# TECHNICAL ASPECTS OF COLOUR SEPARATION OVERLAY

## KEYING WAVEFORM MATRICES, HUE SUPPRESSORS, AND SOFT EDGED SWITCHES

## 1. INTRODUCTION

This handout briefly discusses the development and uses of video effects in television. The emphasis is on the use of colour separation overlay (C.S.O.).

## 2. COLOUR SEPARATION OVERLAY

The principle of colour separation overlay is well known and shown below in a simplified form (Fig. 1).

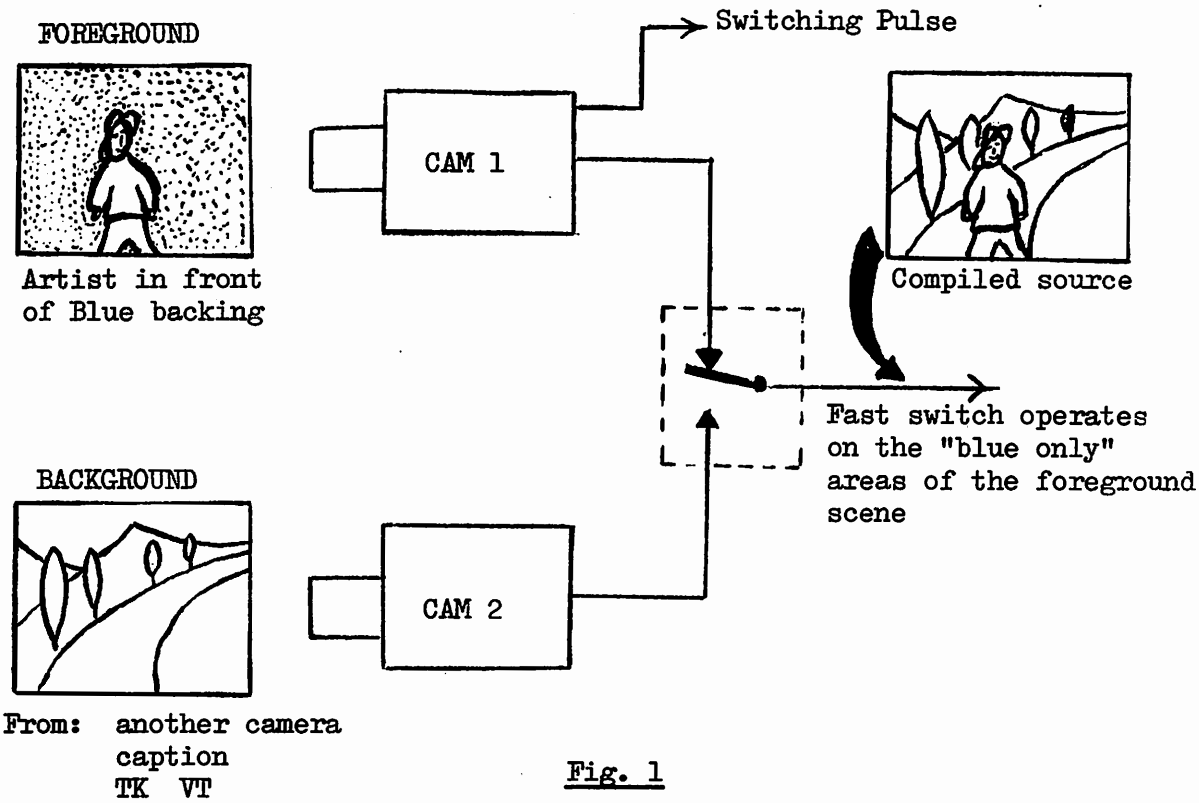



Fig. 1

Overlay may be defined as an electronic process whereby part of one picture (Foreground) is inserted into another picture (Background). The area to be inserted is determined from the "Foreground" camera. In the example above, colour is used to discriminate between the Foreground artist and his backing. A switching or keying signal is derived from camera 1 (Foreground) which operates an electronic switch. The keying signal is a maximum for the chosen keying colour (blue) and this operates the electronic switch to select the "Background" camera. When the amplitude of the keying signal is high - the "Background" is selected.

## 3. CHOICE OF KEYING COLOUR AND KEYING SIGNAL

Initial C.S.O. systems used (B-y) as the keying signal. So why (B-y)? Incidentally 'y' indicates a derived luminance signal from R,G & B signals.

Blue was chosen as the keying colour mainly because it was more or less complementary to face tones. Generally the foreground picture will have face tones, and bearing in mind that the foreground artist must not contain any switching colour, blue seemed to be a good choice of keying colour.

However, deriving the keying signal from the Blue output of the foreground camera is not sufficient. We need to be able to discriminate between "blue only" areas and areas of the picture containing colours which have blue in their make-up, e.g. white, cyan, magenta.

From coding experience we recall that colour difference signals become zero for neutral colours, i.e. white. So if B-y is used we can discriminate between "blue only" and white. What about cyan and magenta colours?

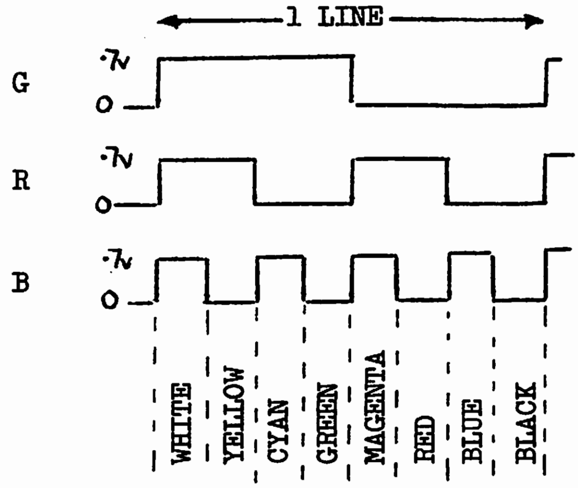
An examination of the B-y signal derived from the colour bars test signal is shown in Fig. 2 opposite, for completeness the colour difference signals for red, green, yellow, magenta and cyan are also shown. (Colour - y)

A study of these graphs shows three important features :-

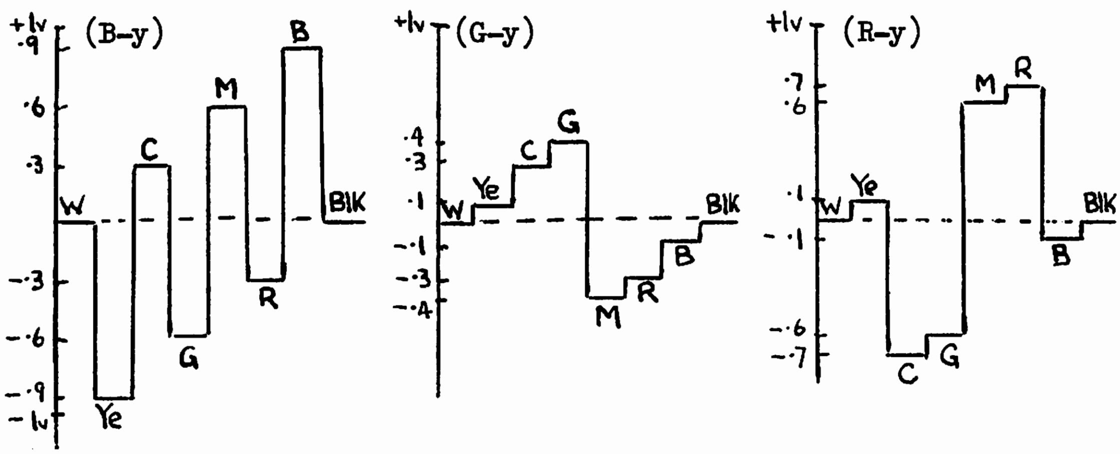
i) For (B-y) there is a 33% difference in signal for blue and magenta colours. What this means is that it is possible to distinguish between "blue only" and other colours by using a B-Y matrix to derive the keying waveform provided we also have <u>amplitude</u> discrimination. Some form of adjustable clipping level is required and the keying signal must be greater than the clipping level before the electronic switch operates.

ii) For (G-y) the difference between the signal for green and cyan is only 25% and for (R-y) the difference is about 16% between the signal for red and magenta areas. This illustrates another reason for choosing B-y, it offered best discrimination between "keying colour" and all other colours.

