PAL CODING REVISION

This information sheet revises the basic system and techniques used in PAL coding, but carries on to show the procedure for adjusting the preset controls on a coder and decoder. The effects of faulty line-up of these controls, and the test signals used to reveal line-up errors are also discussed. Block diagrams for a PAL coder and PAL decoder are provided at the back.

1. The Story so Far

PAL coding and decoding is used to reduce R, G, B & Syncs to one wire for distribution and transmission, and afterwards to recover the R, G, B & Syncs for the colour display. The usual input to a coder comes from a camera (or TK), and the monitor or receiver amplifies the decoder outputs to feed an R, G, B display tube.

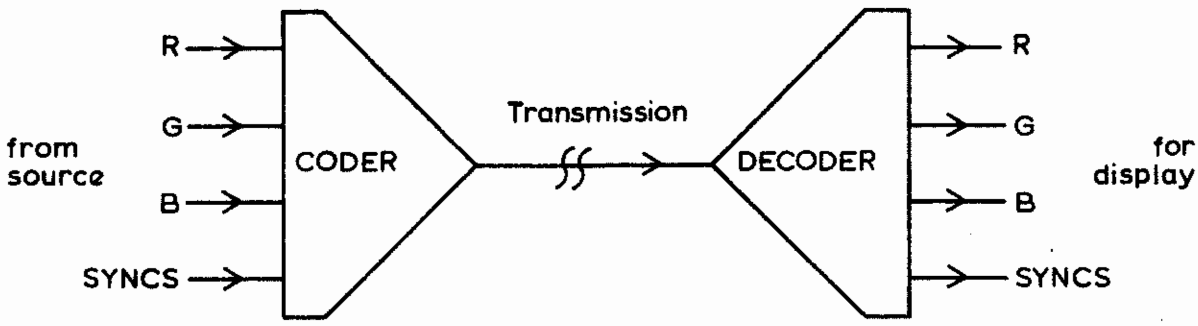

Fig. 1.1 PAL Codec

Remember that a Plumbicon camera tube gives a linear transfer of light intensity into signal output, but that the camera includes pre-correction for the display tube (gamma). The R, G & B signals sent to the coder have a non-linear relationship to the incident light on the R, G & B camera tubes.

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If the camera in fig. 1.1 were focussed onto a black and white card, where the reflectance of the white area gave peak white illumination at the camera tubes, then a correctly lined-up camera would give

R=G=B=0 for the black area

R=G=B=0.7V for the white area

To avoid awkward fractions of a volt in any calculations, assume

0.7V = 100% signal

2. COLOUR BAR TEST SIGNALS

Connect 100.0.100.0 colour bars to the coder input. (100% bars)

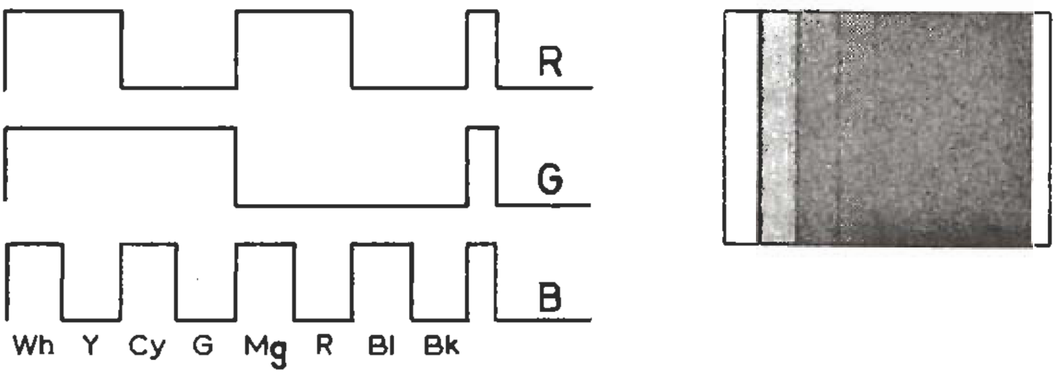

Fig. 2.1 R, G & B Waveforms for 100% Bars

100	.	0	.	100	.	0
white level		black level		colour on		colour off

Now connect EBU bars (100.0.75.0)

100 . 0 . 75 . 0

Input R, G, B is 100% amplitude for the white bar, but drops to 75% for the coloured bars.

Now connect 95% bars (100.0.100.25)

100 . 0 . 100 . 25

This gives a 25% electrical desaturation to the colour bars. The R, G, B decoded outputs will however drive the guns of the display tube with their gamma of 2.something! (2.6 - 2.8)

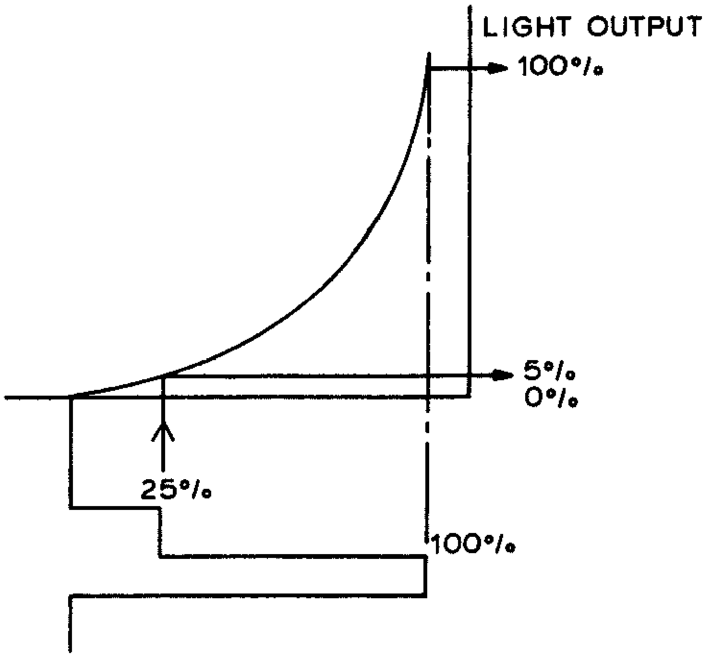

Fig. 2.2 25% Signal Operated on by the Display Gamma (Value of 2.0 used for simplicity)

Unless the brightness control of the display is set correctly, it will be difficult to see this slight desaturation.

3. THE LUMINANCE SIGNAL IN THE CODER

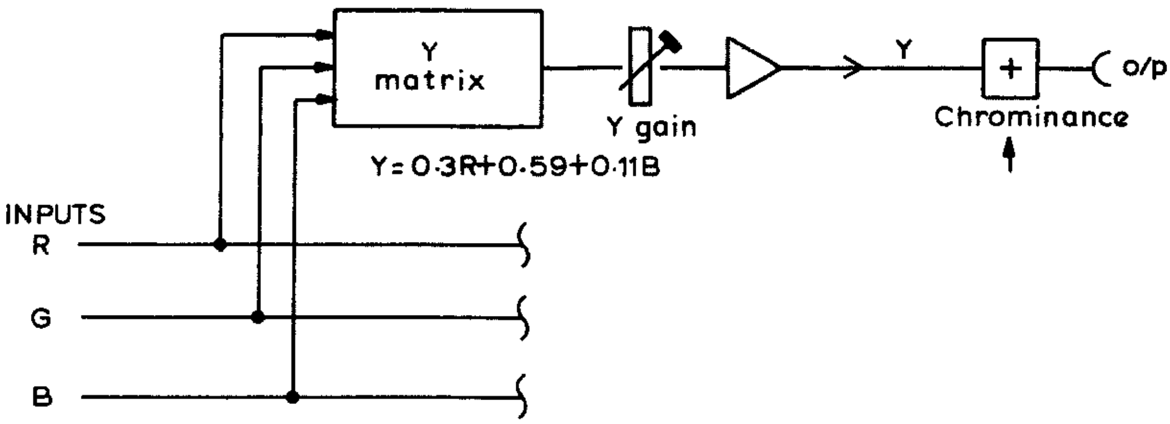

Fig. 3.1 Derivation of the Y Signal

Check Y matrix? Apply R, G & B individually to check 0.3, 0.59 and 0.11 fractions.

