Waveform Distortions And Measurement Methods

I. VIDEO AMPLITUDE AND TIME MEASUREMENTS

This section deals with two fundamental properties of the signal, amplitude and time. In these two dimensions, problems are more frequently caused by operator error than by malfunctioning equipment. Correction of amplitude and pulse width problems often simply involves proper adjustment of the equipment the signal passes through.

Two kinds of amplitude measurements are important in television systems. Absolute levels, such as peak-to-peak amplitude, need to be properly adjusted. The relationships between the parts of the signal are also important. The ratio of sync to the rest of the signal, for example, must be accurately maintained.

Composite NTSC video signals are nominally 1 volt peak-to-peak. Amplitudes are also sometimes described in terms of the IRE scale, which divides the video signal into 140 equal parts. Strictly speaking the IRE scale is a relative one and can be used to compare parts of the signal regardless of overall amplitude. In practice, however, the IRE scale is sometimes treated as an absolute scale with a direct relationship to volts. In the 1780R, 1 IRE is defined as an absolute unit equal to 1/140 of 1 volt. With the VM700T, the user can define IRE to be relative to zero carrier or the white bar or to be an absolute unit (100 IRE = 714 mV).

When setting video amplitudes, it is not sufficient to simply adjust the output level of the final piece of equipment in the signal path. Every piece of equipment should be adjusted to appropriately transfer the signal from input to output. Television equipment is generally not designed to handle signals that deviate much from the nominal amplitude. Signals that are too large may be clipped or distorted and signals that are too small will suffer from degraded signal-to-noise performance.

In most television facilities, video amplitudes are monitored and adjusted on a daily basis. Signal timing parameters are usually checked less frequently, however, it is still important to understand the measurement methods. A periodic verification that all timing parameters are within limits is recommended.

This booklet does not address system timing issues which deal with relative time relationships between the many signals in a television facility. Although system timing is critical to production quality, it is outside the scope of this publication. Only those timing measurements that relate to a single signal are addressed.

Amplitude Measurements

DEFINITION

Video amplitudes are most frequently measured in order to verify that they conform to nominal values. The gain must be adjusted if signals are too large or too small. Similar methods of evaluating the waveform are used for both measurement and adjustment of signal levels.

Measurements of the peak-to-peak amplitude of video signals are sometimes known as insertion gain measurements. For NTSC systems, the nominal peak-to-peak amplitude is 1 volt (140 IRE).

PICTURE EFFECTS

Insertion gain errors cause the picture to appear too light or too dark. Because of the effects of ambient light, apparent color saturation is also affected.

TEST SIGNALS

Insertion gain is most easily measured with a test signal that contains a 100 IRE white level. Color bars and pulse and bar signals are most frequently used (see Figures 1 and 2).

MEASUREMENT METHODS

Waveform Monitor Graticule. Signal amplitude can be measured with a waveform monitor by comparing the waveform to the vertical scale on the graticule. With the waveform monitor vertical gain in the calibrated setting (1 volt full scale), the signal should be 1 volt (140 IRE) from sync tip to peak white (see Figure 3). The graticule in the VM700T WAVEFORM mode can be used in a similar manner.

Added Calibrator Method. Some waveform monitors have a feature that allows the internal calibrator signal to be used as a reference for amplitude measurements. This feature is known as WFM + CAL in the 1780R. In the 1480 it is accessed by depressing both the CAL and OPER buttons.

The WFM + CAL display consists of two video traces vertically offset by the calibrator amplitude. This display is obtained by adding the incoming signal to a calibrated square wave of known amplitude. Signal amplitude is equal to the calibrator amplitude when the bottom of the upper trace and the top of the lower trace coincide.

The WFM + CAL mode is most commonly used to set insertion gain which requires a 1-volt calibrator signal. If using a 1780R, select a calibrator amplitude of 1000 mV (140 IRE). In the 1480, the DC RESTORER setting determines which of two calibrator amplitudes is currently selected. The calibrator amplitude is 1 volt when SYNC TIP is selected and 714 millivolts when BACK PORCH is selected.

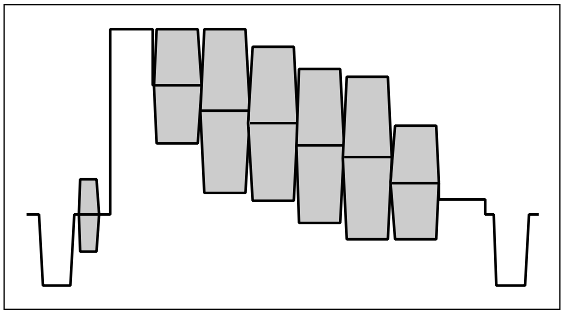


Figure 1. A 75% amplitude color bar signal with a 100% white reference bar.

