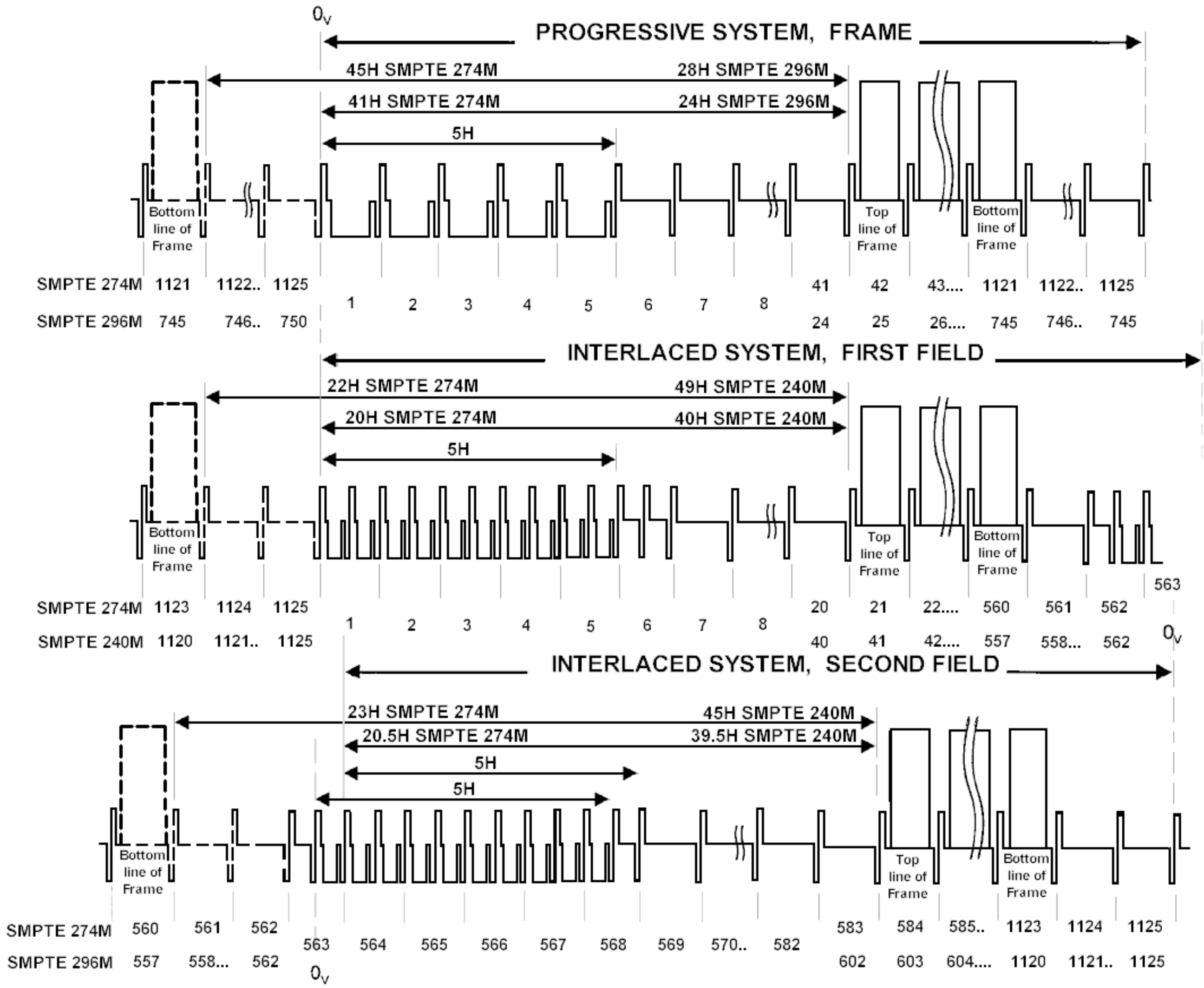

Figure 9. Analog HD vertical interval for SMPTE 240M, 274M and 296M.

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.

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

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.

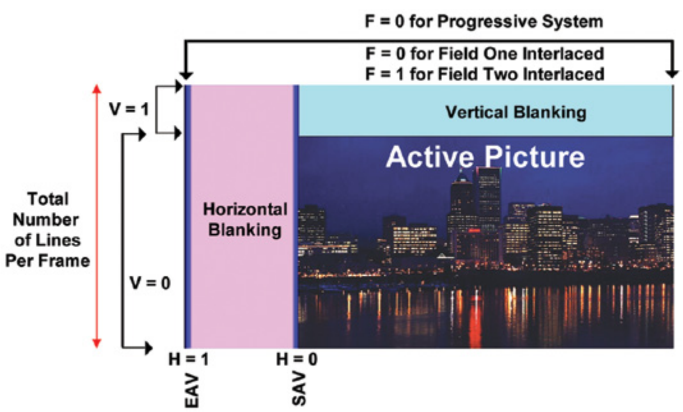

Figure 10. Spatial layout of the digital frame with V, F, and H-bit values.

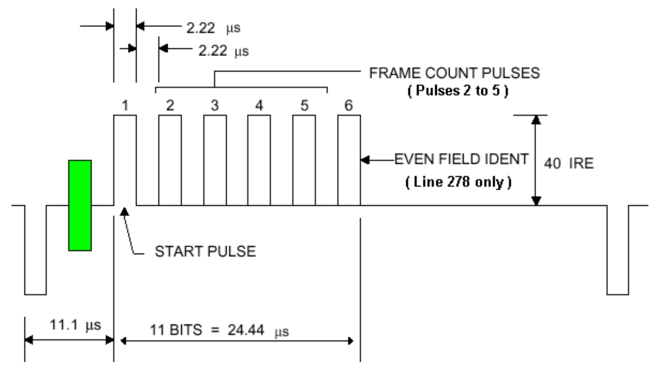

Figure 11. SMPTE318M Timing Reference synchronizing line.

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 SPG8000 Audio Generator option AG provides DARS (Digital Audio Reference Signal) and word clock outputs, as well as four other AES/EBU outputs, which can provide a range of test tones or silence. The audio generator option 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 SPG8000 signal generator platform provides the ability to genlock to SMPTE 318M with the analog genlock module and provides SMPTE 318M output references with the BG 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.

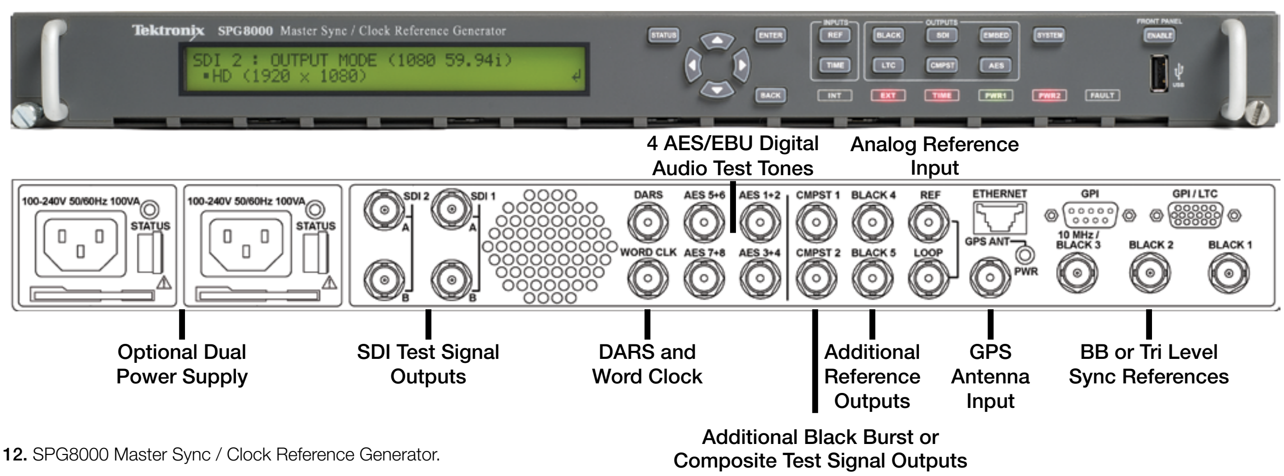

Figure 12. SPG8000 Master Sync / Clock Reference Generator.

SPG8000 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 SPG8000 master sync generator platform Figure 12, with its range of options, 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. The base system provides three independent reference outputs that can be black burst (PAL/NTSC) or tri-level sync. The addition of option BG adds an additional four reference outputs and the user can choose to have two of these outputs as analog (PAL/NTSC) test signal outputs rather than black burst or tri-level reference signals, giving a total of seven reference signals that are all independently timeable. The SPG8000 can be used as a master and free-run with no reference applied or can be genlocked to a reference signal (black burst, tri-level sync or CW signal). Additionally option GPS allows the SGP8000 to be genlocked to a GPS timing reference signal and provide time of day information and synchronized Time Code signals, for more information on this application see appendix A.

Up to four Linear Time Code outputs are provided or a combination of three outputs and one input can be configured that can be used to provide timing reference signal to various pieces of equipment throughout the facility. When the GPS option is installed the time of day information is obtained from the GPS and can be used to synchronize the timecode outputs. Additional the SPG8000 can function as a NTP (Network Time Protocol) server and provide time of day information to PC and other devices. For more information on time code configuration please see appendix B.

Option SDI provides two independently timeable channels with two SDI outputs that can be configured by the user to support SD-SDI or HD-SDI or 3G-SDI (Option 3G adds support for 3Gb/s SDI signals supporting both Level A and Level B formats). A variety of test pattern or full frame bitmap images with Text, Burnt-in Time Code, Circle and Logo overlays are available from the SDI outputs. Additionally the secondary SDI output of each channel can be configured to be Black or the Test signal output. Within the SDI signal up to 16 channels of embedded audio can be added, along with timecode, SMPTE 352 video payload identifier and ANC data payload that can be added by the user to the stream. The SPG8000 base system provides a 48kHz word clock output and the AG option adds support for AES/EBU digital audio signals with DARS that can be timed to the video signal to allow for synchronization of the digital audio throughout the plant.

For critical SPG applications within a facility, such as a Master Sync and Back-up generators it is important to ensure robustness of the sync signals throughout the plant as loss of sync signals could cause certain areas of the system to loose genlock and for equipment to become unlocked to the rest of the system. Therefore a dual hot swappable power supply option (DPW) is available for the SPG8000 that provides a primary and backup power supply system. The system will automatically switch to the backup supply if the primary supply fails without a loss in operation of the instrument. The front panel provides indication of the status of each power supply module. Tektronix uses a fail-safe system to daily check the backup power supply operation so that if needed the backup supply will be switched into operation. In this way the life of the backup power supply is extended, since it is not continually on and only brought into full operation when needed. The user can monitor the temperature weighted hours (TWH) of each power supply module to determine the expected life of the power supply. When the TWH exceeds a value of 131,400 then the power supply indicator will be set to orange indicating the power supply should be replaced, Both power supply are hot swappable so that the user can easily change the power supply that is not operating and still allow continuous operation of the instrument.

The SPG8000 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 (Table 4). 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. The SPG8000 selects the best frame reset frequency for a specific video format combination. This information is available on the front panel of the mainframe menu – SPG8000: Frame Reset Status. The three frame resets that the SPG8000 supports are as follows: Frame Reset 1 runs at 2.997Hz and support the 1/1.001 system signal. It is used for NTSC, 525, or HD / LTC (Linear Time Code) formats with (74.25/1.001)MHz clock. Frame Reset 2 runs at 6.250Hz and supports the integer signal system and is used for PAL, 625, HD / LTC formats with 50Hz or 25Hz frame rates. Frame Reset 3 runs at 3.000Hz and supports HD / LTC formats with 60Hz, 30Hz or 24Hz frame rates. Within an HD facility, Table 4 shows how the Frame Reset will lock to each of the output formats within the generator.

