PRINCIPLES OF DIGITAL SYNCHRONISERS FOR VIDEO SIGNALS

Introduction

A digital synchroniser stores the incoming non-sync video as digitally-encoded samples. Usually, either one or two fields can be stored at a time.

After the necessary delay to match the timing of station reference pulses and subcarrier, the video is read out synchronous with the local sources camera's; T.K.s, etc.

1. Choice of Component or Composite PAL

Two methods of storing colour video may be used. Firstly, if the PAL waveform is decoded to its Y, U, and V component video waveforms, then each one can be separately sampled, converted to digits and stored (effectively in three separate stores).

At the store output, the three component waveforms are PAL-coded using station pulses and colour sub-carrier. Two fields of storage are used to hold the two types of input field.

The second approach involves sampling and storing the Composite PAL waveform, without decoding. This removes the possibitily of a loss of quality in the PAL decode - re-code process used in the first method, but adds the complexity that the store input waveform has an eight-field sequence. It is not practicable to use an 8-field store, and techniques are used to reduce the required storage area to two fields, or one field. (Framestore or Fieldstore).

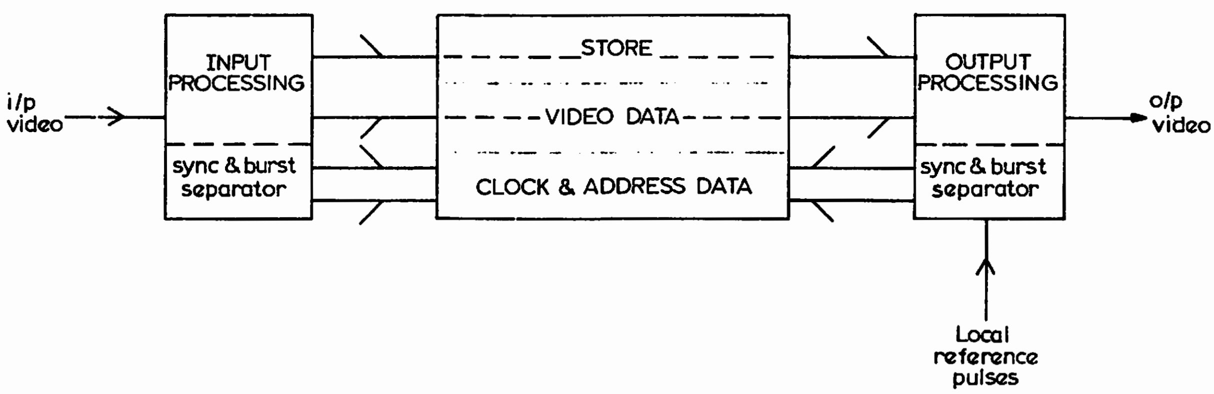

Fig. 1 Generalised Store Block Diagram

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1.1 Y.U.V. Component Store

The store must be capable of handling three video waveforms:-

Y, bandwidth 5.5MHz
U, bandwidth 1.5MHz
V, bandwidth 1.5MHz

and the reason why R.G.B. storage is not used becomes apparent. The reduced bandwidth of U and V enables a lower sampling frequency, and therefore a smaller store size, than if handling three 5.5MHz R.G.B. signals.

Broadcasters have agreed to use sampling rates of: Y ... 13.5MHz, U ... 6.75MHz, V ... 6.75MHz. (Earlier equipment may use lower sampling rates for U and V, since in theory only about 3.3MHz is required).

Using the agreed sample rates, two identical stores may be used, both working at 13.5MHz. One handles luminance; the other handles interleaved, or multiplexed, U and V samples. (U,V,U,V,U,V etc.)

The PAL-decoder at the input must have an excellent separation of luminance and chrominance, and must ensure that there is no time shift of one relative to the other.

For example, a PAL-D decoder separates U and V with a 1-line delay, which averages two lines of vertical chrominance information, reducing resolution and changing the vertical chrominance timing, w.r.t. luminance.

