The Modern Systems Approach to SCH and Color Framing in NTSC

Introduction

SCH and Color Framing have caused more problems, discussions, and confusion than almost any other technical aspect of NTSC television production. This paper presents a modern, standard and proven approach for dealing with these issues. The principles are discussed and the terminology is defined so the problems can be understood. Aspects of equipment performance and system design that are necessary to solve or avoid SCH problems are explained.

RS-170A

In the NTSC television system, the frequency of the color subcarrier (S/C) is 227½ times the horizontal frequency. The one half in that number means that the subcarrier phase relative to H sync reverses (changes 180°) every line. Since there are an odd number of lines (525) in a frame, the phase of subcarrier reverses at the start of every frame. The NTSC specification does not define the phase relationship between subcarrier and H (SCH). RS-170A is the de facto standard which defines the relationship. The EIA (Electronic Industry Association) has officially approved the RS-170A Standard.

The following definitions are based on accepted practice and intent of RS-170A.

Whenever Sync or H are subsequently mentioned in a timing context, we mean the 50% point of the leading edge of sync. Likewise, references to Subcarrier means the Subcarrier of which Burst is a representative sample (i.e. a subcarrier which is in phase with burst).

Correct ("zero") SCH exists if the sync on every line is coincident with a zero crossing of subcarrier (See Figure 1.)

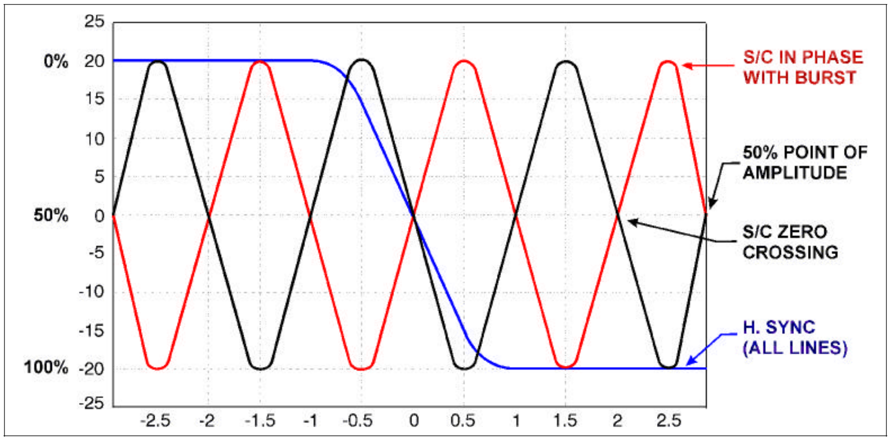


Fig 1. Sync coincident with zero crossing of subcarrier.

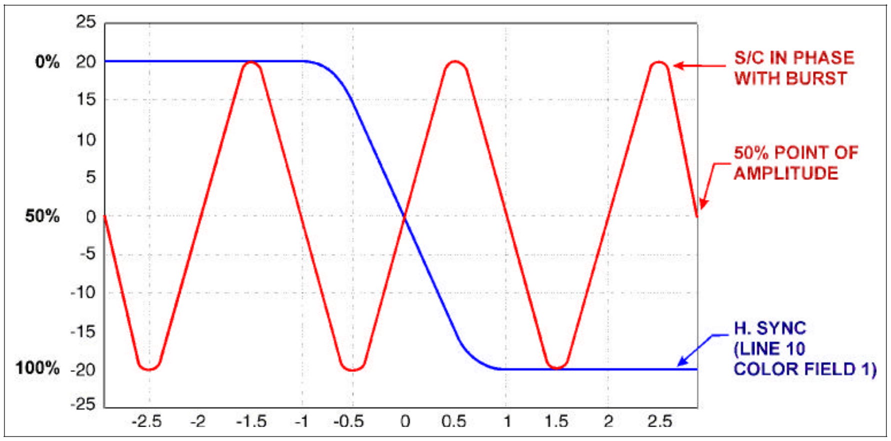


Fig. 2. Sync on Line 10 of Color Field 1 of a Color Frame.