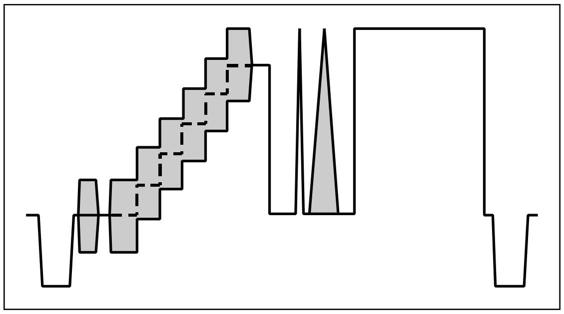


Figure 2. A composite signal (also known as FCC Composite) that includes a 100 IRE white bar.

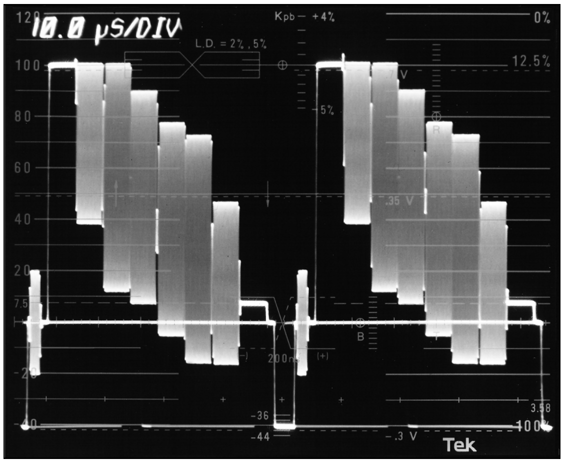


Figure 3. A 1-volt signal properly positioned with respect to the 1780R graticule.

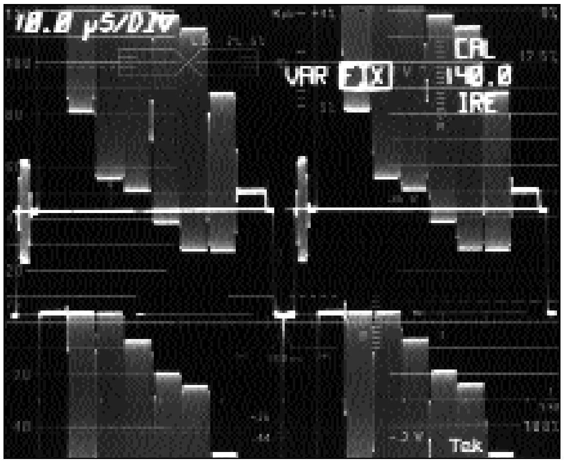


Figure 4. The WFM + CAL mode in the 1780R indicating that insertion gain is properly adjusted.

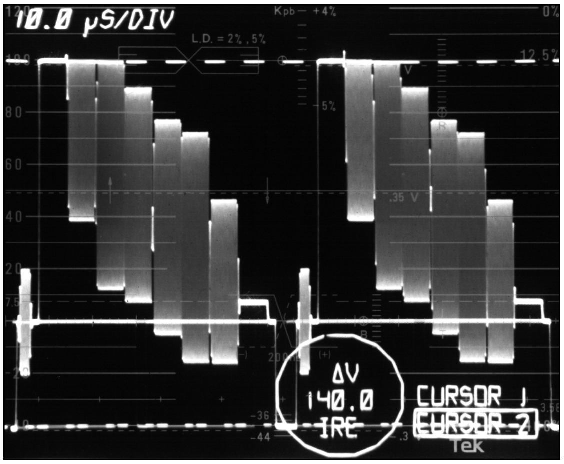


Figure 5. 1780R voltage cursors positioned to measure peak-to-peak amplitude.

Insertion gain is set by externally adjusting the signal amplitude until sync tip of the upper trace and peak white of the lower trace coincide. Figure 4 shows a properly adjusted signal. Since the waveform monitor vertical gain need not be calibrated in this mode, the gain may be increased for greater resolution.

