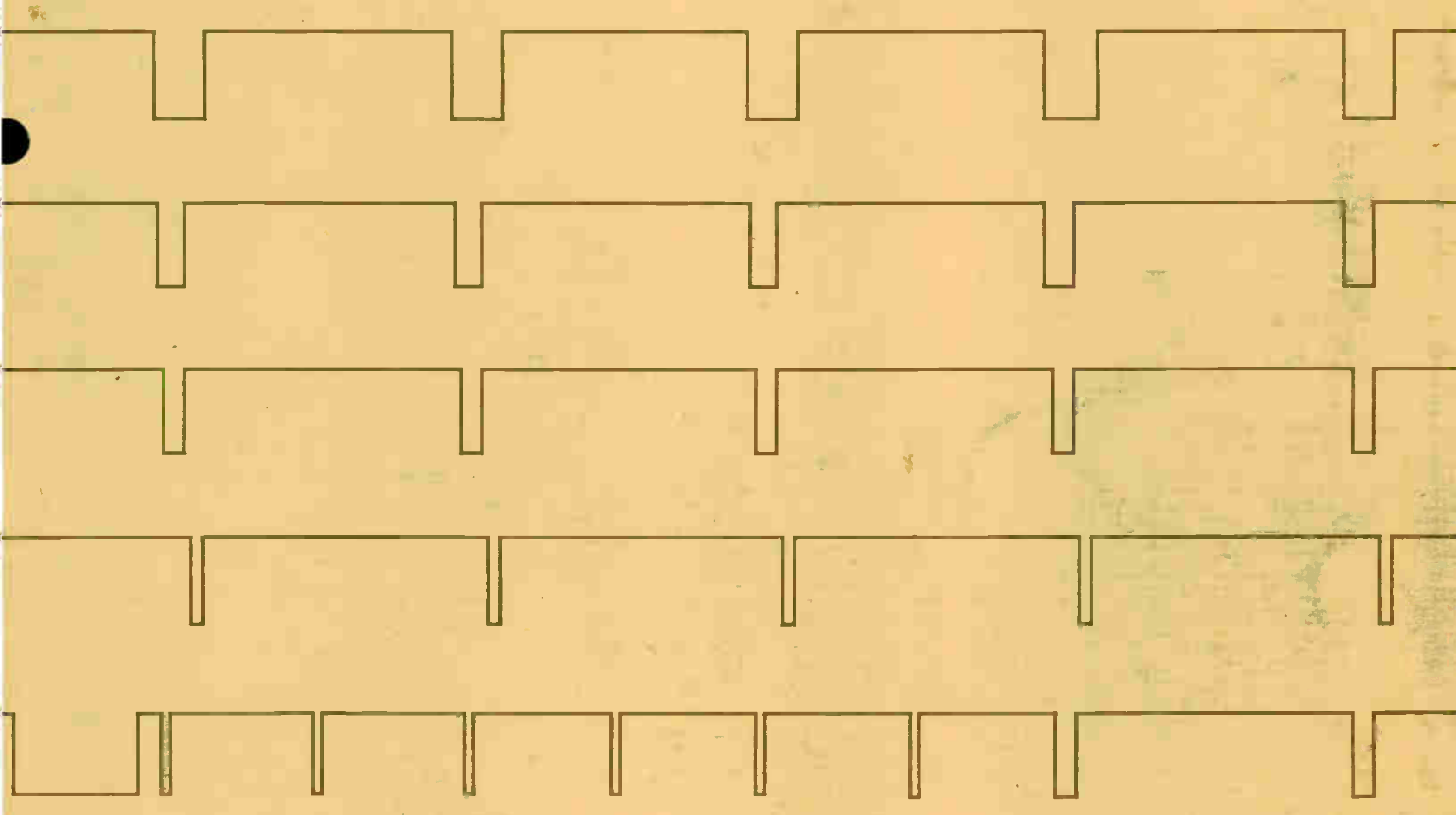
# NTSC Studio Timing: Principles and Applications

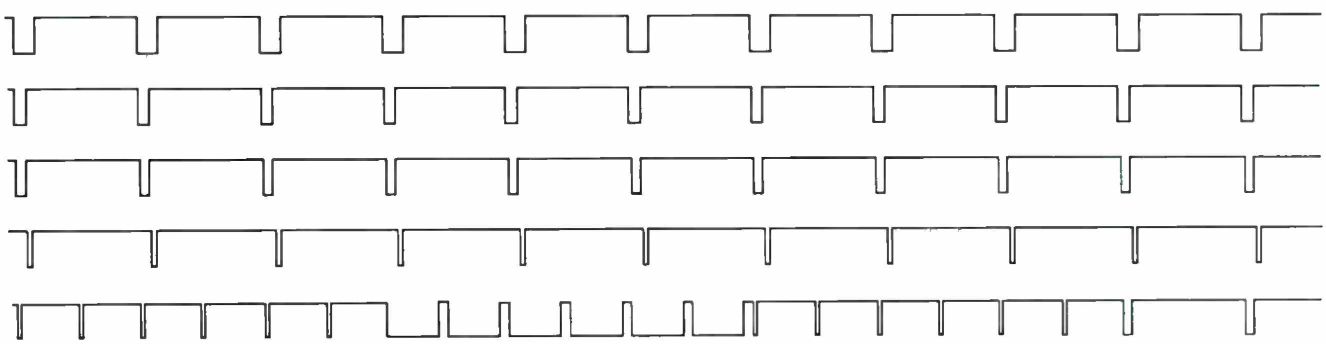


**GRASS VALLEY GROUP®**

*A TEKTRONIX COMPANY*

# NTSC Studio Timing: Principles and Applications

Issue 3



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# Preface

This booklet on studio timing has been structured to meet a variety of needs.

The video novice can read through from Section 1, noting the margin definitions, and gain a general understanding of the subject.

Section 2, starting with system timing, offers approaches and options for the timing of a television facility.

Section 3 emphasizes the importance of SC/H phase, defines and clarifies it, and explains how to achieve it.

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# NTSC Studio Timing: Principles and Applications

## *Introduction*

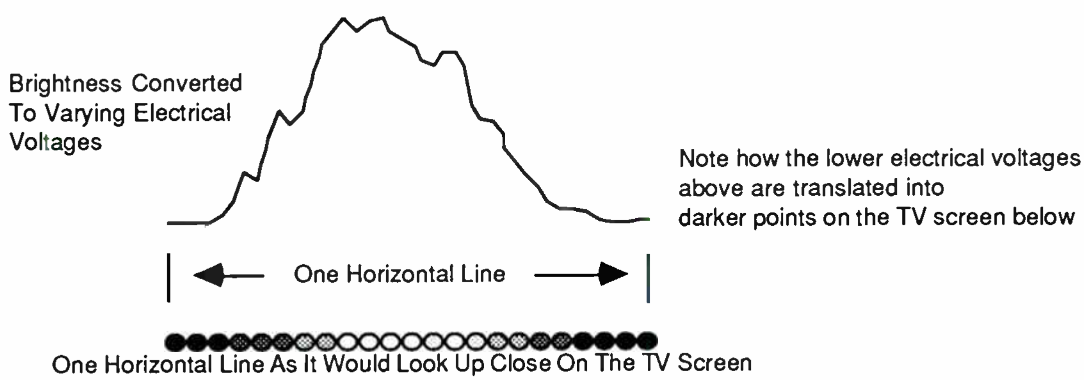
The most critical design in every teleproduction facility is the system timing. The final video product will always reflect the quality of the system design. This booklet will review the principles of video, discuss system timing, and offer approaches to system timing design. A definition of subcarrier to horizontal phase and an explanation of how to achieve and maintain SC/H phase is also included.

## *Section 1*

## *Video Basics*

### The Camera and Pickup Tube

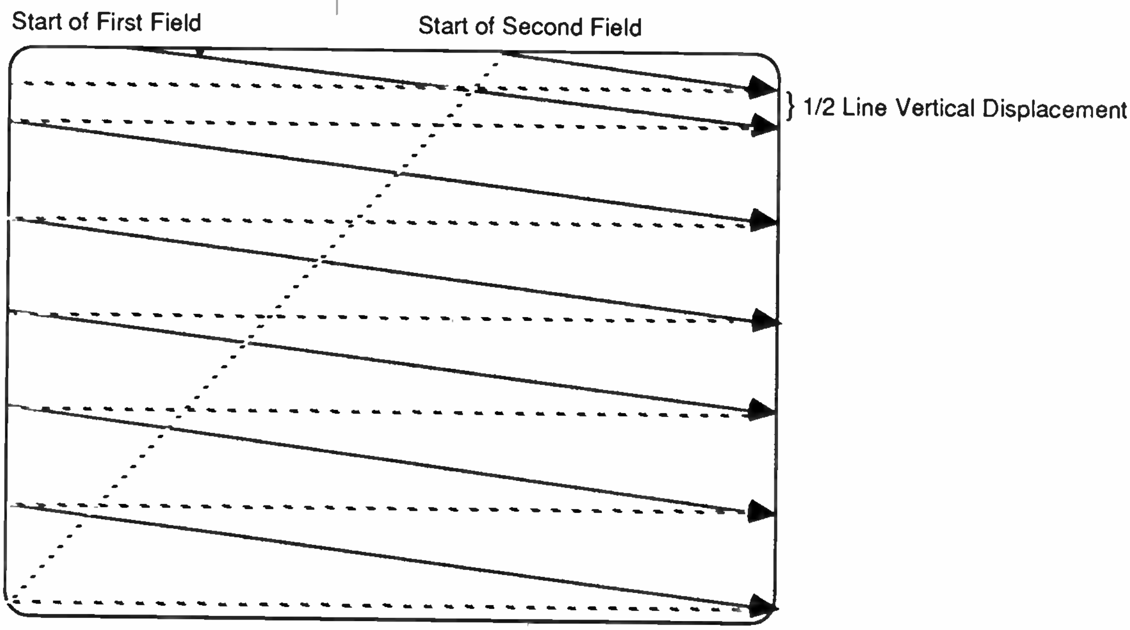
Light from a scene enters the camera through the lens and creates a pattern of electrical charges on the pickup tube's target. An electron beam scans across the target and completes an electrical circuit with the pattern of electrical charges on the target. Electrons representing the scene in lightness or darkness flow from the target and become the video signal. In this way, the pickup tube inside the camera changes the varying brightnesses of light that it "sees" into varying electrical voltages called video.



## Scanning

In order to accurately reproduce a scene, the scanning must be done in an organized way. In both the camera and the television receiver, the scanning of the target or screen is done by an electron beam moving in horizontal lines across the target plate or screen. At the same time, the electron beam gradually moves down the scene. When the beam reaches the bottom of the scene, the beam is sent back to the top. There are 525 horizontal lines in a complete picture.

The horizontal lines are scanned alternately. That is, all the odd numbered lines are scanned first, then the beam returns to the top of the scene and scans all the even numbered lines. This is called "interlaced" scanning.