A Color Frame consists of 4 fields. Color Field 1 is that monochrome Field 1 on which sync on line 10 is closest to being coincident with the positive-going zero crossing of subcarrier. (See Figure 2.)

Several important observations should be made about these definitions:

1 - Since SCH is defined with reference to either the positive-or-negative-going zero crossing of subcarrier, the maximum possible SCH error is 90°

2 - Color Field 1 cannot be identified unless the SCH is approximately correct. If the SCH error is 90° the positive zero crossing of subcarrier is equidistant from sync on line 10 of all frames.

3 - Color Framing cannot be "correct" or "incorrect" without reference to another video signal. When signals are said to be correctly Color Framed, it means that they have both approximately correct SCH, and that Color Fields 1 of both signals are coincident in time.

4 - Two signals which are burst timed, horizontally timed, and vertically timed are correctly Color Framed.

5 - When someone says that the SCH of a signal is “180 out” they are comparing one signal to another (whether they realize it or not). They really mean one of the following:

a) The two signals are horizontally and vertically timed, but their burst phases differ by 180°.

b) The two signals are burst and vertically timed, but their H phases differ by 140nS (or 140nS plus a multiple of 280nS).

c) The two signals are burst and horizontally timed, but their V phases differ by an odd number of lines.

The multiplicity of possibilities shows the danger of confusion inherent in using this terminology.

1

6 - In some versions of the RS-170A, zero SCH is defined by stating that the zero crossings of the first cycle of burst greater than 50% of burst amplitude shall be 19 subcarrier cycles after sync. This does indeed define zero SCH in agreement with the definition previously given. However, this definition simultaneously defines burst position. If the first cycle of burst greater than 50% of burst amplitude fell 18½, 19, 19½, or any multiple of half cycles of subcarrier after the 50% point of the leading edge of sync, the SCH would still be correct. Only the burst position has changed.

Within reasonable limits, burst position has negligible effect on the system performance, and the effects of incorrect burst position are unrelated to those of incorrect SCH. Furthermore, it can be very difficult to identify the first cycle greater than 50% in amplitude, especially in the presence of distortion or noise. Using this definition is just asking for trouble.

SCH and Color Framing in a System

VTR editing and composite digital signal processing require correct SCH. Editing requires correct Color Framing. Before these techniques came into widespread use, SCH and Color Framing were of little importance. Indeed they were not even defined. Let’s discuss these issues with regard to editing since the problems are easier to describe. Also, editing raises the related issue of SMPTE timecode. The importance of SCH and Color Framing can be understood by examining the sequence of events when a typical VTR locks to an external reference. First, the VTR locks the control track frame pulse to a frame pulse derived from the reference. Second, tape H sync is aligned with reference H sync. Third, the TBC aligns the tape burst to the external reference burst. Since, the TBC cannot separate chrominance from luminance, the alignment of tape burst to reference burst may shift tape H sync by up to 140nS (180°). If the tape or reference SCH is random, this H shift can be any amount from 0 to 140nS. If the SCH is the same on both the tape and the reference, the H shift will either be 0 or 140nS. Which of these occurs depends on Color Framing between tape and reference.

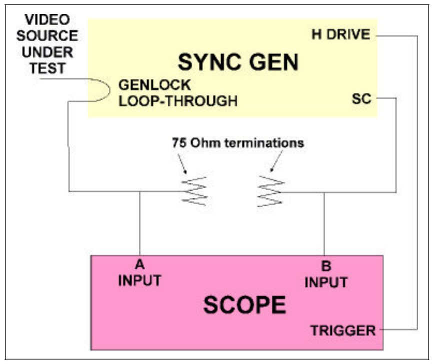


Fig. 3. SCH measurement set-up.