Check Y gain? For white bar, R = G = B and also = Y, ie 100%. Sym coder i/p and o/p on the white bar.

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NOW switch the camera to the coder, and zoom in on a white card. The Y signal is now 100% output, with blanking, as shown in fig. 3.2.

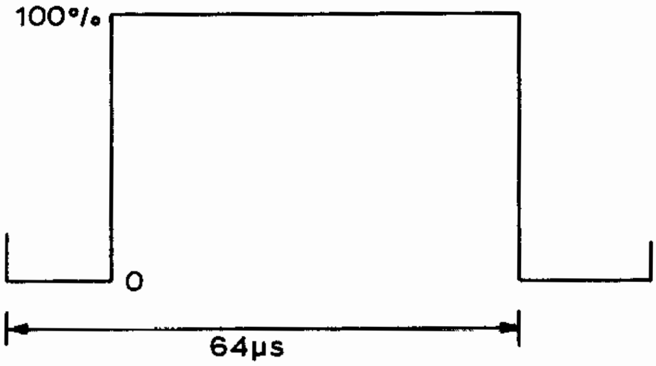

Fig. 3.2. Line-rate Y Waveform for Peak White

This is a rectangular waveshape, repeated at line rate. There is a dc component, proportional to average brightness, and a line-rate fundamental + harmonics in the spectrum plot.

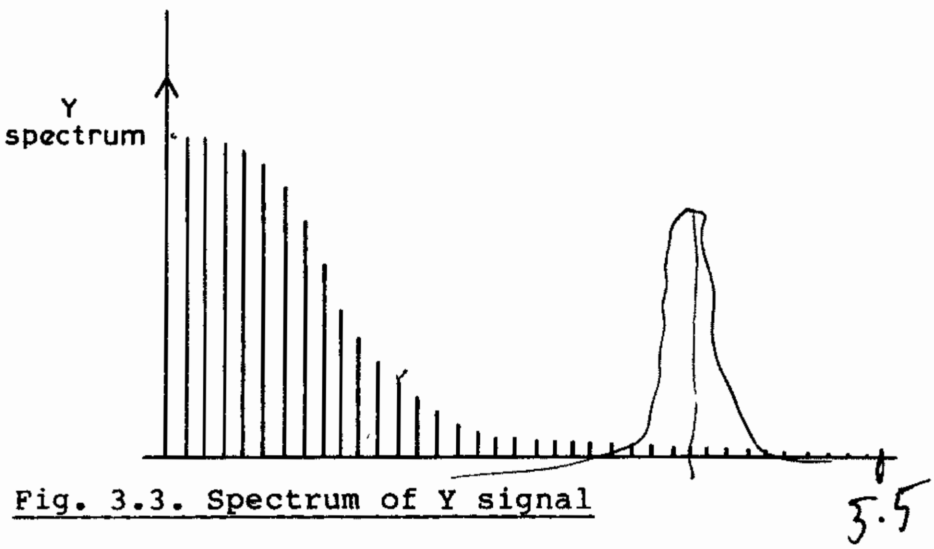

Fig. 3.3. Spectrum of Y signal

It has high energy at the lf end, corresponding to basic platform levels; and low energy at hf corresponding to edges and detail.

The line-rate Y waveform is also modulated by a field-rate rectangular waveform (field blanking) which turns it on or off at field rate, (for a full-field white). In a typical scene, the field-rate modulation depends on picture content.

The final spectrum must show each of the components due to line-rate repetition (above) as having sidebands at field (& picture) frequency around it, due to field blanking and scene movement.

Any stationary vertical lines in the picture must be due to a multiple of the line frequency being present in the spectrum.
Any horizontal bars in the picture must be due to a multiple of field frequency.

If not locked to field, the pattern will move up and down, if not locked to line the pattern will move sideways.

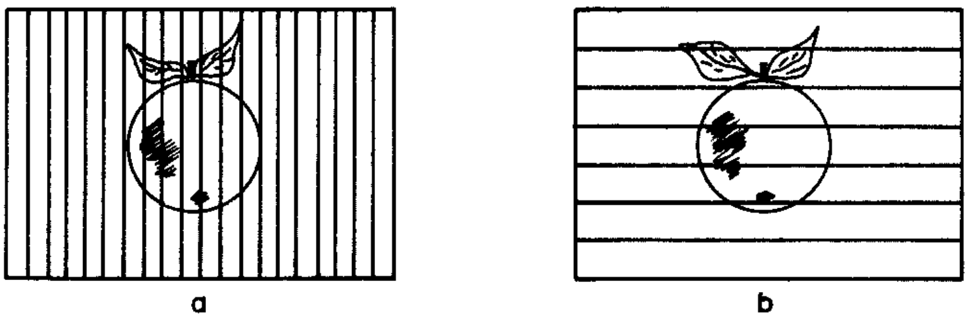

Fig. 3.4 Patterning due to a. N x line, and b, N x Field Frequencies

4. COLOUR DIFFERENCE SIGNALS IN THE CODER

Transmit R-Y and B-Y because G-Y is the smallest (Y=0.59G)

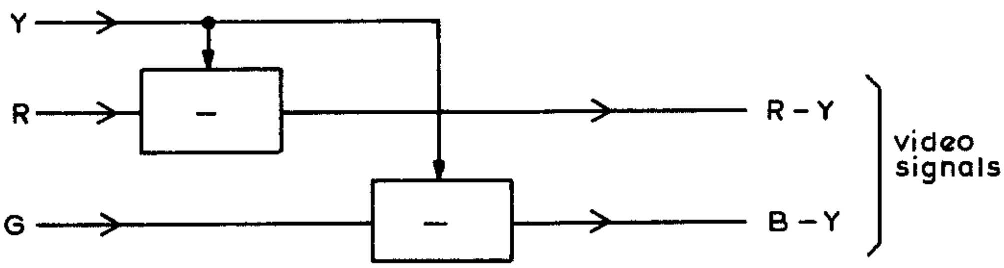

Fig. 4.1 R-Y and B-Y Matrices

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R has a range 0-100%: Y has a range 0-100%, R-Y has a range of ± 70%.

Similarly, B-Y has a range of ± 89%.

(If in doubt, take each 100% fully-saturated colour and calculate Y, R-Y, and B-Y.)

4.1 U and V Deriviation WEIGHTING

B-Y video is attenuated by 0.493 to become U video.

R-Y is attenuated by 0.877 to become V video.

Both signals are bandwidth-limited in the coder to 1.3MHz.

The envelope of the chrominance (U and V modulated onto subcarrier? for 100% saturated colour bars occupies an amplitude range of +133% (yellow and cyan) to -34% (red and blue), relative to the Y range.