Frame Reset 1	Frame Reset 2	Frame Reset 3
NTSC	PAL	1080p 24
525-270	625-270	1080sF 24
1080p 23.98	1080p 25	1080p 30
1080sF 23.98	1080i 50	1080p 60
1080 29.97	1080p 50	1080i 60
1080i 59.94	25fps LTC	720p 60
1080p 59.94		24fps LTC
720p 59.94		25fps LTC
30fps DF LTC		30Fps LTC
23.98fps LTC		

Table 4. SPG8000 Frame Resets

Stay Genlock®

The SPG8000's Stay GenLock® feature avoids "synchronization shock" if the external reference suffers a temporary disturbance, the SPG8000 maintains the frequency and phase of each output signal. When the external reference is restored, Stay GenLock® ensures that any accumulated clock drift is removed by slowly adjusting the system clock within standard limits instead of "jamming" back to the correct phase. Within the configuration menu of the SPG8000 the user should configure "Stay at Current Frequency" for the Reference Lock Loss Action to use the Stay Genlock function. Otherwise the SPG will revert to the internal reference oscillator frequency. A similar system can be employed for GPS signal loss when the user selects GPS Holdover Recovery. Various methods can be configured by the user (Stay Legal, Jam Phase or Fast Slew) to recover from a loss of GPS signal depending on the requirements of the user. See Appendix A for more information.

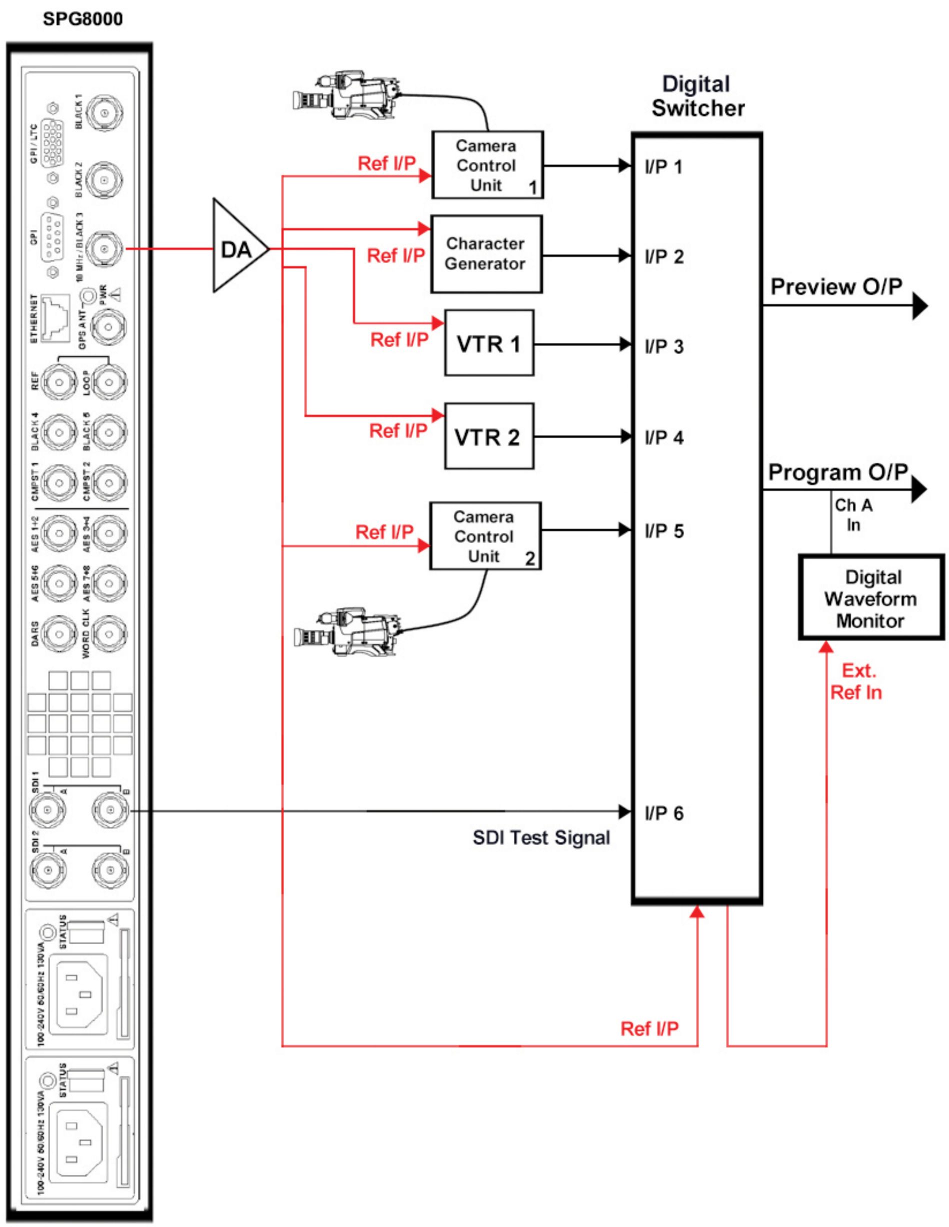

Figure 13. Basic Analog Video System.

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 master sync generator (SPG) such as the SPG8000. 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 13) 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.

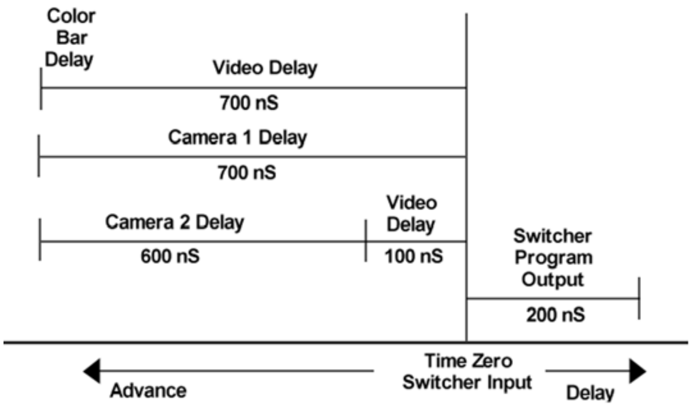

Figure 14. System Timing through the studio.

Figure 14 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 SPG8000.

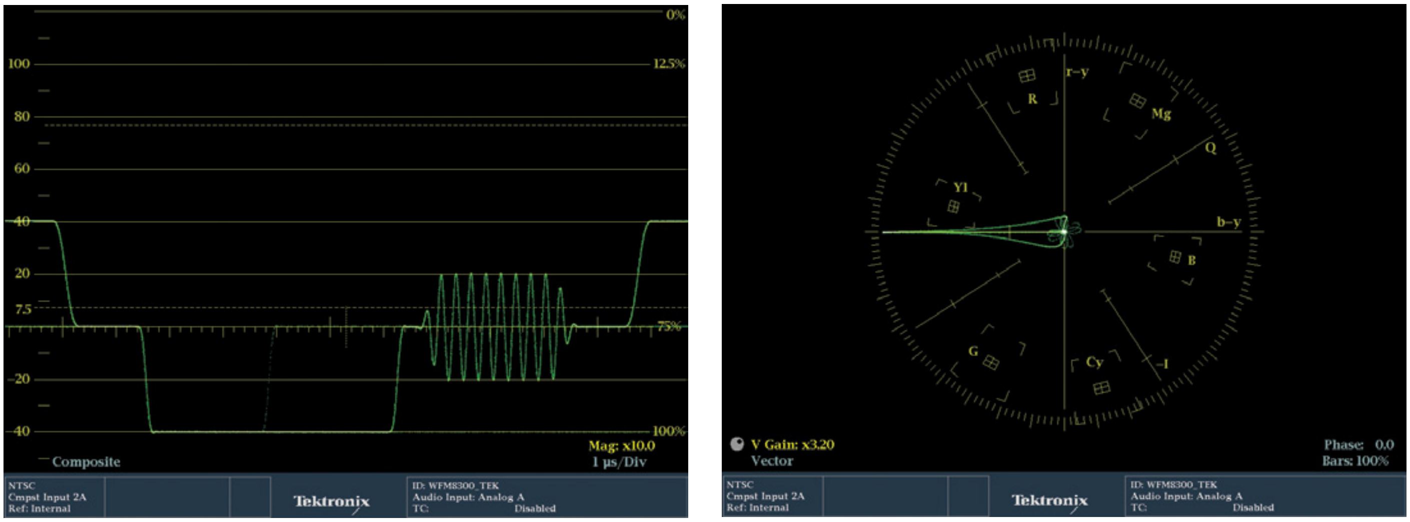

Figure 15. NTSC Waveform and Vector display.

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 13. 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 timing 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.

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 15. 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 16. The PAL burst can be magnified as shown in Figure 17 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 18. 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.

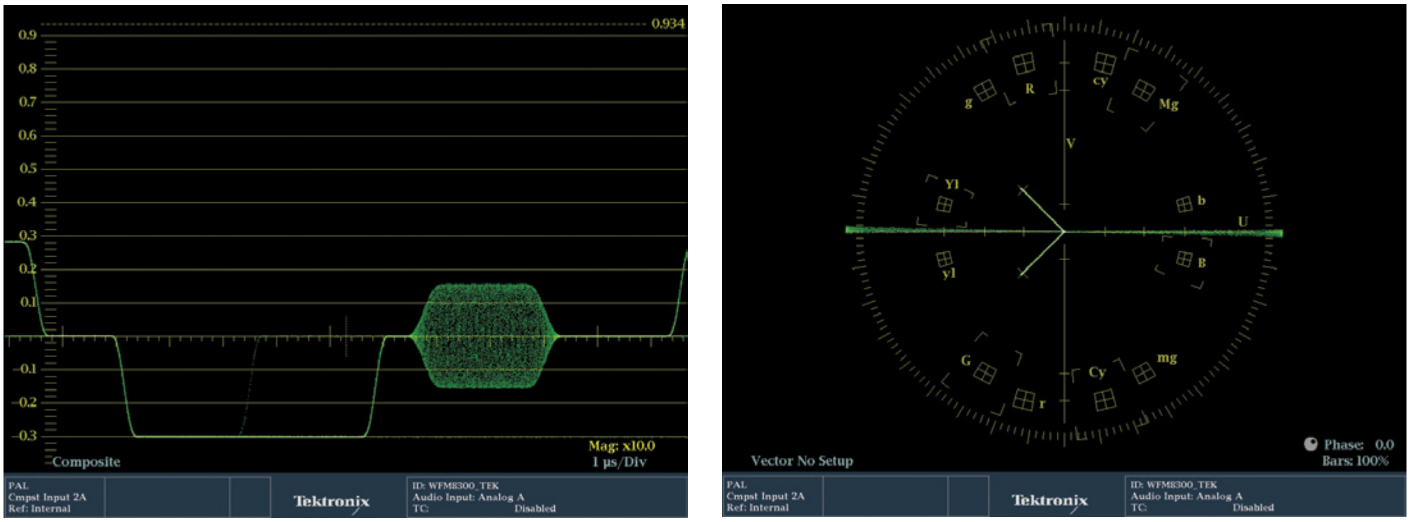

Figure 16. PAL Waveform and Vector. with SCH display.

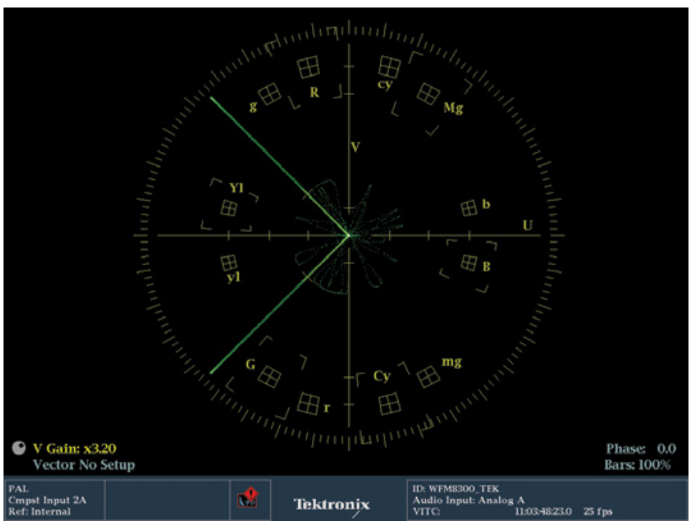

Figure 17. PAL Vectorscope MAG display.