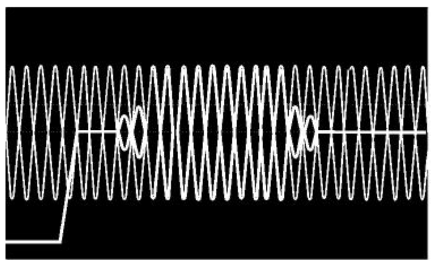


Photo # 1

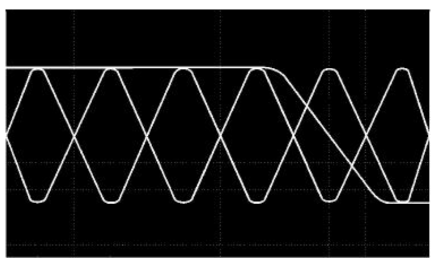


Photo # 2

Several methods exist for eliminating the 140nS H shift, provided that the tape and reference have the same SCH. Therefore, it is necessary to ensure that all signals have the same, standard SCH. If all signals in a system have zero SCH, any piece of equipment can identify Color Frame 1 and take the appropriate action to avoid error. If Color Frame problems exist in a zero SCH system, either a system H timing error (increments of 140nS) exists, or some equipment is defective or obsolete (ie: it is not appropriately dealing with Color Framing). Timecode editing systems can be an exception to the previous statement. To avoid problems, timecode must have a consistent relationship to video. Normally, the even timecode frame numbers should be aligned with Color Field 1. If this relationship exists, requesting an edit that violates a strict odd/even sequence of timecode frame numbers will create a Color Framing violation. Most editing systems will prevent such errors.

The foolproof way to ensure a correct relationship between timecode and Color Frame is to always lock a Color Framing timecode generator to the video being recorded. Failing this, the relationship should be certified at the time of recording.

SCH Measurement

If a system is zero SCH and properly timed, Color Frame problems are an indication of defective equipment. In order to ensure a zero SCH system, it is first necessary to measure SCH. SCH can be measured on any dual channel oscilloscope. One channel is fed video, and the other is fed phaseable source of subcarrier which is frequency locked to the video. A sync generator locked to the video is usually the most convenient source of this subcarrier (see Figure 3).

The phase of the subcarrier is adjusted to exactly match the phase of burst (see photo #1). Then the time difference between the 50% point of the leading edge of sync and the nearest zero crossing of the subcarrier is measured (see photo #2).

This time, measured in nS, can be converted to degrees of subcarrier by multiplying by 1.29. This procedure is simple, but obviously is not suitable as a normal operating procedure. Many companies, including Leitch, manufacture equipment designed to measure SCH. In addition, SCH measurement capability is included in many modern vector monitors and VTR's. Several issues should be borne in mind when choosing and using SCH measurement devices. First, a clear understanding of the difference between measurement resolution and accuracy is required. For example, if a piece of equipment has a resolution of 1° and a specified accuracy of ±5°, then two identical devices may disagree by as much as 10°. This is insidious since the resolution is immediately obvious to the person making the measurement; however, the accuracy can only be found by looking in the equipment manual (if it can be found). Conscientious technicians may try to maintain SCH to an accuracy not reliably measurable. This wastes time and causes frustration. The Leitch SCH measurement devices (SCH-730N, SCH-731N) have a resolution of 6°, and an accuracy of ±5°. We know of no equipment with a better specified accuracy. How accurate must SCH be? The primary purpose of maintaining correct SCH is to allow equipment to correctly identify Color Field 1. Virtually all modern equipment can identify Color Field 1 if the SCH error is less than ±40°, even in the presence of signal distortion and noise. In fact, modern Leitch SPGs and Proc Amps work reliably even if the SCH error of the incoming signal is as great as ±75°. If a system experiences Color Frame problems and the SCH errors are less than ±40°, most likely some equipment is defective. trying to maintain an excessively tight SCH tolerance is unproductive.

Zero SCH Systems

With proper measurement and adjustment, a zero SCH system can be achieved. However, if it can go wrong, it will. Freedom from SCH problems will only be achieved when the SCH of every signal is zero by design rather than by adjustment. The application of digital technology to TV equipment is bringing us closer to this better world.

The ideal solution would be to simply replace all non-zero SCH equipment. However, not all equipment is currently available in a zero SCH version, and economy dictates that existing equipment be used. Nonetheless, it is essential to start the journey to zero SCH on the right foot: with zero SCH sync generators and test signal generators. These devices act as the reference for the timing and certification of video signals. If SCH and Color Framing are not maintained reliably by these devices, there is little hope of establishing a zero SCH plant.