4.2 Chrominance Modulators

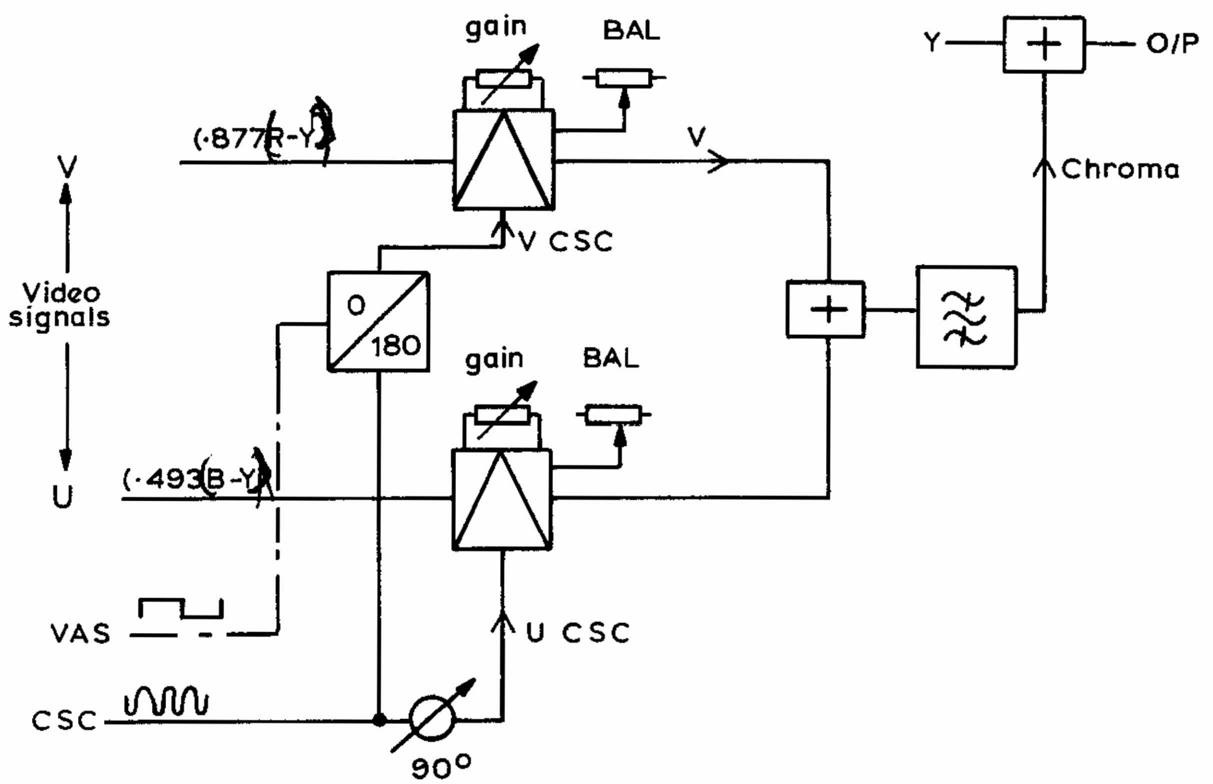

Fig. 4.2 U and V Modulation

Each modulator is a switch operated by the carrier. It switches between the i/p signal (eg U) and an inverted version of the i/p on alternate carrier half-cycles.

Being video signals, U and V must carry a dc component and are clamped before modulation. During blanking, U=0 and V=0, so each modulator should give no output for correct suppressed carrier modulation. This is carrier BALANCE. A modulator looks like fig. 4.3 in schematic.

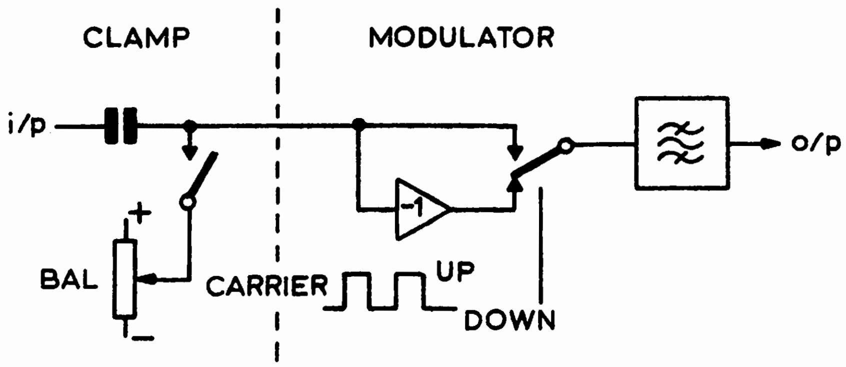

Fig. 4.3 Modulator Schematic

(N.B. A suppressed-carrier modulator gives out zero carrier for zero modulating input. It COULD be made using a normal a.m. modulator, and subtracting a fixed amplitude of neat carrier from the output. This technique produced what was called a 'balanced modulator', since the carrier had been balanced out! The name, if not the construction, has stuck for all supressed carrier modulators.)

The Chrominance signal is the phasor sum of u (u = U.cos wt) and v (v = V.sin wt)

Set 90 error?

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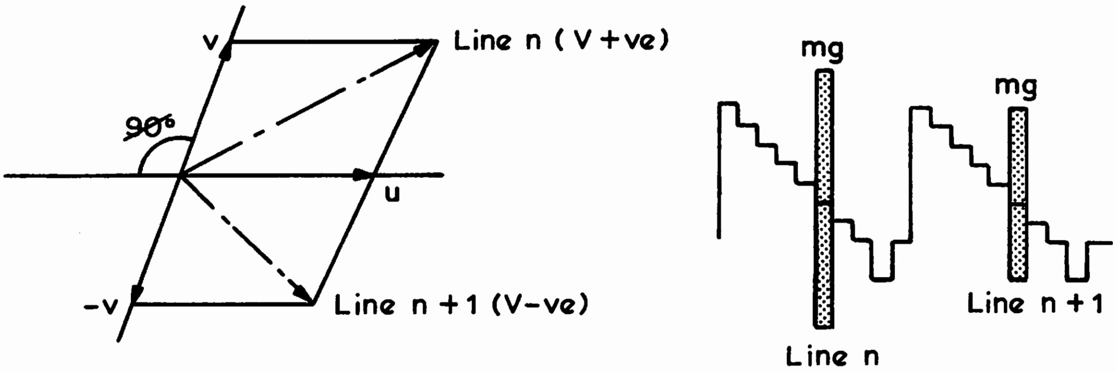

Fig. 4.4 Set 90 error, Effect on Vectors and Waveform

Result:- Hue errors, + ?

Set 180 error?

4.3 Burst Generation

Why is burst inserted as a pulse into the U and V video's prior to modulation?

Don't want two sets of modulators to line-up! That's asking for burst/chroma phase errors. Using the same modulators, burst is correctly related to chroma.

Burst amplitude? Overall amplitude of the shaped burst-gate signal. Burst 90? Preset relative amplitude of burst U to burst V.

