COLOUR SEPARATION OVERLAY

Colour Separation Overlay, usually called CSO, or Chromakey, has been with us almost as long as colour television. Since those early beginnings where its use was confined to static shots such as newsreader backgrounds it has progressed to become a major production tool. Quite a number of recent productions would have been very difficult, if not impossible, to achieve were it not for CSO. This information sheet revises the basic principles of CSO, and looks at some of the developments which have taken place over the years.

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1. BASIC TERMS

CSO, like any other technique, has its definitions, its buzz words and phrases. This section lists those terms together with an explanation of each.

BACKGROUND One of the three video sources required for CSO. The background is the basic picture or scene into which new information (the foreground) is to be placed. Do not confuse background with backing.

FOREGROUND Second of the three videos. The foreground signal replaces those parts of the background signal as defined by the key.

KEY The third video signal. Defines which areas of the background signal are to be replaced by the foreground. Most CSO operations are defined as "Common Key", the key and foreground sources being one and the same.

BACKING Is what the foreground objects are placed in front of. It is coloured to suit the key signal required **(KEY COLOUR)** and represents those areas which will correspond to the Background Signal in the final shot.

OVERLAY PROCESSOR Device which derives the key signal from the video source. The key signal is generally produced directly from RGB signals.

FRINGE ELIMINATOR or Fringe Suppressor. A function of the overlay processor which minimises the adverse effects of spill from the backing onto the foreground objects.

SOFT EDGE SWITCH A misnomer. Really a fast cross fading element. This is where Foreground, Background and Key come together. The soft characteristics minimise the effects of noise on the key signal causing "lively" edges.

SHADOW KEYER A quite separate CSO type system keying on the luminance component of the key source. Used to introduce shadows cast by the foreground objects into the final shot.

2. BASIC CSO

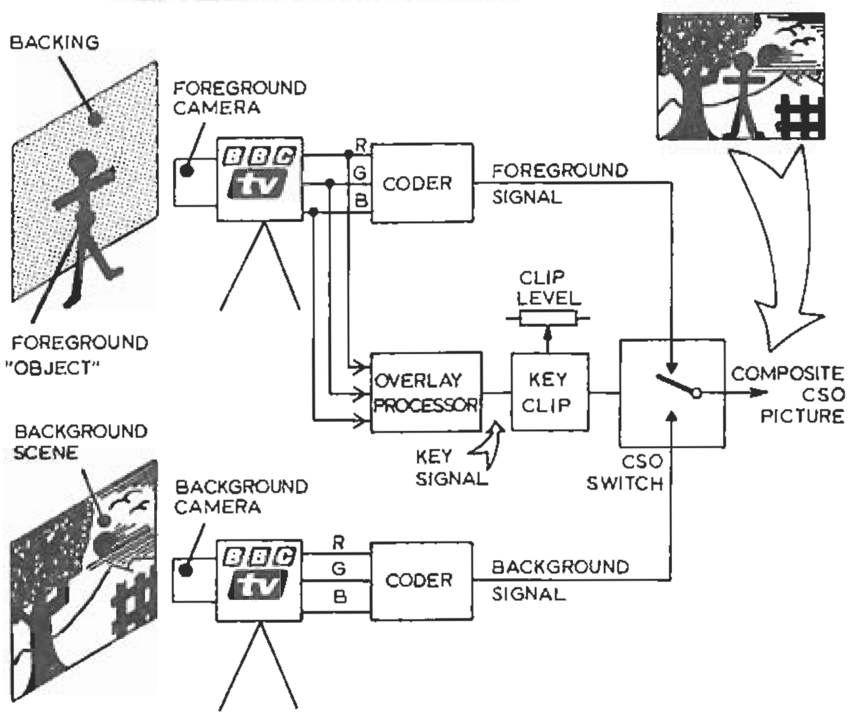

Fig. 2.1 Basic Common Key CSO System

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Figure 2.1 shows a basic, common key, CSO system. RGB outputs from the foreground camera feed both foreground coder and overlay processor. In the latter the key signal is derived. The selected key signal is passed to the key clip circuit, which essentially matches the characteristics of the key signal (level, risetime etc.) to those of the CSO switch. At the CSO switch those periods of the key signal corresponding to the backing cause the switch to select the background signal. The remaining periods select the foreground.