The following criteria are important in selecting these devices:

1 - The output SCH should be zero at all times. No adjustment should be possible, as this usually means that the SCH is not zero by design.

2 - When genlocked, the output signal must always be the same Color Frame as the genlock signal. Again, no adjustment should be possible.

3 - The output Color Frame must be consistent (ie. must not shift) regardless of the SCH of the genlock signal, even in the presence of noise and signal distortion.

4 - The error allowed in the genlock signal SCH while still guaranteeing Color Framing should be as large as possible (at least ±60°).

Needless to say, modern Leitch equipment meets all these requirements. In the past it was difficult to design equipment that could meet these criteria. Hence, there exist several proprietary systems for timing a video facility. Such systems rely on the distribution of a non-standard genlock signal which incorporates a Color Frame flag. While such systems can maintain SCH and Color Framing, the non-standard and single source nature of such systems makes them undesirable in a modern plant. This is especially true since advances in technology and design allow modern devices to achieve the same level of SCH and Color Frame reliability while using standard video or color black as the genlock signal. It is sometimes argued that these proprietary systems are necessary due to the non-phase-linear characteristics of video cable which can introduce an SCH error. this error is small (approximately 3.5° per 30 meters (100 ft.) for Belden 8281 or equivalent) and, as long as a devices meets criterion 4 above, will not normally cause a problem. In any case, cable equalization removes the cable-induced SCH error. Therefore, in the rare instance where genlock cable runs are longer than approximately 300 meters (1000 ft.), the cables should be equalized. Also, in an era when many pieces of video equipment incorporate their own sync generator, it is necessary to distribute a video or color black timing reference anyway.