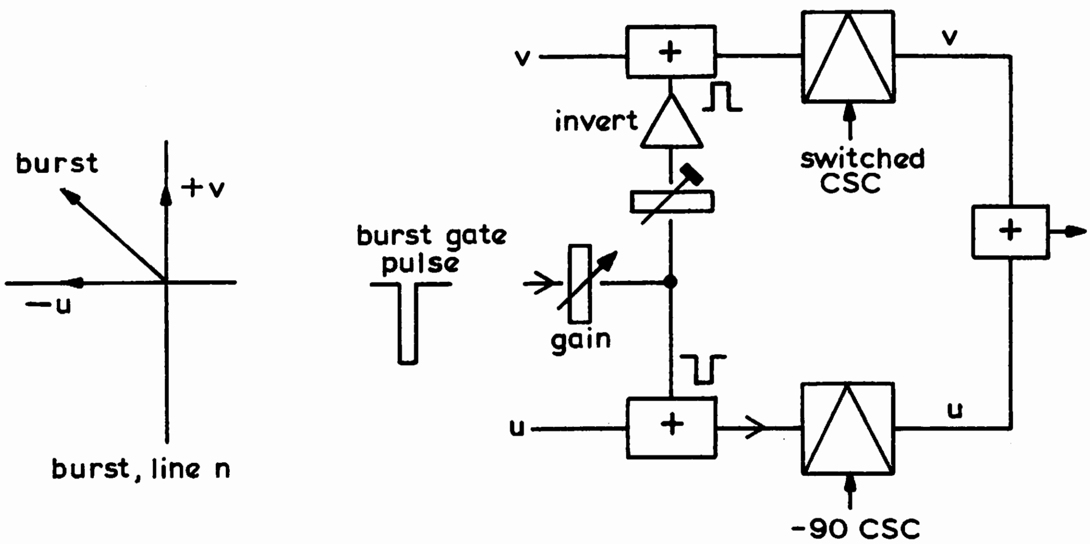

Fig. 4.5 Generation of the Burst

5. CHROMINANCE SPECTRUM AND ITS INTERLEAVING WITH LUMINANCE

B-Y (and therefore U) is a video waveform having a spectrum with a dc component and line-rate fundamental + harmonics, modulated at field rate.

When modulated onto a carrier, this spectrum is arranged symmetrically about the carrier frequency.

R-Y (and V) would be the same except for the PAL inversion at 7.8kHz. Looking at fig. 4.2, the 0/180° inversion is done on the carrier i/p, but would have the same effect if applied to the V signal i/p. A suppressed carrier modulator produces sum and difference frequencies from its two input signals, and the 0/180 switch is simply another balanced modulator.

The dc of the V video becomes a ±7.8kHz, and every other component is shifted by ± 7.8kHz (half line-frequency.)

Fig. 5.1 shows the chrominance spectral components due to u and v, relative to the carrier frequency.

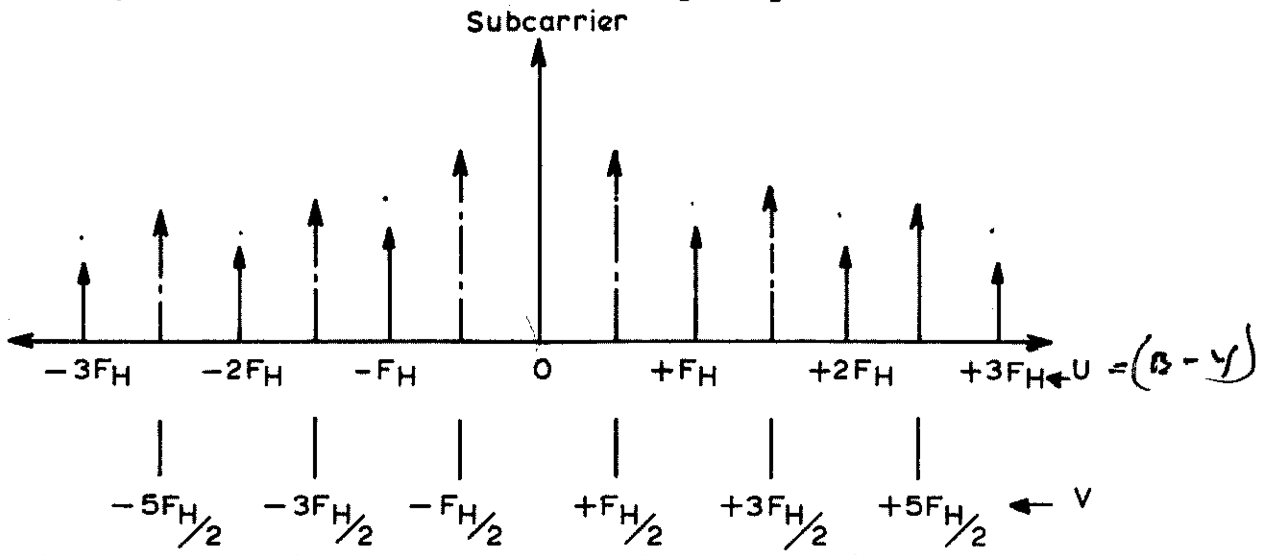

Fig. 5.1 u and v spectra relative to carrier

Fig 5.2, below, shows the u and v spectra relative to the luminance signal (15.625kHz harmonics), using a subcarrier frequency of 283 3/4 x line frequency.

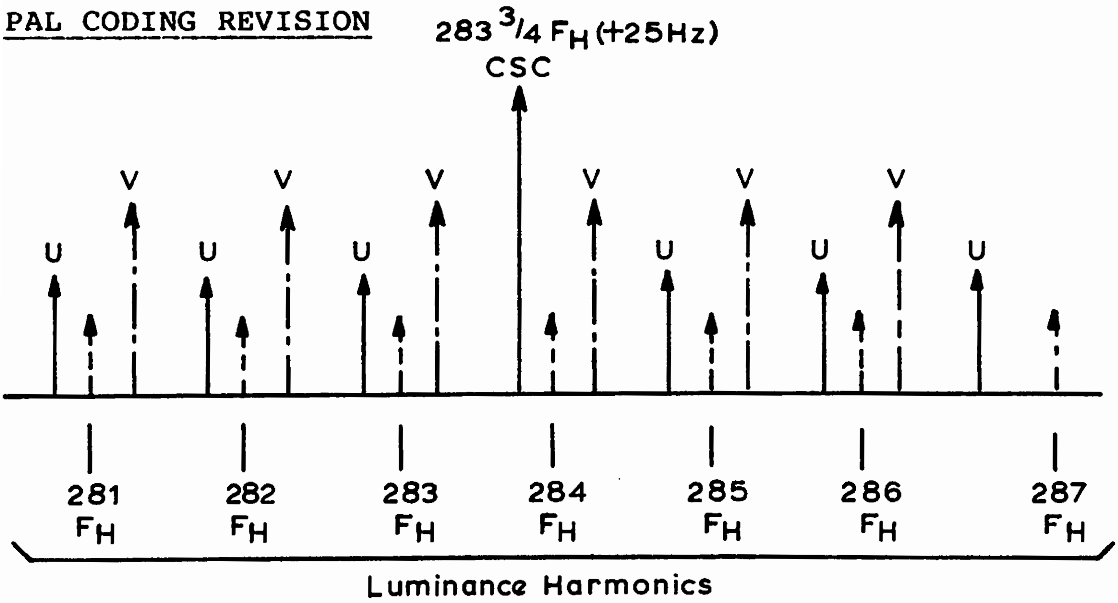

Fig. 5.3 Video Signal Spectrum in Region of Colour Subcarrier, showing Frequency Interleaving

6. DECODER LUMINANCE PATH

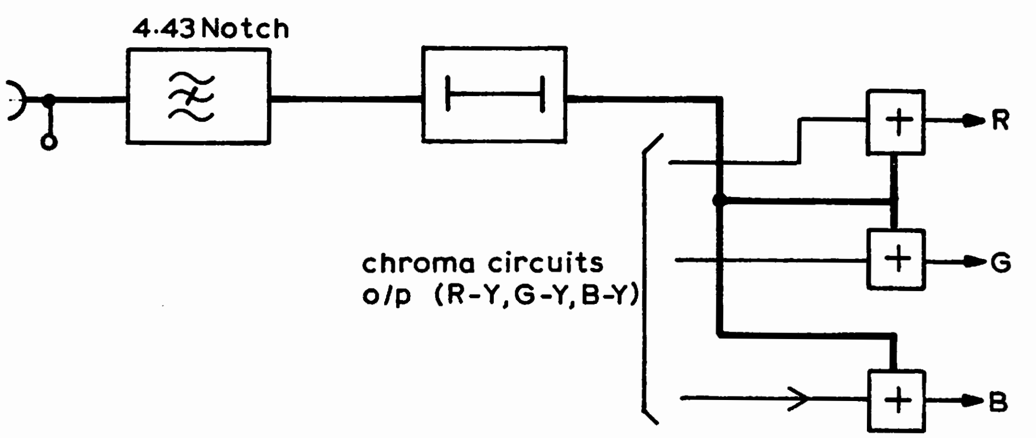

Fig. 6.1 Decoder Luminance Signal Processing

Since U and V waveforms contain dc, there will be a strong subcarrier frequency component in the chrominance signal, which would cause patterning on the display if allowed through on the luminance path.