## Fields and Frames

Each scan of the scene is called a **field** and only involves half of the total 525 lines or 262.5 lines. Two complete scans of the scene (525 lines) is called a **frame**. Because the fields are scanned in rapid sequence (60 per second), the viewer only perceives the completed picture.

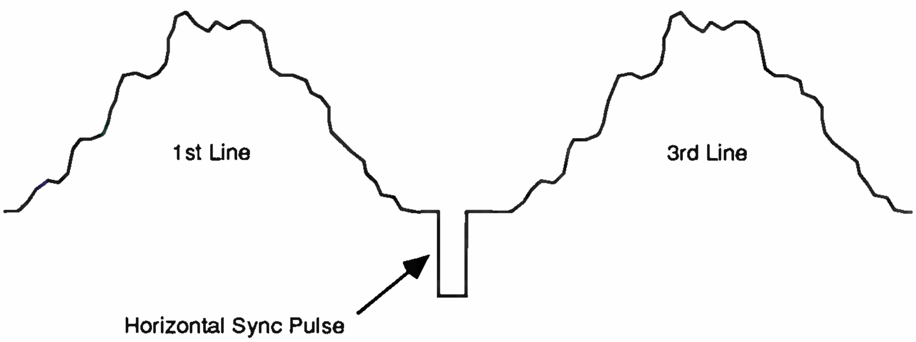
**Field**
Half of the horizontal lines (262.5 in NTSC system) needed to create a complete picture. Two interlaced fields create a complete frame.

**Frame**
A complete picture composed of two fields. In the NTSC system, 525 interlaced horizontal lines of picture information.

## Horizontal and Vertical Sync

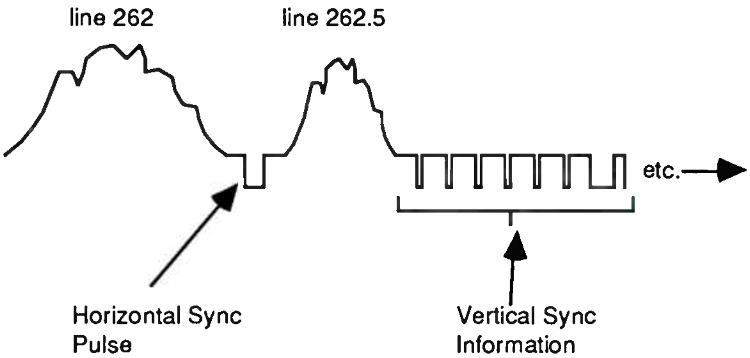
For accurate reproduction, both the camera and the television receiver must be synchronized to scan the same part of the scene at the same time. At the end of each horizontal line the beam must return to the left side of the scene. This is called "horizontal retrace". Coordination of the horizontal retrace is handled by the **horizontal sync pulse.**

**Horizontal Sync Pulse**
The synchronizing pulse at the end of each line that determines the start of horizontal retrace.




At the bottom of the scene, when 262.5 horizontal lines have been scanned, it is time for the beam to return to the top of the scene. The start of vertical retrace is signaled by the **vertical sync pulse** which is different in width than horizontal sync pulses. Since the vertical retrace takes much longer than the horizontal retrace, a longer vertical synchronizing interval is employed.

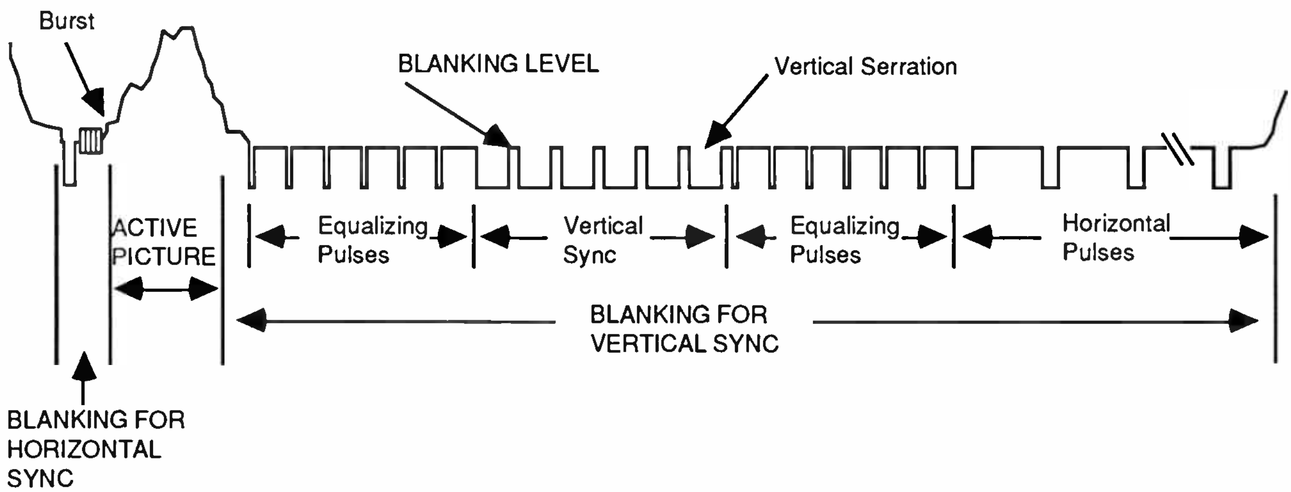
**Vertical Sync Pulse**
The synchronizing pulse at the end of each field which signals the start of vertical retrace.



## Blanking

**Blanking**
The time period when picture information is shut off. Blanking is a voltage level below picture level and acts as a signal to turn off the scanning beam. Synchronizing signals which control invisible retrace of scanning are active during the blanking period.

During the time when horizontal and vertical retrace are taking place, the electron beams in the camera and home TV are cut off. This time period is called blanking. **Blanking** means that nothing will be written on the television receiver screen.



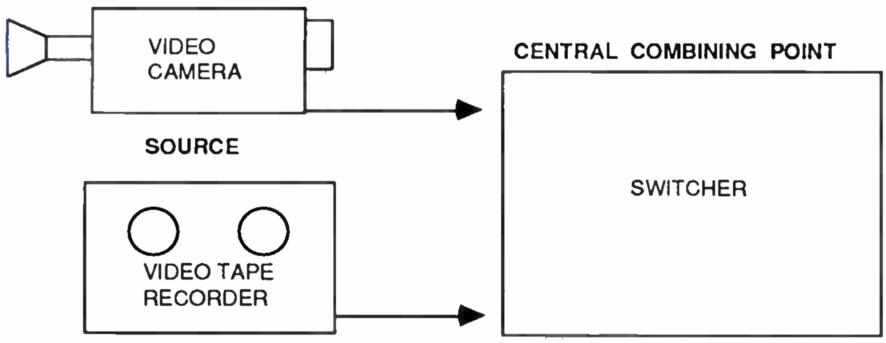

**Equalizing Pulses**
A series of pulses occurring at twice the line frequency before and after the serrated vertical synchronizing pulse. Their purpose is to adjust the scanning sequence for proper interlace.

**Vertical Serrations**
A vertical synchronizing pulse contains a number of small notches called vertical serrations.

During horizontal blanking, sync and "burst" (to be described in more detail later) occur. During vertical blanking, vertical sync, vertical **equalizing pulses**, and **vertical serrations** occur. The equalizing pulses are inserted to cause the video fields to begin at the proper points to achieve interlace. The vertical serrations keep the television receiver's horizontal sync circuitry from drifting off frequency during the time when no horizontal picture information is present.

# *System Timing*

It is imperative that all video signals arrive at the video **switcher** (the central combining point) in synchronization. This means that the scanning sequence of every **source** must start and stay in time. Without this, the picture on the television receiver or monitor will roll, jump, tear, and/or have incorrect colors when the source video signals are combined. Careful system design is necessary to assure synchronization at the point of input to a video switcher.




The degree of accuracy with which these events must occur requires a precision reference. In all television facilities, this timing reference is provided by a **synchronizing pulse generator**. Establishing and maintaining precise timing involves a multitude of variables that will be described in detail in this booklet.

### Advance and Delay

Defining advance or delay between two video signals is dependent on which signal is defined as the **reference**. Advance on Camera 1 means its output occurs earlier in time than Camera 2's output. If viewed from the other perspective, Camera 2 is delayed when referenced to Camera 1.

It must be understood that advance is not really possible. Advance or negative time delay does not exist. Video signals take time to move just as you and I do. A marathon runner wins because he had the least delay in his running time. On the other hand, he is the most advanced at the finish line, but only because the other runners had more delay in their running times. Video **frame synchronizers** make video advance appear possible, but in reality they introduce delay to achieve the apparent advance. This is proven by the fact that the audio associated with the video going through a frame synchronizer must also be delayed to avoid lip-sync errors.

## *Section 2*

**Switcher, Production Switcher**
Device that allows transitions between different video pictures. May also contain special effects generators.

**Source**
Video producing equipment such as a camera, tape recorder, or character generator.

**Synchronizing Pulse Generator**
Equipment that generates synchronizing pulses needed by source equipment. Also known as a sync generator or SPG.

**Reference Video Signal**
A composite video signal used to compare all other video signals to, for timing purposes.

**Frame Synchronizer**
A digital buffer, that by storage, comparison of sync information to a reference, and timed release of video signals, can continuously adjust the signal for any timing errors.

## Studio Planning

Before the actual assembly of a teleproduction facility can begin, a system plan must be completed. This can only be accomplished upon definition of studio timing requirements. It will be necessary to know the timing requirements of the equipment to be installed. This information is usually available from the manufacturer's published specifications.

Most newer source equipment locks to **color black**. This implies the device has its own internal sync generator. Typically this source equipment will have adjustments to allow the video output timing to be adjusted relative to the reference color black. You should verify that the adjustment range is sufficient for your requirements.

### Planning For Timing Advances

The ability to lock to color black has not always existed. In the early years of television, cameras needed separate horizontal and vertical **drive pulses** from the sync generator to drive their scanning circuits. Sync, blanking, and subcarrier were also needed. System design required that all drive pulses be advanced by the path length of the camera. The delay from pulse input to video output may have been as long as one microsecond (a very long delay).

These older cameras would receive pulses directly from the sync generator. Drive pulses to other pieces of source equipment would then have to be delayed to time that equipment. This delay could be several hundred feet of coaxial cable or some equivalent lumped delay.

There are still cameras in use today that require sync, blanking and subcarrier (horizontal and vertical drive are now virtually obsolete). These cameras have no internal timing adjusments so it is necessary to adjust the advanced pulse drives to time the camera. One way to resolve this timing requirement is to drive the camera with a source synchronizing generator. New cameras lock to color black and have internal timing adjustments available.

**Composite Video**
A video signal that contains horizontal, vertical, and color synchronizing information.

**Color Black**
A composite video signal that produces a black screen when viewed on a television receiver.

**Drive Pulse(s), Pulse Drives**
A term commonly used to describe a set of signals needed by source equipment such as a camera. This signal set may be composed of any of the following: sync, blanking, subcarrier, horizontal drive, vertical drive, and burst flag.