The Evolution of Leitch Equipment

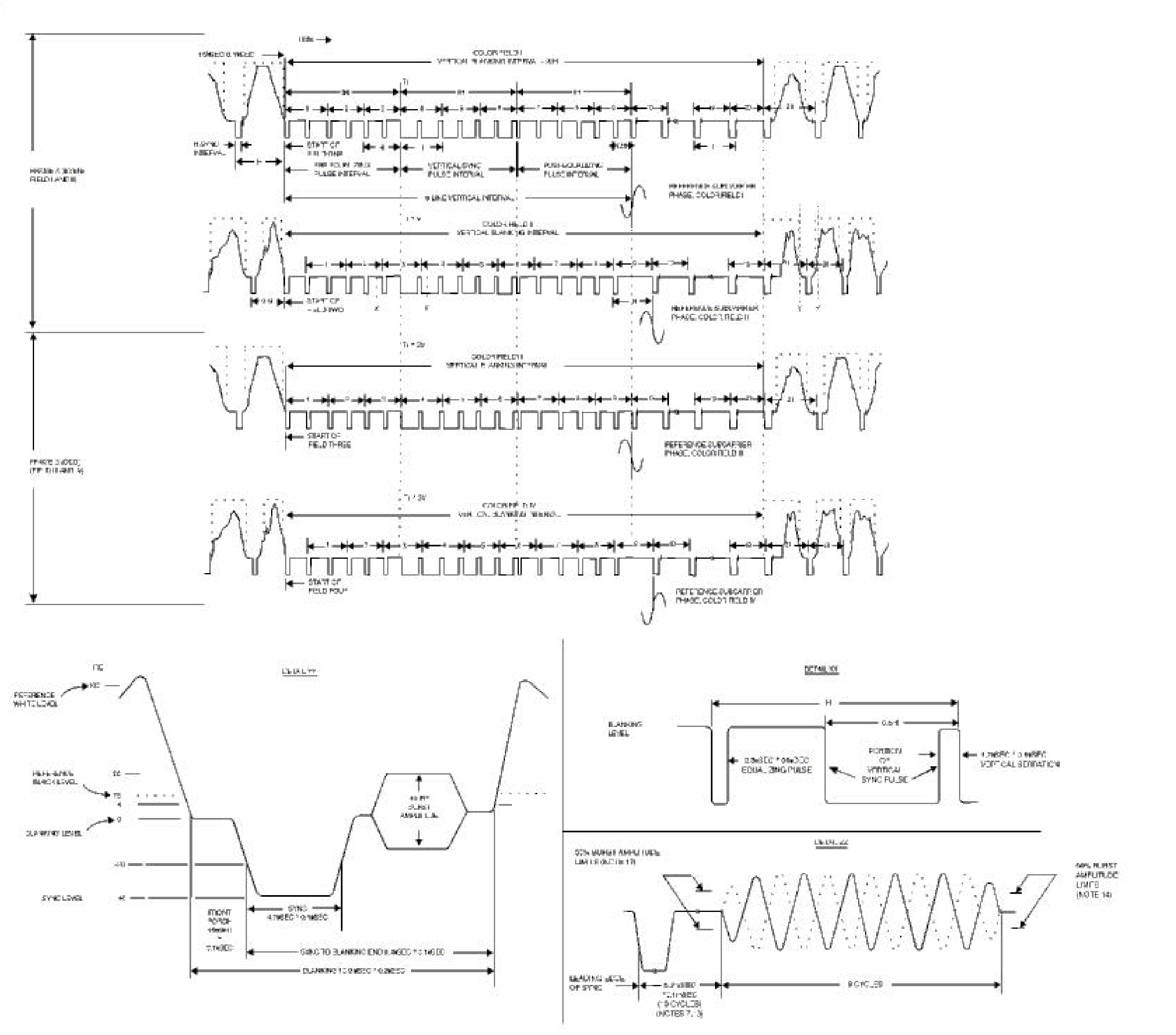
Leitch has been designing and manufacturing sync and test generators for more than 20 years. Technology has changed greatly in that time. Therefore, not all Leitch equipment ever manufactured meets all of the performance criteria described earlier. Despite this, Leitch has been the leader in this area. SCH has been considered in the design of all our equipment. Many customers have Leitch equipment of various vintages. Following is a description of our different series of products, along with the SCH and Color Framing behavior of each.This series of products was designed starting in 1971. No standard then existed for SCH. Much equipment of this vintage did not even have subcarrier locked to H. Nonetheless, SCH was considered in the design of our devices. When not genlocked, the outputs of these products maintained a consistent and stable SCH. Starting in 1974, (serial #74XXXX or later) an adjustment was added to allow the SCH of the composite video outputs to be standardized. The standard we chose at that time is the same as the current standard. These products will maintain zero SCH ±5° when not genlocked. Behaviour when genlocked is not as clear cut. Two modes of genlock are available on these devices:"Coincident" and “Non-coincident”. In non-coincident mode, burst and H lock are independent. This was intended primarily for locking to signals which had burst free running relative to H, ie. “non-coincident”. Coincident mode derives the H from the burst lock, and H phasing is in 70nS steps.

Thus the SCH is either 0 or 90 degrees. It is possible by adjustment to set SCH to zero and establish correct Color Framing. Normally, if the SCH of the genlock signal is close to correct (approximately ±20°) the SCH and Color Framing will be consistent, but this is not specified, and cannot be guaranteed. In short, these series are fully usable today in non-genlock application. They require careful setup and monitoring when genlocked. The 160 Series are unique devices. They were designed primarily for genlock applications and have a random SCH when free running. When genlocked, they are frequency locked only. H, V, and burst phasing are controlled by data sent to the unit on an FSK encoded audio circuit. The control code is developed by a 160 Series phase comparator. This compares the video from the device driven by the 160 (eg. a camera) to a reference video. When provided with zero SCH reference, this was the first system that could reliably maintain zero SCH in a system. This closed loop control technique can automatically correct for SCH drift or errors whenever they occur. Unfortunately, this is incompatible with devices whose outputs will not follow their inputs linearly. Thus, the use of this system today is limited to special applications.These series were an attempt to address a complaint that was frequently levelled at the 100 Series. That is, it is impossible to misadjust the output of the 100 Series generators to correct for the SCH errors of subsequent pieces of equipment. The 130/330’s achieved this while maintaining the low SCH jitter of the 100 Series. When not genlocked, these devices can be set to maintain zero SCH ±10°. When genlocked, the output SCH can be adjusted to any value, and the established relationship between input and output will always be maintained. These series are suitable for free run use in modern systems except in the most demanding applications. When genlocked, it is important that the genlock signal be zero SCH and that the unit be carefully timed and certified. With careful calibration and timing, these units can perform reliably in a modern system.All of these units conform to the criteria described above. They represent the state of the art in this type of equipment. SCH is always 0±1°. Guaranteed. This is much more accurate than any available SCH measurement device. This series forms the basis for a modern, trouble-free, and foolproof system which maintains zero SCH and consistent Color Framing.