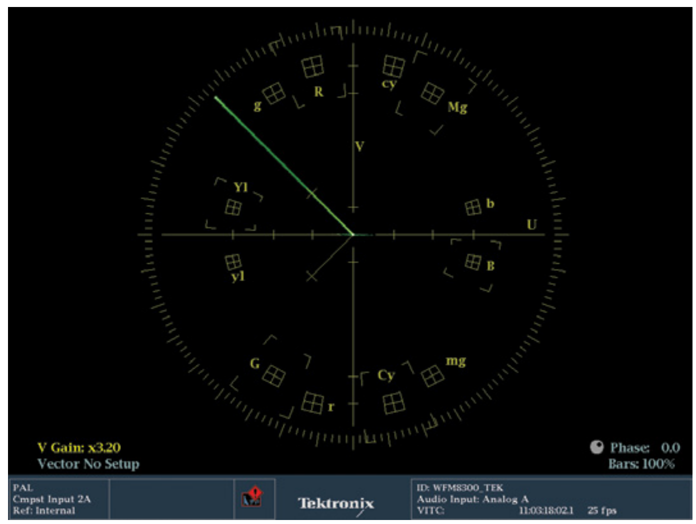

Figure 18. PAL Vectorscope with V axis switched.

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.

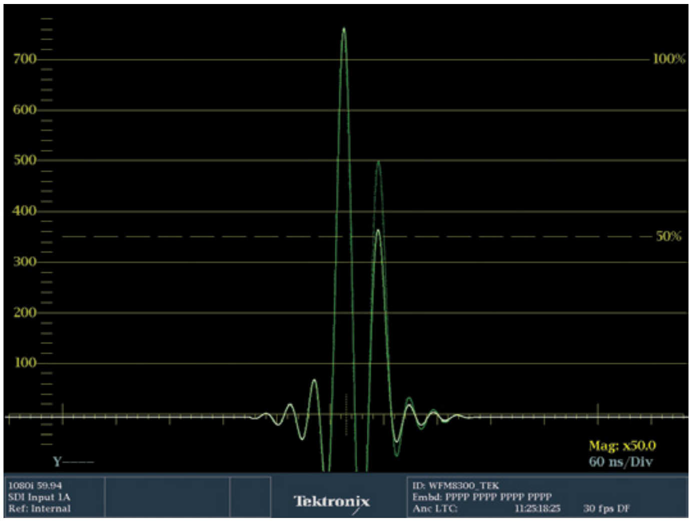

Figure 19. XYZ pulse of Y channel with EAV/SAV pass through selected on WFM8300.

Timing within the Digital Domain

A digital waveform monitor such as the Tektronix WFM8300/8200, WFM7200 or the WFM5200 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 19. 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.

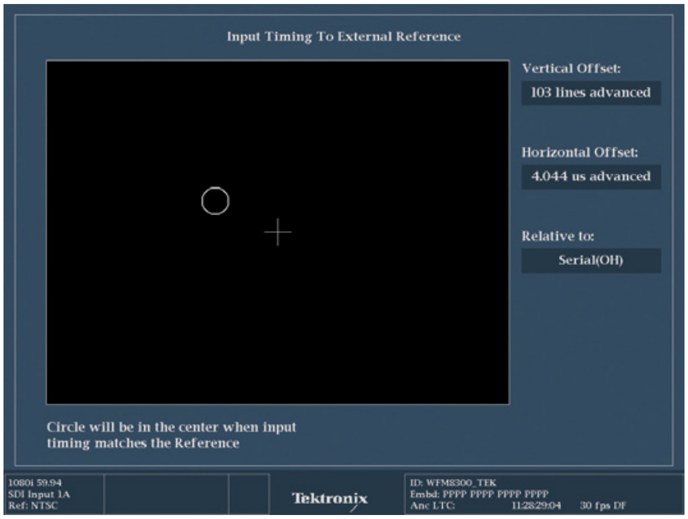

Figure 20. WFM8300 Series timing display.

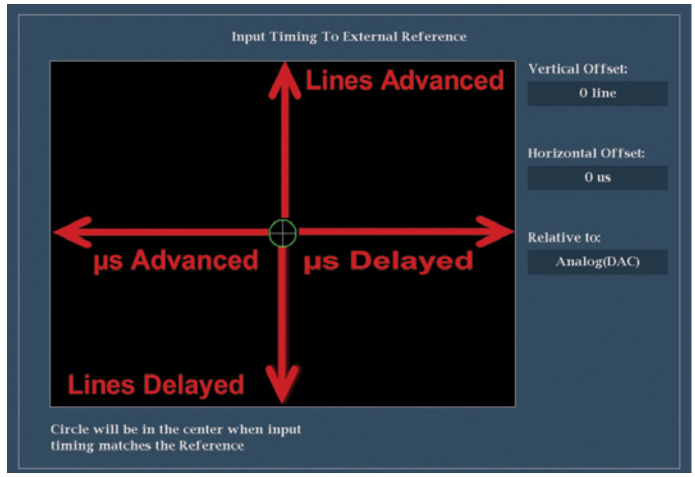

Figure 21. Interpretation of Timing Display.

Tektronix has developed a simple proprietary method for timing of an analog and digital facility within the waveform monitor or rasterizers (WFM8300/8200/7200,WFM52x0 or WVR8300/8200/7200 and WVR52x0). The Timing display provides a simple graphical rectangle window, which shows the relative timing between the external reference and input signal. Measurement readouts, in lines and microseconds (µs) of the difference between the two signals, are also provided as shown in Figure 20. For the WFM/WVR8000 series the input signal can be an 3Gb-SDI with option 3G, HD-SDI, SD-SDI or an analog composite input with option CPS. An external reference signal of black burst or tri-level sync can be used. The rectangle display represents one frame for 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 21. 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 Analog (DAC) this means that a Digital to Analog Converter (DAC) is used to convert the digital signal into analog so that it can be directly compared to the analog reference signal and the delay of the DAC needs to be accounted for in the measurement. This method is described in SMPTE RP168 (Definition of Vertical Interval Switching Point for Synchronous Video Switching) for timing of a hybrid analog and digital facility. In this method the delay of the digital to analog converter has to be accounted for within the measurement (Figure 22). For SD-SDI DAC a delay of 4.6µS is assumed, for HD-SDI DAC a delay of 1.3µS and 0.0 us for 3Gb-SDI. The "0.0us" delay for 3Gb-SDI means the Analog (DAC) and Serial (0H) modes are equivalent for 3Gb/s signals.

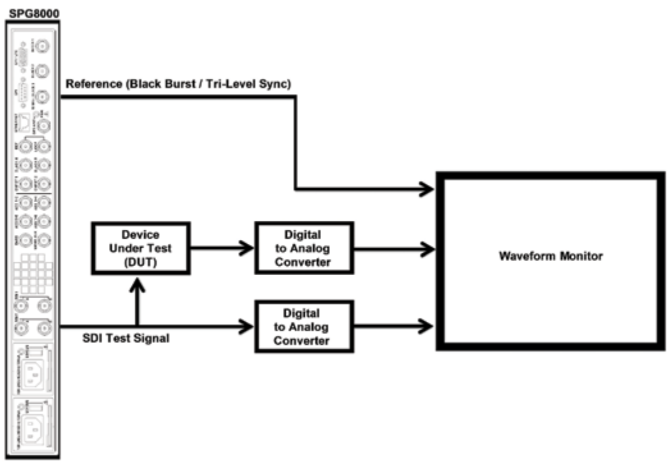

Figure 22. Analog (DAC) Timing Measurement.

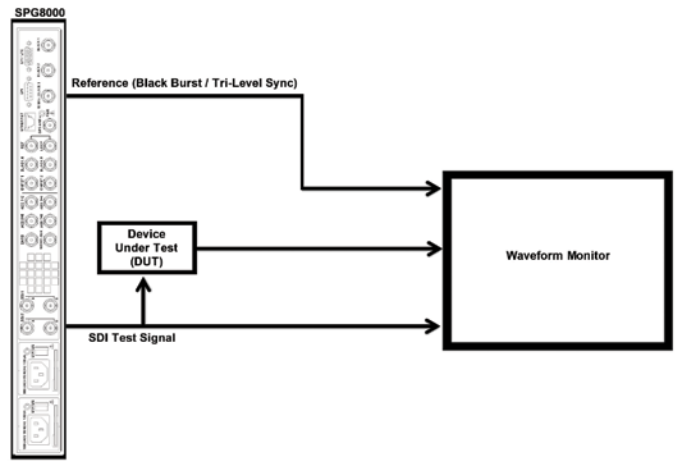

Figure 23. Timing Measurement using Serial(OH).

SDI video output and waveform monitor with analog input

Alternatively the synchronization information can be obtained directly from the SDI and compared to the analog reference input by extracting the horizontal and vertical timing information within the digital domain. In this case the user should select the Serial(OH) from the timing measurement menu the "Relative to" display will then show Serial(OH) within the display (Figure 23).

SDI video output and waveform monitor with HD-SDI input

The user can also choose 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 waveform monitor or rasterizer, 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 waveform monitor or rasterizer 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. Alternatively if the SIM option is available within the waveform monitor the user can select timing to the Other Input. This allows direct comparison of two SDI signals within the timing display.

This intuitive display can save considerable effort in the timing of video systems.

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 automatic change-over unit to ensure a timed referenced signal throughout the facility. Figure 19 outlines the basic principle behind a multiformat 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. 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 24. 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.

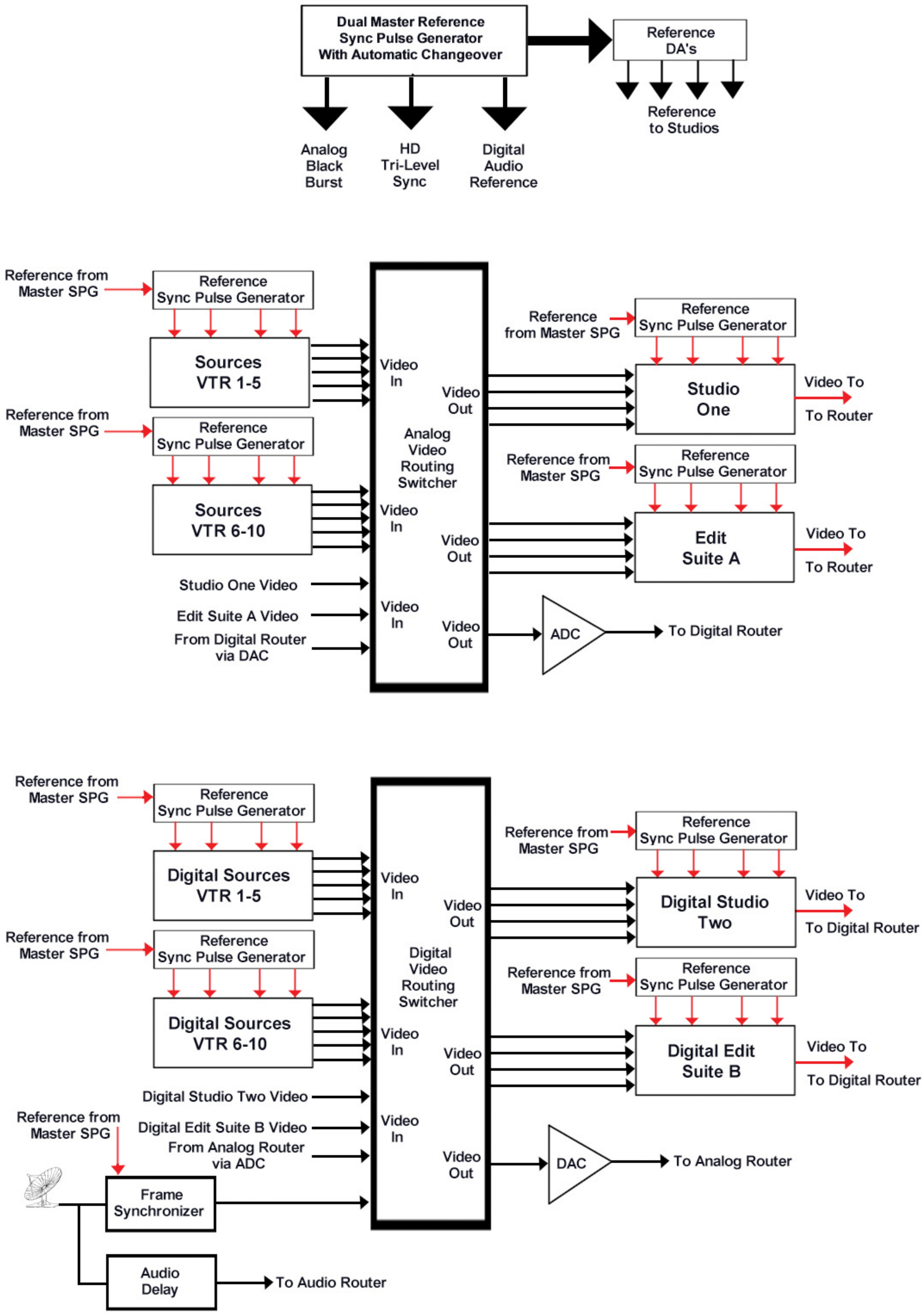

Figure 24. Multi-Format Hybrid Facility.