Until now, most character generators have required pulse drives and external adjustment of timing. This is often done by dedicating a **source synchronizing generator** to the character generator. Newer character generator models, like other devices, are beginning to lock to color black.

Digital video devices such as digital effects generators, time base correctors, and frame synchronizers work on the basis of storing digital video data. This allows timing to be easily adjusted and as such, digital video devices are inherently able to time internally. Color black locking is very common.

Nearly all production switchers require sync, blanking and subcarrier. Some switchers have some limited adjustment of horizontal (H) delay but still require advanced pulse drives. **Subcarrier phasing** is normally built in and allows for color timing of the switcher. Dedication of a source synchronizing generator to a switcher will simplify system design. Some switcher designs now incorporate color black locking.

## Planning For Timing Delays

Coaxial cable is necessary for the proper distribution of video, pulse and subcarrier signals. Coax has an inherent **delay** of up to 1.5 nanoseconds per foot. This is cumulative and must be considered in system design. Very long runs can introduce significant delay. Coaxial cable can be used for delay but it should be remembered that coax introduces **frequency response** loss that increases with frequency and length.

**Distribution amplifiers** (DAs) introduce delay that will need to be planned for. This can vary from 25 to 70 nanoseconds depending on the model. Variable cable **equalization** adjustment will also affect electrical delay. Equalization should be adjusted prior to final system timing. Special purpose video distribution amplifiers are available to provide delay beyond 1 microsecond. These should be used because they have frequency response compensation that is superior to coax and passive video delay lines. Pulse DAs are available to allow for adjustment of pulse delay of up to 4 microseconds and regenerate the pulse to eliminate distortion.

**Source Synchronizing Generator**
A synchronizing pulse generator used to drive a specific piece of source equipment. It is referenced to a master reference synchronizing generator.

**Subcarrier (SC)**
A continuous sinewave used by source equipment to encode the color information into the video signal. A sample of this subcarrier is included during horizontal blanking time and is called color burst.

**Phasing or Timing**
Adjusting the delay of a video signal to a reference video signal to ensure they are synchronous. This includes horizontal and subcarrier timing.

**Path Length or Propagation Delay**
The time it takes for a signal to travel through a piece of equipment or a length of cable.

**Frequency Response**
The maintenance of uniform video signal level (amplitude) over a range of frequencies.

**Distribution Amplifier**
Device used to multiply (fan out) a video signal. May also include cable equalization and/or delay. Referred to as a DA.

**Equalization**
Process of altering the frequency response of a video amplifier to compensate for high-frequency losses in coaxial cable.

**Video Processing Amplifier**
A device that stabilizes the composite video signal, regenerates the synchronizing pulses, and can make other adjustments to the video signal.

**Delay Distribution Amplifier**
An amplifier that can introduce adjustable delay in a video signal path.

**Master Reference Synchronizing Generator**
A synchronizing pulse generator that is the precision reference for an entire teleproduction facility.

**Video processing amplifiers** have a fixed electrical path length even though regenerated sync and color burst are adjustable. The propagation delay of the GVG 3240 Video Processing Amplifier is about 225 nanoseconds.

Sometimes multiple studio facilities have the output of one switcher feeding a second and both share some common video sources. In this instance, the common video sources to the second switcher will need to be delayed by the path length of the first switcher. This delay may be as little as 50 nanoseconds for a small routing switcher to 700 nanoseconds for a large production switcher.

## Final Considerations

There are products available to aid in system design. One such product is the 3230 Isophasing System. This is an automatic **delay distribution amplifier** that will correct source timing errors of up to ±15nS. The Isophasing System can provide up to 32 channels with 5 outputs each, keeping all outputs within one degree of subcarrier phase. The 3230 simplifies system design and daily system maintenance.

Once all the timing requirements of the equipment are known, you can begin to actually lay out a system plan on paper. It is important that a specific piece of equipment be defined as the zero timing point. It will become the timing reference by which all calculations and measurements are made. It is desireable to have this be a source in the plant that is not easily altered, such as the test output from the **master reference sync generator**.

# *System Design Using Delay*

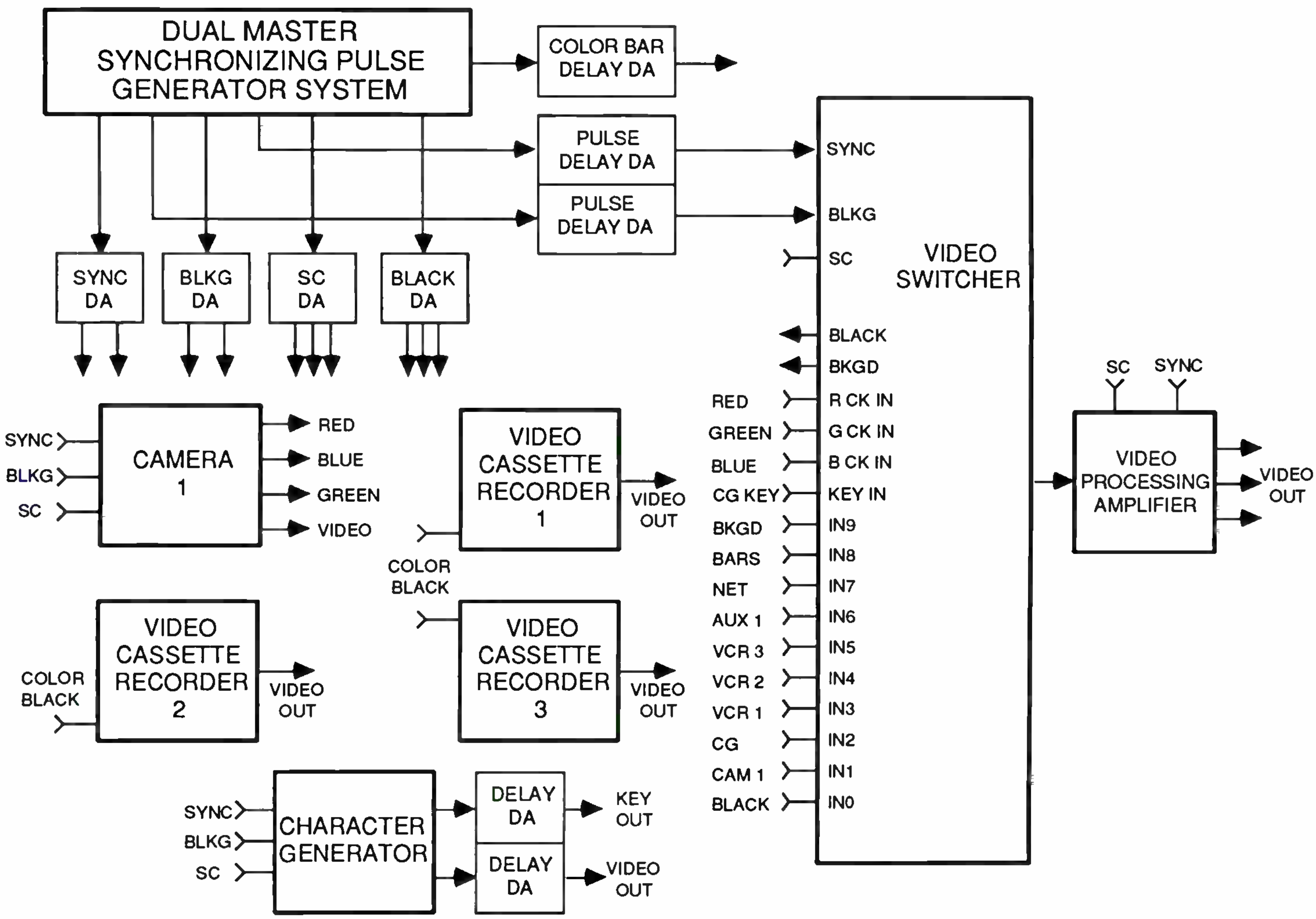
The illustration below shows a small system that will use cumulative delay to achieve system timing. This system consists of a camera, a **character generator**, two 1/2" and one 3/4" video cassette recorders (VCRs). All of the video cassette recorders have **time base correctors** that lock to the color black reference. The color black comes from the master synchronizing generator and is distributed by a DA. These time base correctors provide ample timing adjustment for the VCRs.

The sources in this system that are to be mixed, keyed or wiped with the video switcher must be exactly in time at the switcher input. Hence the obvious point of reference for this system is at the switcher input. This point is therefore designated the **zero timing point**, or time 0.

**Character Generator**
A device used to generate text or captions for television broadcast.

**Time Base Corrector**
Device used to stabilize the timing of a tape machine so it will meet FCC specifications and match other "house" (your video production facility) sources.

**Zero Timing Point**
The point at which all the video signals must be in synchronization (typically the switcher input).



**Composite Sync (CS)**
Horizontal and vertical sync pulses combined. Often referred to simply as "sync". Sync is used by source and monitoring equipment.

**Composite Video**
A video signal that contains horizontal, vertical, and color synchronizing information.

**Color Bars**
A video test signal widely used for system and monitor setup.

**Color Background Generator**
Circuit that generates a full-field solid color for use as a background in a video picture.

**Key**
A signal that can electronically "cut a hole" in the video picture to allow for insertion of other elements such as text or a smaller video picture.

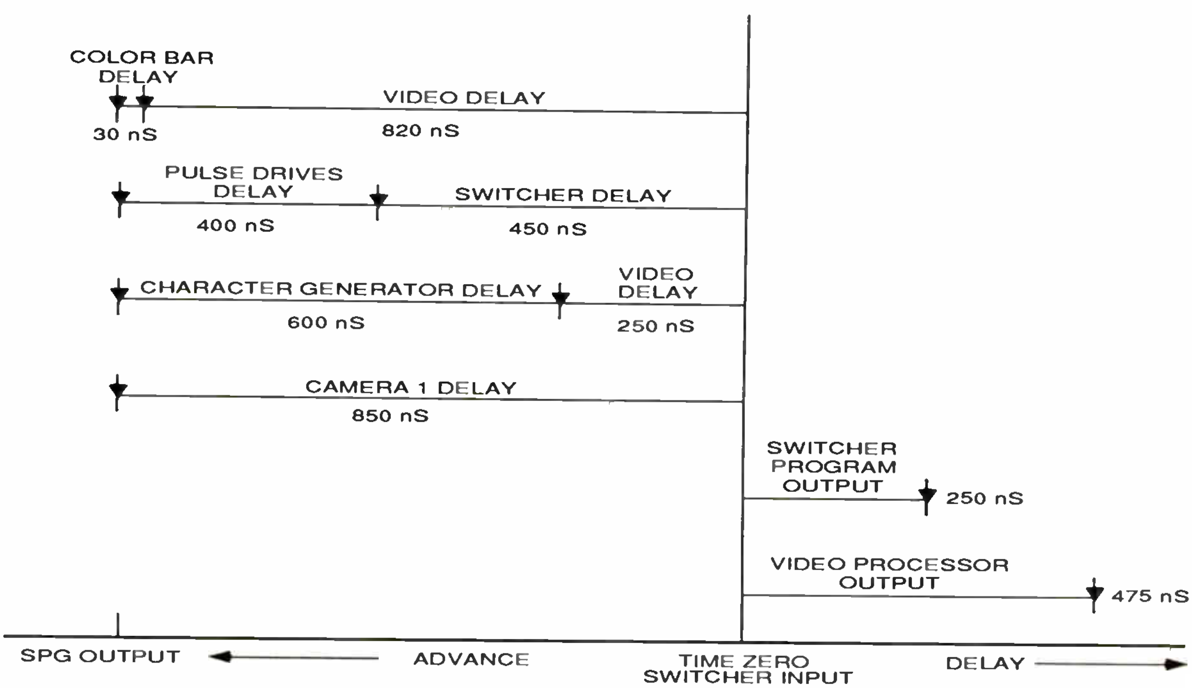
In the illustration below the timing requirements of the equipment have been plotted relative to Time Zero.