Conclusion

As a general policy, Leitch does not discontinue older products when a new design becomes available. Often customers will want to continue using an older product in order to maintain uniformity in their systems. Occasionally the different design philosophy employed in an older design will fulfill a particular need not addressed in the current design. For example, if it is necessary to establish an incorrect SCH in order to correct an otherwise non-SCH-adjustable device, the 130 Series is a good choice. As a result, Leitch currently supplies products from each of these series of equipment even though the current series accounts for the largest production volume by far. If Leitch ever made it, we support it. This is something to remember when planning for the future.

As we strive for SCH nirvana, that blessed state where SCH and Color Frame are always right, we must remember that there are three stepping stones on this path: understanding, measurement, and the equipment selection. This application note has given you the necessary background for implementing a standard Color Black distribution system which maintains precise SCH. You can now start your journey on the right path. Non-standard signal distribution systems may be considered as side paths, best left untravelled since they can only divert us from our objective. As an additional aid on your journey, we have included a copy of RS-170A with this application note. We trust you will find it useful.



NOTES

1. SPECIFICATIONS APPLY TO STUDIO FACILITIES. COMMON CARRIER, STUDIO TO TRANSMITTER AND TRANSMITTER CHARACTERISTICS ARE NOT INCLUDED.

2. ALL TOLERANCES AND LIMITS SHOWN IN THIS DRAWING PERMISSIBLE ONLY FOR LONG TIME VARIATIONS.

3. THE BURST FREQUENCY SHALL BE 3.579545 MHz ± 10Hz.

4. THE HORIZONTAL SCANNING FREQUENCY SHALL BE 2/455 TIMES THE BURST FREQUENCY (ONE SCAN PERIOD (H) = 63.556 μSEC).

5. THE VERTICAL SCANNING FREQUENCY SHALL BE 2/525 TIMES THE HORIZONTAL SCANNING FREQUENCY (ONE SCAN PERIOD (V) = 16.683 μSEC).

6. START OF COLOR FIELDS I AND III IS DEFINED BY A WHOLE LINE BETWEEN THE FIRST EQUALIZING PULSE AND THE PRECEDING H SYNC PULSE. START OF COLOR FIELDS II AND IV IS DEFINED BY A HALF LINE BETWEEN THE FIRST EQUALIZING PULSE AND THE PRECEDING H SYNC PULSE. COLOR FIELD I: THAT FIELD WITH POSITIVE GOING ZERO-CROSSINGS OF REFERENCE SUBCARRIER NOMINALLY COINCIDENT WITH THE 50% AMPLITUDE POINT OF THE LEADING EDGES OF EVEN NUMBERED HORIZONTAL SYNC PULSES.

7. THE ZERO CROSSINGS OF REFERENCE SUBCARRIER SHALL BE NOMINALLY COINCIDENT WITH THE 50% POINT OF THE LEADING EDGES OF ALL HORIZONTAL SYNC PULSES. FOR THOSE CASES WHERE THE RELATIONSHIP BETWEEN SYNC AND SUBCARRIER IS CRITICAL FOR PROGRAM INTEGRATION, THE TOLERANCE ON THIS COINCIDENCE IS ± 40° OF REFERENCE SUBCARRIER. REFERENCE SUBCARRIER IS A CONTINUOUS SIGNAL WITH THE SAME INSTANTANEOUS PHASE AS BURST.

8. ALL RISE TIMES AND FALL TIMES UNLESS OTHERWISE SPECIFIED ARE TO BE 0.14 μSEC ± 0.02 μSEC MEASURED FROM 10% TO 90% AMPLITUDE POINTS. ALL PULSE WIDTHS ARE MEASURED AT 50% AMPLITUDE POINTS, UNLESS OTHERWISE SPECIFIED.