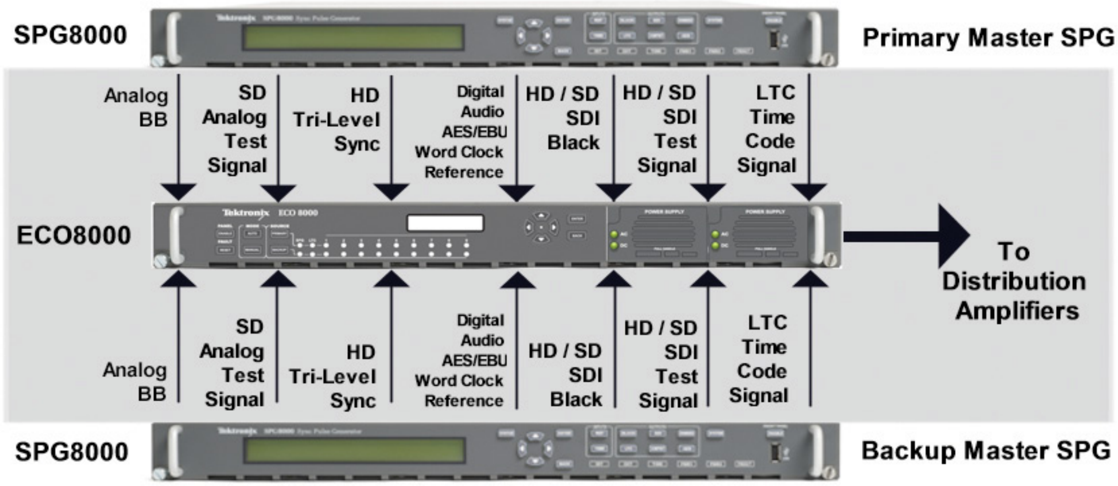

Figure 25. Dual Master Sync Pulse Generators with Automatic Change-Over unit.

Redundant synchronization

Two master reference SPG8000s (Master and Back up) are used with an automatic changeover unit (ECO8000/8020) as shown in Figure 25. The master SPG8000 is setup to meet the timing requirements of the facility. Once the instrument is configured the settings of the master can be cloned to the back up SPG8000. This is achieved by using the Backup/ Restore function within the system menu of the instrument. When a backup operation is performed all the instrument preset and all user data can be copied to a USB device connected to the front panel of the SPG8000. Once the operation is complete the user can then remove this USB device from the master and insert the stick into the back up SPG8000. The user can then restore the data from the USB device into the SPG8000 and now the settings and signal files are duplicated in both the master and backup generators.

The Tektronix ECO8000/8020 is able to detect a loss of sync signal at the master input and automatically switch to the back-up master SPG. Maintaining the sync signal at the output of the ECO8000/8020 prevents a loss of a critical sync signals 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 completely fault-tolerant, flexible, and robust system. In many broadcast and post-production facilities, Automatic Change- Over units such as the Tektronix ECO8000 (Figure 26) or ECO8020 (Figure 27) are used to automatically switch from one Master SPG source to another upon fault detection to any critical active source with minimal loss of service within a facility. The Tektronix SPG8000 can be used in combination with another SPG8000 unit to provide a back-up in case of failure of one of the components within the timing system. The reference signal from each of the generators are applied to the master and back up input channels of the automatic changeover unit and the output of this reference signal is the distributed throughout the facility.

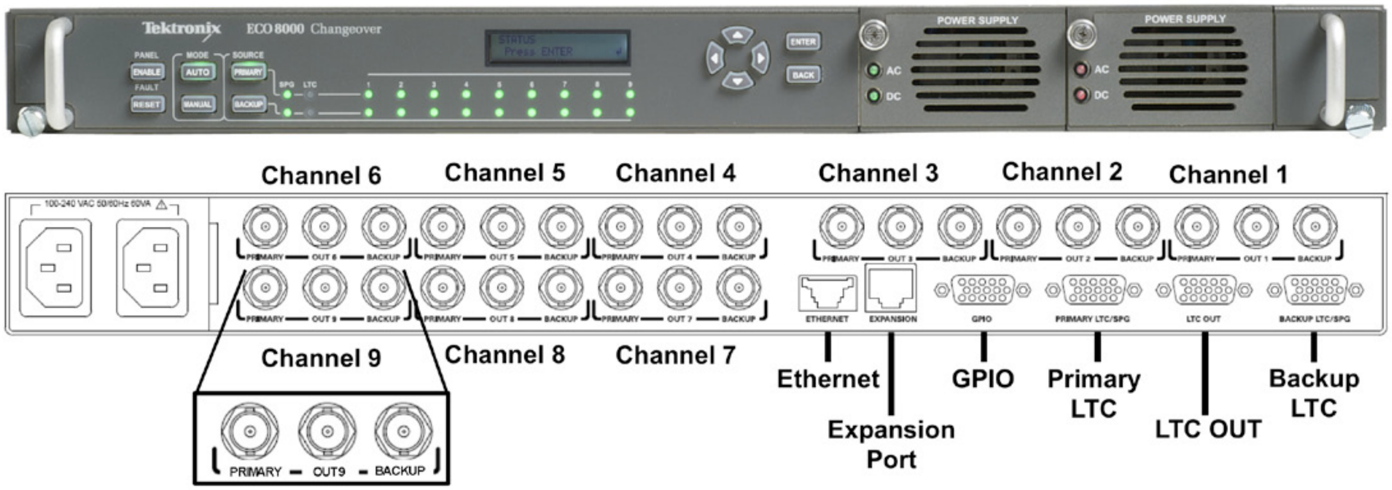

Figure 26. Front and Rear Panel of ECO8000.

The number of channels that are required to have redundancy will be dependent on the system configuration of the facility. Tektronix provides a variety of configuration options for automatic change over units to suit your applications. The ECO8000 has up to nine user-configurable channels along with a LTC switched input and can be configured to support analog Black Burst (PAL or NTSC), HD tri-level sync, audio word clock, AES/EBU digital audio, SD-SDI, HD-SDI or 3G-SDI. The base system supports three channels that are each 50MHz bandwidth with electronic fast switch change over for minimal disturbance of the signal and provides relay back up if power is removed from the unit. The base channel configuration supports analog black burst, tri-level sync, word clock and AES/EBU digital audio signals. Additional three channels of 50MHz switching can be added with the REF option. For high bandwidth SDI signals the HREF option provides three 3GHz relay switching channels. The REF and HREF options can be combined in a variety of ways to provide a maximum on nine channels. If the user requires additional channels, this can be achieved by using two ECO8000 instruments configured to operate as a single system or by using an ECO8020 that provides up to 20 channels in a1RU instrument. The base system of the ECO8020 supports five channels that are each 50MHz bandwidth with electronic fast switch change over for minimal disturbance of the signal and provides relay back up if power is removed from the unit. For high bandwidth SDI signals the ECO8020 HREF option provides five 3GHz relay switching channels. The ECO8020 can be configured with a variety of different configuration using a combination of the REF option that provides five 50MHz channels or five channels of the high bandwidth 3GHz (option HREF) until a maximum of 20 channels are installed within the ECO8020. If further additional channels are required two ECO8020 instruments can be configured to operate as a single system providing up to 40 channels.

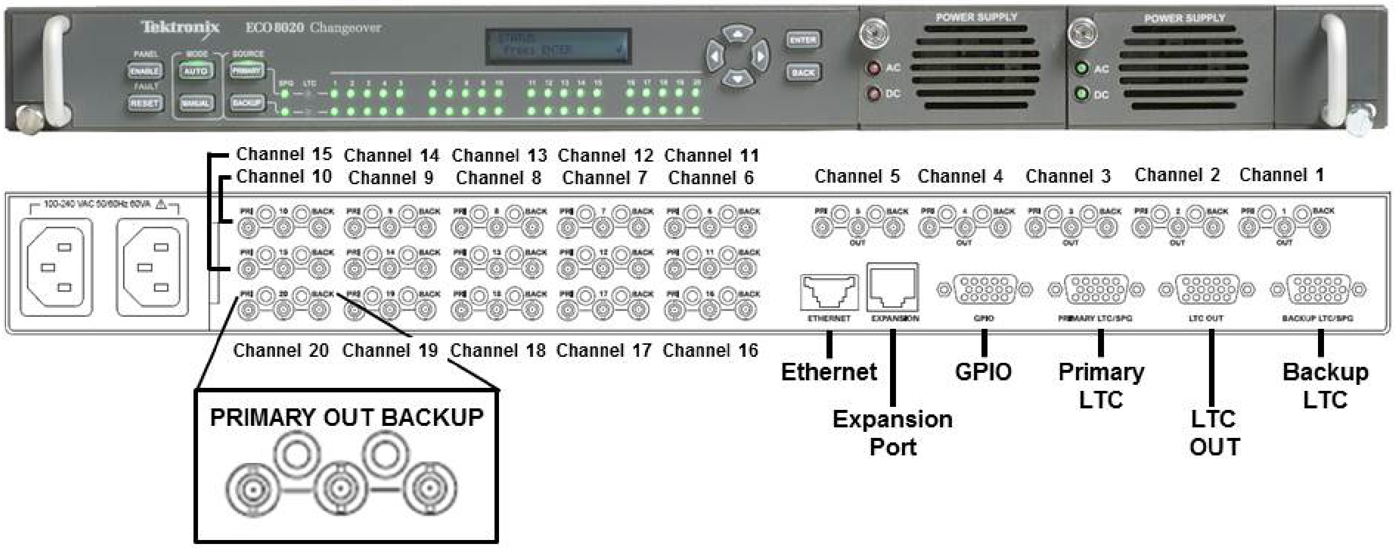

Figure 27. Front and Rear Panel of ECO8020.

Both the ECO8000 and ECO8020 can support four channels of automatic switching of Linear Time Code (LTC) with the option LTC to provide redundancy of time code signals throughout the facility. With the ability to configure two instruments together this can give a maximum of eight LTC channel switching.