The notch filter attenuates the luminance response close to subcarrier frequency. (typically -20dB, ±300kHz)
This is usually disabled in 'mono'. (absence of PAL burst detected)

NOTE At a vertical boundary between two colours, the chroma changes from the phase representing Hue 1 to the new phase representing Hue 2. To get to this new phase the output frequency must rise, or fall, at the boundary. The frequency shift depends on the rate with which the coder output assumes its new phase, which in turn depends on the rise-time allowed to the U and V video waveforms in the coder. The instantaneous frequency of the CSC at a vertical boundary usually comes outside the notch for a change between highly saturated colours, and becomes visible.

The delay line re-times the luminance to match the recovered colour difference signals which have been delayed in the chroma circuits and low pass filtering.

Check gain of the lum. path? Apply mono signal, eg stepwedge, and sym. i/p and o/ps of the decoder. Since no chroma is present the chroma circuits are not contributing to the output.

R = G = B = INPUT for MONO picture signal.

This also checks for minor differences in the gain of the R, G, and B output amps.

7. DECODER CHROMINANCE CIRCUITS

7.1 Chrominance Amplification

Manual control of chroma gain is by means of the 'saturation' control. Its correct setting can easily be obtained by comparing the amplitude of white and blue bars at the blue output, ideally using a coded signal with adjacent white and blue areas.

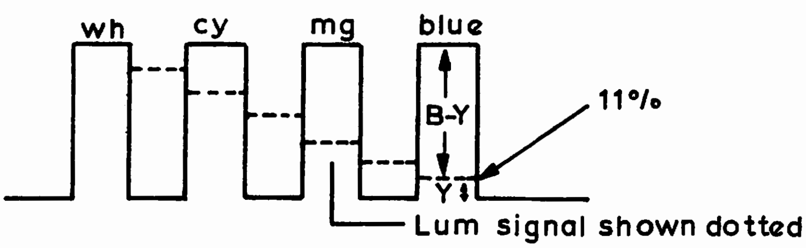

Fig. 7.1 Blue decoder o/p for 100% bars

The lhs bar has come through the lum signal path (white) and the rhs bar (blue) has come mostly (89%) through the chrominance circuits, and the correct setting of saturation makes these two the same amplitude.

The transmitter/receiver combination may suffer lum/chrom gain errors of ±2-4dB (eg main tx spec, +0dB, -2dB) due mainly to filtering/tuning in the if stages.
To avoid manual resetting of the saturation every time the channel is changed, receivers have ACC. This is a feedback loop, which samples burst amplitude and adjusts the chroma gain automatically to give constant burst level at the output.

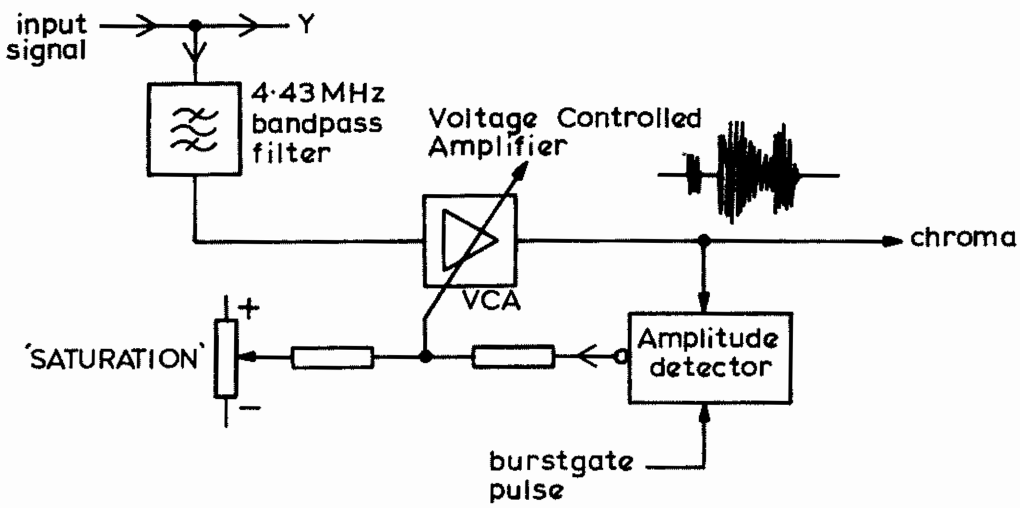

Fig. 7.2. Chroma Gain Control

7.2 Subcarrier Regeneration

A crystal controlled Burst Locked Oscillator (BLO) receives the chroma and a burst gate pulse derived from the back edge of sync in the sync separator. The separated burst is phase-compared with the oscillator o/p, and this locks the oscillator via a long time-constant loop. The precise phase of the output is preset, and allows for propagation time variations between the oscillator and the chroma circuits. The exact setting is the one that gives correct performance at the demodulator outputs!

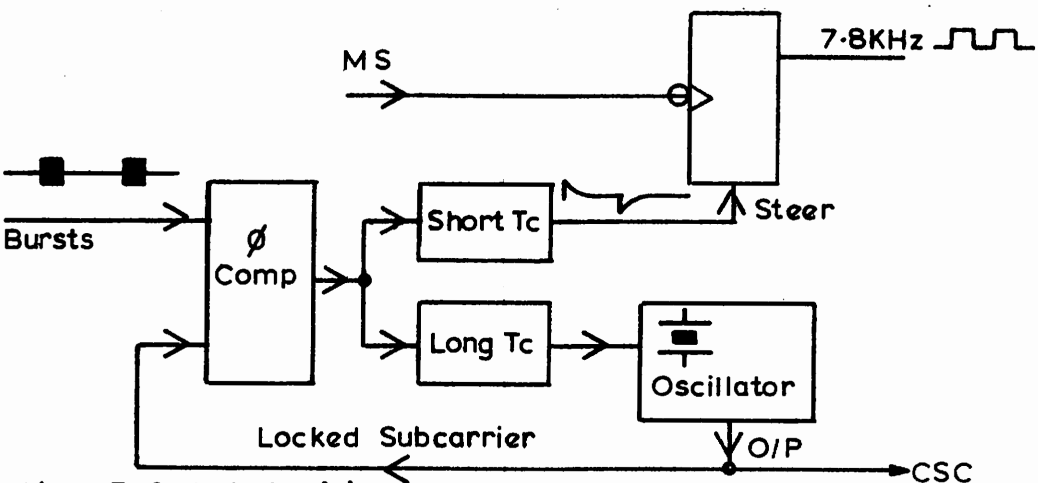

Fig. 7.3 BLO Locking

A short time-constant output of the phase-comparator carries the 7.8kHz advance and retard of the burst relative to the mean phase of the oscillator. This steers a bistable which is dividing syncs by 2, giving it a hard reset every alternate line.