The 1780R has a variable calibrator so the WFM + CAL mode can be used to measure signal amplitudes. Measurements are made by adjusting the calibrator amplitude (with the large knob on the 1780R front panel) until the traces meet. At this point the calibrator amplitude equals the signal amplitude and can be read from the screen.

Voltage Cursors (1780R). Some waveform monitors, such as the 1780R, are equipped with on-screen voltage cursors for making accurate amplitude measurements. Peak-to-peak amplitude can be measured by positioning one cursor on sync tip and the other on peak white (see Figure 5). The 1780R vertical gain control affects the cursors and the waveform in the same manner so vertical gain can be increased to allow for more accurate positioning of the cursors.

When setting insertion gain, it may be convenient to first set the cursor separation for 1000 mV (140 IRE). The video signal amplitude should then be adjusted to match the cursor amplitude.

Cursors (VM700T). Manual amplitude measurements can be made with the VM700T by selecting CURSORS in the WAVEFORM mode. The horizontal baseline in the middle of the screen is used as a reference. To measure insertion gain, first position sync tip on the baseline. Touch the RESET DIFFS selection on the screen to reset the voltage difference to zero. Now move the waveform down until the white bar is on the baseline and read the voltage difference from the screen.

VM700T Automatic Measurement. The VM700T provides amplitude measurements in the AUTO mode.

NOTES

1. Sync to Picture Ratio. When the signal amplitude is wrong, it is important to verify that the problem is really a simple gain error rather than a distortion. This can be accomplished by verifying that the ratio of sync to the picture signal (the part of the signal above blanking) is 40:100. If the ratio is correct, proceed with the gain adjustment. If the ratio is incorrect, there is a problem and further investigation is needed. The signal may be suffering from distortion or equipment that reinserts sync and burst could be malfunctioning.

2. Sync and Burst Measurements. Sync and burst should each be 40/140 of the composite video signal (286 millivolts for a 1-volt signal). Most of the methods discussed in this section can be used to measure sync and burst amplitudes. When using the 1780R voltage cursors, the TRACK mode is a convenient tool for comparing sync and burst amplitudes. In this mode, the separation between the two cursors remains fixed and they can be moved together with respect to the waveform.

3. Measurement Accuracy. In general, the added calibrator and voltage cursor methods are more accurate than the graticule technique. However, some cursor implementations have far more resolution than accuracy creating an impression of measurements more precise than they really are. Familiarity with the specifications of the waveform monitor and an understanding of the accuracy and resolution available in the various monitoring modes will help make an appropriate choice.

4. Using the Luminance Filter. When setting insertion gain with a live signal rather than a test signal, it may be useful to enable the waveform monitor luminance filter (also called lowpass or IRE). This filter removes the chrominance information so that peak white luminance levels can be used for setting gain.

5. White Levels. When setting insertion gain, make sure a 100 IRE bar is used as the reference peak white level. As noted in Appendix A, some color bar signals have a 77 IRE white bar rather than 100 IRE.

6. Setup. Most NTSC signals use "black level setup" which is often simply referred to as "setup". In a signal with setup, video black is 7.5 IRE above the blanking level. The peak-to-peak amplitude and sync amplitude do not change. The peak white level therefore remains at 100 IRE so the 7.5 IRE pedestal reduces the amplitude range available for picture information. Both luminance and chrominance levels of the entire signal are scaled down in order to fit into the 92.5 IRE range which remains above the pedestal.

Virtually all NTSC program material has setup but many test signals do not. When measuring amplitudes, it is necessary to know whether or not the signal has setup and to understand the differences associated with it. When working with signals that have setup, do not to confuse the black level (7.5 IRE) with the blanking level.