For additional system reliability the ECO instruments can be configured with a dual power supply hot swappable system (option DPW). The user can define one power supply to be the master and the other module to be the backup. A simple green LED (Light Emitting Diode) shows powered operation and if a module loses power a flashing red LED will indicate the problem for a period of time allowing the user to replace the module. Both instrument use the Tektronix fail-safe system to daily check the backup power supply operation so that if needed the redundant supply will be switched into operation. In this way the life of the backup power supply is preserved, since it is not continually on and only brought into full operation when needed.

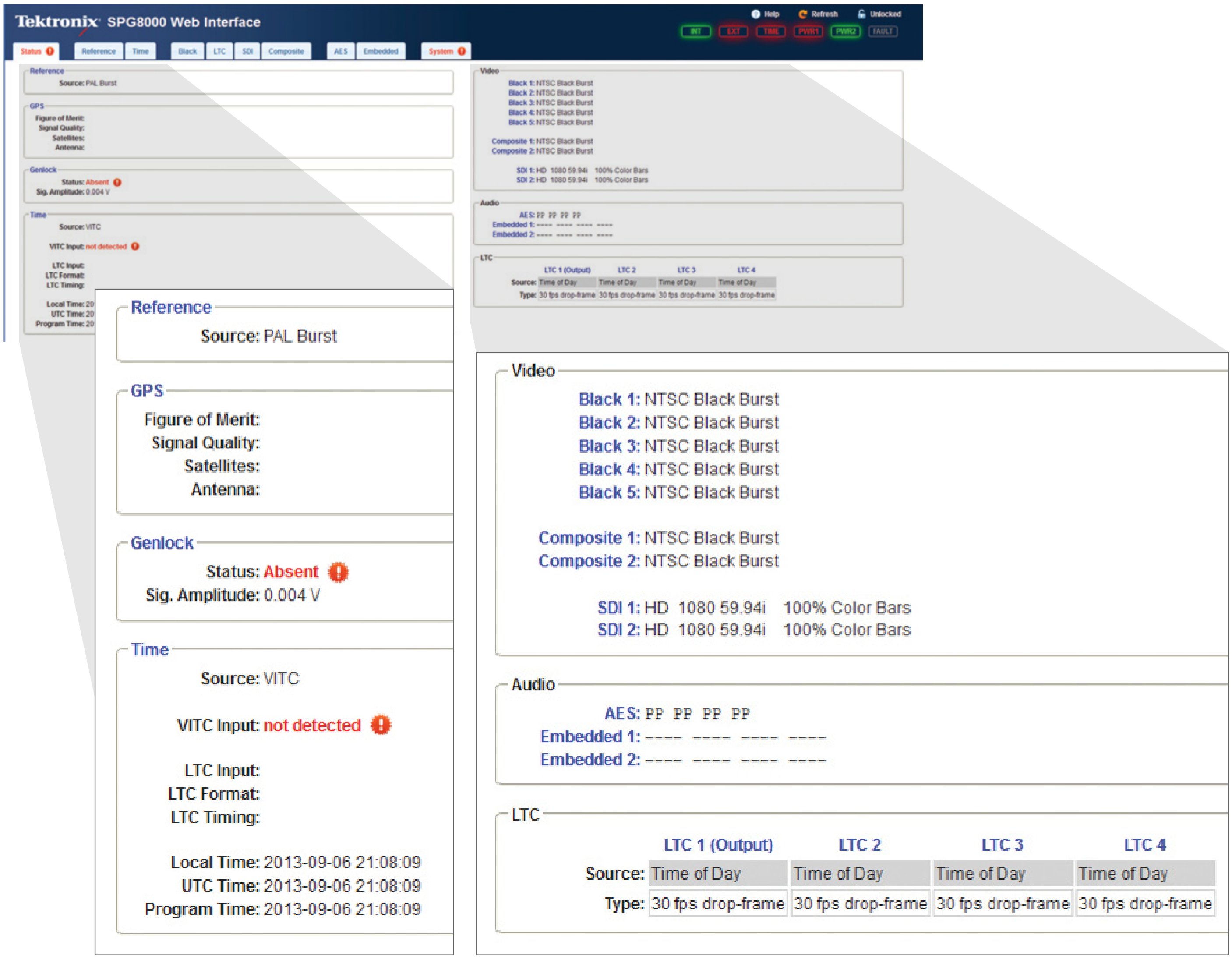

Figure 28. Web User Interface for setup and status monitoring.

Remote Access and Control

The SPG8000, ECO8000 and ECO8020 provide a web interface that allows control of the operations of the instrument via a Local Area Network (LAN). Once the instrument is connected to the network and an IP address is obtained the user can configure the instrument to be web enabled from the system menu.

During set up of the instrument the user may want full control via the web page to allow easy configuration of the various menus within the instrument. Then when the instrument is in service the user can select read only access that will not permit changes to be made to the instrument, or alternatively the user can disable the web interface access. From a web browser enter the IP address of the instrument and the web page will be loaded and show the Status and configuration pages, Figure 28. The status page provides a summary of the operation of the SPG8000 and the icons on the upper right of the page represent the same information as the front panel of the instrument.

- Internal & External Reference Indicators
- State of the Time Indicator
- States of Power Supply Modules (PWR1 & PWR2)
- Fault Indicator

The user may wish to have the SPG and ECO system continually monitored as part of their network management system and be informed of the status of the instruments. The SPG8000, ECO8000 and ECO8020 support SNMP (Simple Network Management Protocol) and the MIBs (Management Information Base) for the instrument can be downloaded from the systems tab on the web user interface.

The following settings can be set as SNMP traps on the SPG8000

- Main fan fault
- Voltage Error
- Temperature Error
- GPS signal missing
- Genlock input missing
- Loss of lock
- Near loss of lock
- VITC/LTC missing
- LTC out of SMPTE specifications
- GPS Figure of Merit
- Alarm Time
- (PS1) Power Supply 1 Fault
- (PS 2) Power Supply 2 Fault
- PS1 TWH (Temperature Weighted Hours)
- PS2 TWH (Temperature Weighted Hours)

By monitoring these various parameters via a network management system the user can track the status of the SPG or ECO and this information can be used to isolate problems within the facility. For instance the GPS lock was lost during the last evening when a thunderstorm occurred.

Alternatively the user can use the (General Purpose Interface) GPI/O interface to provide alarms or trigger to the instrument to perform a certain action.

The following GPI input triggers can be set within the SPG8000.

- Reset Program Time
- Reacquire GPS Position
- Jam Sync

The following GPI output alarms can be set

- Hardware Fault
- Power Supply Fault
- Lock Error
- Lock Warning
- Time Error
- Time Warning
- Alarm Time

These GPI or SNMP alarms can be used to alert the user to a condition or problem with the instrument. In this manner the user can be alerted to a potential problem with the synchronization system. This could be a warning of the loss of GPS signal due to a thunderstorm or warn of a potential failure of a power supply within the instrument. Corrective action can then be taken by the user to resolve these issues and help maintain this critical synchronization system.

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 master sync generators (SPG8000) and test signal generators (TG8000) provide a wide variety of reference and test signals for a facility. The automatic changeover units (ECO8000/ECO8020) when used in combination with two SPG8000s provides a master and backup system for a reliable synchronization system for a facility.

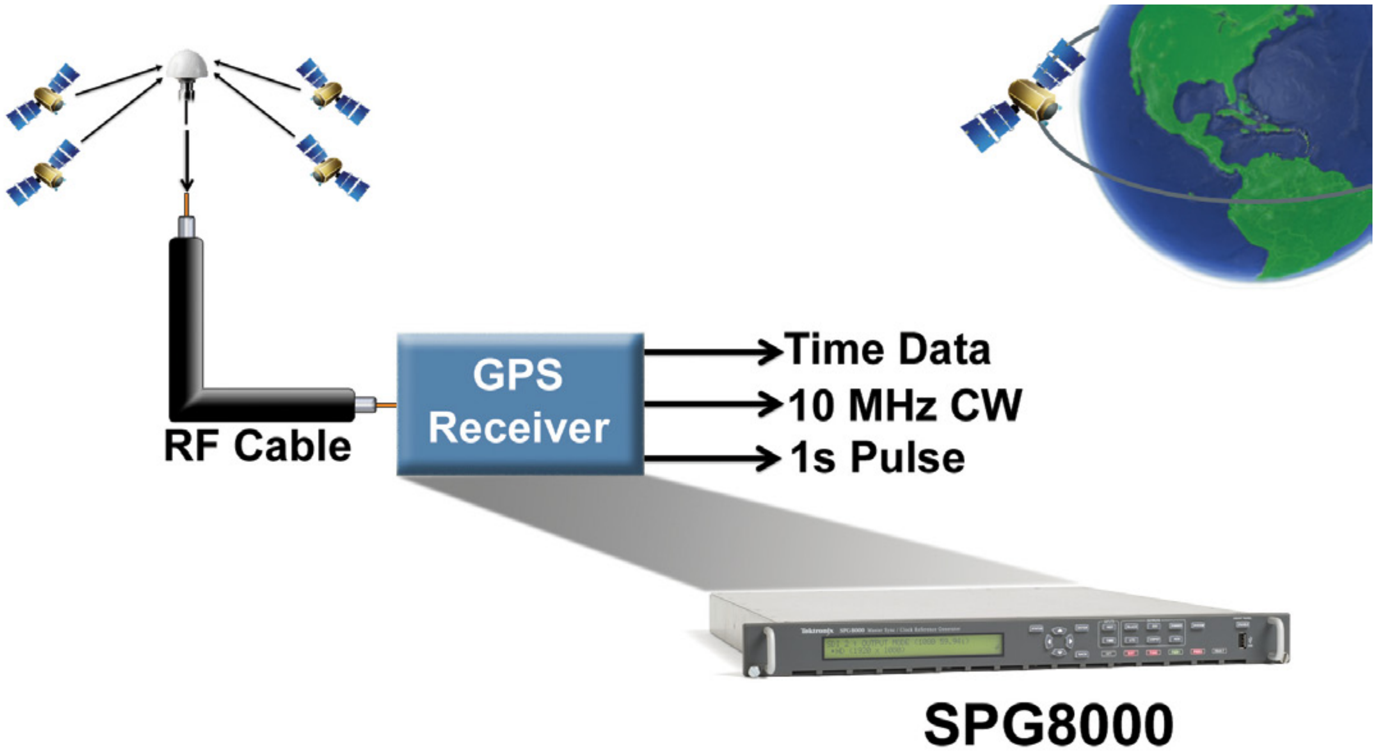

Figure A1. GPS Receiver System with option GPS installed in SPG8000.

Appendix A Global Positioning System (GPS)

The GPS option installed in the SPG8000 requires a GPS antenna (Option ANT) that is located with clear site to the sky in order to be able to receive the signal from the various satellites orbiting the earth, Figure A1. Objects such as trees and buidlings may block the receiver's view of the sky and this could limit the number of satellites available, so careful planning is needed in order to ensure an appropriate location for the antenna. The GPS receiver is in-built into the SPG8000. Therefore the user has to choose the appropriate antenna, cable length and power amplifier if required for the system in order to ensure the GPS signal can be decoded by the receiver that is located within facility. Antenna systems vary depending on the operating environment and on safety and regulatory requirements. Therefore it is important to understand the trade-offs when selecting the various components of the system as shown in Figure A2. A GPS antenna needs to have appropriate gain to receive the satellite signal and may need to provide amplification of the signal so that the signal can be driven along a reasonable length of cable while providing enough filtering to reject interfering signals at other frequencies. For example a Trimble Bullet III has 35dB preamp when using a 5V power source. The GPS receiver in the SPG8000 can provide power at either 5V or 3.3V for the various available antennas or can disable DC power if an external power supply is used. Care should be taken to ensure the equipment meets voltage and current requirements of the specific device. In this case the user would configure the instrument to provide the 5V power source to drive the Trimble antenna. The length and type of the cable chosen will determine the attenuation of the GPS carrier frequency of 1575MHz along the cable length. The SPG8000 requires a received signal that is greater than 18dB above the ambient level. Therefore in this example for a 35dB antenna the allowed cable loss is 35dB-18dB = 17dB.