If the 7.8kHz o/p disappears, then the input must have a non-PAL burst or be mono. This causes the 'colour killer' to shut down the chroma circuits and remove the luminance notch.

8. THE PAL 1-LINE DELAY

The delay line is of 283.5 cycles of subcarrier long. Its output transformer is centre-tapped producing inverted (283 1/2 cycles delay) and upright (=284 cycles delay) signals at the winding ends relative to the centre. By feeding the centre tap with the correct level of the input to the delay-line, the sum and difference of the chroma over two lines is obtained.

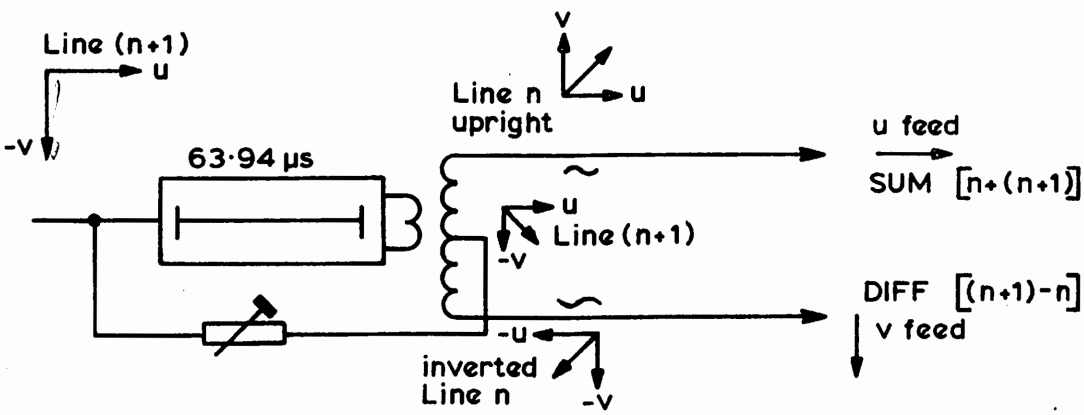

Fig. 8.1 Addition and Subtraction at the Output of the PAL Delay Line

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Thus the delay line has produced two separated sinewaves, u = U.cos wt and v = V.sin wt from the combined chrominance signal. These pass to two separate synchronous demodulators and do not contain crosstalk of u into v and vice-versa. Sampling each waveform at the peak demodulates the correct maximum output of U or V: sampling at the wrong time causes a reduced output which reaches zero when the blo phase is 90° out.

Delay-line separation relies on each line containing the same chrominance information. Without the delay line, the circuit operates as a simple PAL decoder (although the chroma at each modulator input now only comes from 1 line, and is therefore half-amplitude).

At the boundary between horizontal bands of colour, the decoder is simple-PAL decoding the average of the last line of one band, with the first line of the next band. A correctly-phased blo will decode this without error, except for the slurring of vertical resolution.

A wrongly phased blo will decode the boundary with hue and brightness errors, but these are usually masked by the luminance change at the horizontal boundary.

8.1 Delay Line Adjustment

The relative gain of the delay-line path and the direct path is adjustable; and the delay can be fined-tweaked using the transformer tu ning.

Consider a signal with a u chrominance component only.
If the delay line is working correctly, it will separate u and v, giving no output from the v feed. For the v o/p to be zero, both gain and delay must be set correctly.

Consider a signal generated along the V-axis, but without the PAL V-axis swing during active line-time.

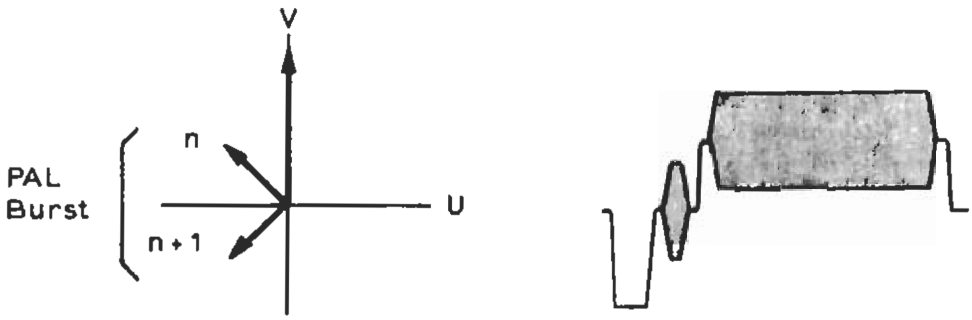


Fig. 8.2 Delay Line Test Signal

No output will come from the v feed, since the signal has the same carrier phase on successive lines. This signal can still be used for setting delay-line gain and delay.
The signal emerges from the u feed and reaches the U demodulator. The U decoding subcarrier should be at 90° to the unswitched v test signal, if the blo phase is correct. Therefore a 'scope on the U demod o/p will also reveal blo phase errors at the U demod.

8.3 Demodulators

The identical circuit to the modulators, less the clamp, can be used as a demod. Fig. 8.3 shows the effect of supplying in-phase and 90° phased decoding subcarrier to the signal.

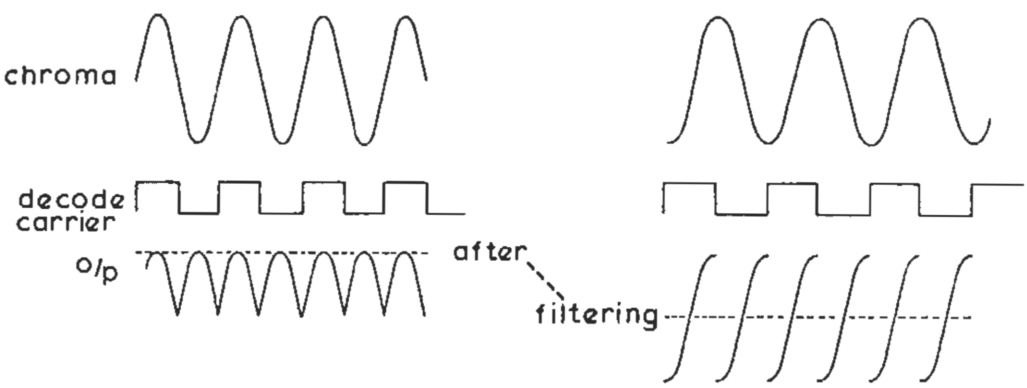


Fig. 8.3 Demodulation

For correct V signal amplitude on alternate lines, the separated v signal sent to the V demod must be the same amplitude and phase on the alternate lines. (this gives zero twitter on R-Y)
The decoder 0/180 switch must have the same gain in 0 and 180 states, and be an exact 0/180!