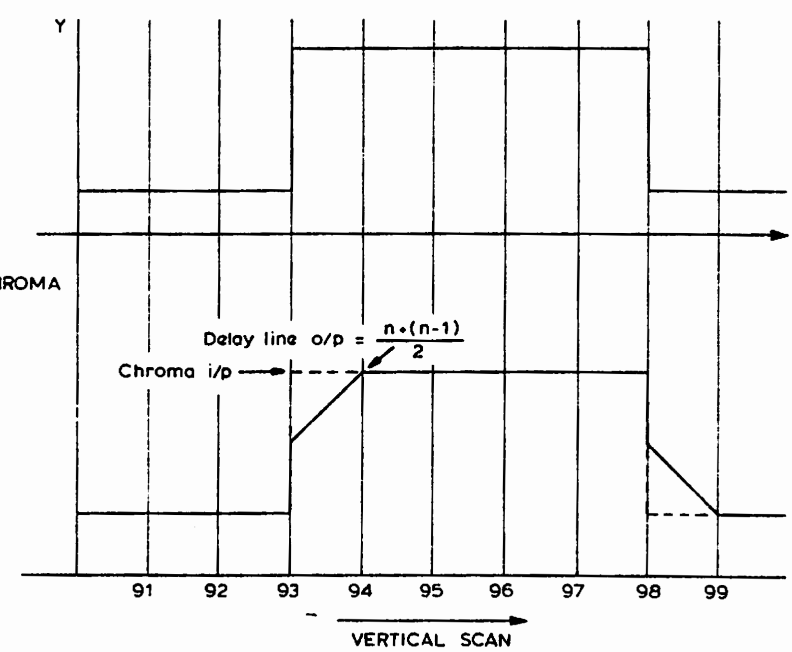

Fig. 2 Effect of PAL-D decoder on Vertical Timing

In addition, all residual CSC must be removed from the luminance, Y, signal, so that it cannot affect the PAL encoder at the store output, and give rise to 'PAL Footprint'.

1.2 Composite PAL Store

The PAL composite waveform has an eight-field sequence. Looking at a chosen point along any one line of the monochrome picture sequence (two fields), it will take 8 fields before the CSC phase and VAS polarity are once more the same at this point.

To be sure of being able to read the correct one of the 8-fields for any input field phase, 8 fields of store are needed, about 14.4 M bits! Worse still, the maximum store delay is about one sixth of a second, ie 4 frames out of lip-sync with the accompanying sound.

14.4 M bits in an 8 field store? - Assume 8-bit encoding of each sample; 3 x CSC sample rate, 13.3 MHz; and each field will take 1.8 M bits if the blanked parts are not stored.

2. STORE SIZE REDUCTION - The Composite PAL Store

In theory 8 fields of store would be required. However, the PAL signal is identical at any point in a chosen line of fields 1-4 with the corresponding point in fields 5-8, EXCEPT that the colour subcarrier phase is 180° different. i.e. if the picture information in fields 1-4 were read out 180° of CSC late (or early), a time shift of 113ns, it could be used as that of fields 5-8. (NOTE that since CSC to-line phase is not defined accurately in the PAL system, some re-timing of the CSC phase on the input signal would be necessary, even if the line and field timing of the input and output were identical, since the input and output signals come from two different sync pulse chains).

Using a 4-field store

If Field 4 were currently being written into a 4-field store, and a field 5 was needed at the output, then the stored field 1 would be read out, but time-shifted by 113ns relative to output syncs. The stored field 2, also shifted by 113ns, would be read out next as field 6, and so on, giving a constant picture shift to the right (or left) relative to the new (station) syncs added at the synchroniser output.

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2.1 How May we Get Away with only 1 Frame or 1 Field of Store