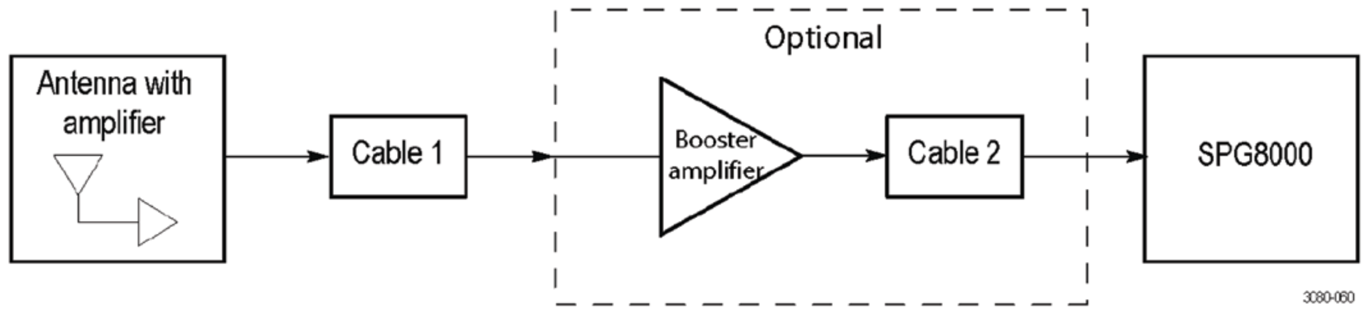

Figure A2. Simplified GPS Antenna system.

Attenuation varies significantly depending on the type of cable used. For example cable loss is about 13 dB/100 feet for a miniature coaxial cable like Belden 1855, while for a RG11 style cable like the Belden 7731, the loss is only 5.5 dB/100 feet. This correlates to an allowable length of 130 feet for the Belden 1855 cable, to over 300 feet for the Belden 7731 cable. A booster amplifier can be added if additional length of cable is needed, as shown in the optional block in the signal path system, Figure A2. The location of the amplifier can be critical as placing the amplifier just before the SPG8000 may result in the GPS signal been too attenuated and the amplification of signal at this point maybe too noisy to be decoded. If a 20 dB amplifier is added with the signal path, then 20 dB more cable loss can be accommodated. This equates to another 150 feet of Belden 1855 coax, or 360 feet of Belden 7731 coax for this example. Although the GPS input and most of the other components are 50 Ω, either 50 Ω or 75 Ω cables can be used in most installations. The reflections from the impedance mismatch will not cause significant changes in the system because the signal is narrow band and the cable loss is usually many dBs. However, you should not mix short cable lengths of different impedances, as this might create reflections with the potential to cause signal degradation. For complex systems, a variety of booster amplifiers, powered and passive splitters, DC blocks, and filters are available from a number of vendors to ensure transmission of the GPS signal to the receiver.

Once the configuration is complete and the GPS signal is connected to the Tektronix SPG8000 generator it can take several minutes for the signal quality to reach its nominal potential. How long the system takes depends on such things as antenna site, cable plant design, and available satellites. Typically it requires at least four satellites to correlate the timing information and the SPG8000 provides a Figure of Merit to provide a gauge of the receiver ability to decode the GPS signal. These Figure of Merit (FOM) numbers (Table A1) are a compendium of the GPS signal quality and the processes that occur as the instrument progresses through the states needed to lock on to the GPS signal. The FOM provides a simple scale to evaluate the state of the GPS lock for the user. Additionally the user can verify the number of satellites that the receiver has acquired within the menu of the SPG8000. During the initial installation of the system it is important to monitor the figure of merit over several days to ensure correct operation of the system.

The user can configure the SPG8000 to use the GPS Signal as the reference source using the timing reference signals from the GPS receiver of 10MHz and one pulse per second. Additional timing data is used for timing reference signal such as time of day and time code discussed in appendix B. Once lock is achieved a solid green LED on the front panel will be illuminated. If this green LED is flashing then this is an indication that the FOM is below 6 and the user should check the Status display for additional information on the signal strength. Depending on the environment the GPS signal could be lost because of atmospheric conditions or limited number of satellites available and the user can setup alarms to be triggered on GPS signal quality. The Tektronix SPG8000 offers a unique function of “Hold Over Recovery” as part of the Stay Genlock system.

Figure of Merit	Indicator	Description
0	No Signal	This means that no usable satellite signals are detected. This is normal for a short time after the signal is applied, but if it lasts more than a minute or so, then it usually means one of the following: that there is a problem in the antenna or cable, the antenna is blocked from direct line of sight to the satellites, or the power is not getting to the antenna.
1	Low signal	This means that some signal is detected, but that the signal quality is too low for extraction of useful timing or position information. This is a normal situation for a short duration, but if it persists, the causes are likely to be similar to those for FOM state 0.
2	Acquire satellites	This means that the instrument is receiving data from the satellites and is determining which signals to use.
3	Bad position	This means that the instrument detects that the stored position is different from the current position. In this case, the instrument will automatically go to FOM state 4 and reacquire the position.
4	Acquire position	This means that the instrument is acquiring multiple fixes of the satellite position and averaging this into a new position to store in flash. This state will also be displayed if you manually perform a new position acquisition. This state normally lasts 60 seconds with good GPS signal quality.
5	Adjust phase	This means that the instrument is adjusting the time base or frame timing to correctly line up with the GPS signal.
6	Locked > Signal quality is ≤ 16	These states indicate that the phase of the frame signals is within 150 ns of the GPS signal. The number of arrows indicates the signal quality. It is normal for this to vary with the time of day as the different satellites move through their orbits, as well as with changes in weather and other conditions.
7	Locked >> Signal quality is > 16	
8	Locked >>> Signal quality is > 26	
9	Locked >>>> Signal quality is > 42	
10	Locked >>>>> Signal quality is > 68	
11	Locked >>>>>> Signal quality is > 110	

Table A1. Figures of merit for signal quality.

When the GPS signal is lost the user can configure certain action to be performed by the GPS Hold Over Recovery system

- **Stay Legal:** Adjusts the module timing to match the recovered GPS signal while staying within the specified frequency offset and frequency rate of change specifications for NTSC and PAL reference signals.
- **Jam Phase:** Adjusts the module timing to match the recovered GPS signal immediately but will typically cause a sync “shock” to the system.
- **Fast Slew:** Adjusts the module timing to match the recovered GPS signal at a rate 25 times faster than the legal rate without jumping.

Stay Legal would typically be used by a facility that in the event of a loss of GPS lock they would prefer to maintain reference signal within specified limits and not cause a shock to the system when the GPS signal is decoded in order to maintain facility timing. Jam Phase may be used by an outside broadcast vehicle or mobile truck to quickly establish GPS lock when the system is powered up to help quickly establish lock of all systems within the vehicle and the user is not concerned about a sync shock to the system as each of the devices is powered up. Alternatively the user can use the Fast Slew mode that quickly will attain synchronization and lock without causing a major shock to the system. In this way the Tektronix SPG8000 can ensure a shock-free re-alignment of frequency and phase when the GPS signal is restored. Otherwise a typical SPG will return to the internal free run frequency of its oscillator when the synchronization signal was lost and will likely cause a shock to the system when the reference signal is reapplied.

Appendix B Time of Day

The Tektronix SPG8000 can provide a variety of timing reference signals. When option GPS is installed and the user configures to use GPS signal as the external timing reference Then the timing information can be derived from the satellite signals and provides a UTC ((Universal Time Code) time of day clock for timecode outputs and as a phase reference for video outputs. The GPS epoch is defined as 00:00:00 January 6th 1980 from which the GPS signal will report a timestamp in weeks and seconds. For instance a 06:25:00 UTC of November 5th 2008 will be reported as 1504 weeks and 282,314 seconds by the GPS system. The GPS signaling also provides information on the number of leap seconds, in this example 14 leap seconds would have occurred between January 6th 1980 and November 5th 2008.

In order to provide video system synchronization an adjustment between SMPTE epoch and GPS epoch should be made. The SMPTE epoch is defined as 0:00:00 of January 1st 1958 (TAI International Atomic Time) and is considered the “big bang” moment when all frames were aligned. From that moment there have been exactly 30,000 NTSC frames and 25,025 PAL frames every 1001 seconds. Therefore in our example we need to add an additional 8040 day plus 19 more leap seconds that is the difference between SMPTE Epoch (TAI) and GPS Epoch, producing a total of 1,604,557,533 seconds and corresponding to 96,177,274,705,2947 NTSC fields. From this calculation we can determine how may frames to adjust for the current time in order to achieve frame alignment within the SPG. This can be done by using Jam Sync that will align the reference signals quickly but will produce a shock to the system. Alternatively the clock can be slowly slewed to gradually provide alignment of the reference signals.

When the GPS signal is used as the external timing reference signal the UTC information can be used to derive time code information and act as a NTP server. The user should select the Time of Day reference as the source of the time and date information from the GPS signal. If the SPG does not have the GPS option installed or has configured the SPG to be in internal mode. Then the Time Setup will be in internal mode and the user can configure a user defined master time. When a video reference signal (NTSC/PAL) is applied that has Vertical Interval Time Code (VITC) present then the user can configure to use this time code signal to derive the timecode reference outputs. Alternatively the SPG8000 LTC 1 can be configured as an input and the time code information can be obtained from this signal for the various timecode outputs.

When an external timecode signal from LTC or VITC input is used for the timing reference the phase reference for the video output will not be derived from these timing signals.

Leap Second Information

A leap second is a one second adjustment that is made to compensate for the difference between UTC and the mean solar time Typically these occasional adjustments are made on 30th June or December 31st at 23:59:60 UTC and occur worldwide at the same time with compensation made for each local time zone. In some cases this maybe an inconvenient time to make a local clock adjustment and the user can defer making the leap second adjustment on these dates for up to 24 hours. The GPS signal provides signaling information of the number of leap seconds between GPS time and UTC. There have been a total of 35 leap seconds between SMPTE Epoch (TAI) and UTC as of December 31, 2012. The GPS option is required in order to obtain the Leap Second information from the GPS signal and is updated every 20 to 30 minutes. This leap second information is then stored within the instrument and used when the instrument is rebooted or the GPS signal is missing.

Timing Adjustments

The SPG8000 provides a number of ways to make local time adjustments to the various time code outputs. For instance a network may have different facilities located in various time zones and local facilities may wish to use their local time zone. Then within the configuration menu of the SPG a time zone offset can be applied in hours:minutes:seconds. This allows a great deal of flexibility in setting the offset time for not only the typical hour offset but parts thereof. In certain geographical regions Daylight Saving Time (DST) is used and when this is the case the time will be changed twice a year. Within the SPG8000 the user can program the adjustment of DST by adding or subtracting the specified amount from the current time and can schedule the data and time the change should be made. In addition to the Time of Day the user can use a Program Time this can be configured as a specific time and then used as a timecode source for any output. For example this could be used during the creation or mastering of content to place a specific timecode start at the beginning of the program material. Each of the timecode sources available within the SPG8000 is independently timeable and the user can add a specific timing offset to each output. This could be used by a network to produce timing offsets for the various time zones that the broadcaster operates and provide feeds with each specific time zone offset applied.

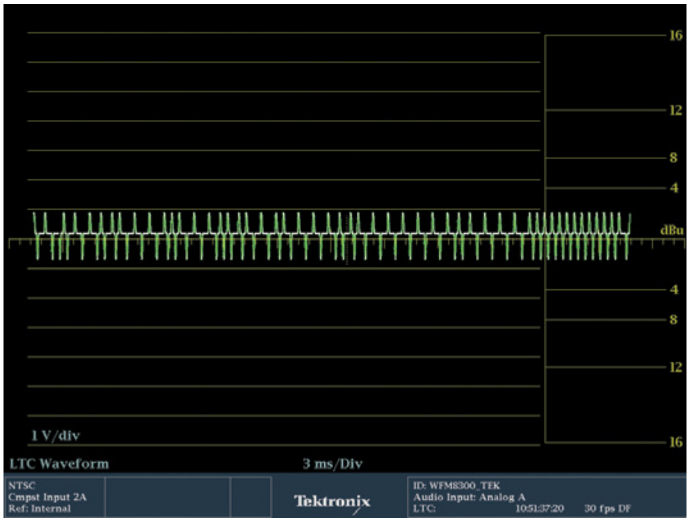

Figure 1B. Linear Time Code waveform display with decode of data in status bar.