The set 90° should give maximum R-Y output (consistent with correct zero B-Y when the delay-line test w/f is then observed OR maximum B-Y output on normal colour bars)

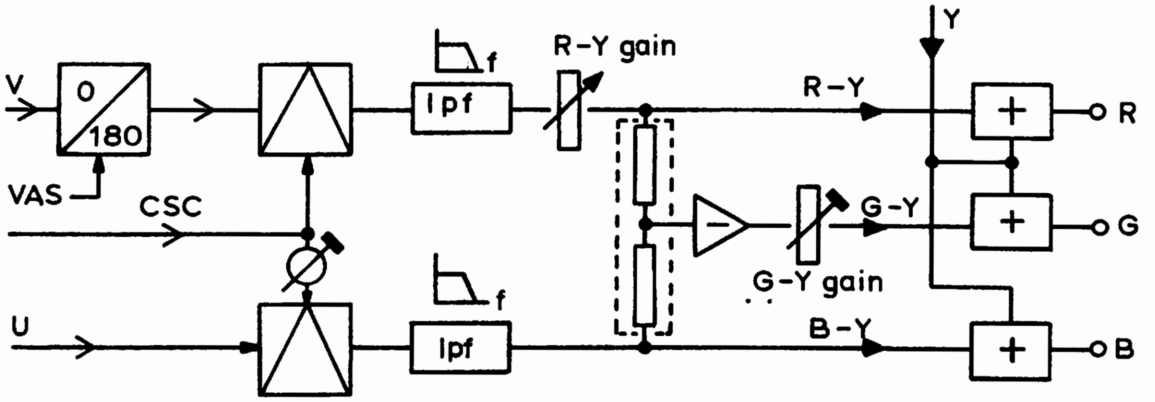


Fig. 8.4 Colour Difference Signal Processing

On 100% bars, the level of B-Y should convert the luminance signal (falling staircase) into the "on,off,on, off,on,off,on,off" blue decoded signal output.

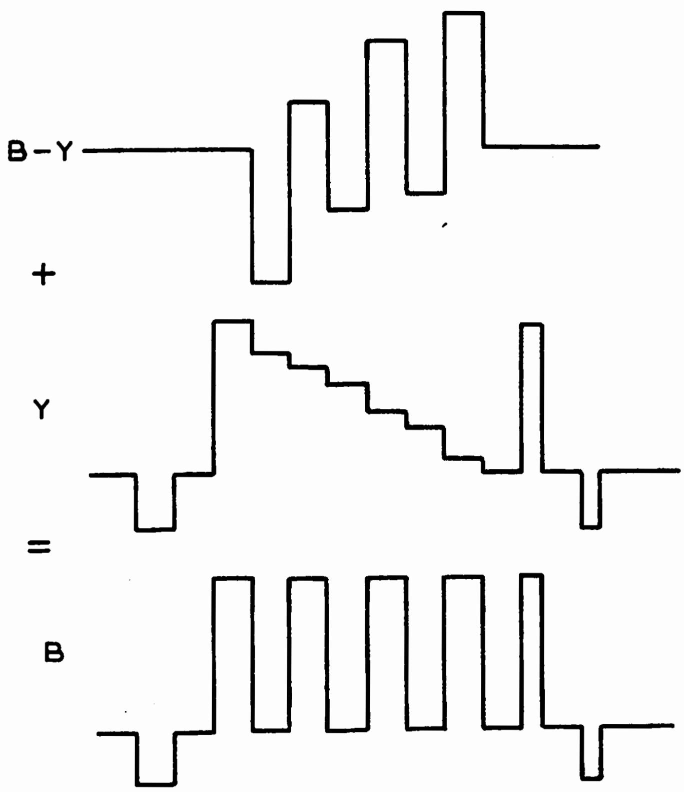


Fig. 8.5 (B-Y) + Y = B, for 100% Bars

The B-Y amplitude is set using the saturation (overall chroma gain) control, and any remaining gain error on R-Y is adjusted using the R-Y gain tweak, to give "on,on,off,off, on,on,off,off" at the R output.

Finally R-Y and B-Y are matrixed together to give G-Y, and a G-Y gain control is provided to produce the correct "on,on,on,on,off,off,off,off" green o/p with Y.

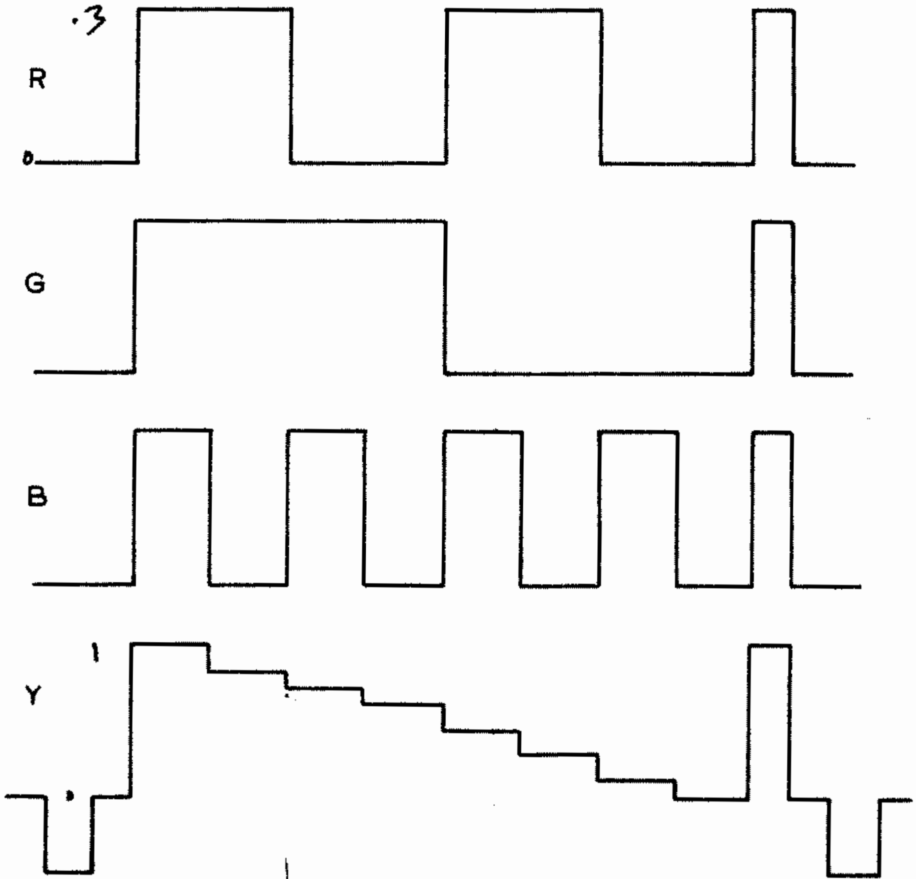
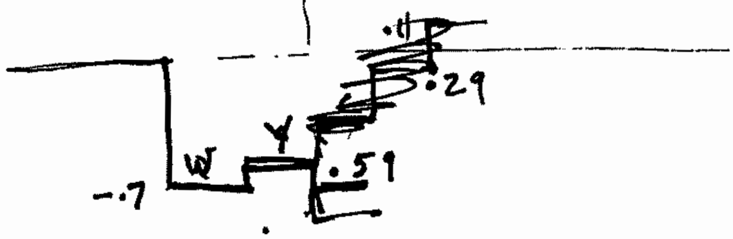
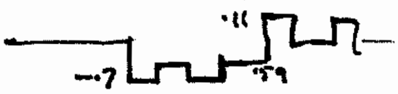
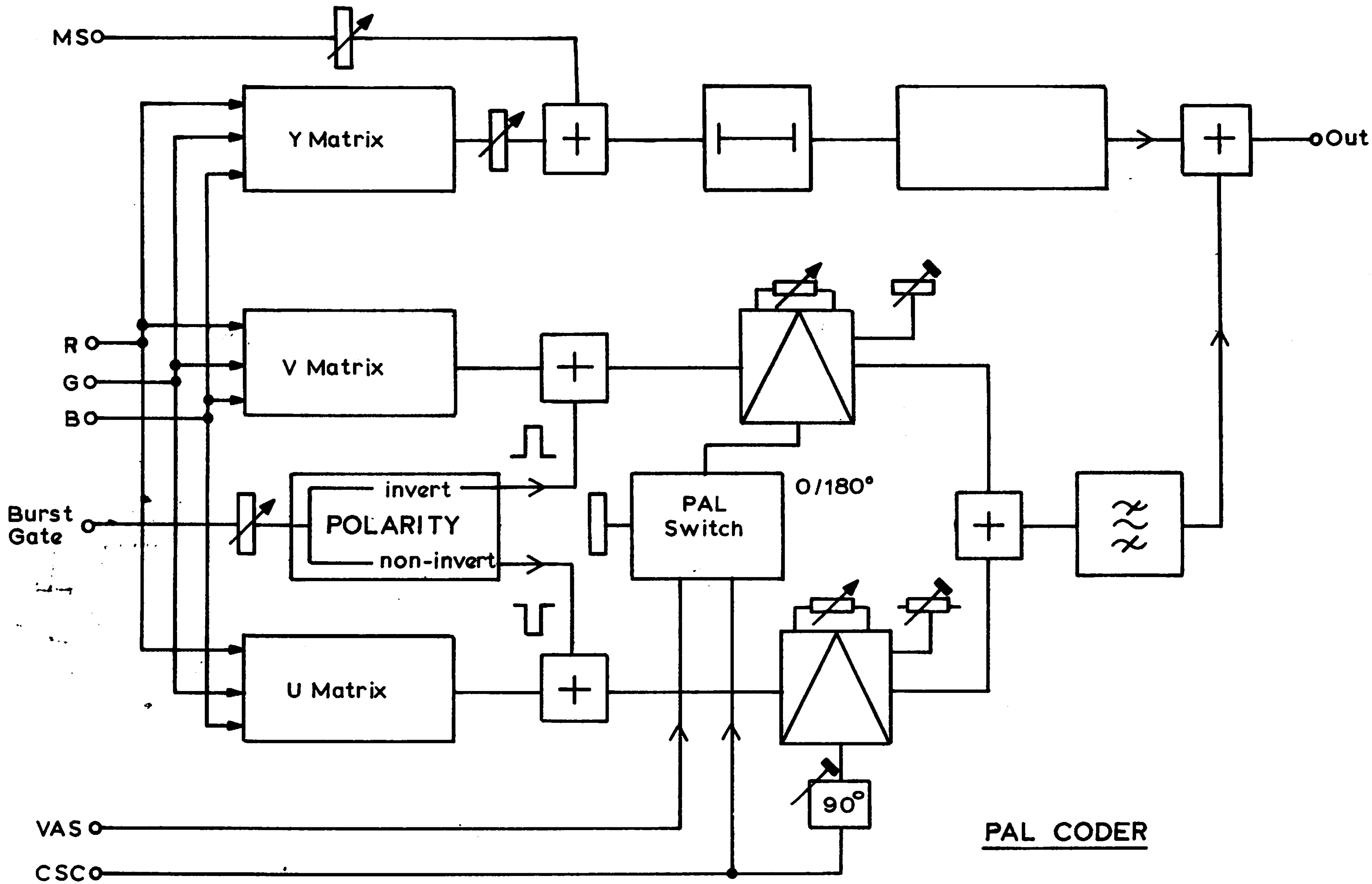