Although figure 2.1 shows a dedicated background camera the background signal could just as easily be any video source - V.T., T.K., Slide Scanner etc. Also a number of telecines are equipped to provide key signals and so may be used as foreground sources.

2.1 Separate Key

Figure 2.1 shows a common key operation where foreground and key sources are one and the same. It is possible to derive them independently, although this is generally reserved for special effects. In all other respects operation is identical with the common key system.

3. KEYS, SWITCHES AND CLIPPING

3.1 The Key Signal

Probably the biggest development has concentrated on the choice of key signal.

The principle requirement of the key is that it produces a large voltage distinction between the chosen backing colour and the remainder of the foreground scene. Throughout this information sheet we shall assume blue to be the keying colour, although the explanations apply equally well to any of the primary colours or their complementaries.

It is not merely sufficient to take account of the level of the keying colour in the scene. For example the camera's blue output is unable to distinguish between a saturated blue backing and white! Notice must be taken of the level of the other colours as well. In early CSO operations this was achieved by using a B-Y signal as the key. It was readily available from the foreground coder and gave reasonable results, especially if it could be picked off before the coder low pass filtering. As we shall see in figure 3.3 the voltage difference between blue and some other colours (notably magenta) is not great. This led to the investigation of other types of key.

3.1.1 B-M Keying

The first signal specifically produced for CSO keying was known as B-M. (M = mean). It was very similar to B-Y but instead of using Y a signal which gave equal weighting to the three primary colours was chosen. Hence:

M = 0.33R + 0.33G + 0.33B

or

B-M = 0.67B - 0.33R - 0.33G

Figure 3.1 shows such a signal being derived.

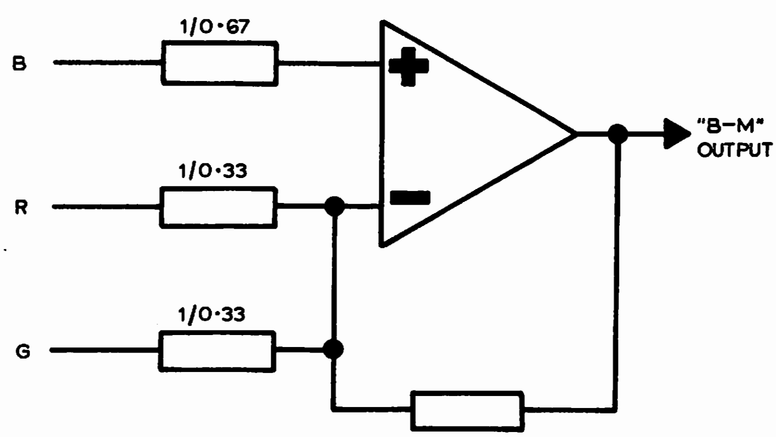

Figure 3.1 Derivation of B-M Key

B-M was a step in the right direction but did not entirely meet the requirements. What is really needed is a signal which indicates when the keying colour is dominant in the foreground scene. This is achieved by the present generation of overlay key processors which generate "excess colour" key signals.

3.1.2 Excess Blue Keying

If blue is the chosen keying colour then an ideal key signal will indicate when blue in the foreground scene dominates all other colours. The key processor therefore determines the degree to which the blue signal is in excess of red and green - hence the name excess blue.

Thus an expression for such a key signal is

Key = B - (greater of R and G)

Figure 3.2 shows the derivation of an excess blue key.

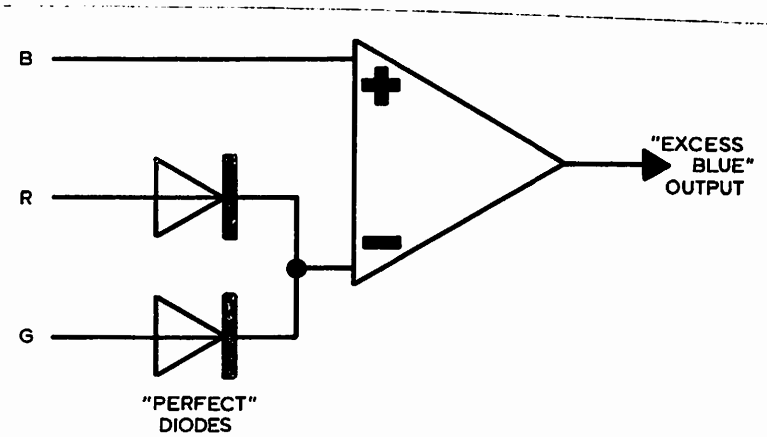

Figure 3.2 Derivation of Excess Blue Key

3.2 Key Signal Performance

Earlier it was mentioned that the ideal key signal produces the greatest voltage distinction between the chosen backing colour and all others. Figure 3.3 shows how the three key signals described perform with 100% saturated colours. The waveforms shown would be those resulting if the foreground camera was replaced by a colour bar generator.