Time Code

Time Code is a critical reference signal within a facility that is used to provide timing and control code information for a variety of equipment with the facility and is used by such equipment as servers and automation systems for playout of material. Time Code described time in terms of Hours, Minutes, Seconds and Frames (HH:MM:SS;FF) with frame rates of 60, 59.94, 50, 30, 29.97, 25, 24 and 23.98 supported. There are several ways in which this Time Code information can be carried within the system.

Linear Time Code (LTC)

This is an analog low frequency signal that was originally recorded on tape or transported as a separate serial signal over a separate interface. The LTC signal can be carried on a balanced XLR audio interface or on a single ended unbalanced output of a BNC connector. One of the LTC signals produced by the SPG8000 can be connected to the rear of the waveform monitor via the 15 pin remote connector. The waveform display of the LTC signal can then be viewed on the waveform monitor to check presence and level of the signal Figure 1B. The preferred amplitude is between 1-2 Volts but can have an allowable range between 0.5V to 4.5V. The waveform monitor can also be configured to decode the LTC value. Within the configuration menu of Aux/ANC Data Settings->Time Code Source menu select LTC and the time code information will decoded and shown in the status bar if present Figure 1B.

The LTC codeword consists of 80 bits as shown in Table 1B for various frame rates.

There are three Binary Group Flags (BFG0,BFG1,BFG2) that depending on their bit values define what the Binary Group information can be used for. In some cases the binary groups are used for date and time zone information or page/line multiplex with clock information. The bit values for this additional information can be found in the Aux Data Status display of the waveform monitor showing Time Code Flags, BG Flags and BG Data.

Bit Value	30 Frame Bit	25 Frame Bit	24 Frame Bit
0	Frame 1	Frame 1	Frame 1
1	Frame 2	Frame 2	Frame 2
2	Frame 4	Frame 4	Frame 4
3	Frame 8	Frame 8	Frame 8
4	Binary Group 1 LSB	Binary Group 1 LSB	Binary Group 1 LSB
5	Binary Group 1	Binary Group 1	Binary Group 1
6	Binary Group 1	Binary Group 1	Binary Group 1
7	Binary Group 1 MSB	Binary Group 1 MSB	Binary Group 1 MSB
8	Frame 10	Frame 10	Frame 10
9	Frame 20	Frame 20	Frame 20
10	Drop Frame	- “0”	- “0”
11	Color Frame	Color Frame	- “0”
12	Binary Group 2 LSB	Binary Group 2 LSB	Binary Group 2 LSB
13	Binary Group 2	Binary Group 2	Binary Group 2
14	Binary Group 2	Binary Group 2	Binary Group 2
15	Binary Group 2 MSB	Binary Group 2 MSB	Binary Group 2 MSB
16	Unit Second 1	Unit Second 1	Unit Second 1
17	Unit Second 2	Unit Second 2	Unit Second 2
18	Unit Second 4	Unit Second 4	Unit Second 4
19	Unit Second 8	Unit Second 8	Unit Second 8
20	Binary Group 3 LSB	Binary Group 3 LSB	Binary Group 3 LSB
21	Binary Group 3	Binary Group 3	Binary Group 3
22	Binary Group 3	Binary Group 3	Binary Group 3
23	Binary Group 3 MSB	Binary Group 3 MSB	Binary Group 3 MSB
24	Unit Second 10	Unit Second 10	Unit Second 10
25	Unit Second 20	Unit Second 20	Unit Second 20
26	Unit Second 40	Unit Second 40	Unit Second 40
27	Polarity Correction	Binary Group Flag BGF0	Polarity Correction
28	Binary Group 4 LSB	Binary Group 4 LSB	Binary Group 4 LSB
29	Binary Group 4	Binary Group 4	Binary Group 4
30	Binary Group 4	Binary Group 4	Binary Group 4
31	Binary Group 4 MSB	Binary Group 4 MSB	Binary Group 4 MSB
32	Unit Minute 1	Unit Minute 1	Unit Minute 1
33	Unit Minute 2	Unit Minute 2	Unit Minute 2
34	Unit Minute 4	Unit Minute 4	Unit Minute 4
35	Unit Minute 8	Unit Minute 8	Unit Minute 8
36	Binary Group 5 LSB	Binary Group 5 LSB	Binary Group 5 LSB
37	Binary Group 5	Binary Group 5	Binary Group 5
38	Binary Group 5	Binary Group 5	Binary Group 5
39	Binary Group 5 MSB	Binary Group 5 MSB	Binary Group 5 MSB
40	Unit Minute 10	Unit Minute 10	Unit Minute 10

Table 1B. LTC Bit Values.

Bit Value	30 Frame Bit	25 Frame Bit	24 Frame Bit
41	Unit Minute 20	Unit Minute 20	Unit Minute 20
42	Unit Minute 40	Unit Minute 40	Unit Minute 40
43	Binary Group Flag BGF0	Binary Group Flag BGF2	Binary Group Flag BGF0
44	Binary Group 6 LSB	Binary Group 6 LSB	Binary Group 6 LSB
45	Binary Group 6	Binary Group 6	Binary Group 6
46	Binary Group 6	Binary Group 6	Binary Group 6
47	Binary Group 6 MSB	Binary Group 6 MSB	Binary Group 6 MSB
48	Hour 1	Hour 1	Hour 1
49	Hour 2	Hour 2	Hour 2
50	Hour 4	Hour 4	Hour 4
51	Hour 8	Hour 8	Hour 8
52	Binary Group 7 LSB	Binary Group 7 LSB	Binary Group 7 LSB
53	Binary Group 7	Binary Group 7	Binary Group 7
54	Binary Group 7	Binary Group 7	Binary Group 7
55	Binary Group 7 MSB	Binary Group 7 MSB	Binary Group 7 MSB
56	Hour 10	Hour 10	Hour 10
57	Hour 20	Hour 20	Hour 20
58	Binary Group Flag BGF1	Binary Group Flag BGF1	Binary Group Flag BGF1
59	Binary Group Flag BGF2	Polarity Correction	Binary Group Flag BGF2
60	Binary Group 8 LSB	Binary Group 8 LSB	Binary Group 8 LSB
61	Binary Group 8	Binary Group 8	Binary Group 8
62	Binary Group 8	Binary Group 8	Binary Group 8
63	Binary Group 8 MSB	Binary Group 8 MSB	Binary Group 8 MSB
64	Sync Word “0”	Sync Word “0”	Sync Word “0”
65	Sync Word “0”	Sync Word “0”	Sync Word “0”
66	Sync Word “1”	Sync Word “1”	Sync Word “1”
67	Sync Word “1”	Sync Word “1”	Sync Word “1”
68	Sync Word “1”	Sync Word “1”	Sync Word “1”
69	Sync Word “1”	Sync Word “1”	Sync Word “1”
70	Sync Word “1”	Sync Word “1”	Sync Word “1”
71	Sync Word “1”	Sync Word “1”	Sync Word “1”
72	Sync Word “1”	Sync Word “1”	Sync Word “1”
73	Sync Word “1”	Sync Word “1”	Sync Word “1”
74	Sync Word “1”	Sync Word “1”	Sync Word “1”
75	Sync Word “1”	Sync Word “1”	Sync Word “1”
76	Sync Word “1”	Sync Word “1”	Sync Word “1”
77	Sync Word “1”	Sync Word “1”	Sync Word “1”
78	Sync Word “0”	Sync Word “0”	Sync Word “0”
79	Sync Word “1”	Sync Word “1”	Sync Word “1”

Table 1B. LTC Bit Values.

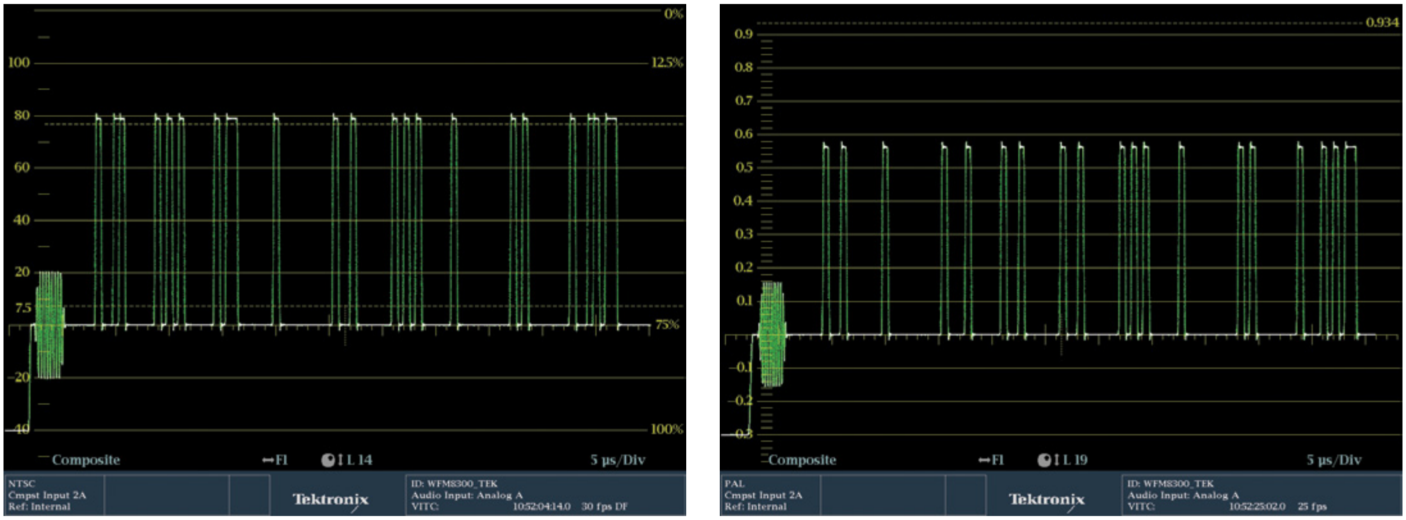

Figure 2B. Vertical Interval Timecode waveform display for NTSC and PAL.

Vertical Interval Time Code (VITC)

The Tektronix SPG8000 can configure the time code information to be added to the analog blanking interval of a 525 or 625 signal and is referred to a Vertical Interval Time Code (VITC). Additionally this analog signal may be digitized within the SD-SDI signal and it is typically referred to as D-VITC. The number of bits used to carry the time code information in VITC code words is slightly longer than that used for LTC with a total of 90 bits used. An additional two bits are used for synchronization code words ("1,0") followed by the eight data bits. This VITC signal produces eight 10 bit groups that contain the time code information plus an additional ninth group that provides a Cyclic Redundancy Code (CRC) word. Figure 2B shows a line select waveform view of one of the VITC signals. Using the waveform display you can measure the amplitude and timing of the VITC signal. Typically the amplitude of the signal should be 70-90IRE for 525 and 500-600mv for 625 with timing starting at 10µS for 525 and 11.2µS for 625 from negative sync. Typically the VITC lines are inserted between line 10-20 of a 525 system with preferred location of line 14 (277) or optionally on line 16 (279). For legacy equipment it is necessary to provide the VITC on two consecutive lines (14 & 16). In the case of 625 systems the VITC can be placed between line 6 (319) and line 22(335). The preferred lines are 19(332) and 21 (334). The waveform monitor allows the user to select the lines they wish the VITC information to be decoded from and the status bar will show the decoded time code value Figure 2B. The preferred lines for each standard are used as the default values for VITC decoding.