Time Measurements

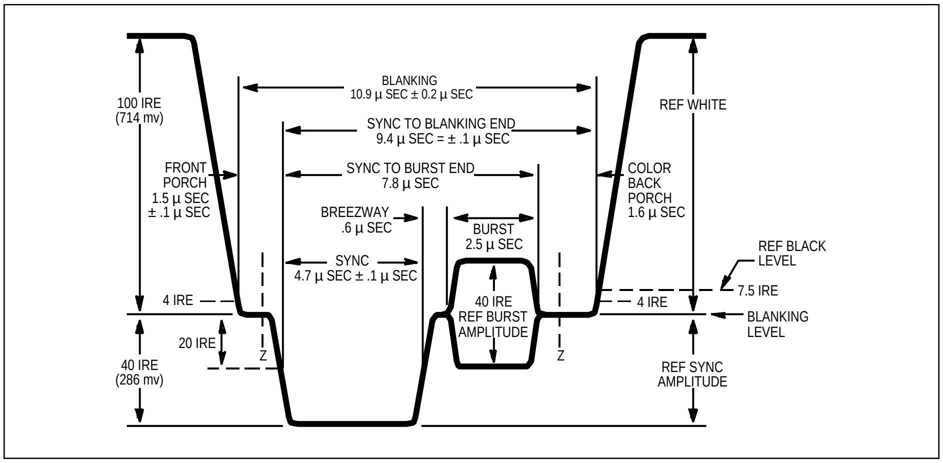


Figure 6. RS-170A pulse width requirements.

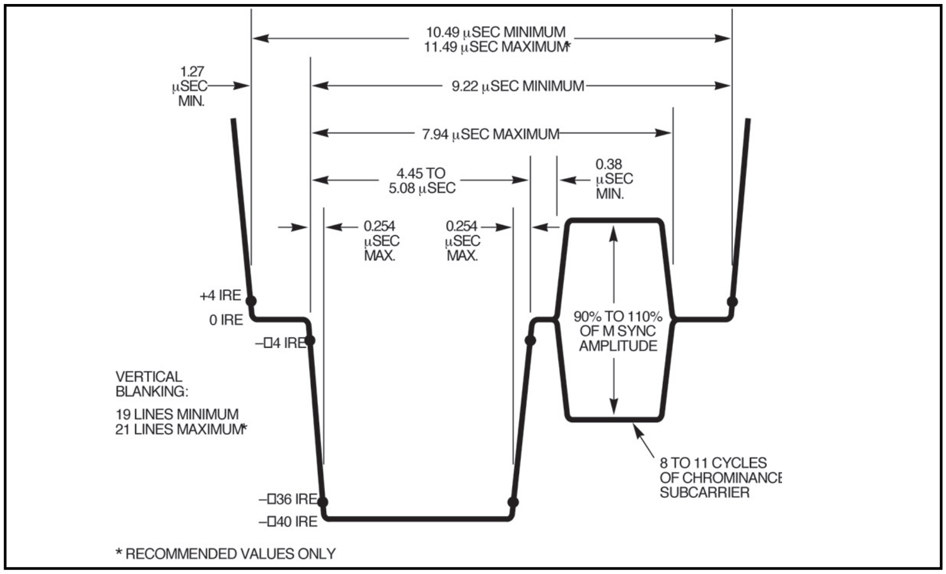


Figure 7. FCC pulse width requirements.

DEFINITION

Horizontal and vertical synchronization pulse widths are measured in order to verify they fall within specified limits. Rise times, fall times, and the position and number of cycles in burst are also specified.

Both RS-170A and the FCC provide recommended limits for these parameters. However, the two standards have different definitions for the various time intervals. For example, the FCC specifies sync width between the 90% (-4 IRE) points of the two transitions while RS-170A specifies sync width between the 50% (-20 IRE) points. The definition for each parameter should be clearly understood before measuring it.

Even when differences in definition are taken into account, RS-170A and the FCC give different recommended limits for the various sync pulse parameters. The RS-170A requirements are generally more stringent. Pulse width requirements for the two standards are given in Figures 6 and 7.

PICTURE EFFECTS

Small errors in pulse widths will not affect picture quality. However, if the errors become so large that the pulses cannot be properly processed (by equipment), picture breakup may occur.

TEST SIGNALS

Timing measurements may be made on any composite signal containing horizontal, vertical and subcarrier (burst) synchronization information.

MEASUREMENT METHODS

Waveform Monitor Graticule. Time intervals can be measured by comparing the waveform to the marks along the horizontal baseline of a waveform monitor graticule. In order to get adequate resolution, it is usually necessary to magnify the waveform display horizontally. Select the setting that provides as much magnification as possible while still keeping the interval of interest entirely on-screen. The scale factor, typically microseconds per major division, changes with horizontal magnification. The 1780R displays the microseconds per division setting on the screen while for the 1480 it is obtained from the switch setting.

To make measurements between the 90% (-4 IRE) points, it is generally most convenient to use the waveform monitor variable gain control to normalize the sync height to 100 IRE. The blanking level may then be positioned at +10 IRE and a reading obtained from the marks on the baseline (see Figure 8).

For measurements specified at the 50% amplitude points, normalizing to 100 IRE is probably not necessary. In this case, place the top of the pulse at +20 IRE and the bottom at -20 IRE. The pulse width can then be read from the horizontal scale (see Figure 9).