Camera 1 has 850 nanoseconds delay from its **composite sync** input to its **composite video** output and represents the longest signal path of any source device in the system. The character generator, switcher, and **color bars** will need delay added to make their total delays the same as the camera. Since the camera has the longest path length, the pulse drives will be provided directly from the sync generator so that the camera gets the most advanced pulses. The camera has a subcarrier phase control for color timing adjustment. The Camera 1 output becomes the reference input at the switcher.

To make the video switcher internal color black and **color background generator** synchronize with the camera, both sync and blanking drives must be delayed to the switcher by 400 nanoseconds. This is accomplished with two adjustable pulse delay distribution amplifiers. The switcher has a subcarrier phase control for color timing adjustment.

Timing of the character generator can be handled in two ways. Delay can be introduced either in the pulse drives, or in the video and **key** outputs of the character generator. In this system, video delay distribution amplifiers are added to the character generator video and key outputs. This method provides six timed outputs. The amount of delay necessary is 250 nanoseconds as calculated in the illustration below.

The last source to be timed is the color bars from the master sync generator. The color bar output is 30 nanoseconds later than the sync output from the sync generator. With the camera as a reference, we can calculate that 820 nanoseconds delay to the color bar output is required to match the camera's delay.



The sync and subcarrier required as external reference inputs for the video processing amplifier should come from the distribution amplifiers feeding the switcher. The video processing amplifier has sufficient timing range for both sync and subcarrier.

The sync generator is a known **SC/H phased** source, and the color bar output will be SC/H phase correct. Fine system timing can now begin by adjusting the color bars and the camera. Measurements are made at the switcher output by selecting between the reference source and the source under adjustment on the switcher. An externally locked waveform monitor and vectorscope should be connected to the switcher output.

**SC/H Phase**
The phase relationship of the subcarrier to (the leading edge of) horizontal sync. More about SC/H phase in the last section of the booklet.

The following steps, in this order, are necessary to ensure correct timing and SC/H phase of all sources.

√ The first step will be to adjust the color bar delay DA. Adjust so that the timing of the half amplitude (50%) point of the color bar horizontal sync leading edges match the timing of the camera sync. A timing match within 10nS is desirable.

√ Camera 1 subcarrier phase needs to be adjusted to match its burst phase to the color bar burst phase.

√ The switcher sync and blanking pulse delay DAs must be adjusted so that the switcher color background sync 50% point and blanking are in time with the sync and blanking of camera one's output.

√ Switcher color timing (internal color black and background) is matched to Camera 1 with the switcher subcarrier phase control.

√ The character generator video delay DA should be adjusted to match the character generator and Camera 1 horizontal sync leading edges.

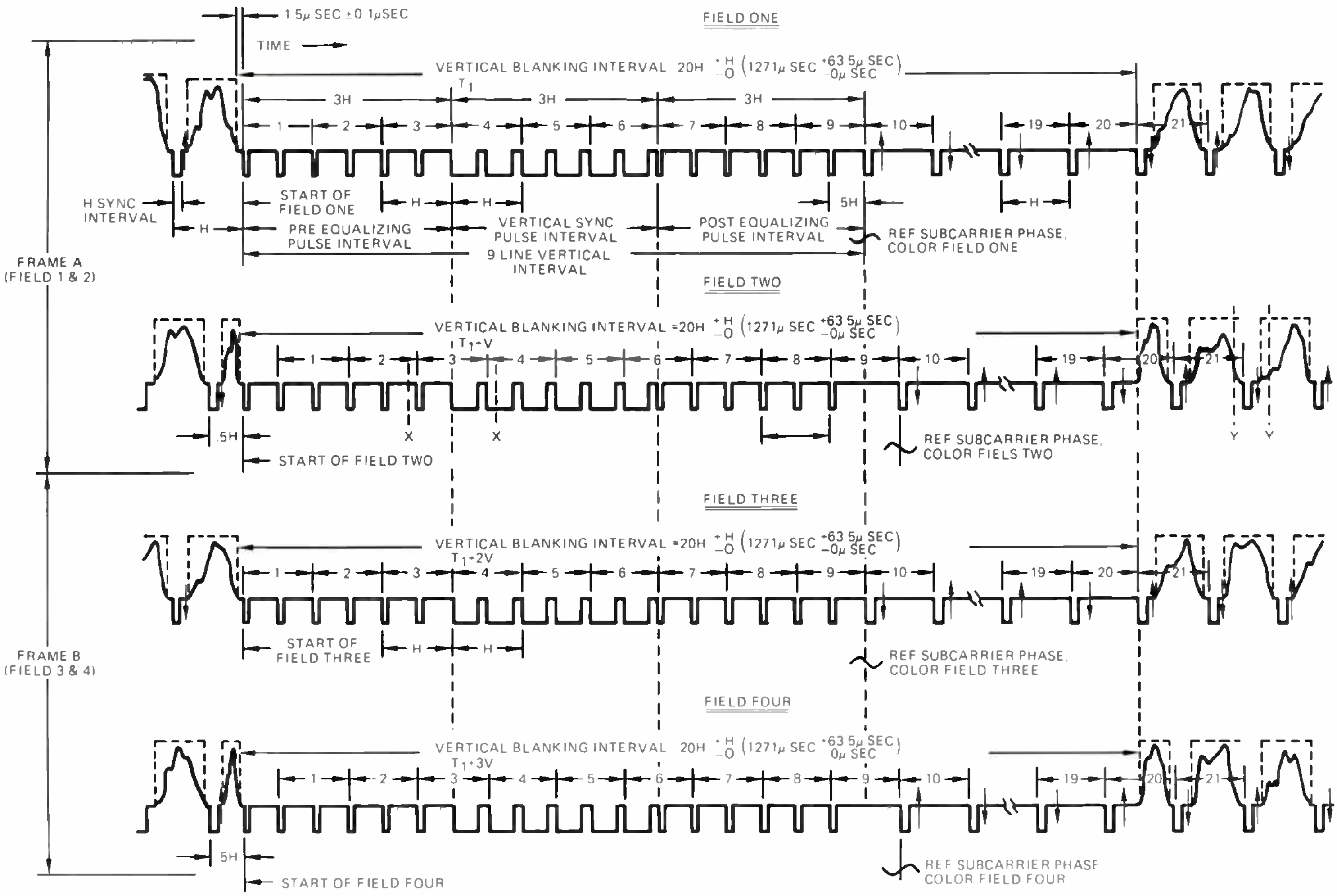
√ Adjust the internal subcarrier phase to color time the character generator.

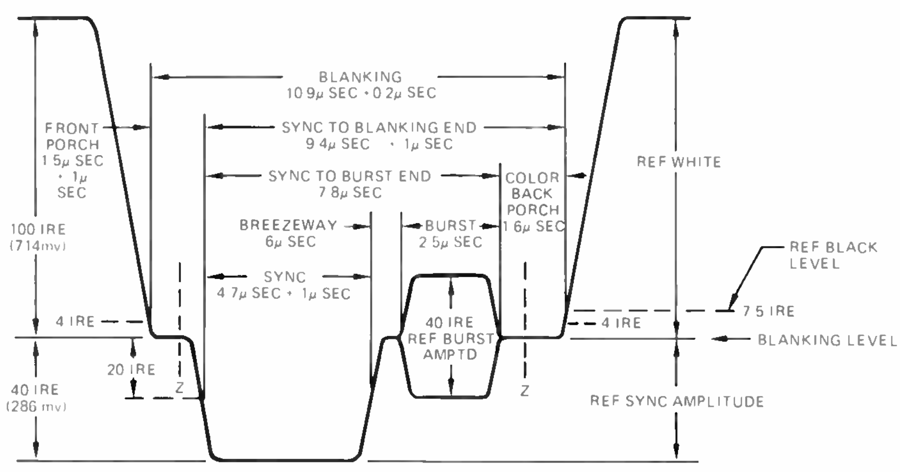
√ The key delay will be adjusted to center the character generator **fill** video within the hole produced by the key signal.

**Fill**
The video information that fills the "hole" cut in the video picture by the key signal.

√ Finally, adjust the VCR time base corrector H and SC phase controls to match each VCR to Camera 1 at the switcher.

The procedure will result in all sources being SC/H phase correct only if the color bar video signal is SC/H phase correct. If an SC/H phase meter is available, the SC/H phase of all sources can be verified. This approach to system design is usually the least expensive but does have serious deficiencies. We are distributing sync and subcarrier to equipment through many different paths. This will make establishing and maintaining SC/H phase very difficult. With the many variables in this system, SC/H phase may drift with time and temperature. Additional source equipment may be difficult to integrate in the future and could require major system design changes.