Within the SPG8000 analog black burst reference (NTSC/PAL) outputs a VITC signal can be added onto the preferred lines numbers (default) or the user can select specific line numbers. The timecode time of day information can be derived from the GPS signal (Option GPS) and a timing offset can be applied if necessary to account for different time zones. Alternatively the user can set up their own Program Time from which to start the timecode value. This can be used to insert a specific timecode value onto program material that needs to have a specific timecode start such as 01:00:00:00.

Bit Value	30 Frame Bit	25 Frame Bit	24 Frame Bit
0	"1" Sync Bit	"1" Sync Bit	"1" Sync Bit
1	"0" Sync Bit	"0" Sync Bit	"0" Sync Bit
2	Frame 1	Frame 1	Frame 1
3	Frame 2	Frame 2	Frame 2
4	Frame 4	Frame 4	Frame 4
5	Frame 8	Frame 8	Frame 8
6	Binary Group 1 LSB	Binary Group 1 LSB	Binary Group 1 LSB
7	Binary Group 1	Binary Group 1	Binary Group 1
8	Binary Group 1	Binary Group 1	Binary Group 1
9	Binary Group 1 MSB	Binary Group 1 MSB	Binary Group 1 MSB
10	"1" Sync Bit	"1" Sync Bit	"1" Sync Bit
11	"0" Sync Bit	"0" Sync Bit	"0" Sync Bit
12	Frame 10	Frame 10	Frame 10
13	Frame 20	Frame 20	Frame 20
14	Drop Frame	- "0"	- "0"
15	Color Frame	Color Frame	- "0"
16	Binary Group 2 LSB	Binary Group 2 LSB	Binary Group 2 LSB
17	Binary Group 2	Binary Group 2	Binary Group 2
18	Binary Group 2	Binary Group 2	Binary Group 2
19	Binary Group 2 MSB	Binary Group 2 MSB	Binary Group 2 MSB
20	"1" Sync Bit	"1" Sync Bit	"1" Sync Bit
21	"0" Sync Bit	"0" Sync Bit	"0" Sync Bit
22	Unit Second 1	Unit Second 1	Unit Second 1
23	Unit Second 2	Unit Second 2	Unit Second 2
24	Unit Second 4	Unit Second 4	Unit Second 4
25	Unit Second 8	Unit Second 8	Unit Second 8
26	Binary Group 3 LSB	Binary Group 3 LSB	Binary Group 3 LSB
27	Binary Group 3	Binary Group 3	Binary Group 3
28	Binary Group 3	Binary Group 3	Binary Group 3
29	Binary Group 3 MSB	Binary Group 3 MSB	Binary Group 3 MSB
30	"1" Sync Bit	"1" Sync Bit	"1" Sync Bit
31	"0" Sync Bit	"0" Sync Bit	"0" Sync Bit
32	Unit Second 10	Unit Second 10	Unit Second 10
33	Unit Second 20	Unit Second 20	Unit Second 20
34	Unit Second 40	Unit Second 40	Unit Second 40
35	Field Identification Flag	Binary Group Flag BGF0	Field Identification Flag
36	Binary Group 4 LSB	Binary Group 4 LSB	Binary Group 4 LSB
37	Binary Group 4	Binary Group 4	Binary Group 4
38	Binary Group 4	Binary Group 4	Binary Group 4
39	Binary Group 4 MSB	Binary Group 4 MSB	Binary Group 4 MSB
40	"1" Sync Bit	"1" Sync Bit	"1" Sync Bit
41	"0" Sync Bit	"0" Sync Bit	"0" Sync Bit
42	Unit Minute 1	Unit Minute 1	Unit Minute 1
43	Unit Minute 2	Unit Minute 2	Unit Minute 2
44	Unit Minute 4	Unit Minute 4	Unit Minute 4
45	Unit Minute 8	Unit Minute 8	Unit Minute 8
46	Binary Group 5 LSB	Binary Group 5 LSB	Binary Group 5 LSB

Table 2B. VITC Bit Values.

Bit Value	30 Frame Bit	25 Frame Bit	24 Frame Bit
47	Binary Group 5	Binary Group 5	Binary Group 5
48	Binary Group 5	Binary Group 5	Binary Group 5
49	Binary Group 5 MSB	Binary Group 5 MSB	Binary Group 5 MSB
50	"1" Sync Bit	"1" Sync Bit	"1" Sync Bit
51	"0" Sync Bit	"0" Sync Bit	"0" Sync Bit
52	Unit Minute 10	Unit Minute 10	Unit Minute 10
53	Unit Minute 20	Unit Minute 20	Unit Minute 20
54	Unit Minute 40	Unit Minute 40	Unit Minute 40
55	Binary Group Flag BGF0	Binary Group Flag BGF2	Binary Group Flag BGF0
56	Binary Group 6 LSB	Binary Group 6 LSB	Binary Group 6 LSB
57	Binary Group 6	Binary Group 6	Binary Group 6
58	Binary Group 6	Binary Group 6	Binary Group 6
59	Binary Group 6 MSB	Binary Group 6 MSB	Binary Group 6 MSB
60	"1" Sync Bit	"1" Sync Bit	"1" Sync Bit
61	"0" Sync Bit	"0" Sync Bit	"0" Sync Bit
62	Hour 1	Hour 1	Hour 1
63	Hour 2	Hour 2	Hour 2
64	Hour 4	Hour 4	Hour 4
65	Hour 8	Hour 8	Hour 8
66	Binary Group 7 LSB	Binary Group 7 LSB	Binary Group 7 LSB
67	Binary Group 7	Binary Group 7	Binary Group 7
68	Binary Group 7	Binary Group 7	Binary Group 7
69	Binary Group 7 MSB	Binary Group 7 MSB	Binary Group 7 MSB
70	"1" Sync Bit	"1" Sync Bit	"1" Sync Bit
71	"0" Sync Bit	"0" Sync Bit	"0" Sync Bit
72	Hour 10	Hour 10	Hour 10
73	Hour 20	Hour 20	Hour 20
74	Binary Group Flag BGF1	Binary Group Flag BGF1	Binary Group Flag BGF1
75	Binary Group Flag BGF2	Field Identification Flag	Binary Group Flag BGF2
76	Binary Group 8 LSB	Binary Group 8 LSB	Binary Group 8 LSB
77	Binary Group 8	Binary Group 8	Binary Group 8
78	Binary Group 8	Binary Group 8	Binary Group 8
79	Binary Group 8 MSB	Binary Group 8 MSB	Binary Group 8 MSB
80	"1" Sync Bit	"1" Sync Bit	"1" Sync Bit
81	"0" Sync Bit	"0" Sync Bit	"0" Sync Bit
82	CRC X^8	CRC X^8	CRC X^8
83	CRC X^7	CRC X^7	CRC X^7
84	CRC X^6	CRC X^6	CRC X^6
85	CRC X^5	CRC X^5	CRC X^5
86	CRC X^4	CRC X^4	CRC X^4
87	CRC X^3	CRC X^3	CRC X^3
88	CRC X^2	CRC X^2	CRC X^2
89	CRC X^1	CRC X^1	CRC X^1

Table 2B. VITC Bit Values.

			User Data Words (UDW)																
DID	**SDID**	**DC**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**B**
260h	260h	110h	B8	B8	B8	B8	B8	B8	B8	B8	B8	B8	B8	B8	B8	B8	B8	B8	B9
			Parity Bit																B8
			Time Code Data See Table 4B																B7
																			B6
																			B5
																			B4
			Bit 3 = DBB 1								Bit 3 + DBB 2								B3
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	B2
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	B1
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	B0

Table 3B. Time Code Ancillary packet format.

Ancillary Time Code

For SDI formats both the LTC and VITC time code information can be embedded as ancillary data packet as defined in SMPTE 12-2 (Transmission of Time Code in the Ancillary Data Space). The data conforms to SMPTE 291 (Ancillary Data Packet and Space Formatting) with ancillary data flag (ADF) 000h, 3FFh, ,3FFh followed by a Data Identification Data (DID) of 60h and a Secondary Data Identification Data (SDID) of 60h. The Data Count 10h indicates that there are 16 User Data Words (UDW) used for time code and the final packet of the ancillary data is a checksum value. The data structure of the ANC time code is shown in Table 3B and the time code data is shown in Table 4B.

ANC Time Code		
UDW	**BIT**	**Time Code Value**
1	4	Frame 1
	5	Frame 2
	6	Frame 4
	7	Frame 8
2	4	Binary Group 1 LSB
	5	Binary Group 1
	6	Binary Group 1
	7	Binary Group 1 MSB
3	4	Frame 10
	5	Frame 20
	6	Flag
	7	Flag
4	4	Binary Group 2 LSB
	5	Binary Group 2
	6	Binary Group 2
	7	Binary Group 2 MSB
5	4	Unit Second 1
	5	Unit Second 2
	6	Unit Second 4
	7	Unit Second 8
6	4	Binary Group 3 LSB
	5	Binary Group 3
	6	Binary Group 3
	7	Binary Group 3 MSB
7	4	Unit Second 10
	5	Unit Second 20
	6	Unit Second 40
	7	Flag
8	4	Binary Group 4 LSB
	5	Binary Group 4
	6	Binary Group 4
	7	Binary Group 4 MSB

ANC Time Code		
UDW	**BIT**	**Time Code Value**
9	4	Unit Minute 1
	5	Unit Minute 2
	6	Unit Minute 4
	7	Unit Minute 8
10	4	Binary Group 5 LSB
	5	Binary Group 5
	6	Binary Group 5
	7	Binary Group 5 MSB
11	4	Unit Minute 10
	5	Unit Minute 20
	6	Unit Minute 40
	7	Flag
12	4	Binary Group 6 LSB
	5	Binary Group 6
	6	Binary Group 6
	7	Binary Group 6 MSB
13	4	Hour 1
	5	Hour 2
	6	Hour 4
	7	Hour 8
14	4	Binary Group 7 LSB
	5	Binary Group 7
	6	Binary Group 7
	7	Binary Group 7 MSB
15	4	Hour 10
	5	Hour 20
	6	Flag
	7	Flag
16	4	Binary Group 8 LSB
	5	Binary Group 8
	6	Binary Group 8
	7	Binary Group 8 MSB

Table 4B. Time Code Data Mapped into ANC Data space.

Figure 1C. ANC Data Display with SMPTE 12-2 Time Code present.

The Tektronix WFM8300 waveform monitor can display the ancillary data of SMPTE 12-2 timecode information if present within the signal. Figure 1C shows the ANC Data Inspector display of the extracted timecode user data words and the decoded timecode information is show in the status bar of the display.

Drop Frame

The timecode value is represented in Hours, Minutes, Seconds and Frames (HH:MM:SS:FF) each of the values is a whole integer number and in even rate video system such as 60, 50, 30, 25, 24 there are a whole number of frames within each time interval. In the case of NTSC the frame rate is 30/1.001 (29.97) and this slight difference between the integer time code value and the non-integer NTSC frame rate will cause a divergence from “real time”. In one hour there are 108,000 frames and for NTSC at 29.97 there are about 107,892.11 frames. Therefore there is a difference of approximately 108 frames between 29.97 and 30 frames. The Drop Frame (DF) algorithm is designed to minimize this difference by skipping frames. The first two frames (00 & 01) shall be skipped from the start of each minute except at 00, 10, 20, 30, 40 and 50 minutes. Therefore using this algorithm a total of 110 frames shall be skipped using drop frame compensation and reducing the difference in time to approximately 3.6ms. In a 24-hour period the divergence in time will be minimized to 86ms instead of 86 seconds in no drop frame compensation was applied. To further minimize this difference jam sync can be applied that will skip an additional two frames. Other non-even frame such as 59.94, 29.97, 23.98 can also use Drop Frame to compensate for the timing difference between the integer values and the 1/1.001 frame rate. The waveform monitor and sync generator will show “DF” when the drop frame algorithm is applied to the timecode values.

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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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