## Colour Bar generation




## (Colour-y) derived from Colour bars




-(B-y) Yellow

-(G-y) Magenta

-(R-y) Cyan

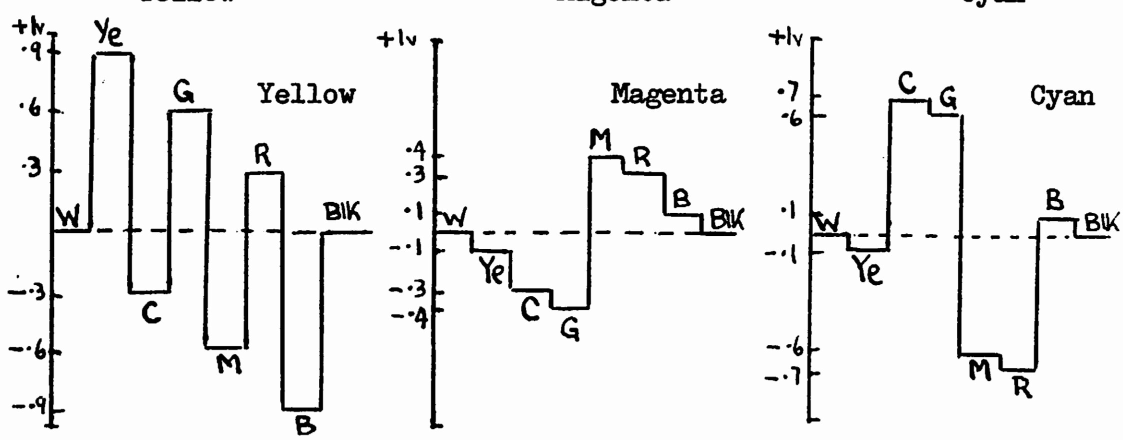



Figure 2

iii) For Yellow,(-(B-y) ) the discrimination is similar to (B-y), so provided the "foreground" scene does not contain yellow this will work as well as the (B-y) matrix. But, because yellow was felt to be near to the face tone it was not used for earlier C.S.O. systems.

However, yellow has been successfully used (Dr. Who), the major difference in the composite picture being the colour of the fringe to the foreground subject, i.e. either blue with a (B-y) matrix or yellow with a -(B-y) matrix.

4. (B-m) MATRIX

This idea was conceived in late 1969. It was realised that the derivation of the 'y' signal is solely required by the coding/decoding process and in itself has little to do with colour. In colorimetry it will be recalled all three primaries have equal importance and so the principle of an "equal weighting" colour difference signal (Colour-m) was developed where :-

$$m = \tfrac{1}{3}R + \tfrac{1}{3}G + \tfrac{1}{3}B$$

and when normalised for 1.0 V maximum amplitude :-

$$B-m = 0.5R - 0.5G + 1B$$

This has two advantages over the (Colour-y) keying waveform :-

i) Better discrimination against unwanted colours. Figure 3 shows the (Colour-m) signal for colour bars. From this can be seen that when using Blue as the keying colour, the % amplitude difference between (B-m) for a saturated blue and saturated magenta is 50% (compared to 33% for a (B-y) matrix). Note that due to the symmetrical nature of the equations this 50% discrimination is true for all the other colours, e.g.

| | | | |
|---|---|---|---|
| (G-m) | GREEN/CYAN | - | 50% |
| (R-m) | RED/MAGENTA | - | 50% |
| -(B-m) | YELLOW/GREEN | - | 50% |
| -(R-m) | CYAN/GREEN | - | 50% |
| -(G-m) | MAGENTA/RED | - | 50% |

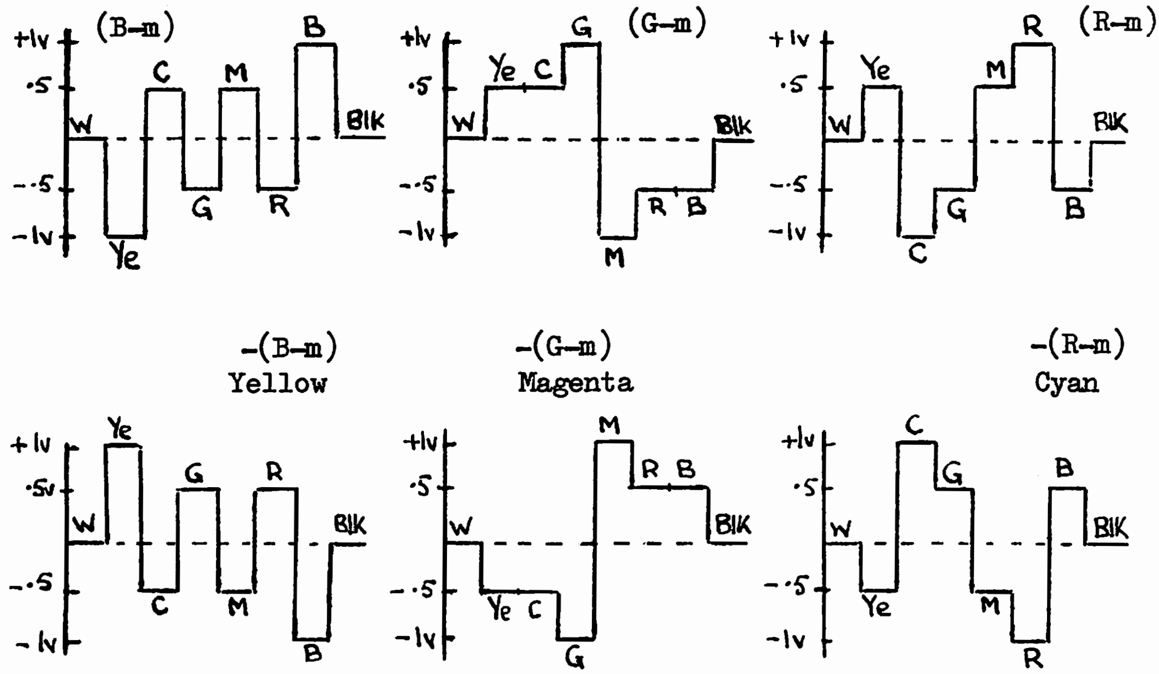



Figure 3

ii) Only two coeficients are needed in the matrix, 0.5 and 1, to provide the key waveform for any of the six colours.

Key W/F for

| | | |
|---|---|---|
| Blue | (B-m) | = -0.5R - 0.5G + 1B |
| Cyan | - (R-m) | = -1R + 0.5G + 0.5B |
| Green | (G-m) | = -0.5R + 1G - 0.5B |
| Yellow | - (B-m) | = +0.5R + 0.5G - 1B |
| Red | (R-m) | = +1.0R - 0.5G - 0.5B |
| Magenta | - (G-m) | = 0.5R - 1G + 0.5B |

Thus it is easier to make a switchable matrix for (Colour-m) than (Colour-y). Several "six colour" matrices have been in service for some time.

If a wide choice of C.S.O. keying colour is necessary, it is thought that the switchable six colour matrix using the (Col-m) principle will meet all requirements.

It should be mentioned at this time that there are commercially available Chroma Key systems which use a $360^{\circ}$ selection of keying colour.

COLOUR SEPARATION OVERLAY

These require a sine/cosine potentiometer and this is expensive. Operationally, the six colour matrix is capable of giving satisfactory results, indeed it will always provide a keying signal amplitude no less than 0.866 of that obtainable in a continuously variable hue matrix, e.g. Colour A in Figure 4.

Figure 4 is a hypothetical vector diagram based on an equal weighting principle which results in the major colours being spaced at $60^{\circ}$ intervals.