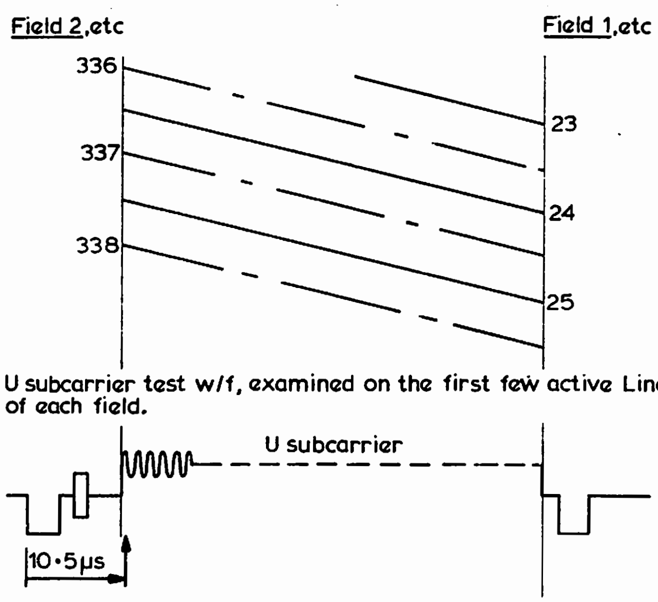
Once the idea of a slight overall shift of picture information has been accepted (approximately 0.17%), in the horizontal direction; it is easier to accept a possible vertical picture shift of say 1/2 line. (Approximately 0.18%).

Using a 2-field Store

If a field 4 is required when fields 1 and 2 are in store, field 1 can be read out as a field 4, field 2 as field 5 etc., giving a constant downward vertical shift of 1/2 line in each case since we are reading out the interlace field. See Fig. 2.

If we use only one field of store, it is possible by shifting the stored information by ± 113ns horizontally, or ± 1 line vertically, to convert any field in the store to a field 1, 2, 3, etc. at the output. If the two s.p.g.s are running at the same frequency, the shift will remain in a constant direction to convert any i/p field to a desired o/p field.

The drawing that follows describes the sequence followed by VAS and colour subcarrier phase, relative to a line rate edge, on the first few active lines of each field. To examine the CSC-to sync phase, a signal containg +u subcarrier (no V) is being processed and we look at say, a point exactly 10.50µs after the leading edge of sync, (ie just inside active line time).



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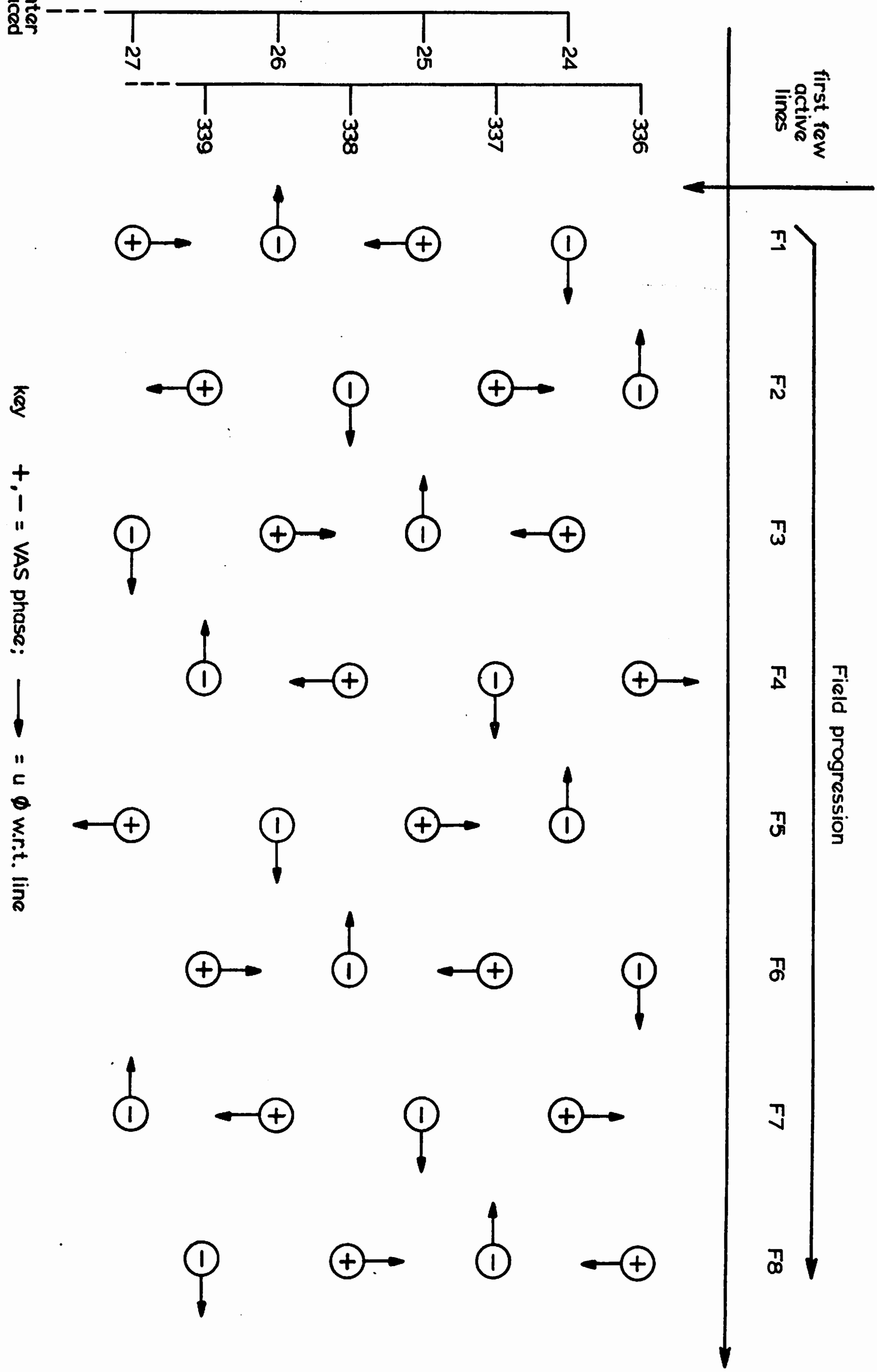