1 5µ SEC ± 0 1µSEC
TIME
FIELD ONE
VERTICAL BLANKING INTERVAL 20H +H/−0 (1271µ SEC +63 5µ SEC/−0µ SEC)
3H
H SYNC INTERVAL
START OF FIELD ONE
PRE EQUALIZING PULSE INTERVAL
VERTICAL SYNC PULSE INTERVAL
9 LINE VERTICAL INTERVAL
POST EQUALIZING PULSE INTERVAL
REF SUBCARRIER PHASE, COLOR FIELD ONE
FRAME A (FIELD 1 & 2)
FIELD TWO
START OF FIELD TWO
REF SUBCARRIER PHASE, COLOR FIELS TWO
FIELD THREE
START OF FIELD THREE
REF SUBCARRIER PHASE, COLOR FIELD THREE
FRAME B (FIELD 3 & 4)
FIELD FOUR
START OF FIELD FOUR
REF SUBCARRIER PHASE COLOR FIELD FOUR


BLANKING
10 9µ SEC ± 0 2µ SEC
FRONT PORCH 1 5µ SEC ± 1µ SEC
SYNC TO BLANKING END
9 4µ SEC ± 1µ SEC
SYNC TO BURST END
7 8µ SEC
COLOR BACK PORCH 1 6µ SEC
REF WHITE
BREEZEWAY
6µ SEC
BURST
2 5µ SEC
100 IRE (714mv)
SYNC
4 7µ SEC ± 1µ SEC
REF BLACK LEVEL
7 5 IRE
4 IRE
40 IRE REF BURST AMPTD
BLANKING LEVEL
20 IRE
40 IRE (286 mv)
REF SYNC AMPLITUDE

DETAIL YY

20 003 49A

NOTES

1 SPECIFICATIONS APPLY TO STUDIO FACILITIES NETWORK AND TRANSMITTER CHARACTERISTICS ARE NOT INCLUDED

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

3 BURST FREQUENCY SHALL BE 3 579545 MHz ± 10 Hz

4 HORIZONTAL SCANNING FREQUENCY SHALL BE 2 455 TIMES THE BURST FREQUENCY

5 VERTICAL SCANNING FREQUENCY SHALL BE 2 525 TIMES THE HORIZONTAL SCANNING FREQUENCY

6 START OF COLOR FIELDS ONE AND THREE IS DEFINED BY A WHOLE LINE BETWEEN THE FIRST EQUALIZING PULSE AND THE PRECEDING H SYNC PULSE START OF COLOR FIELDS TWO AND FOUR DEFINED BY A HALF LINE BETWEEN THE FIRST EQUALIZING PULSE AND THE PRECEDING H PULSE COLOR FIELD ONE IS THAT FIELD WITH POSITIVE GOING ZERO CROSSINGS OF REFERENCE SUBCARRIER NOMINALLY COINCIDENT WITH 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 ±45 OF REFERENCE SUBCARRIER

8 ALL RISE TIMES AND FALL TIMES UNLESS OTHERWISE SPECIFIED ARE TO BE 0 140 μSEC ±0 02 μSEC MEASURED FROM TEN TO NINETY PER CENT AMPLITUDE POINTS ALL PULSE WIDTHS EXCEPT BLANKING ARE MEASURED AT FIFTY PER CENT AMPLITUDE POINT

9 OVERSHOOT ON ALL PULSES DURING SYNC AND BLANKING (VERTICAL AND HORIZONTAL) SHALL NOT EXCEED TWO IRE UNITS ANY OTHER EXTRANEOUS SIGNALS DURING BLANKING INTERVALS SHALL NOT EXCEED TWO IRE UNITS, MEASURED OVER A BANDWIDTH OF 6 MHz

10 BURST ENVELOPE RISE TIME IS 0 30 μSEC MEASURED BETWEEN THE TEN AND NINETY PERCENT AMPLITUDE POINTS IT SHALL HAVE THE GENERAL SHAPE SHOWN

11 THE START OF BURST IS DEFINED BY THE ZERO CROSSING (POSITIVE OR NEGATIVE SLOPE) THAT PRECEEDS THE FIRST HALF CYCLE OF SUBCARRIER THAT IS 50% OR GREATER OF THE BURST AMPLITUDE.

12 THE END OF BURST IN 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.

13 MONOCHROME SIGNALS SHALL BE IN ACCORDANCE WITH THIS DRAWING EXCEPT THAT BURST IS OMITTED, AND FIELDS THREE AND FOUR ARE IDENTICAL TO FIELDS ONE AND TWO RESPECTIVELY.

14 REFERENCE SUBCARRIER IS A CONTINUOUS SIGNAL WHICH HAS THE SAME INSTANTANEOUS PHASE AS BURST

15 PROGRAM OPERATING LEVEL WHITE IS 100 IRE, +0, −2 IRE.

16 PROGRAM OPERATING LEVEL BLACK IS 7.5 IRE, ±2.5 IRE

17 PROGRAM OPERATING LEVEL SYNC IS 40 IRE, ±2 IRE.

18 PROGRAM OPERATING LEVEL BURST IS 40 IRE, ±2 IRE.

19 BURST PEDESTAL NOT TO EXCEED ±2 IRE.

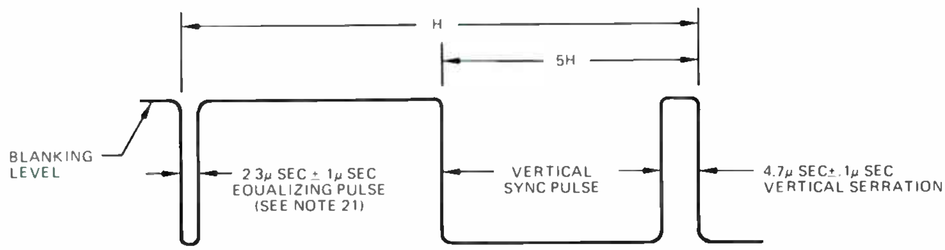
20 BREEZEWAY, BURST, COLOR BACK PORCH, AND SYNC TO BURST END ARE NOMINAL IN DETAIL BETWEEN YY. SEE DETAIL BETWEEN ZZ FOR TOLERANCES.

21 RATIO OF AREA OF VERTICAL EQUALIZING PULSE TO SYNC PULSE SHALL BE WITHIN 45 TO 50 PER CENT

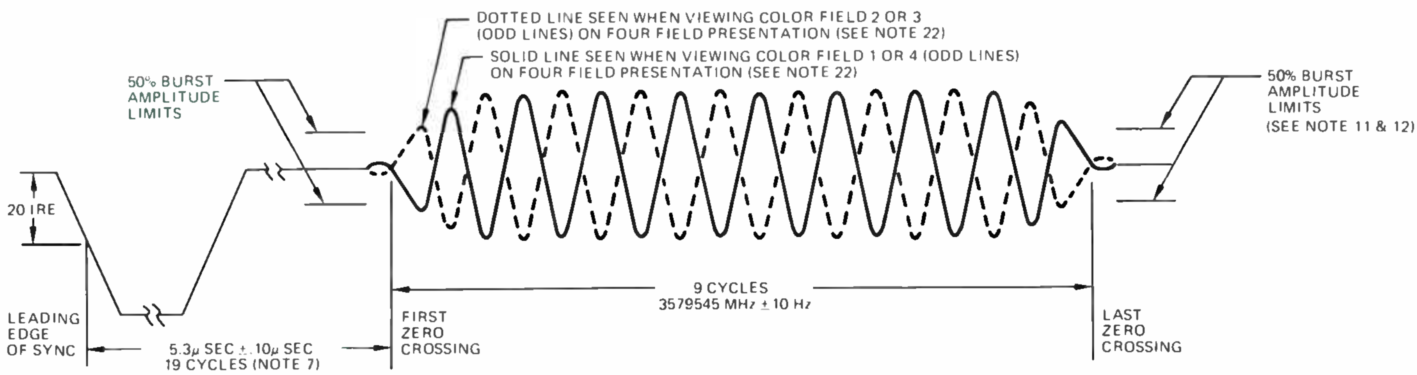
22 THERE WILL BE A 100 DEGREE REVERSAL OF PHASE WHEN VIEWING EVEN LINES ON A FOUR FIELD PRESENTATION A FOUR FIELD PRESENTATION MEANS A DISPLAY DEVICE WHICH IS TRIGGERED BY FOUR FIELD (15 Hz) INFORMATION

THIS DRAWING CORRESPONDS TO PROPOSED RS 170A VIDEO STANDARD

COLOR TIMING DATA
1 776 ns
INS = 1 289
FOR CABLE WITH 66% PROPAGATION FACTOR,
1 = 6.035" − 503'
INS = 7.77B" = 64B'




DETAIL XX




DETAIL ZZ

## ADVANTAGES OF A SYSTEM DESIGN USING SOURCE SYNCHRONIZING GENERATORS

1. **Independent Adjustment** of timing is possible by dedicating a source synchronizing generator to each source requiring external timing.

2. **Far Less Cabling** is needed since DAs are not required for separate pulse outputs. A single composite signal is sent from the master to the source generators. The source generators are located at the sources themselves which means connecting cables are very short.

3. **Devices driven by source synchronizing generators continue to function** in the event of master SPG failure.

# *System Design Using Source Synchronizing Generators*

Most of the difficulties encountered in system design can be avoided with a master/source sync generator system. This system provides maximum flexibility and the best SC/H phase stability. The approach below will be used with the same equipment employed in the previous delay system.

This time, rather than using the camera as the reference at the switcher input, the master synchronizing generator's color bars will be used. These color bars are fixed in their time relationship to the other outputs of the master sync generator and thus make a rock solid, SC/H phase-correct reference. All the sources still need to be in exact time at the switcher input. This time SC/H phased pulse drives will be provided to the camera and character generator by their own dedicated source sync generators.

The source synchronizing generator has the convenience of a single-line locking signal and output advance or delay relative to the lock reference provided. This results in a much simpler system to design and maintain that uses far less cabling. There is also redundancy in the system since the source sync generators will continue to freerun if the master should fail.

Camera 1 still requires drives which are advanced 850 nanoseconds to produce a timed, composite video output, but this advance will now come from the source synchronizing generator. The same is true for the character generator and video switcher, provided they each have a dedicated source synchronizing generator.

Final system timing is now a matter of looking at the switcher output and comparing each of the sources to the master sync generator's color bars. Each source sync generator is adjusted to time the source it is driving. If the source device has a subcarrier phase control built in, you should adjust horizontal phase using the source sync generator and subcarrier with the source device's SC phase control. This will establish correct SC/H phase and afterwards only the source sync generator should need adjustment. A SC/H phase meter will allow the source to be SC/H phased prior to adjusment of the source synchronizing generator for final timing.

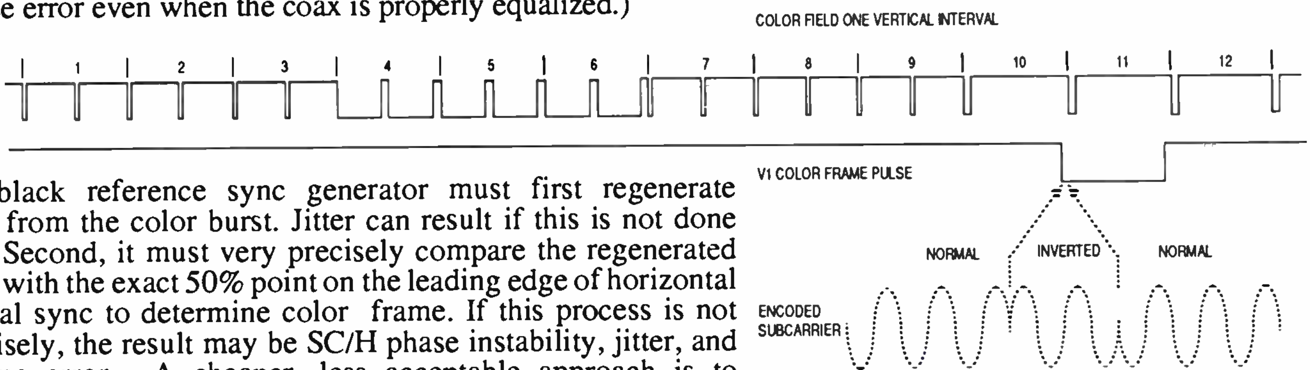
Sync and subcarrier for the 3240 Video Processing Amplifier should come from the switcher source sync generator. The source synchronizing generator on the video switcher could be removed and the video switcher and processor could be driven directly from the master sync generator. This would require that about 430 nanoseconds of delay be placed in the color bar path going to the switcher. This is the amount of delay required to generate switcher color black and background from the applied drives.