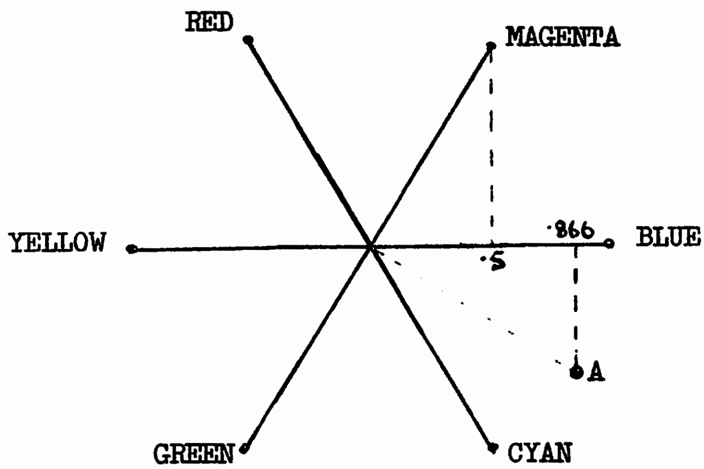



Figure 4

If the keying colour is Blue, then the Blue/Yellow axis represents (B-m) and -(B-m), i.e. the locus of (B-m). Dropping a perpendicular from any of the colours to this axis will indicate the value of (B-m) for that particular colour, e.g. Magenta = 0.5.

5. EXCLUSIVE HUE MATRIX (EXCESS HUE MATRIX)

This is a further development of the keying signal matrix which produces better keying colour discrimination. With the (B-y) and (B-m) matrices the keying waveform reduces to zero for neutral colours but still contains positive components for cyan and magenta. The Exclusive Hue Matrix produces a keying signal which reduces to zero for cyan and magenta. The waveform is only allowed to go positive when blue is larger than green or red.

This is achieved using non additive mixing techniques in the matrix. Figure 5 shows the basic system and the derivation of the exclusive hue waveform for colour bars (Blue being the chosen Exclusive Hue for this example).

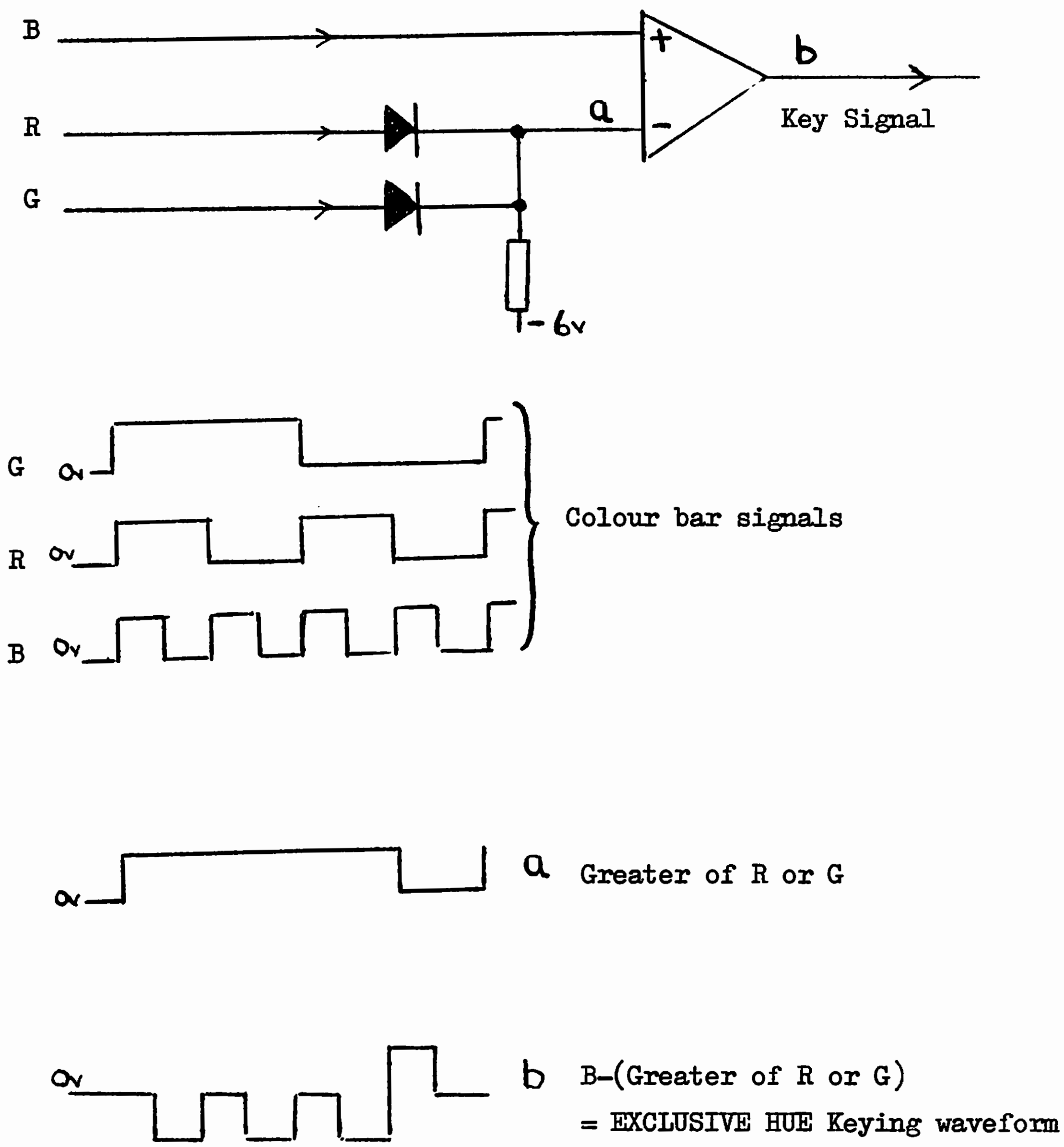


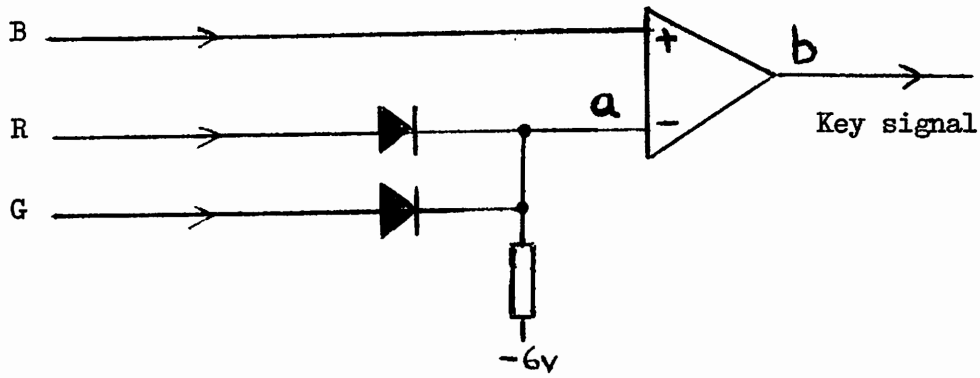

Figure 5

Thus, from Figure 5 it can be seen that the keying signal is exclusively Blue, i.e. only present when Blue is the dominant colour.

What happens if the scene colour is not a saturated blue?

On page 8 are two examples of such colours, a de-saturated blue and a blue/cyan colour (Figure 6).