Time Cursors (1780R). Some waveform monitors are equipped with cursors to facilitate the measurement of time intervals. The time cursors in the 1780R appear as bright dots on the waveform. To find the 90% points of the sync transitions, it is best to normalize the sync pulse to 100 IRE and use the vertical graticule scale to locate the proper level. Alternatively, the voltage cursors in the RELATIVE mode can be used to locate the 90% points.

Similar procedures can be used to find the 50% points of the transitions (see Figure 10), but in this case it may not be necessary. Since it is easier to visually locate the halfway point of a transition, 50% point measurements can often be made without using an amplitude reference.

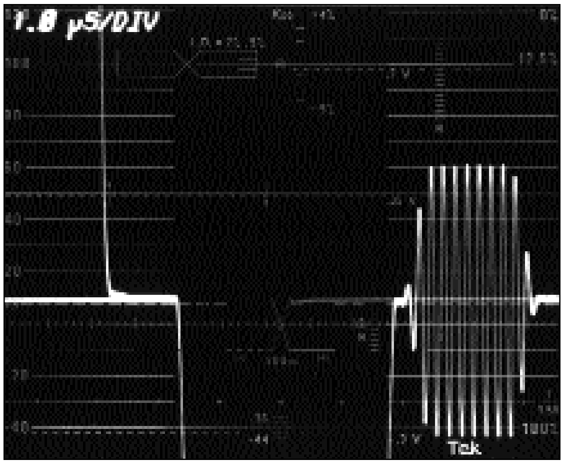


Figure 8. Horizontal sync width measurement at the 90% amplitude (4 IRE) points.

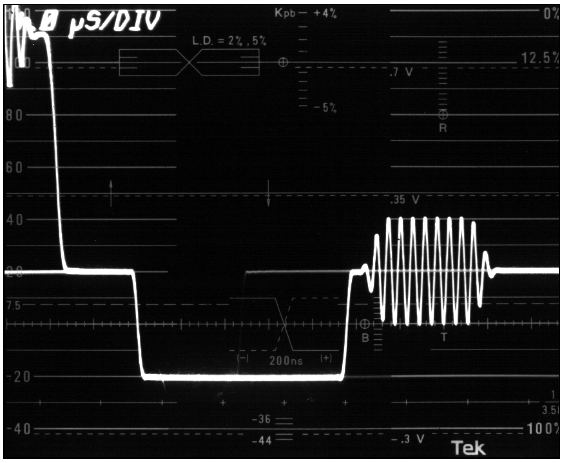


Figure 9. Horizontal sync width measurement at the 50% amplitude points.

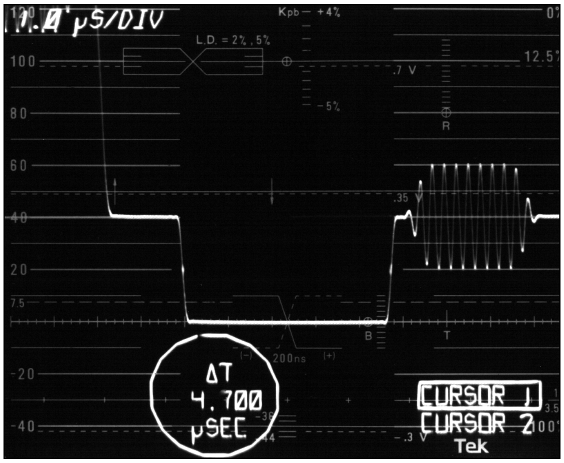
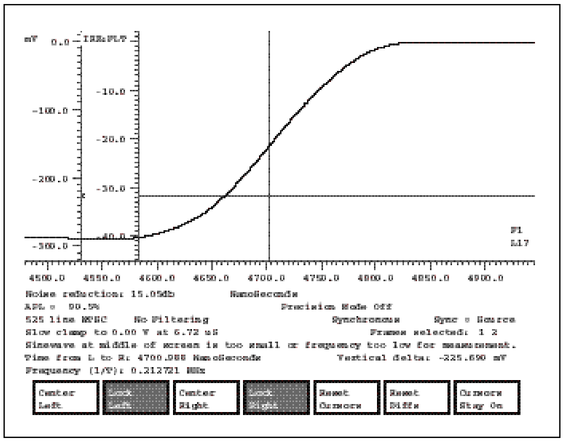