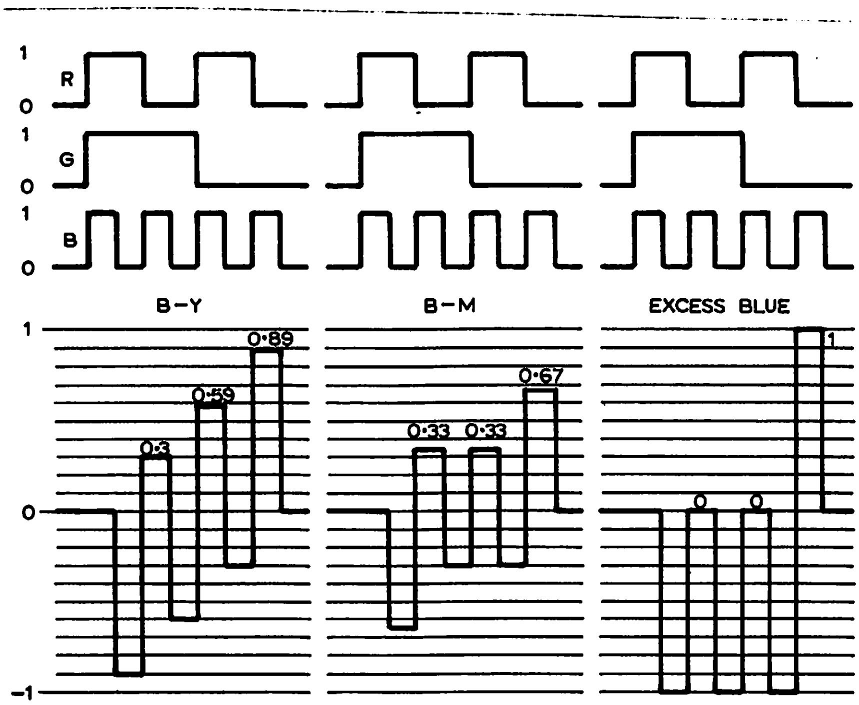

Figure 3.3 Comparison of B-Y, B-M and Excess Blue Keys

Figure 3.3 shows the improvement the various keys offer. B-M, although smaller than B-Y, offers an improved Blue-Magenta separation (2:1 instead of 1.5:1). For fully saturated colours however the separation of blue over all other colours is perfect with the excess blue signal.

If the three signals are "normalised" to 1 volt for blue then in absolute terms the blue magenta separation is 0.33V for B-Y, 0.5V for B-M and 1.0V for Excess Blue. Note that these figures are directly proportional to the scene saturation and under practical conditions the voltage margins could be somewhat smaller.

3.3 Switches and Clipping

As the function of the key clip stage is to match the key signal characteristics to those of the switch it is sensible to consider them together. Early CSO operations did, indeed, use a switch to key the foreground into the background signal. A true switch can have only two states, foreground or background connected to the output. The key signal applied to it must also have only two levels, as at some intermediate point the switch is uncertain as to which signal it should be selecting and erratic operation results.

The clipper associated with such a switch needs a high gain, thus exhibiting a hard clipping action. Noise and other transients superimposed on the keying signal will cause problems around the clipping threshold, the result being a picture with "lively" transitions, particularly on fine detail around the edge of the foreground object (e.g. hairlines etc.).

Figure 3.4 shows a hard switch and its clipper, together with the problem described above.