COLOUR SEPARATION OVERLAY



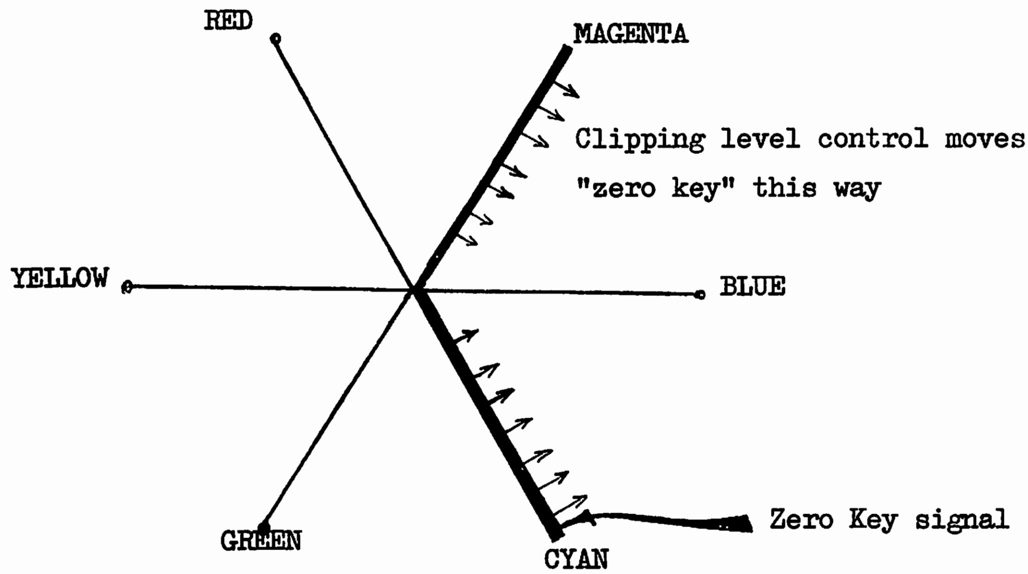

| De-saturated Blue, say :- | Blue/Cyan, say :- |
|---|---|
| R = .2 V | R = 0 |
| G = .2 V | G = .6 V |
| B = .7 V | B = .7 V |
| Waveform a = Greater of R & G = .2 V | Waveform a = Greater of R & G = .6 V |
| Waveform b = B - a = .5 V | Waveform b = B - a = .1 V |

Key Signal is the Excess Blue

Figure 6

This illustrates further the principle of the exclusive hue matrix. The keying signal is in fact the Excess of blue over the other primaries, this matrix is sometimes referred to as an Excess Hue Matrix.

The operation of the Exclusive Hue matrix can be shown on the hypothetical vector diagram on page 9 (Figure 7).




All colours to the left of the zero line produce zero key signal.

Figure 7

6. HUE SUPPRESSOR (Fringe Suppressor)

One defect of the basic C.S.O. system is an objectionable colour fringe to the inserted foreground. This colour fringe is caused by :-

i) Spill of blue light from the blue backing onto the foreground subject (assuming Blue to be the keying colour).

ii) Dynamic flare defects in the camera optical system.

iii) Subcarrier from the blue backing area "spilling" outside the switched area because of the limited bandwidth of the chrominance signal.

Whilst this fringe can be minimised by careful lighting and artist position, useful reduction of the fringe can be obtained by using a Fringe Suppressor or Hue Suppressor.

The principle of fringe suppression is to subtract an "exclusive blue" signal from the foreground camera blue signal, prior to coding. The effect of this is to remove all the "blue only" areas from the foreground scene. A saturated blue is reduced to black and a de-saturated blue is reduced to a neutral grey.

Figure 8 on page 10 shows the block diagram of a hue suppressor and illustrates its effect on a colour signal.

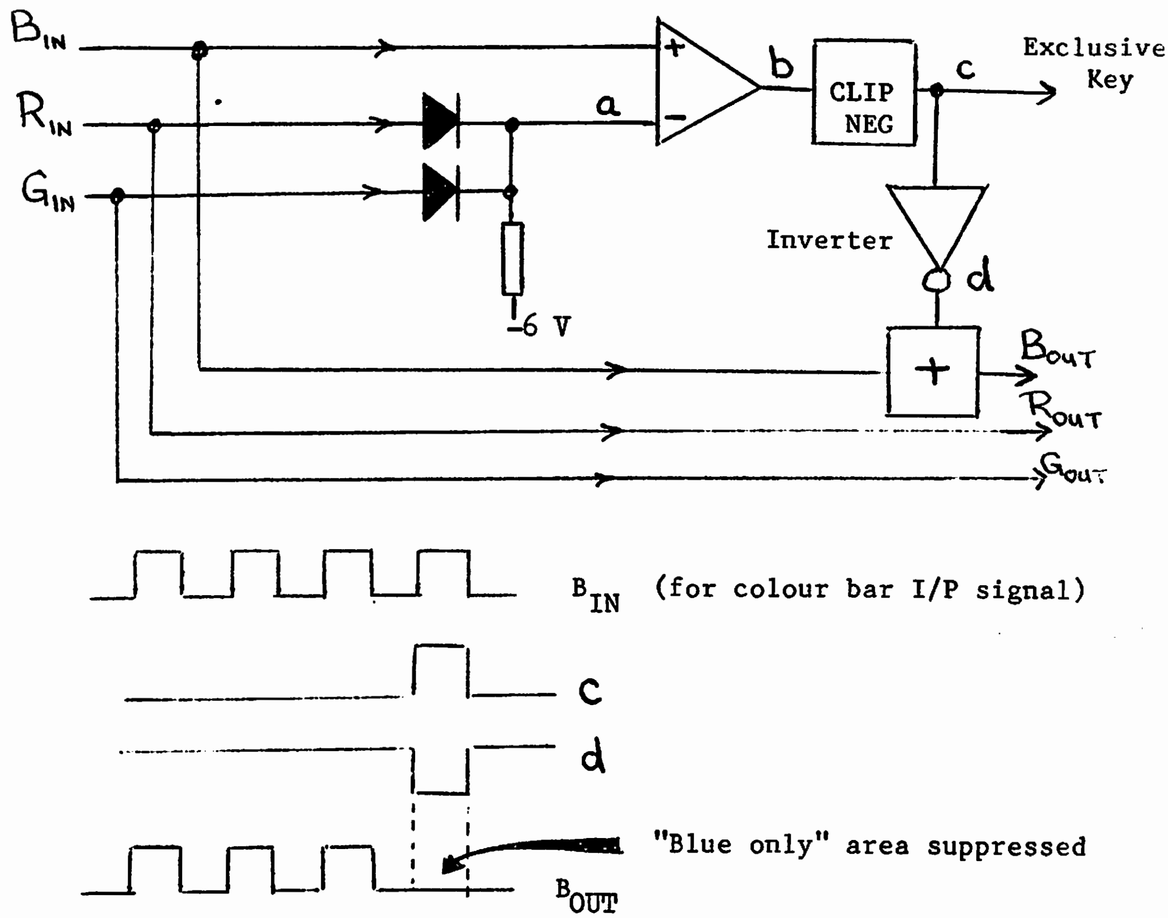



Figure 8

The next question to ask is "What effect does the Hue Suppressor have on colours which contain "blue"? The correction signal is the amount by which the Blue signal is in excess of Red or Green so when this is subtracted from the Blue signal, Blue will no longer be dominant, i.e. the Blue signal, when greater than Red or Green, will be reduced to the level of the greater of Red or Green.

e.g. effect on a BLUE/CYAN (B > G)

Foreground camera outputs, say, R = 0 V
G = 0.5 V
B = 0.7 V

The amount by which the Blue signal is in excess of R or G is 0.2 V. If the blue signal is reduced by 0.2 V in the Hue Suppressor we get :-

Colour signals after F.E. R = 0 V
G = 0.5 V
B = 0.5 V

The Blue signal now equals the Green signal, the Hue Suppressor has produced distortion of the original colour. Some distortion of the colour of the foreground scene will always occur for areas where B > R or G.

Figure 9 shows further examples of the effect of the Hue Suppressor

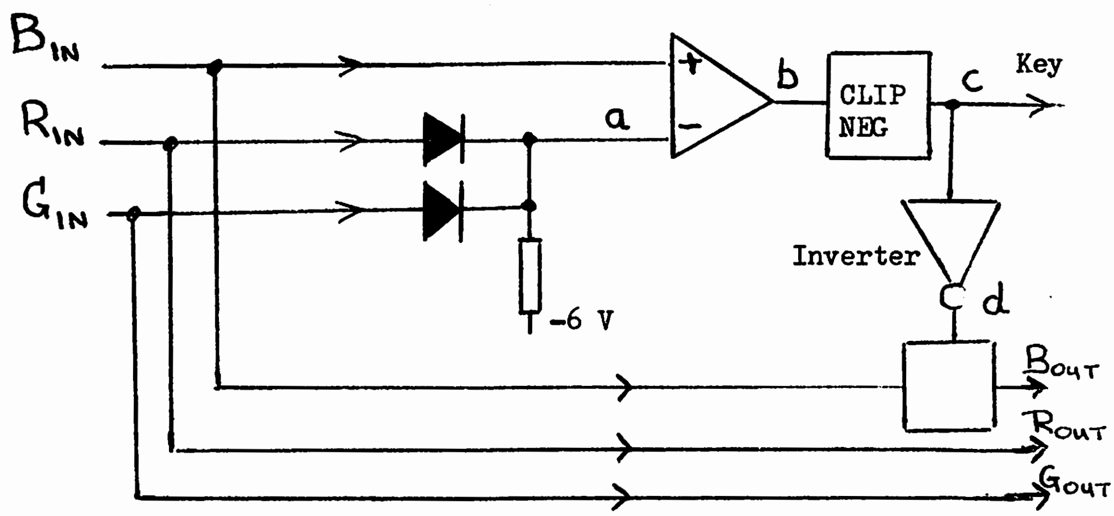



Figure 9

| | R > B<br>.7 V/.5 V | B > G > R<br>.7 V/.5 V/.3 V | B > R > G<br>.7 V/.5 V/.4 V |
|---|---|---|---|
| a | 0.7 V | +0.5 V | +0.5 V |
| b | -0.2 V | +0.2 V | +0.2 V |
| c | 0 V | +0.2 V | +0.2 V |
| d | 0 V | -0.2 V | -0.2 V |
| B OUT | 0.5 V | 0.5 V | 0.5 B |