### Master/Source Reference Selection

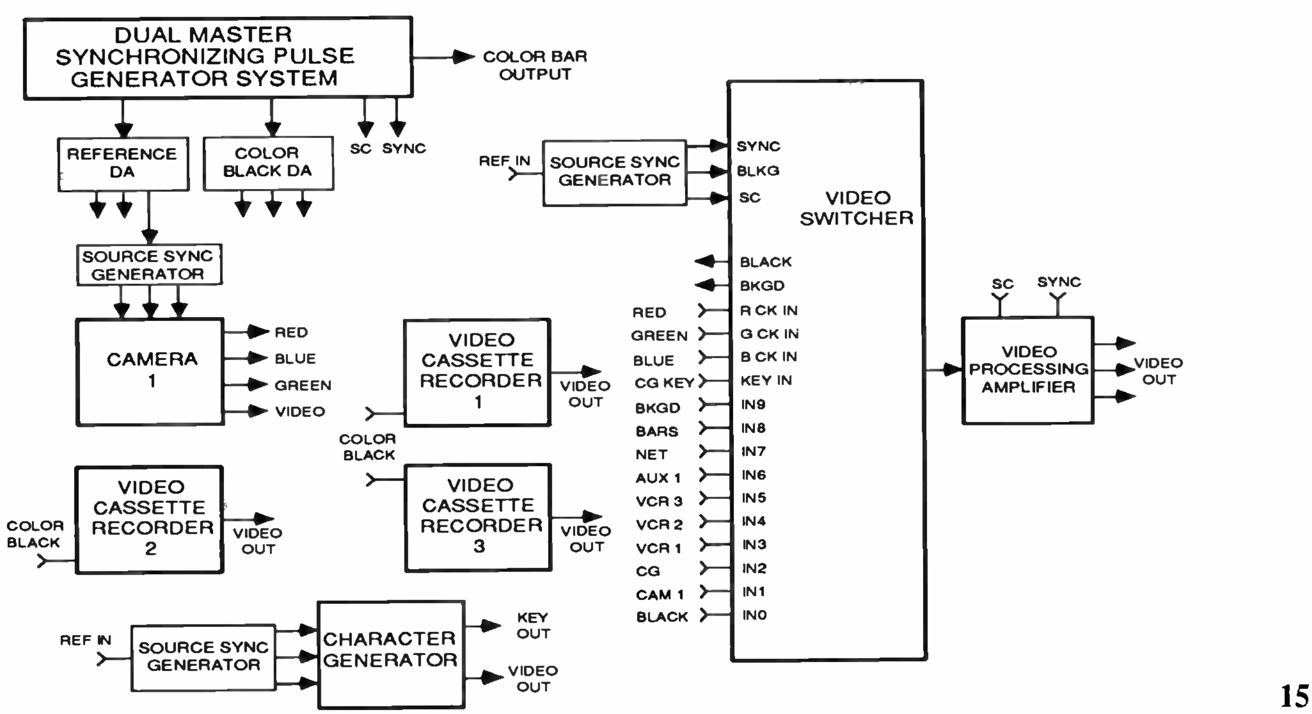
The single line reference signal for this master/source synchronizing generator system can be color black or encoded subcarrier. Grass Valley Group developed encoded subcarrier to improve and simplify the locking of source synchronizing generators. The encoded subcarrier signal consists of a continuous 3.579545MHz sine wave which contains two phase inverted cycles, once per **color frame**. This brief phase inversion is very precisely positioned on the front porch of blanking preceding line 11 on field 1 of the four field sequence. The phase inversion thus communicates horizontal, vertical, and color frame information to the source synchronizing generators. Encoded subcarrier provides a number of advantages over color black as a locking signal. Subcarrier does not have to be regenerated from the periodic color burst, so jitter becomes much less of a problem. Non-ambiguous color frame lock is guaranteed. Since encoded subcarrier is a single frequency, the **group delay** problem encountered with color black traveling through coaxial cables does not exist. (Group delay will cause large SC/H phase errors if the coax is not equalized, and some SC/H phase error even when the coax is properly equalized.)

**Color Frame**
In NTSC color television it takes four fields to complete one color frame. For a detailed definition, see page 18, SC/H PHASE.

**Group Delay**
A defect in a video signal caused by different frequencies having differing propagation delays (delay at 1MHz is different than delay at 5MHz). In the television picture, group delay will cause an object's color to shift outside the object's outline.




A color black reference sync generator must first regenerate subcarrier from the color burst. Jitter can result if this is not done precisely. Second, it must very precisely compare the regenerated subcarrier with the exact 50% point on the leading edge of horizontal and vertical sync to determine color frame. If this process is not done precisely, the result may be SC/H phase instability, jitter, and color frame error. A cheaper, less acceptable approach is to independently lock to sync and subcarrier. An independent locking sync generator cannot provide a color frame output because the color frame was never determined. The output SC/H phase will track reference input SC/H phase error. Sometimes SC/H error indicators are provided to help overcome these deficiencies.



## Multiple Studio Timing

The illustration on the facing page shows a three studio system in which the timing of entire source clusters and studios can be changed. This will allow one studio to feed any other studio in time. It will also allow for the priorities to change very easily.

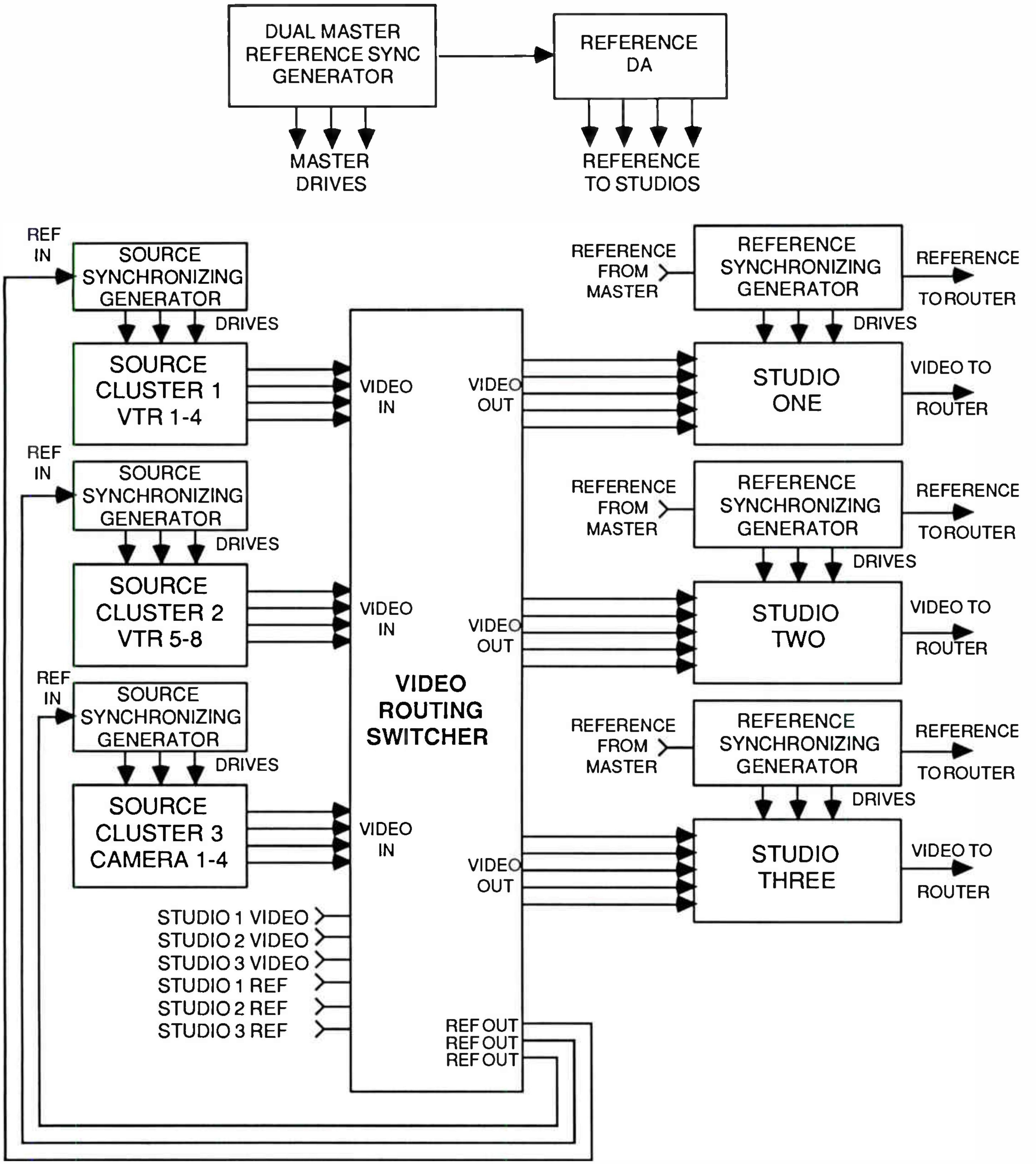
This entire system is being driven by a dual master reference synchronizing generator with an automatic changeover switch. This provides additional security since each master sync generator is powered from a different circuit. The master sync generators can have **ovenized crystal oscillator** options for higher frequency stability against temperature variations. An external frequency reference option allows a rubidium or cesium frequency standard to be used as the frequency standard, with the internal oscillator as a backup.

**Ovenized Crystal Oscillator**
A crystal oscillator that is surrounded by a temperature regulated heater (oven) to maintain a stable frequency in spite of external temperature variations.

Each of the three studios are similar to the one just designed. The studios have some dedicated source devices, with additional cameras and/or video tape machines that can be assigned. A routing switcher is used to assign these sources to the studios. Every studio output is fed to a routing switcher input for assignment as a timed input to another studio. Every studio is being driven by a reference synchronizing generator which will adjust the timing of that entire studio. Each source cluster is driven by a source synchronizing generator so the source cluster timing will stay together. The reference output from each studio reference synchronizing generator is sent to the routing switcher. The reference input to any source cluster synchronizing generator can be assigned to any studio. This automatically times the source cluster to the studio using it. If the reference synchronizing generator has a phase preset option installed, the phase setting for every configuration can be stored and recalled. A typical configuration could be Source Cluster 1 timed into Studio 1, the output of Studio 1 and Source Cluster 3 timed into Studio 2, Source Cluster 2 timed into Studio 3, which is also a timed input to Studio 2. These timing assignments can easily be interchanged with the phase preset option and routing switcher once the initial timing is completed and stored in each reference synchronizing generator.