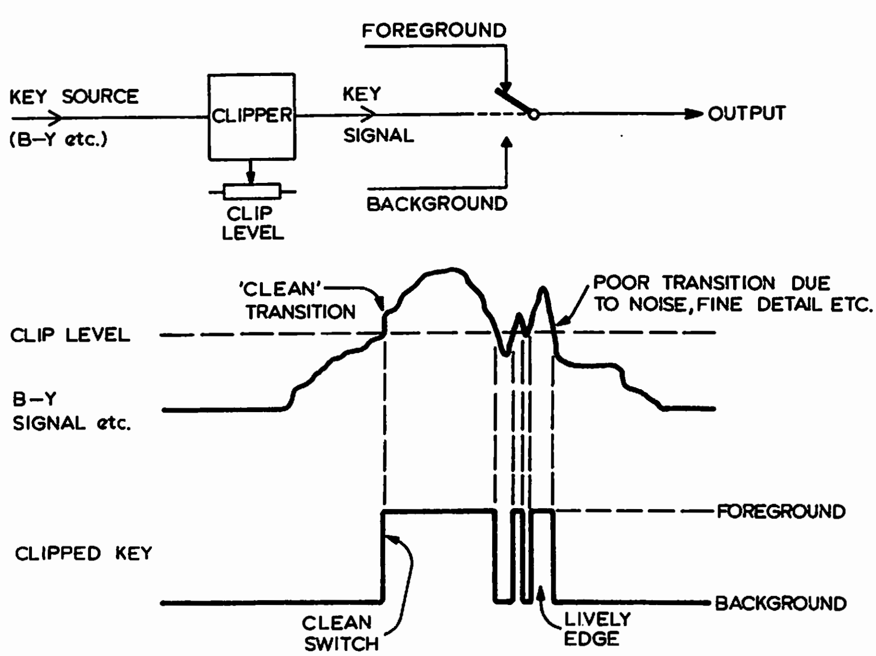

Figure 3.4 Problems of Hard Switching

3.3.1 Soft Edged Switch

The problems due to noise and fine detail are minimised by a soft edged switch. Here the "switch" is not a true switch as such but a pair of voltage controlled amplifiers configured as a cross fading element. Figure 3.5 shows such an arrangement, together with a simple analogy which shows the switch as a cross fader. The instantaneous level of the key signal now determines the relative position of the "slider", and hence the mix of foreground and background signals produced.

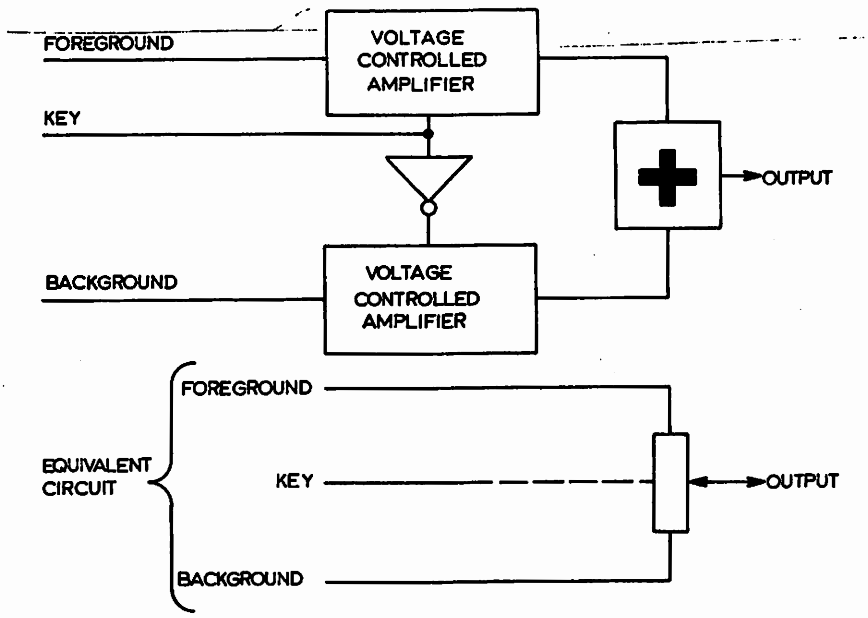

Figure 3.5 Soft Edged Switch

The soft edged switch recognises not just the key signal levels corresponding to foreground and background only but intermediate levels as well. This enables the transition from foreground to background to be achieved by a rapid cross fade rather than an instant switch.

The clipper associated with such a "switch" has a much lower gain than its hard counterpart. This means that a much bigger input voltage change is required to swing the output from one extreme to the other. As a result a "window" opens up around the clipping threshold, within which linear amplification of the input signal occurs. In this way the problems which would have resulted in lively edges now produce blurred ones. Figure 3.6 shows this.