To summarise, the Hue Suppressor (Fringe Suppressor) :-

i) Only operates on the chosen hue, e.g. Blue spill + Red Surface = Magenta fringe. NO EFFECT !

ii) Reduces saturated "key colour" areas of the foreground picture to black. Therefore on Preview monitor the key colour will not be present as a hue but as a black area.

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iii) As always, registration of the foreground camera is extremely important. Any registration errors of the Blue tube will produce a black edge on the composite picture (Figure 10).

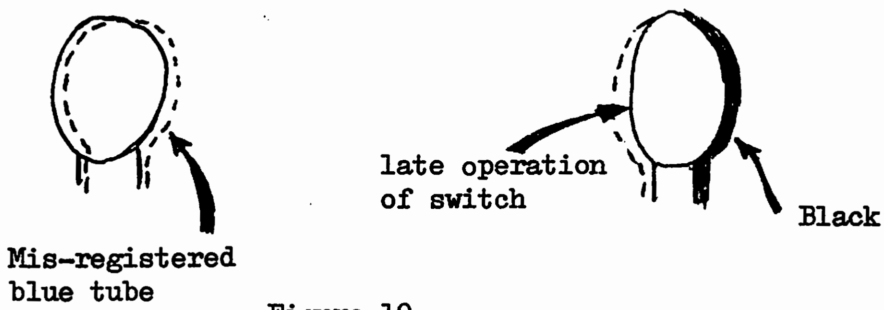


Figure 10

iv) Produces a colour distortion if B > R or G.

7. DE-CODED C.S.O.

Sometimes it is necessary to use a decoded key signal. This can occur when the foreground contribution is :-

a) a remote source, e.g. an O.B.
b) recorded on video tape
c) recorded on film

The advantages and disadvantages of the several methods of decoding are shown below. Usually it is sufficient to decode the U axis only and use this (B-y) signal as the keying waveform.

| SYSTEM | ADVANTAGES | DISADVANTAGES |
|---|---|---|
| Simple PAL decoder | | Hanover bars possible. Luminance crosstalk. |
| 1 line delay decoder | No Hanover bars. Improved noise performance (3 dB) | Luminance crosstalk. 1 line delayed O/P. Reduced vert. resolution. |
| 2 line delay decoder | As above and Luminance crosstalk reduced. | Two line delayed O/P. Reduced vert. resolution. |
| Full RGB decoder | Choice of matrix system and colour, e.g. switchable. | Complex. |
| Any type | | Limited bandwidth in coding. |

It must be remembered that a decoded keying signal is not as good as one derived from camera R G & B signals. This is because the coding produces a degraded B-y signal :-

i) Bandwidth reduced to 1 MHz.

ii) Luminance to chrominance crosstalk at 4.43 MHz (cross-colour).

iii) B-y sampled at 4.43 MHz producing a "serration" of the keying signal.

The use of soft edge switches (see later notes) may partly mitigate some of the above disadvantages but it must be stressed that no method of decoding a key waveform is entirely satisfactory and so should be avoided whenever possible !

For example, in Figure 11 the situation of TK supplying the C.S.O. foreground scene is illustrated. It is recommended to use a keying waveform derived from RGB signals, despite the problem of timing it to the mixing point.

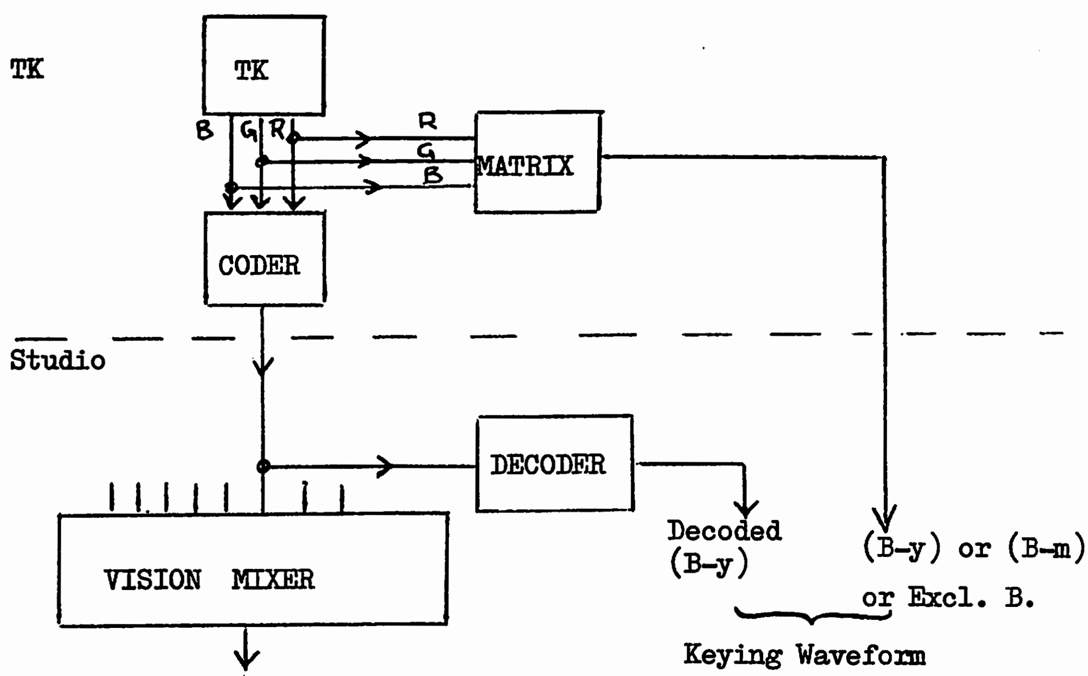


Figure 11

Obviously there will be occasions when it is not possible to use a keying signal derived from RGB. In these circumstances it is recommended that a synthetic blue (or appropriate keying colour) be overlayed as a background at the point of origin , i.e. before recording, or at a remote site.

## 8. CHROMA KEY

For completeness in our discussion on coded C.S.O. a mention should be made of the original Chroma Key technique employed in the U.S.A. with the N.T.S.C. system. This technique is illustrated in Figure 12 below, and allows 360° selection of the keying colour.