Figure 10. The 1780R time cursors positioned to measure horizontal sync width at the 50% amplitude points.



```
Noise reduction: 15.05db          NanoSeconds
APL = 90.5%                                 Precision Mode Off
525 line NTSC    No Filtering                    Synchronous     Sync = Source
Slow clamp to 0.00 V at 6.72 uS                        Frames selected: 1 2
Sinewave at middle of screen is too small or frequency too low for measurement.
Time from L to R: 4700.988 NanoSeconds             Vertical delta: -225.690 mV
Frequency (1/T): 0.212721 MHz
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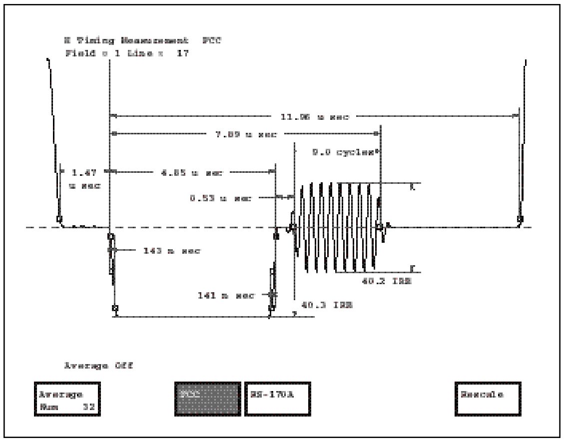
Figure 11. Horizontal sync width measurement at the 50% amplitude points using the VM700T cursors.



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H Timing Measurement  FCC
Field = 1 Line =  17
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Figure 12. The H Timing Measurement display in the VM700T MEASURE mode.

Cursors (VM700T). The cursors in the VM700T WAVEFORM mode can be used to make pulse width measurements. After establishing the 100% and 0% points of sync, the cursors can be moved to either the 50% or 90% points to obtain a time measurement (see Figure 11). Consult the manual for detailed instructions on how to use the cursors.

VM700T Automatic Measurement. The H TIMING selection in the VM700T MEASURE mode displays all horizontal blanking interval timing measurements (see Figure 12). Note that either FCC or RS-170A measurements can be selected. Timing measurements are also available in the AUTO mode.

NOTES

7. Rise and Fall Time Measurements. Both the FCC requirements and RS-170A include specifications for the rise time and fall time of the sync pulse. These measurements are indicators of how fast the transitions occur. They are typically made between the 10% and 90% points of the transition. The methods used for measuring pulse widths can generally be applied to rise and fall times.

8. Burst Position and Number of Cycles. The position of burst with respect to sync and the number of subcarrier cycles in burst are specified and it may be desirable to occasionally verify these parameters. RS-170A calls for 9 cycles in burst while the FCC allows 8 to 11 cycles.

RS-170A specifies burst position with respect to sync in terms of subcarrier cycles. There are nominally 19 subcarrier cycles between the 50% point of the leading edge of sync and the start of burst (defined as "the zero crossing that precedes the first half-cycle of subcarrier that is 50% or greater of the burst amplitude"). The 1780R FSC TIME MARKS mode may be used to check this parameter. Refer to the SCH Phase section of this book for the measurement methodology.

9. Checking the Vertical Interval. The number of pulses in the vertical interval, as well as the widths of the equalizing pulses and vertical serrations, are also specified. Recommended limits can be found in Appendices C and D and most of the pulse width measurement methods discussed in this section can be applied.

DEFINITION

SCH (SubCarrier to Horizontal) Phase refers to the timing relationship between the 50% point of the leading edge of sync and the zero crossings of the reference subcarrier. Errors are expressed in degrees of subcarrier phase.