9. TOLERANCE ON SYNC LEVEL, REFERENCE BLACK LEVEL (SETUP) AND PEAK TO PEAK BURST AMPLITUDE SHALL BE ±2 IRE UNITS.

10. THE INTERVAL BEGINNING WITH LINE 17 AND EXTENDING THROUGH LINE 20 OF EACH FIELD MAY BE USED FOR TEST, CUE AND CONTROL SIGNALS.

11. EXTRANEOUS SYNCHRONOUS SIGNALS DURING BLANKING INTERVALS INCLUDING RESIDUAL SUBCARRIER SHALL NOT EXCEED 1 IRE UNIT. EXTRANEOUS NON-SYNCHRONOUS SIGNALS DURING BLANKING INTERVALS SHALL NOT EXCEED 0.5 IRE UNIT. ALL SPECIAL PURPOSE SIGNALS (VITS, VIR ETC.) WHEN ADDED TO THE VERTICAL BLANKING INTERVAL ARE EXCEPTED. OVERSHOOT ON ALL PULSES DURING SYNC AND BLANKING, VERTICAL AND HORIZONTAL, SHALL NOT EXCEED 2 IRE UNITS.

12. BURST ENVELOPE RISE TIME IS 0.3 μSEC + 0.2 μSEC MEASURED BETWEEN THE 10% AND 90% AMPLITUDE POINTS.

13. THE START OF BURST IS DEFINED BY THE ZERO-CROSSING (POSITIVE OR NEGATIVE SLOPE) THAT PRECEDES THE FIRST HALF CYCLE OF SUBCARRIER THAT IS 50% OR GREATER OF THE BURST AMPLITUDE. ITS POSITION IS NOMINALLY 19 CYCLES OF SUBCARRIER FROM THE 50% AMPLITUDE POINT OF LEADING EDGE OF SYNC. (SEE DETAIL ZZ)

14. THE END OF BURST IS DEFINED BY THE ZERO-CROSSING (POSITIVE OR NEGATIVE SLOPE) THAT FOLLOWS THE LAST HALF CYCLE OF SUBCARRIER THAT IS 50% OR GREATER OF THE BURST AMPLITUDE.

15. MONOCHROME SIGNALS SHALL BE IN ACCORDANCE WITH THIS DRAWING EXCEPT THAT BURST IS OMITTED AND FIELDS III AND IV ARE IDENTICAL TO FIELDS I AND II RESPECTIVELY.

16. HORIZONTAL BLANKING WIDTH IS FUNDAMENTALLY BASED ON THE BLANKING OF THE PICTURE SIGNAL WHEN THE EQUIPMENT THAT IS USED TO INSERT SETUP INTO A PICTURE SIGNAL DIRECTLY CONTROLS THE BLANKING OF THE PICTURE, THEN A MEASUREMENT AT 4 IRE UNITS WILL ALSO BE A MEASURE OF THE PICTURE BLANKING. FREQUENTLY THE EQUIPMENT THAT IS USED TO INSERT SETUP (SUCH AS A STABILIZING AMPLIFIER) WILL NOT DIRECTLY CONTROL THE PICTURE BLANKING SO THAT THE BLANKING MAY BE WIDER THAN THAT MEASURED AT 4 IRE UNITS. IN SUCH CASES, A MEASUREMENT MUST BE MADE AT SOME PICTURE LEVEL TO ESTABLISH THE ACTUAL PICTURE BLANKING, WHICH MUST SATISFY THE DIMENSION IN DETAIL YY. IT IS RECOGNIZED THAT OCCASIONALLY THE PICTURE CONTENT AT THE EDGE(S) OF THE PICTURE MAY BE BLACK. UNDER SUCH CIRCUMSTANCES, THE PICTURE MUST BE VIEWED ON A PROPERLY ADJUSTED PICTURE MONITOR TO VERIFY THAT BLACK EDGE(S) ARE CONSISTENT WITH THE SCENE CONTENT AND NOT THE RESULT OF IMPROPER EQUIPMENT ADJUSTMENT.

COLOR TELEVISION STUDIO
PICTURE LINE AMPLIFIER OUTPUT

RS 170 A

(SP 1281)