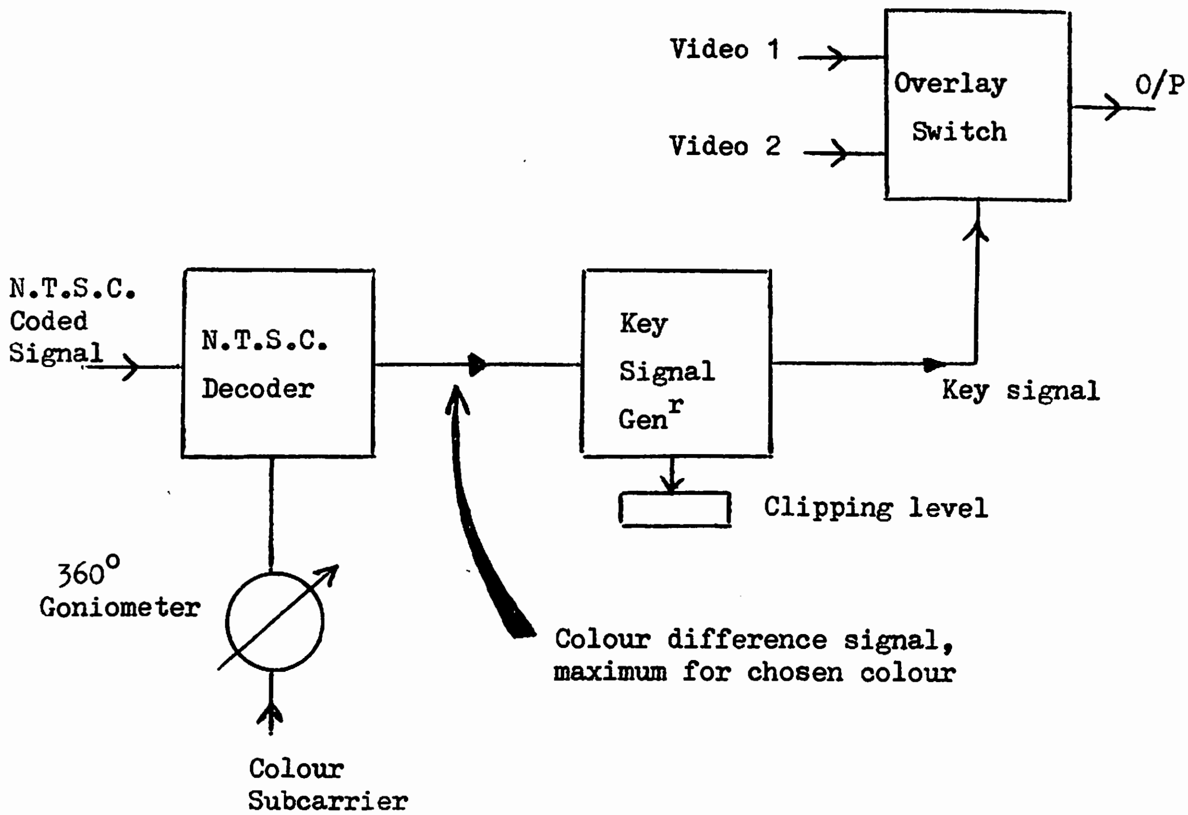


Figure 12

Figure 13 on page 15 illustrates the principle of decoding the N.T.S.C. signal to derive a keying waveform from a magenta keying colour. If the decoding is done along the (B-Y) axis, the amplitude of the keying signal will be small, (a) on Figure 13.

If the phase of the sub-carrier used for decoding is changed by Ø degrees then the decoding will be done along the Magenta/Green axis and this will result in a maximum signal being decoded for a magenta colour, (b) on Figure 13.

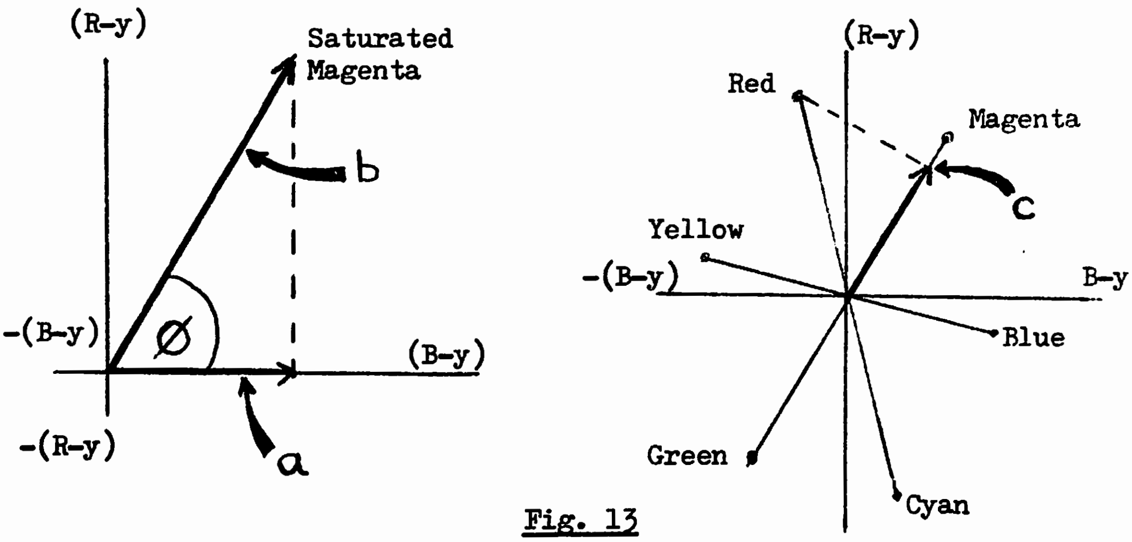


Fig. 13

This system does not give an exclusive waveform, as Figure 13(c) shows there will be positive signal decoded for other colours, e.g. red and blue.

However, this does allow an easy selection of keying colour.

Unfortunately it is not possible to use this system with the PAL coded signal because of the difficulty of coping with the PAL switching. Figure 14 illustrates the problem.

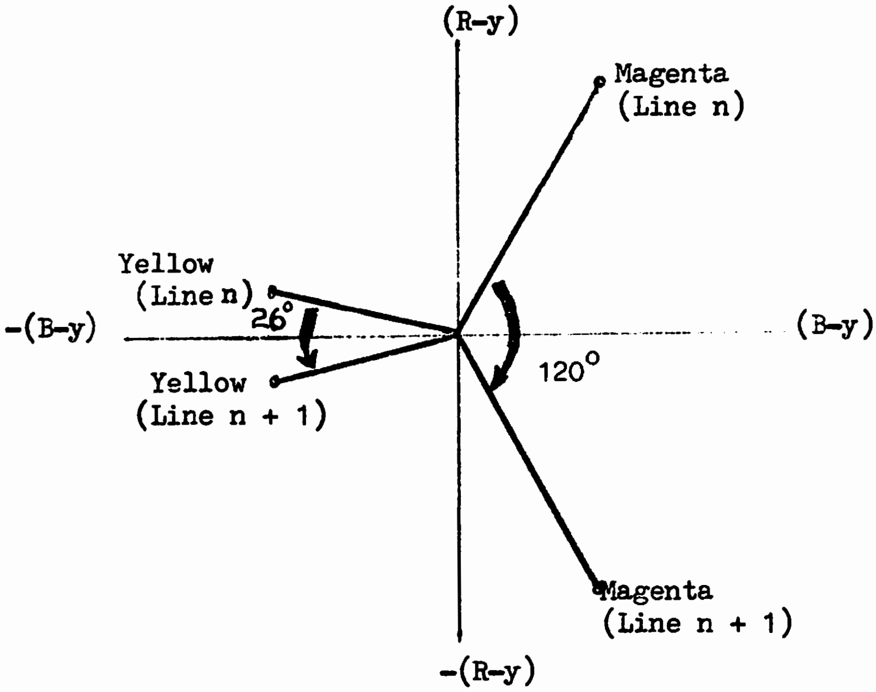


Figure 14

This shows that to decode a magenta keying signal the phase of the decoding subcarrier would have to be shifted by 120° on alternate lines, in addition to a 60° phase shift from B-Y phase.

For other colours the values would be different, e.g. yellow requires a 26° phase shift on alternate lines. Clearly this is not a simple system to achieve in practice, the PAL subcarrier used for decoding would have to be switched in a non-simple way.

## 9. SOFT EDGED SWITCHES

Historically it was thought that a very fast switch (i.e. very hard) was required for good C.S.O. operation. Consequently the original switches were designed to be very fast in operation.

The development of the soft edged switch has resulted in significant improvements to C.S.O. operations. Its main advantages are the reduction of the "liveliness" of the switching between foreground and background, and reduction of blue fringes.

Figure 15 illustrates the basic principle of the soft edged switch compared to a hard edged switch. Figure 16 illustrates the advantage of the soft edged switch over a hard edged switch.