RS-170A specifies that SCH phase must be within ±40 degrees. Practically speaking, much tighter tolerances are generally maintained. Modern facilities often try to ensure that SCH phase errors do not exceed a few degrees.

PICTURE EFFECTS

SCH phase becomes important only when television signals from two or more sources are combined or sequentially switched. In order to prevent color shifts or horizontal jumps from occurring when a switch is made, the sync edges of the two signals must be accurately timed and the phase of color burst matched. Since both sync and subcarrier are continuous signals with a fixed relationship to one another, it is possible to simultaneously achieve both timing conditions only if the two signals have the same SCH phase relationship.

Because of the complex relationship between the sync and subcarrier frequencies, the exact SCH phase relationship for a given line repeats itself only once every four fields. In order to understand why this four-field sequence exists, first consider the fact that there are an odd number of subcarrier half-cycles in a line. This implies that SCH phase must be 180 degrees apart on adjacent lines. Since there are also an odd number of lines in a frame, the exact phase relationship between sync and burst for a given line repeats itself once every four fields (two frames).

In order to achieve the sync and burst timing conditions required for a clean switch between two signals, the four-field sequence of the signals must be properly lined up (i.e., Field 1 of Signal A and Field 1 of Signal B must occur at the same time). When this condition is achieved, the two signals are said to be "color framed." It is important to remember that color framing is inextricably tied to other system timing parameters and is by no means an independent variable. Only if two signals have the same SCH phase relationship and are properly color framed can the sync timing and burst phase matching requirements be achieved.

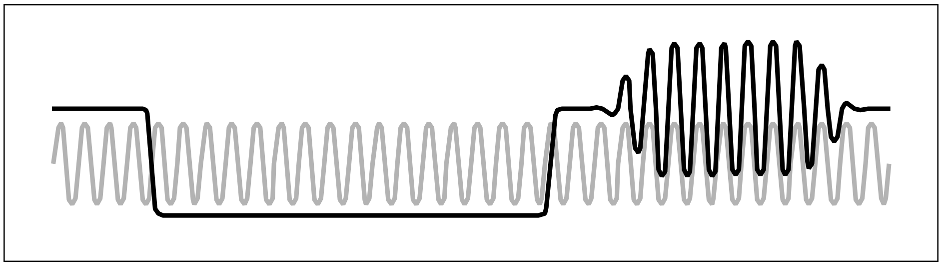

Figure 13. The SCH phase error of this signal is 0 degrees. Note that the 50% point of the leading edge of sync and a zero crossing of the extrapolated subcarrier are time coincident.

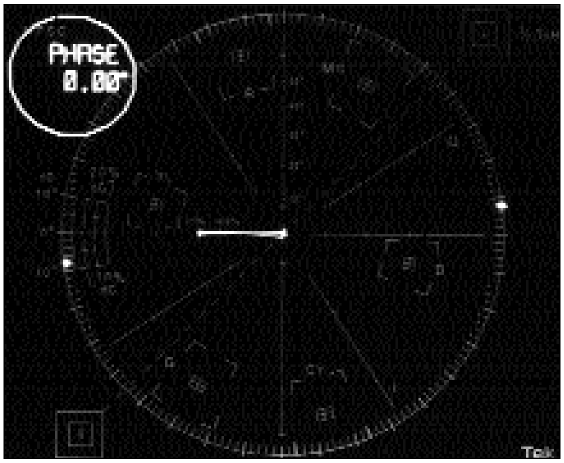

Figure 14. The 1780R polar SCH phase display showing an 8 degree error. Internal reference is used for synchronization.

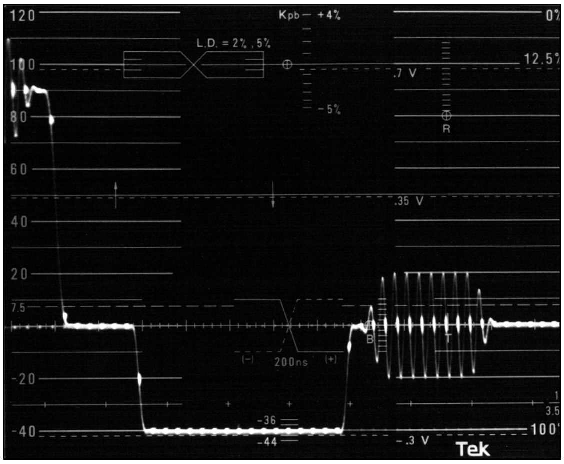

Figure 15. The 1780R FSC TIME MARKS display indicates that this signal has no SCH phase error.

Since signals must have the same SCH phase relationship in order to be cleanly combined, standardization on one value of SCH phase will clearly facilitate transfer of program material. This is the reason for trying to maintain 0 degrees of SCH phase error. Another reason for keeping SCH phase within reasonable limits is that various pieces of equipment need to be able to distinguish between the color frames in order to process the signal properly. This cannot be done accurately if the SCH phase error is allowed to approach 90 degrees.

TEST SIGNALS

SCH phase measurements can be made on any signal with both sync and color burst present.

MEASUREMENT METHODS