Figure 2. CSC & VAS sequence relative to sync pulses

3. COMPOSITE STORAGE USING 3 X COLOUR SUBCARRIER FREQUENCY SAMPLING

Each active line is sampled at 3 x subcarrier frequency, and the analogue voltage encoded as an 8-bit word. There are 283 3/4 cycles of subcarrier in each line period, giving approximately 851 sampel points per line. However, this includes the line blanking period, with syncs and burst, which can be regenerated at the output of the store from station pulses.

It is possible therefore to reduce the nuamber of sample points, e.g. to 768 per line (a factor of 3 x 256, ie 3 x 2^8, which should make store organisation easier. Only about 6µs of the line time is not stored (238 3/4 - 256) = 27 3/4 cycles of CSC. ie 6.24µs). This means that some of the back porch is stored, which is vital for a SECAM version, since the SECAM reference must be stored with each line. (Secam uses line-locked clock).

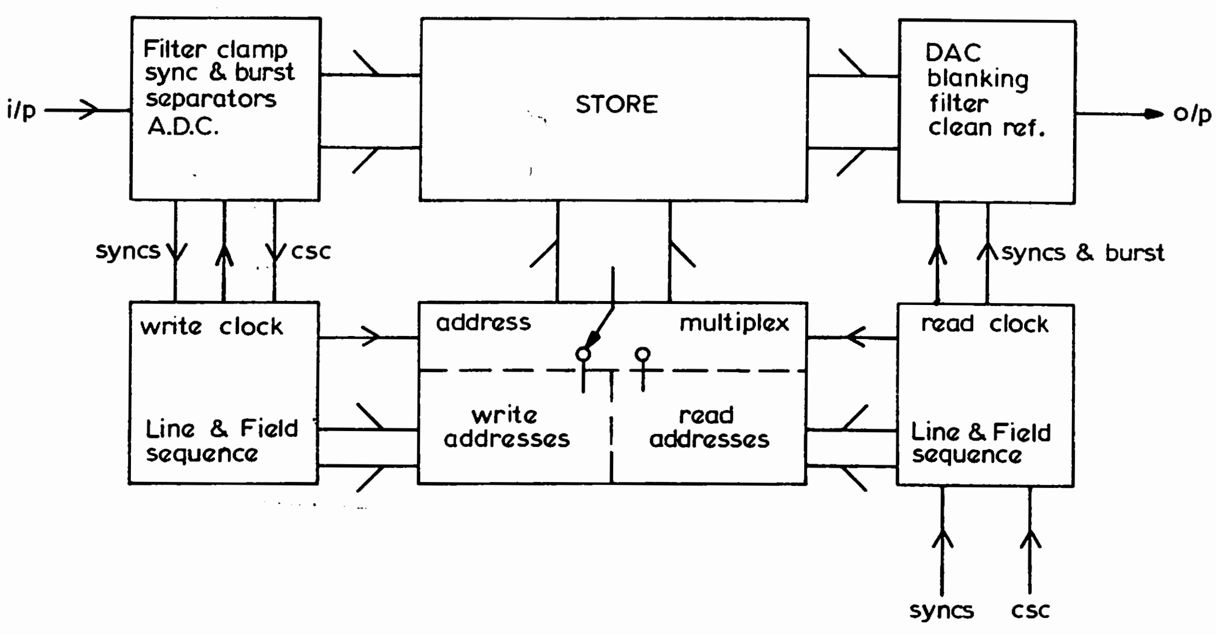

Fig. 4 Simple Synchroniser Block Diagram

The subcarrier from the input signal is used to derive a 'write clock' at 3fsc to command the A-D converter to convert a new sample, and the store to provide a new storage location for the 8-bit encoded sample.

Station 3fsc commands a read operation for a new location, and enables the DAC to produce the new analogue sample.

3.1 Change in the input to output field offset - HOPPING

The incoming and outgoing subcarriers may be different in frequency (±1HZ tolerance for PAL). If the incoming is high relative to station, the store is being written into faster than the read process is using the data. The store will fill up, until a point occurrs when the next input field has to be written over information that has not yet been read out. This over-written field is lost causing a temporal hop, which can be seen as a momentary jerk in moving parts of the picture.

Now the output-field offset has also changed, which may require a shift of CSC phase by 180°; or a vertical shift of 1/2 line with a 2 field store, or 1 line with a field store. So a picture shift across, or up/down or both also occurs.

The input subcarrier is slow relative to output, the store will gradually empty and, to satisfy the output need for data, are input field will be read out twice, causing a momentary temporal freeze and a pciture displacement to correct output timing with the new field offset between input and output.