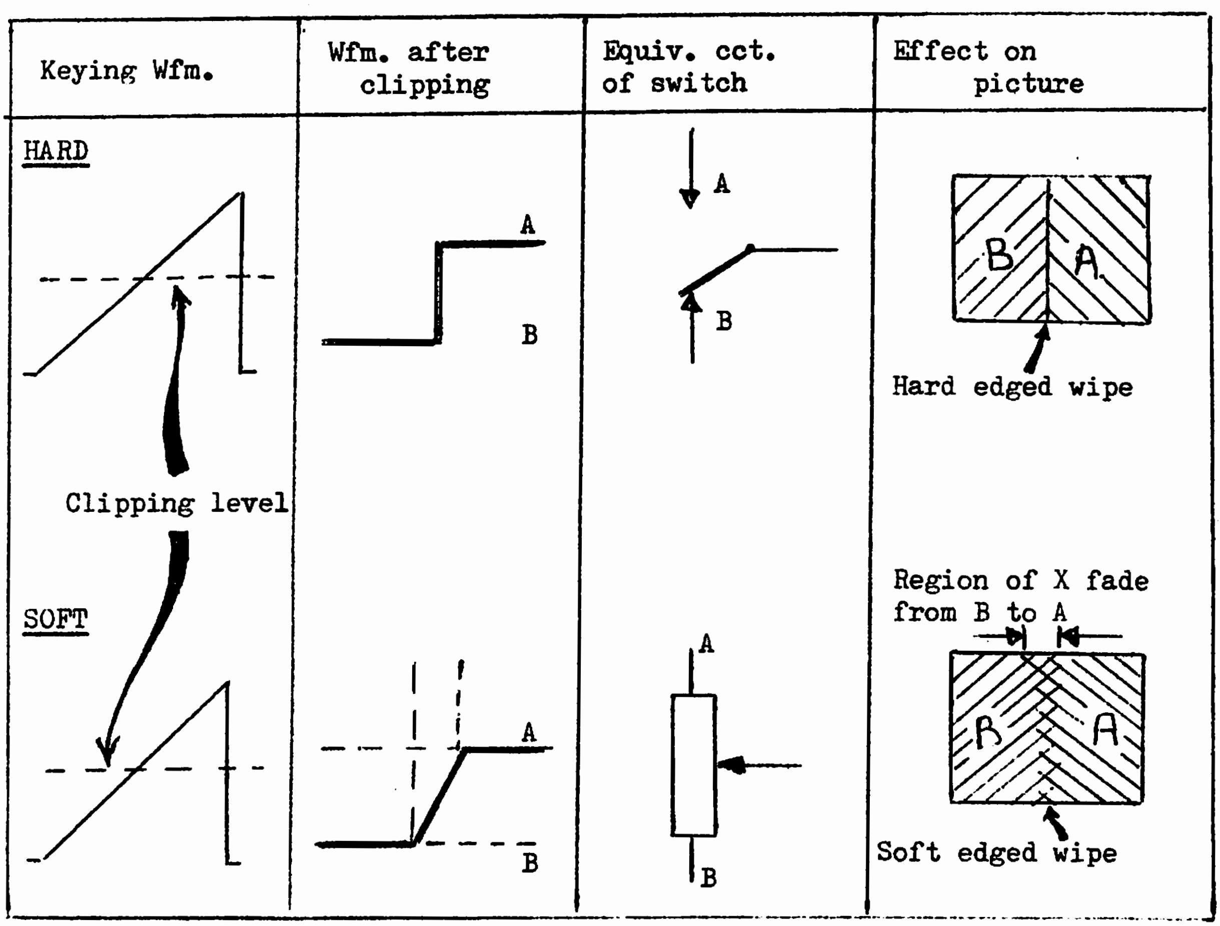


Figure 15

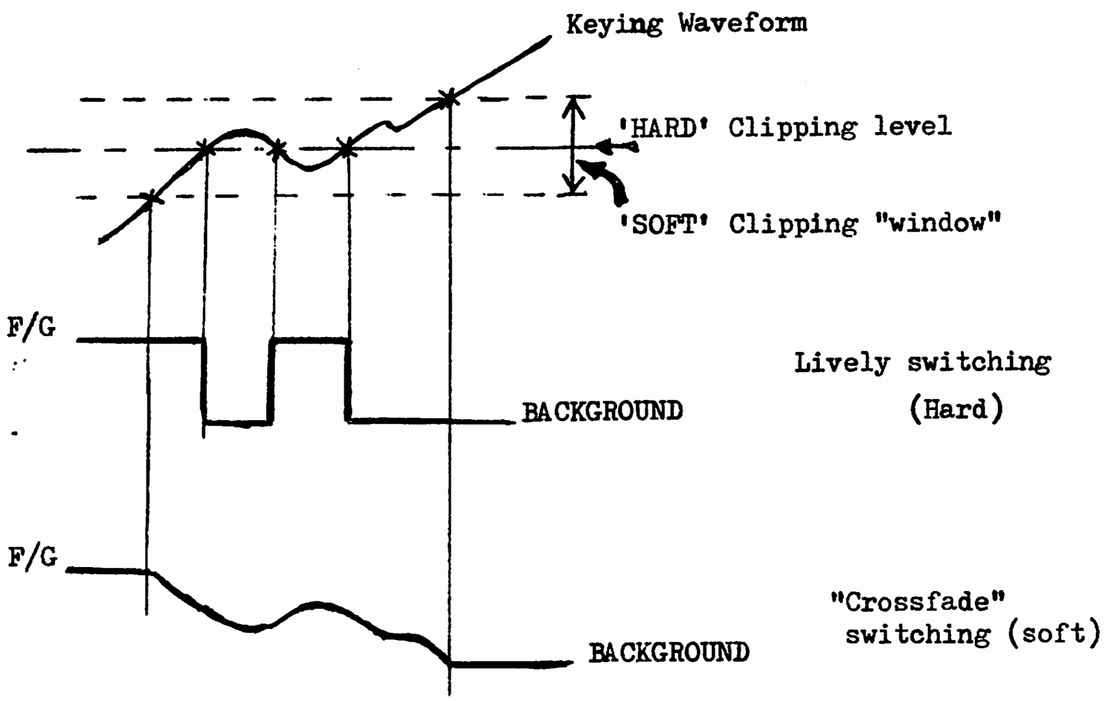


Figure 16

The "softness" of the soft edged switch can be controlled by altering the amplitude of the clipping window or by changing the gain of the key waveform generator, e.g.

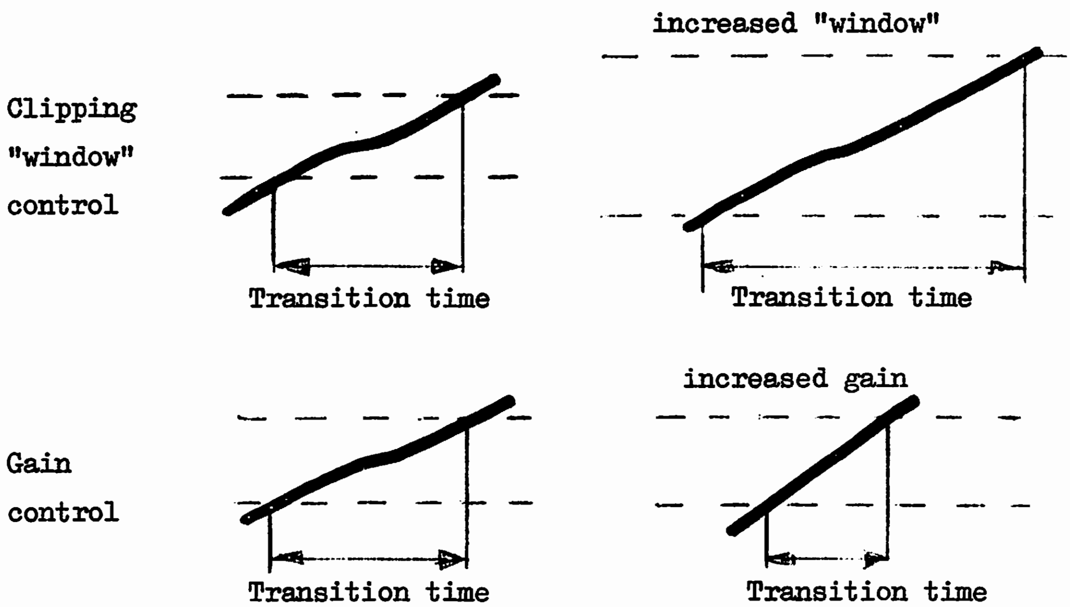


Figure 17

COLOUR SEPARATION OVERLAY

The C.S.O. switch will basically consist of two circuits :-

i) Keying waveform generator - this will incorporate some form of clipping level which enables a suitable switching or keying waveform to be generated when the input signal (keying signal derived from the foreground camera) is equal in amplitude to the clipping level.

ii) Split screen switch - this will effectively be a changeover "switch" operating between the two video inputs. The action of the switch is controlled by the keying waveform generator.