Fig. 8.6 Comparison of Y,R,G,B at the Decoder

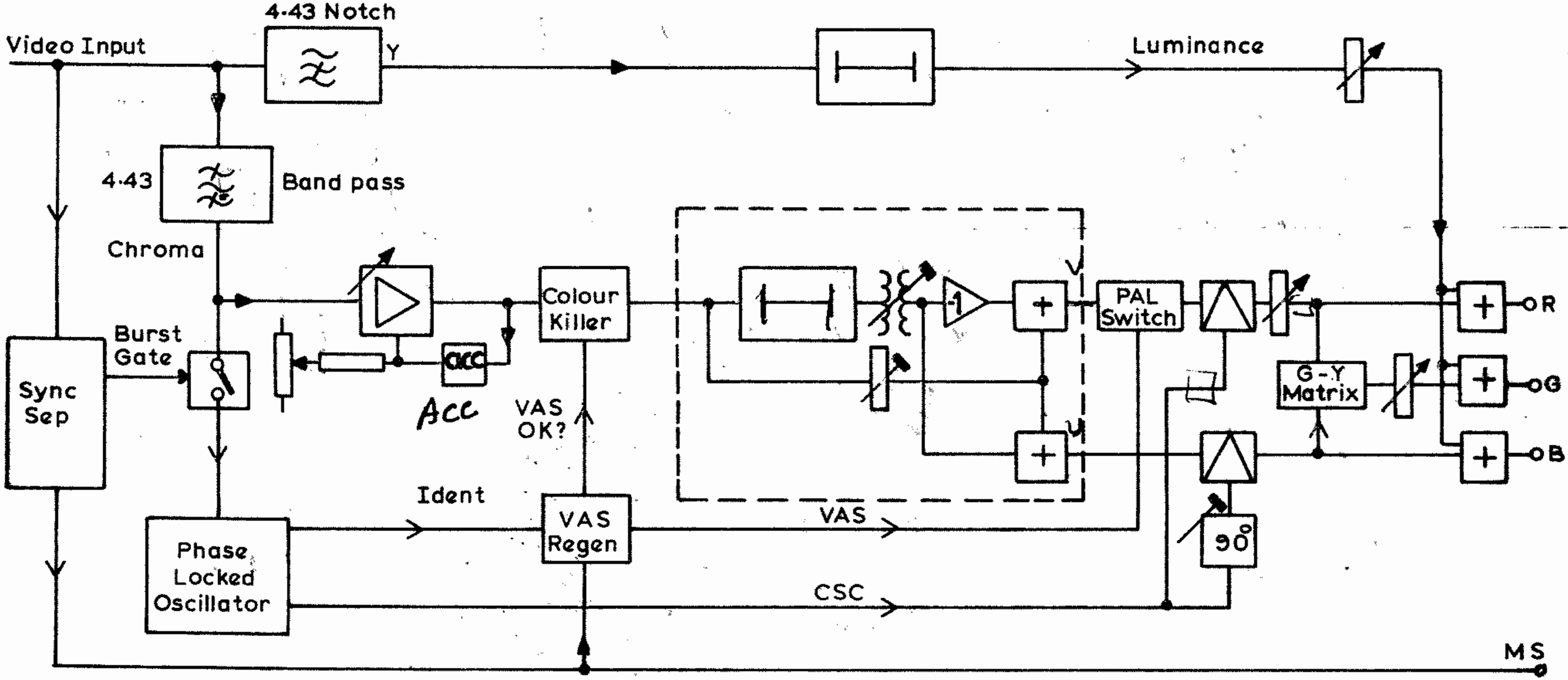


P.J. Harris/MB/PALCDREV
6th March 1984




MS
Y Matrix
Out
R
G
B
V Matrix
Burst
Gate
invert
POLARITY
non-invert
PAL
Switch
0/180°
U Matrix
90°
VAS
CSC
PAL CODER

PAL DECODER



4·43 Notch
Video Input
Y
Luminance
4·43
Band pass
Chroma
Colour Killer
Burst Gate
Sync Sep
ACC
Acc
VAS OK?
-1
+
V
U
PAL Switch
G-Y Matrix
90°
R
G
B
Ident
VAS Regen
VAS
Phase Locked Oscillator
CSC
MS

APPENDIX A, COLOUR BARS, RGB & CODED WAVEFORMS