Polar Display. Some instruments, such as the 1780R, are equipped with a polar SCH display that consists of the burst vector and a dot representing horizontal sync. The phase relationship between the two can be determined by reading directly from the vector graticule or by using the precision phase shifter (see Figure 14).

The instrument must be internally referenced to measure the SCH phase of a single signal. Sync and burst of the selected signal are compared to each other in this mode. In the 1780R, two sync dots (180 degrees apart) are displayed along with the burst vector when internal reference is selected.

When external reference is selected, both burst and sync of the selected signal are displayed relative to burst of the external reference signal. A single sync dot appears with the burst vector in this mode. This display is used to determine whether or not two signals are color framed. Assuming that both the reference signal and the displayed signal have no SCH phase error, the sync dot will be in phase with the burst vector if the signals are color framed and 180 degrees away if they are not.

FSC Time Marks (1780R). The 1780R has a mode called FSC TIME MARKS which is accessible through the MEASURE menu. In this mode, bright dots appear on the waveform at intervals of precisely one subcarrier cycle. The dots can be advanced or delayed with respect to the waveform with the precision phase shifter.

To make a measurement, use the phase shifter to set one of the dots on the 50% point of the leading edge of sync. If there is no SCH phase error, the dots on the burst should fall on the zero crossings at the blanking level (see Figure 15). If there is an error and a numeric measurement result is desired, press REF SET to zero the phase readout and use the phase shifter to position the burst dots on the zero crossings. At this point the phase readout indicates the amount of SCH phase error.

This method is not as precise as the polar display but has the advantage of allowing verification that there are 19 subcarrier cycles between sync and burst. Since this mode is independent of instrument calibration, it is also useful for checking calibration of the polar display.

VM700T Automatic Measurement. Select SCH PHASE in the VM700T MEASURE menu to obtain a display of SCH phase. Figure 16 shows the VM700T polar SCH phase display which is similar to the SCH phase display of the 1780R. The VM700T full field SCH phase display (see Figure 17) plots the SCH phase of each line in the field and provides an average result. SCH phase measurements are also available in the AUTO mode.

NOTES

10. For More Information. For a comprehensive discussion of SCH phase and color framing issues, see Tektronix Application Note 20W-5613-2, “Measuring and Monitoring SCH Phase with the 1750A Waveform/ Vector Monitor”.

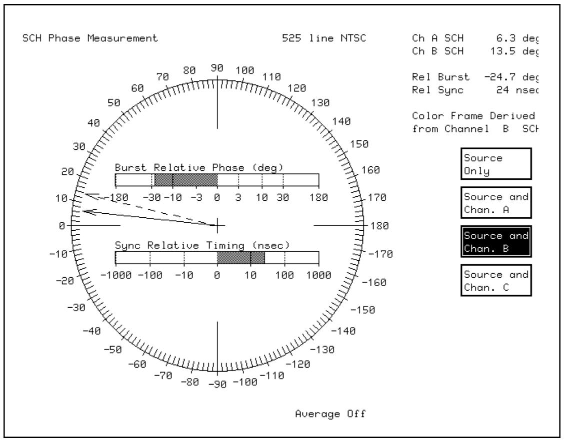
SCH Phase Measurement
525 line NTSC
Ch A SCH 6.3 deg
Ch B SCH 13.5 deg
Rel Burst -24.7 deg
Rel Sync 24 nsec
Color Frame Derived from Channel B SCH
Average Off

Figure 16. The VM700T polar SCH Phase Measurement display.

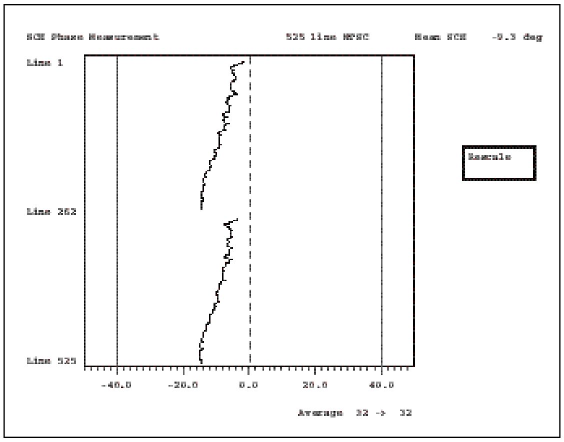
SCH Phase Measurement
525 line NTSC
Mean SCH -9.3 deg
Average 32 -> 32

Figure 17. The VM700T full field SCH Phase Measurement display.