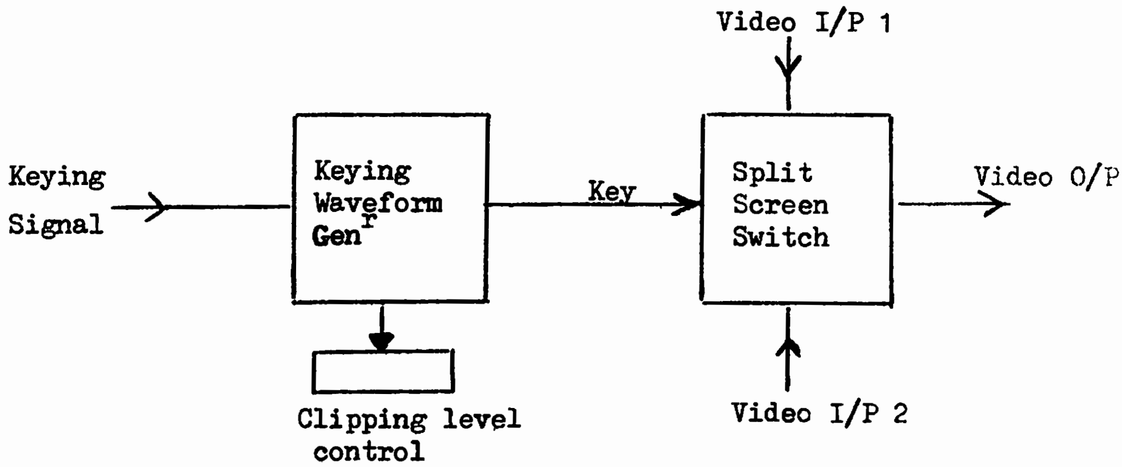


Figure 18

The diagram of a soft edge switch is shown, simplified, in Figure 19.

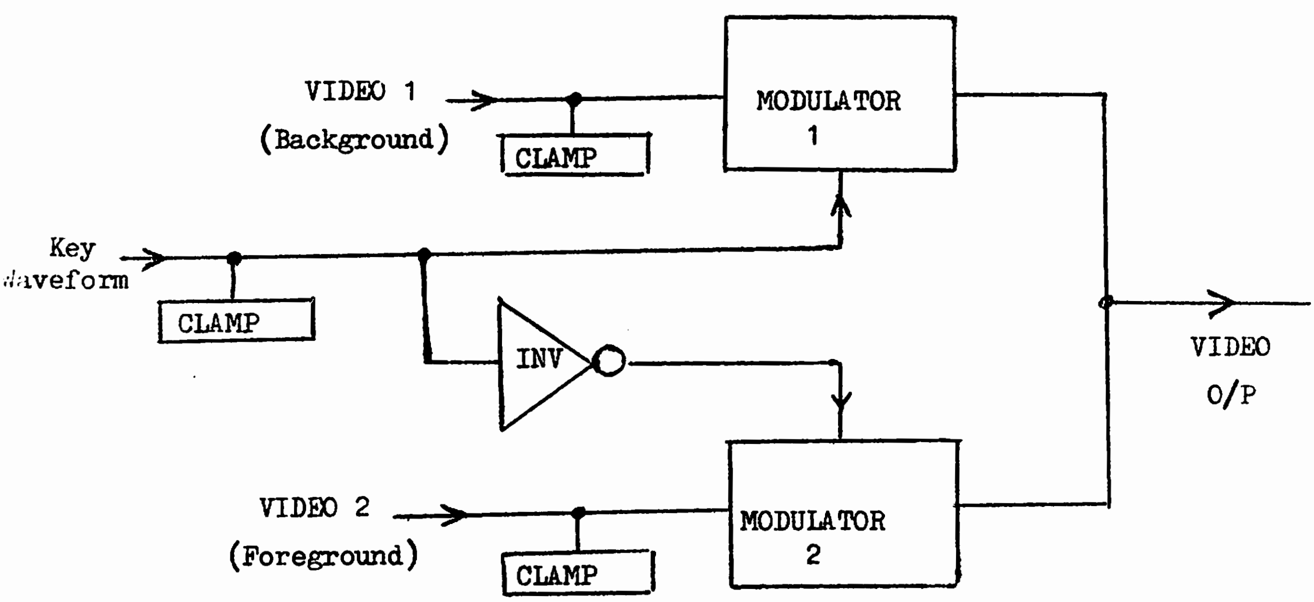


Figure 19

The switch consists basically of two voltage controlled amplifiers, (Modulator 1 and Modulator 2).

If the initial condition is that the key waveform is of high amplitude (background to be selected) then Modulator 1 is turned on to maximum gain and Modulator 2, because of the inverter, is turned off (minimum gain of zero). So output is VIDEO 1 - Background.

When the key waveform reduces in amplitude, Modulator 1 is turned off and Modulator 2 is turned on to maximum gain and the output of the "switch" is VIDEO 2 - Foreground.

The important features to bear in mind with this circuit are :-

i) The amplifier gain is being controlled by the keying waveform.

ii) The rate of changeover from VIDEO 2 at the output to VIDEO 1 at the output is determined by the shape, i.e. rise time of the keying waveform.

iii) The action can be likened to a fast CROSSFADE between VIDEO 1 and VIDEO 2 not a CUT (Figure 20).

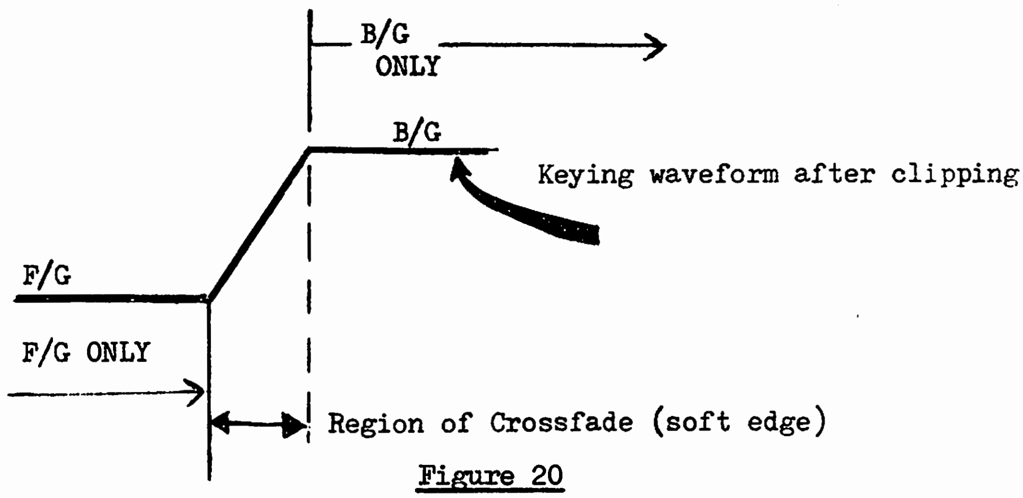


Figure 20

Incidentally, if the C.S.O. keying waveform should happen to contain a rapid change (fast rise time) then the switch would operate fast.

The soft edged switch, in addition to improvement in C.S.O. operation, has enabled the development of shadow, glass and smoke techniques and also fadable inlayed captions, these are discussed in a separate handout "C.S.O. Techniques".

A.P. Bermingham/MAG
5th May 1977