The use of a picture offset in the H or V direction means that the blanking is lengthened in one part of thescreen and shortened in the other. For example, a right shift of 113ns shortens front porch by that amount, and lengthens back porch. To avoid this fore-shortened front porch, the output video is correctly re-blanked relative to output syncs.

The final output picture will have an active line length which is shortened by 113ns. In the vertical direction, one line could be lost during re-blanking at the output. Aftetr several passes through synchronisers, cumulative shifts could cause a serious reduction in active picture area, which is especially noticeable when using wipes or decoded CSO.

4. Comparison of Composite and Component PAL Synchronisers

SPECIFICATION	COMPOSITE PAL SYNCHRONISER	COMPONENT Y.U.V. SYNCHRONISER
Colour and Mono Operation	Sub-carrrier locked sampling PAL. Line locked sampling SECAM and Mono.	Line locked sampling all standards.
Store Size	Min. storage capacity 1.8 MBits	Min. storage capacity 3.7 MBits.
For all relative i/p to O/P Field relationships.	Up to 1.5 lines vertical shift and 1 cycle sub-carrier horiz. shift relative to blanking.	No shift of output picture for all conditions.
NON-SYNCHRONOUS CUTS position shift.	Possible picture possible shift Multiple field locking time.	No shift of picture Fast locking - typically one field.
GEN-LOCK Response to non-mathematical PAL on i/p or o/p.	Shifts or cycle hopping to input and reference gen-lock.	No picture disturbances for gen-lock on input or reference.
CODING STANDARD	Direct 8-bit coding of composite colour signal	8-bit coding of Y, V, and U gives equivalent of 9-bit composite coding.
QUANTISATION ERRORS	Signal/Noise Ratio 48dB Diff. Phase and Gain 2.5° & 4.3%.	Signal/Noise Ratio 54dB Diff. Phase and Gain 1° & 2%.
SIGNAL PERFORMANCE	Marginal for main path use.	Meets main path requirements with high performance color decode and recode.
VIDEO SPECIAL EFFECTS	No - without additional colour decoding & larger store.	Yes to same level of performance as synchroniser.
T.B.C. OPERATION	No - without additional decoding or other input processing.	Yes.
TRANSCODING	No.	Yes.
INTERFACE COMPATIBILITY	No direct compatibility	Yes - at decoded analogue or digital component level.

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19th July 1982