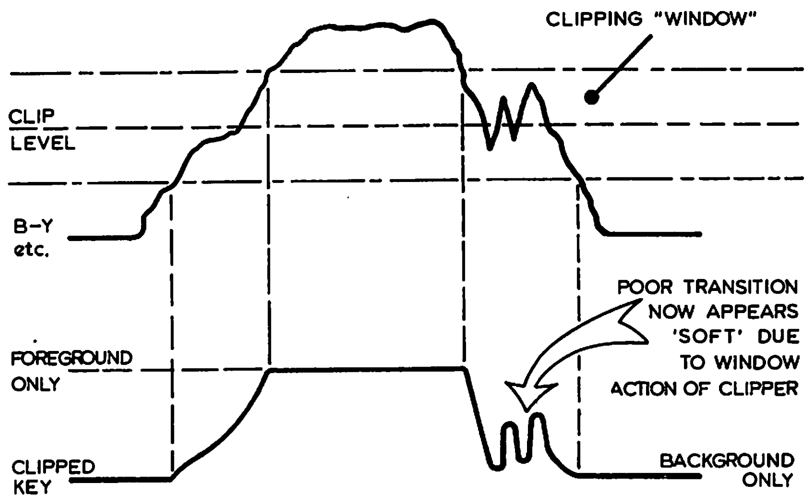

Figure 3.6 Action of the Soft Clipper

The lower the gain of the comparator the softer the transition can become. Most CSO systems use a fixed level of softness which combines optimum "sharpness" with minimum degradation on noisy signals. Note that no amount of softness will degrade a perfect key transition. (i.e. one with zero risetime).

4. FRINGING

So far the only problems considered have been those associated with the key signal and the switching process. A perfect switch and an immaculate key signal do not guarantee perfect CSO shots however. The key signal is derived from the wideband RGB camera outputs and suffers the minimum degradation possible. The CSO switch on the other hand "switches" between two coded signals. Even if the switch cut a perfect "hole" out of the background what goes into it is far from perfect.

The biggest problem is that of colour fringing. For best results the backing should be as bright and saturated as possible. Generally there will be a limit, often quite small, on just how far in front of the backing the foreground can be placed. Under such conditions spill from the backing round the edges of the foreground objects is inevitable. This causes two problems. Firstly the edges of the foreground objects take on a blue finge, which in early days was one of the biggest "giveaways" when CSO was used. The second effect is a loss of fine detail round the edges of the foreground object.

Take a typical example of an artist in front of a blue backing. Spill from the backing will cause a blue fringe around the edge of the artist. Blue fringing will also be readily apparent around the head, particularly where it shows through the hair. Due to the problems of the PAL coding process bright, highly saturated colours lack sharpness as much of the information is carried by the narrowband colour difference signals. As the spill from the backing artifically colours the edges round the foreground object much of the original detail is lost due to coding and decoding.

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4.1 Fringe Elimination

The excess blue key signal affords a means whereby the worst effects of fringing can be eliminated. Assume that the foreground object is white and the backing blue. Spill from the backing causes the foreground to have desaturated blue edges. Remember that the excess key signal is directly proportional to the intensity of the key colour. In the region of the spill the key signal amplitude represents the amount of blue in the spill. Figure 4.1 shows this.