This system provides maximum flexibility in tailoring each studio for the production it is to be used for. The cameras would be assigned to a studio doing live production and the video tape machines could be used for post production in another studio. Many more sources can be added with this design without causing major system design problems.

Distributed synchronizing generator systems also provide what may be and important advantage: redundancy. Should a failure occur in the master generator, the reference and source generators will freerun and thus the equipment being driven by them will continue to function.


DUAL MASTER REFERENCE SYNC GENERATOR
REFERENCE DA
MASTER DRIVES
REFERENCE TO STUDIOS
REF IN
SOURCE SYNCHRONIZING GENERATOR
DRIVES
SOURCE CLUSTER 1 VTR 1-4
REF IN
SOURCE SYNCHRONIZING GENERATOR
DRIVES
SOURCE CLUSTER 2 VTR 5-8
REF IN
SOURCE SYNCHRONIZING GENERATOR
DRIVES
SOURCE CLUSTER 3 CAMERA 1-4
VIDEO IN
VIDEO OUT
VIDEO ROUTING SWITCHER
STUDIO 1 VIDEO
STUDIO 2 VIDEO
STUDIO 3 VIDEO
STUDIO 1 REF
STUDIO 2 REF
STUDIO 3 REF
REF OUT
REF OUT
REF OUT
REFERENCE FROM MASTER
REFERENCE SYNCHRONIZING GENERATOR
REFERENCE TO ROUTER
DRIVES
STUDIO ONE
VIDEO TO ROUTER
STUDIO TWO
STUDIO THREE

## Section 3

# *SC/H Phase: Problems & Solutions*

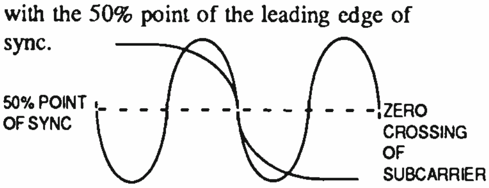
### Definition of SC/H Phase

In the late 1940s the Electronic Industries Association (EIA) established monochrome television standard RS-170. In recent years proposed color standard RS-170A has received increasing acceptance. RS-170A fully outlines the phase relationship of the color subcarrier to horizontal sync. A graphic representation of this standard is included on pages 12 - 13. If we look at the equation that relates horizontal sync to subcarrier and consider the number of lines in each frame, several conclusions can be made.

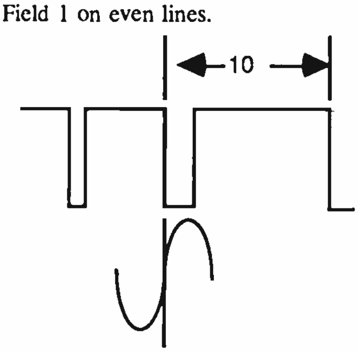
$$H = \frac{2 \times 3579545}{455}$$

First, there are 227.5 subcarrier cycles per horizontal line, so subcarrier phase reverses every line. This is desirable to reduce the visibility of color subcarrier on monochrome receivers. Second, with 525 lines per frame, there are 119437.5 subcarrier cycles each frame. This causes subcarrier phase to reverse every frame. Because of the extra half cycle of subcarrier, it takes two frames to complete one full four field color sequence, called a color frame. It is clear from the horizontal frequency equation above that horizontal is frequency locked to subcarrier, but it does not define the phase relationship between them. Proposed color standard RS-170A clearly defines **SC/H phase** as: the zero crossing of the extrapolated subcarrier of color burst shall align with the fifty percent point of the leading edge of horizontal sync. For color field one, the extrapolated subcarrier zero crossing will be **positive going** on even lines. This definition of sync to subcarrier phase (SC/H) is required for the unambiguous identification of the four field color sequence. The operational ramifications of these definitions are not obvious and require further explanation.

**SC/H Phase**
Alignment of the zero crossing of subcarrier with the 50% point of the leading edge of sync.




Reference subcarrier is **Positive Going** in Color Field 1 on even lines.




### Operational Importance Of SC/H Phase

The importance of SC/H phase lies primarily in the video tape editing environment. If during playback the video signal coming off the tape is not of the same color frame as the house reference, the video at the machine's time base corrector output must be shifted horizontally. The shift can be in either direction and be up to 140 nonoseconds (one half subcarrier cycle). This may result in loss of active picture and a widening of blanking since the output processor blanking is referenced to the house. Even if the off-tape video is of the correct color frame, the machine-output video will be shifted horizontally to a smaller degree in an amount equal to any SC/H phase difference between the off-tape and house video.

These horizontal shifts are troublesome in a tape editing environment, especially when editing scenes together of similar content. At the edit point the background will appear to jump horizontally. This is unacceptable and thus dictates the need for an entirely SC/H phased facility.

To insure the proper operation of the tape machine color framing circuits (to avoid incorrect color frame operation), the SC/H phase relationship of the video recorded on tape and house video must match. As a matter of uniformity correct SC/H phase is defined by RS-170A. It is important that all recorded video have a constantly correct SC/H phase relationship. The reference input to the tape machine should also be a stable SC/H phase source.

## Problems Achieving and Maintaining SC/H Phase

Subcarrier timing in a studio is a well understood concept in the industry; if it is not correct, there will be color hue shifts between sources. If sync timing is not correct, horizontal shifts will occur at the video switcher. The concept of SC/H phasing in a studio requires a higher level of thought regarding each element within the studio.

First, and most obvious is the house sync generator. If the sync generator cannot generate consistent SC/H phased outputs, maintaining SC/H phase in the plant will never be possible. It is equally important that all the sync generators in a multiple sync generator facility maintain correct SC/H phase and color frame relationships.

Once SC/H phase has been defined by the sync generator none of the elements in the system should alter the SC/H phase. Some elements are obvious like the video processor which regenerates sync and burst. If the phase of the regenerated sync or burst is different from the incoming video, the SC/H phase is altered. Less obvious are sources which derive timing from externally applied sync and subcarrier. If sync and subcarrier are fanned out through DAs, then their phase can be altered independently. This dictates the output of each source device be SC/H phased prior to or at the input of the switcher. There are many distortions which make the determination of color frame and SC/H phase difficult. The most prominent is sync to subcarrier time base error. This can be generated by many devices, such as sync generators with noise in the horizontal sync circuits, **linear and regenerative pulse DAs** which suffer from **pick-off jitter** or low frequency response problems, or any device that has separate sync and subcarrier regeneration circuitry.

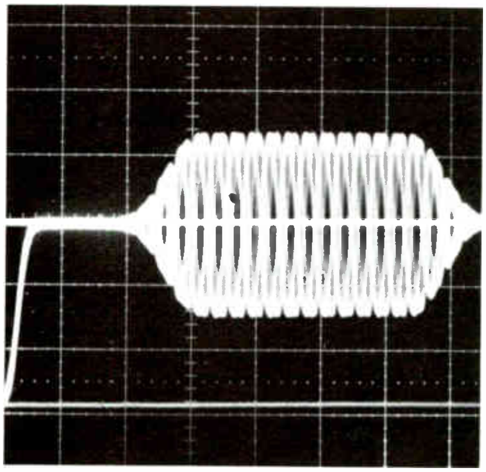
Noise, low-frequency smear, hum, and power glitches are distortions that may occur in signal transmissions. If these are not removed prior to sync separation, determination of the exact fifty percent point of sync will be difficult.

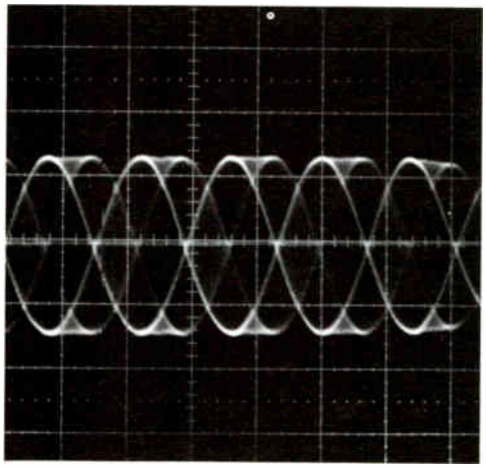
**Linear and Regenerative Pulse DAs**
Linear pulse DA will handle 4V p-p signals (pulses) but is limited to amplifying and fanning out the signal. Regenerative pulse DA reconstructs the signal and allows for adjustment of delay.

**Pick-Off Jitter**
Jitter is a random aberration in the time period due to noise or time base instability. Pick-off means sample point.

**Video Time Base Error**
Where all components of the video signal jitter (change in time) together in relation to another video signal.

**Sync To Subcarrier Time Base Error**
A random variation in the phase relationship between sync and subcarrier (see below).





**Video time base error** is different than **sync to subcarrier time base error.** Sync to subcarrier time base error is seen when triggering a scope on the leading edge of sync and viewing color burst. What should be seen are two overlapping cycles of subcarrier that are not blurred. An example of sync to subcarrier time base error is shown in the accompanying oscilloscope photos.

If sync to subcarrier time base error occurs either on the reference pulses to a tape machine, or exists on the recorded video tape, color frame lock will be difficult. In the normal playback mode, excessive sync to subcarrier time base error will cause the tape machine to shift horizontal lines by 279nS (subcarrier cycle) increments. This phenomenon is seen as a tearing of the picture.

## Building An SC/H Phased Plant

The first consideration must be the heart of every system, the synchronizing generator. The requirements for the sync generator should include the following:

1) Less than 1nS sync to subcarrier timebase error
2) Less than 10nS long term SC/H phase stability
3) Consistent SC/H phase regardless of operational mode or initial conditions
4) Compatibility with other equipment

Many studios use multiple sync generators to provide advanced drive pulses and subcarrier to various source equipment. Every source synchronizing generator must meet these requirements as well as being able to precisely color frame lock to the master reference synchronizing generator.

This need has been met by the 9500 Series Synchronizing Generators. The 9500 Series can address any system requirement, including both ultra precise encoded subcarrier locking and color black locking source synchronizing generators. Every model in the 9500 Series is unconditionally SC/H phased, whether locked or freerunning.

Every video locking 9500 Series Synchronizing Generator will lock to a non SC/H phased reference and produce correctly SC/H phased outputs. This is done by identifying color frame of the incoming video and assigning the nearest color frame. Once this has been achieved, the sync generator will tolerate SC/H phase drift beyond 100 degrees for the source synchronizing generator and over 330 degrees for the master. Should the incoming SC/H phase exceed the 100 degree limit, the source synchronizing generator will shift its horizontal phase by one-half subcarrier cycle to maintain color frame match to its reference. The master generator will shift its horizontal timing by a full subcarrier cycle should the 330 degree limit be exceeded and thus not change color framing. A stable reference is ensured under any condition.