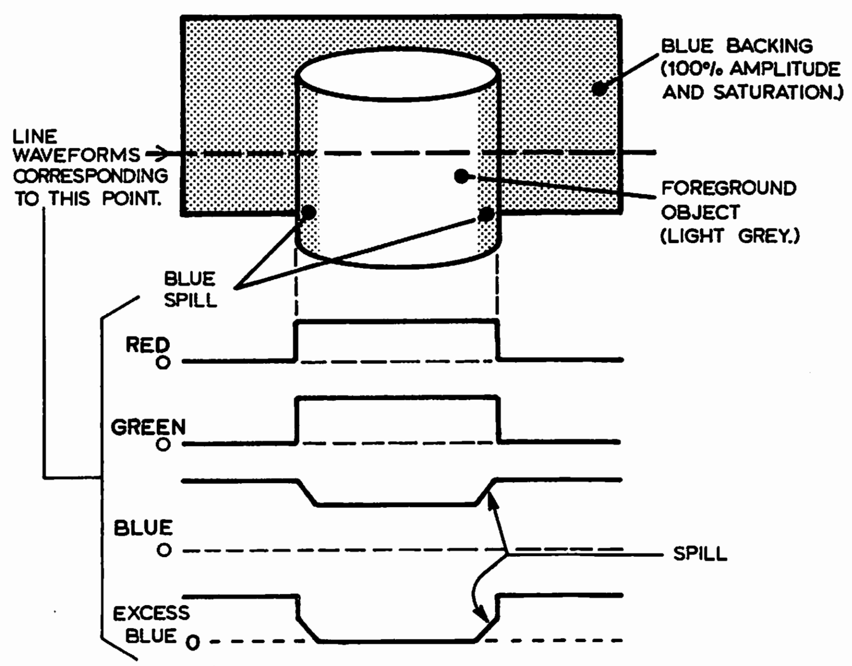

Figure 4.1 Excess Blue Key Showing Effects of Spill

The effect of the spill can be minimised if the key signal is subtracted from the original blue signal before it is connected to the foreground coder. This means that the amplitude of blue in the coded foreground signal can never exceed that of red or green. As a result the fringe is not "eliminated" as such but transformed from blue to one determined by the colour of the foreground object, and generally of much reduced saturation. In the case of figure 4.1 the resulting fringe becomes a neutral one, as shown in figure 4.2.

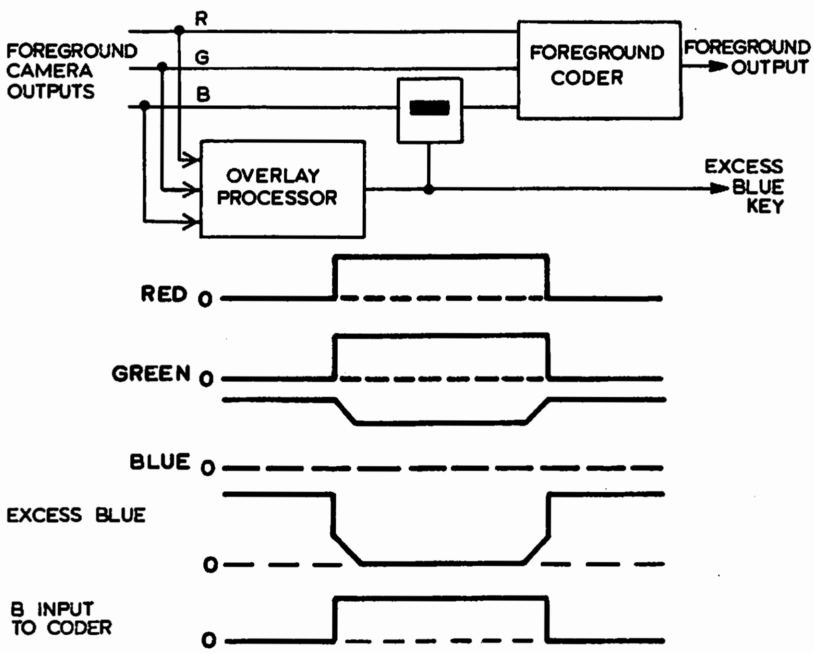

Figure 4.2 Spill Removed by Fringe Eliminator

The fringe eliminator has two effects therefore. It changes the colour of the fringe and reduces its saturation. In the rather perfect example of figure 4.1 the fringe is eliminated altogether. In many cases this will not happen but the saturation is still reduced. This means that less information will be conveyed by the narrowband colour difference signals and so more detail in the original foreground object is preserved.

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With the fringe eliminator in operation a monitor displaying the foreground camera output will show the foreground objects against a black (or at least dark grey) backing. The foreground camera output cannot contain any colours where blue exceeds the red or green component, i.e. those colours lying between cyan and magneta on a vectorscope. Figure 4.3 shows this.

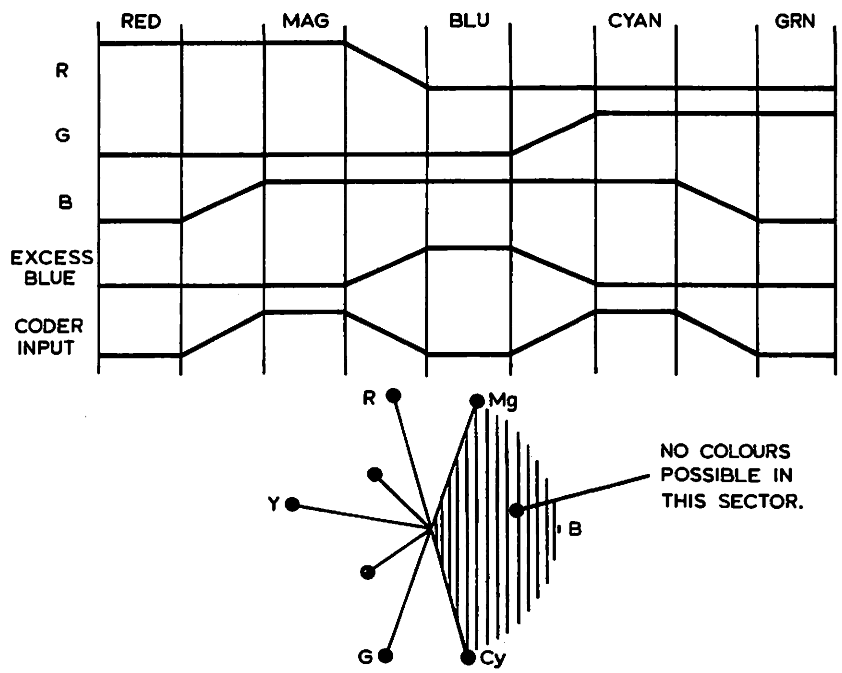

Figure 4.3 Effect of Fringe Eliminator on Foreground Coder Output

5. SHADOWS

Normally objects and artistes appearing in front of a camera cast shadows. In a simple CSO system it is essential that the lighting prevents shadows from being cast on the backing otherwise it will be difficult to key properly. As a result the final scene has no shadows - leastways not from the foreground! (could look very odd if there are background shadows though).

A further development of CSO has enabled shadows to be keyed into the final shot, thus adding considerably to the realism and the headaches of the lighting director.

5.1 Shadow Keying

Shadow keying relies on the cross fading properties of the soft edged switch. Imagine such a switch with background on one input and black level on the other. The switch is now a fader, the amplitude of the key signal determining the precise attenuation of the background signal. Figure 5.1 shows this.

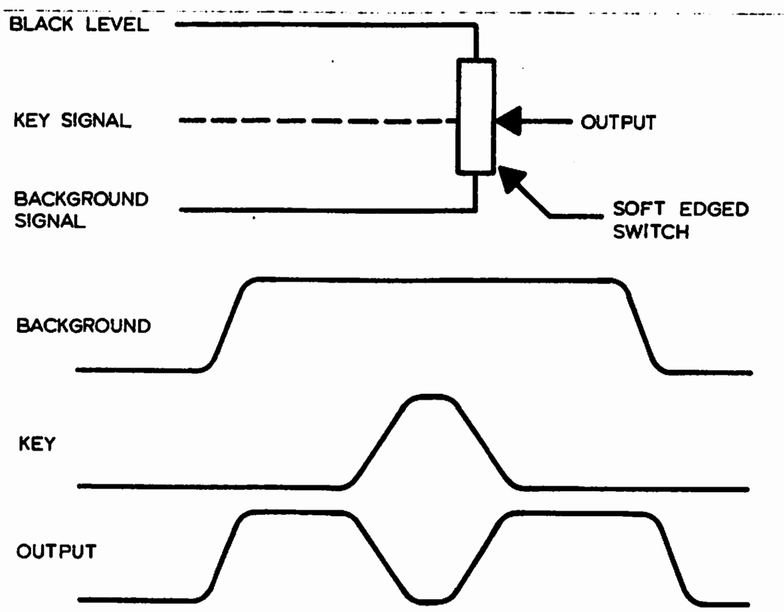

Figure 5.1 Basic Principle of Shadow Keying

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Imagine now that the key signal corresponds to a shadow cast by the foreground. A full amplitude key signal completely fades down the background signal in the area of the shadow, as a result a dense, black shadow is produced. If the key signal is not at full amplitude then only a partial fade is produced. The shadow appears less dense and hence only partially obscures the background. Just two questions then, where do the shadow and key signals come from?

The shadows are produced in the foreground scene by ensuring that the foreground objects cast shadows onto the backing. The key signal is derived from the luminance component of the foreground camera. The luminance level of the blue backing is fairly high and enables the background to pass through unaffected. The low level of key which corresponds to the shadow is used to key in those parts of the foreground camera corresponding to the shadow. (Remember that the fringe eliminator has resulted in the foreground scene appearing to have a black backing). An attenuator in the key signal feed enables the density of the shadow to be controlled. (Maximum density = minimum attenuation).
Figure 5.2 shows this.