The 9510 and 9520 Master Synchronizing Generators feature protected video genlock. In this mode the generator achieves color frame lock and then maintains frequency lock to the color burst of the incoming video only. This mode provides immunity to incoming jumps in video sync which would otherwise cause severe perturbations in the generator's output. The transition out of protected video genlock into free run will occur if the burst abruptly changes phase, dissappears, or there is a complete loss of video. The transition to freerun will be smooth and not disturb the plant.

Every model in the 9500 Series has a wide retiming range of 2.5 lines advance to 1.5 lines delay. Output SC/H phase is correct at any timing setting. A one line wide color frame pulse which occurs on line 11 of field one of the color frame is available on every model. This color frame pulse provides absolute, positive identification of color framing to all equipment in the plant that will accept it. All pulse outputs are negative going four volt peak-peak and are shaped.

The 9505 Source Synchronizing Generator is available for either color black reference or ultra precise encoded subcarrier reference. Both models are unconditionally SC/H phased and have superior performance specifications.

Test signals are optional in every 9500 Series Synchronizing Generator. An optional Source Identification submodule can be added to the Test Signal Generator module to place up to a 14 character identification over the test signal output. This identification is also positionable both vertically and horizontally.

The 9520 will accept two Test Signal Generator/Source Identification options, a High Stability Ovenized Crystal Oscillator option, and an External Frequency Reference option. The External Frequency Reference option permits the 9520 to frequency lock to an external 3.579545, 5.0, or 10.0MHz atomic frequency source for superior timebase stability.

The 9510 has a phase preset option that will store 16 different phase settings in a non-volatile memory. These can be recalled via local or remote control. This option permits retiming of a source device or entire studio with a single binary control.

## Conclusions

To achieve an SC/H phased plant, the timing of sync becomes as important as subcarrier, and each element should be viewed in that light. To aid video tape editing, it is important to record video with proper SC/H phase and also supply SC/H phased reference to the machine in playback. These criteria do not have to be compromised with the system approach offered by the Grass Valley Group.

# *Measuring SC/H Phase*

The SC/H (subcarrier-to-horizontal) phase is the time relationship between the subcarrier and the leading edge of horizontal sync. A properly adjusted SC/H phase occurs when the 50% points of the leading edge of sync and the subcarrier zero crossings are coincident.

The color frame pulse (V1) appears on line 11 of field 1. V1 identifies field 1 of the 4 field color sequence.

## Test Equipment Required

The following test equipment is required to perform the SC/H phase measurement procedure. Equivalent test equipment may be substituted but must be equal to or superior in performance.

| | |
|---|---|
| Dual Trace Oscilloscope (with delayed sweep and one channel input inversion) | Tektronix 465 |
| Switchable Delay Line or Subcarrier Delay DA (360° range) | Mathey 511 |

## Test Procedure

### SC/H Phase Measurement

1. Connect a video source requiring SC/H phase measurement to the inverting channel of the oscilloscope.

2. Connect subcarrier (3.58 MHz continuous) to the second channel of oscilloscope.

3. While observing the oscilloscope (triggered at a horizontal rate), adjust subcarrier to match amplitude of burst.

4. At the oscilloscope, invert the video display and set mode to alternate sweep.

   Figure A shows inverted video (top) and continuous subcarrier (bottom).

5. Adjust the oscilloscope for A plus B mode.

6. Adjust subcarrier phase and fine level at the generator or delay line for a null at burst as shown in Figure B.

7. Adjust the oscilloscope for chop mode, non-inverted video, and adjust vertical positions to exactly overlay subcarrier and sync.

8. Adjust the oscilloscope delayed sweep for a display showing the leading edge of sync and the subcarrier. A proper phase relationship requires coincidence at the 50% points of the leading edge of sync and the subcarrier zero crossings. See Figure C. An improper phase relationship is shown in Figure D.

### Color Frame Pulse (V1) Identification

9. Adjust the SC/H phase as described in steps 1 through 8, for proper coincidence.

10. Trigger the oscilloscope on the leading edge of the V1 pulse with video and subcarrier connected to the two input channels. See Figure E.

11. Increase the oscilloscope sweep rate and, using the delayed sweep option, view a display showing the first leading edge of sync following the trigger.

12. If the negative transition of the subcarrier is coincident with the leading edge of sync, the triggering V1 pulse is a color frame identification pulse that occurs on line 11 of field 1. See Figure F.

**NOTE:** The SC/H phase is easiest to observe on a display that is horizontally triggered. Because of the low repetition rate of V1 and the fast sweep rates (50nS/div.) required, only the direction of subcarrier signal can be easily observed by triggering on V1.

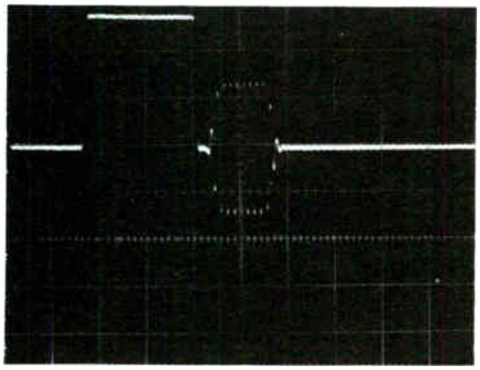


*Fig. A*

INVERTED VIDEO

CONTINUOUS SUBCARRIER

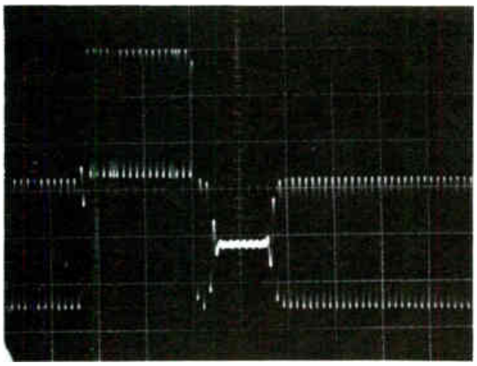
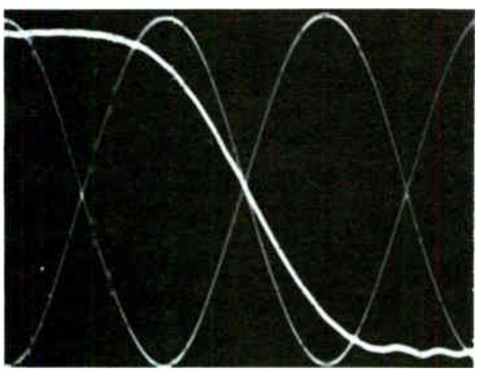


*Fig. B*



SUBCARRIER

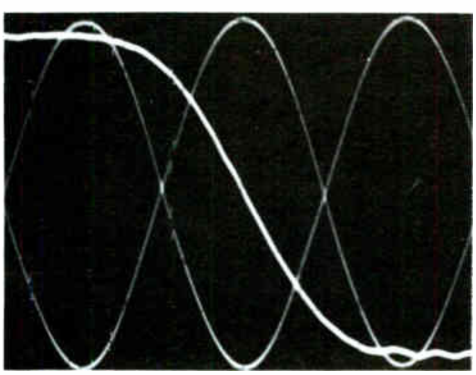
*Fig. C*

CORRECT SC/H PHASE

COINCIDENCE AT 50% POINT OF LEADING EDGE OF SYNC AND SUB-CARRIER ZERO CROSSINGS.

(50nS/Div.)

LEADING EDGE OF SYNC



SUBCARRIER

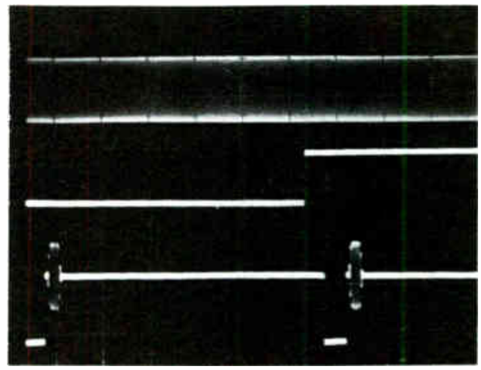
*Fig. D*

INCORRECT SC/H PHASE

NON-COINCIDENCE AT 50% POINT OF LEADING EDGE OF SYNC AND SUB-CARRIER ZERO CROSSINGS.

(50nS/Div.)

LEADING EDGE OF SYNC

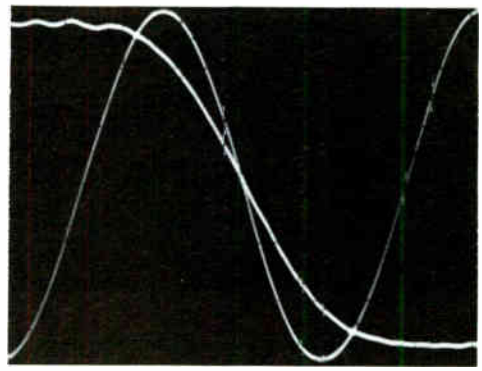


SUBCARRIER

*Fig. E*

V1 PULSE (TRIGGER VIEW)

VIDEO



SUBCARRIER

*Fig. F*

COINCIDENCE

(50nS/Div.)

LEADING EDGE OF SYNC

## Figures

A: Inverted Video and Continuous Subcarrier
B: Subcarrier Phase Adjusted for Null at Burst
C: Properly Phased SC/H Signal
D: Improperly Phased SC/H Signal (70 phase error)
E: Subcarrier, V1 Pulse, and Video Display
F: Leading Edge of Line 11 Field 1 and SC

## NTSC REFERENCE TIMING DATA

| | |
|---|---|
| Subcarrier Frequency | 3.579545MHz |
| Subcarrier Period | 279.37nS |
| Horizontal Frequency | 15.734264KHz |
| Horizontal Period | 63.556µS |
| Vertical Frequency | 59.94Hz |
| Vertical Period | 16.683mS |
| Vert. Equalizing Pulse Width | 2.3µS |
| Horizontal Sync Width | 4.7µS |
| Horizontal Blanking Width | 10.9µS |
| Vertical Sync Width | 27.1µS |
| Vertical Blanking Width | 21 lines |
| Front Porch Width | 1.5µS |
| Breezeway | 0.6µS |
| Burst Width | 2.5µS |
| Color Back Porch Width | 1.6µS |

Color Timing Data:

1° = .776nS

1nS = 1.289°

For Cable With 66% Propagation Factor

1° = 6.035" = .503'

1nS = 7.778" = .648'

Zero SC/H phase is the coincidence of the zero crossing of a subcarrier the same phase as color burst with the 50% point of the leading edge of horizontal sync. On color frame one, the subcarrier zero crossing will be negative going on odd numbered lines.

**Your Feedback Is Appreciated.**

Please give us your corrections, additions, and suggestions for improving this booklet. Send to:

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