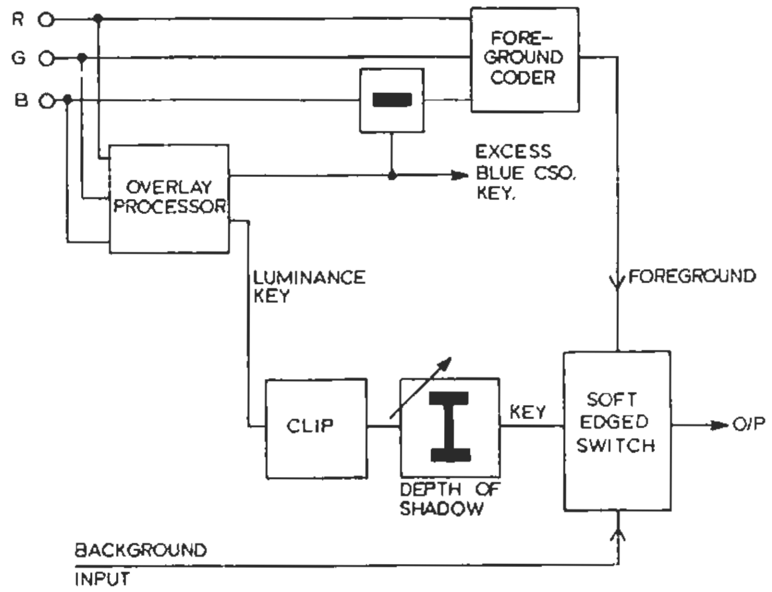

Figure 5.2 Basic Shadow Keyer

The shadow switch passes background information when the bright backing colour is present, and the foreground camera during the darker shadows. What happens in the areas occupied by the foreground detail? In these areas the operation of the switch is indeterminate as it depends on the luminance level of the scene detail. In fact it doesn't actually matter as the shadow switch is followed by the main CSO switch. This replaces those parts of the scene which correspond to foreground detail only, the final output therefore being foreground + shadows + background. Figure 5.3 shows the complete system.

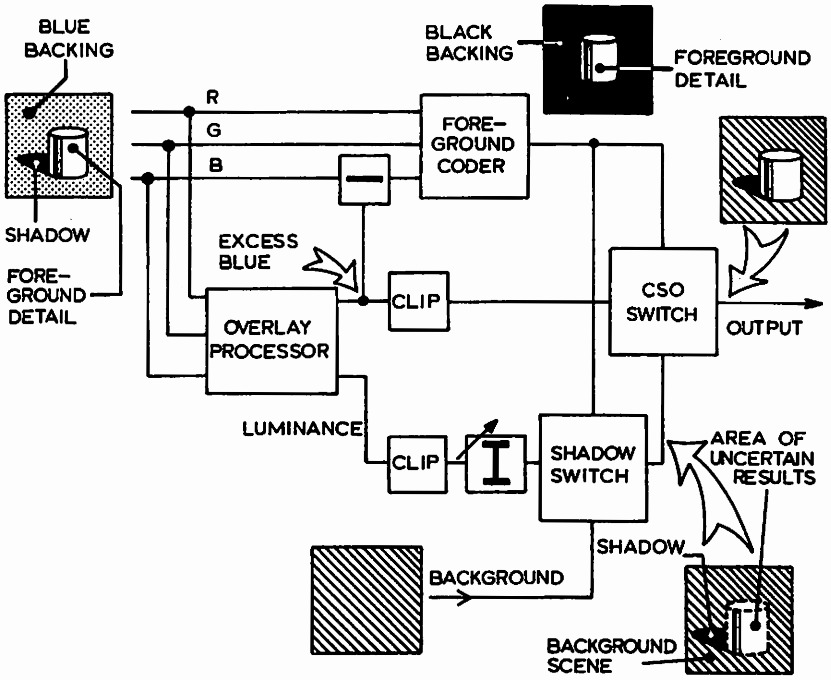

Figure 5.3 Complete System for Shadow Keying

In the arrangement of figure 5.3 the shadow key clipper will be set up to give shadows with clean edges, the intensity of the shadow being subsequently determined by the attenuator.

And the lighting director's headaches? He's got to make sure that the foreground and background shadows fall in the same direction!

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