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Automatic facilities of the Mark IX camera

Summary

In the Marconi Mark IX colour television cameras a number of automatic facilities are available, comprising a group of line-up controls to set up the camera and a group of dynamic controls which can be adjusted during operation.

Whilst automatic controls are not regarded as a substitute for circuit stability, automatic line-up provides rapid and convenient alignment, and the dynamic controls enable good pictures to be obtained with the camera control panel unattended. The automatic facilities are, nevertheless, optional, and may be omitted where operational conditions permit.

The line-up controls are Automatic Registration, Black Balance and White Balance. Registration is carried out in an automatic sequence consisting of White Balance followed by automatic registration of the red and blue images to the green, using an internal diascope test pattern.

Automatic Black Balance adjusts the lift controls of the three video channels so that the black levels are equal. White Balance sets the gains of the red and blue channels to make the signal levels equal to that of the green.

The dynamic controls consist of Automatic Iris, which adjust the exposure of the camera. Automatic Master Black adjusts the master black level to bring the most negative excursion of the green, red or blue signals to blanking level. Automatic Centring compares picture transitions and applies appropriate corrections if centring errors occur.

Introduction

In a colour television camera, there are a number of adjustments for which automatic controls can be provided. They can be divided into two groups; firstly, line-up controls, which are set up to prepare the camera channel for use, and secondly, dynamic adjustments which may be made while the camera is in operation as required by the contents of the scene being televised.

Automatic controls cannot be regarded as a substitute for stability in the circuits they control. This is especially true of the first group of controls, since one cannot expect to be able to take the camera channel out of service for re-alignment to correct for drift. However, automatic line-up facilities allow rapid and convenient alignment, whilst dynamic automatic controls enable good pictures to be obtained with the camera control panel unattended. The comprehensive range of automatic facilities available in the Mark IX camera family[1,2] will be particularly valuable in outside broadcast operations, especially in small units such as the Marconi Mini Mobile and in ENG (electronic news gathering) operations with minimal crew. The automatic facilities are, however, optional, and where environmental conditions and operational procedures permit they can be omitted.

The Mark IX camera automatic line-up controls are black balance and white balance (together ensuring colour balance through the grey scale), and registration; and the dynamic controls are centring, master black and iris (lens aperture). The units are housed in three plug-in modules in the Camera Control Unit and comprise the Automatic Registration Module shown in figure 4, the Automatic Balance Module shown in figure 7 and the Automatic Centring Module shown in figure 11. In order to minimize printed wiring board space and power consumption, circuits are shared between functions as far as possible, and low-power Schottky TTL is extensively used.

Potentiometers, driven by small electric motors, which can be seen in the photographs, form an ideal medium for storage of control information established by the automatic systems. They retain information indefinitely when the camera is switched off, they are easily controlled by logic circuits, and have the advantage over digital storage methods that manual override can be implemented easily.

A further feature for which automatic control is provided, Dynamic Gain, is described in another article in this issue.

The automatic systems except for automatic centring may be controlled either from the Remote Control Panel (RCP) (figure 1) or from the Camera Control Panel attached to the Camera Control Unit (CCU).

Automatic registration

LINE UP SEQUENCE: STUDIO AND O B CAMERA

Automatic Registration is achieved in a sequence of operations which follow automatically when the process is initiated. This is done by turning the rotary Camera State switch on the CCP or RCP to REGISTER and pushing the adjacent button. The following operations then take place automatically:

1. The camera is capped.
2. A special test pattern is projected directly into the front of the light-splitting prism from a built-in diascope (slide-projector).
3. The camera is white balanced for the colour

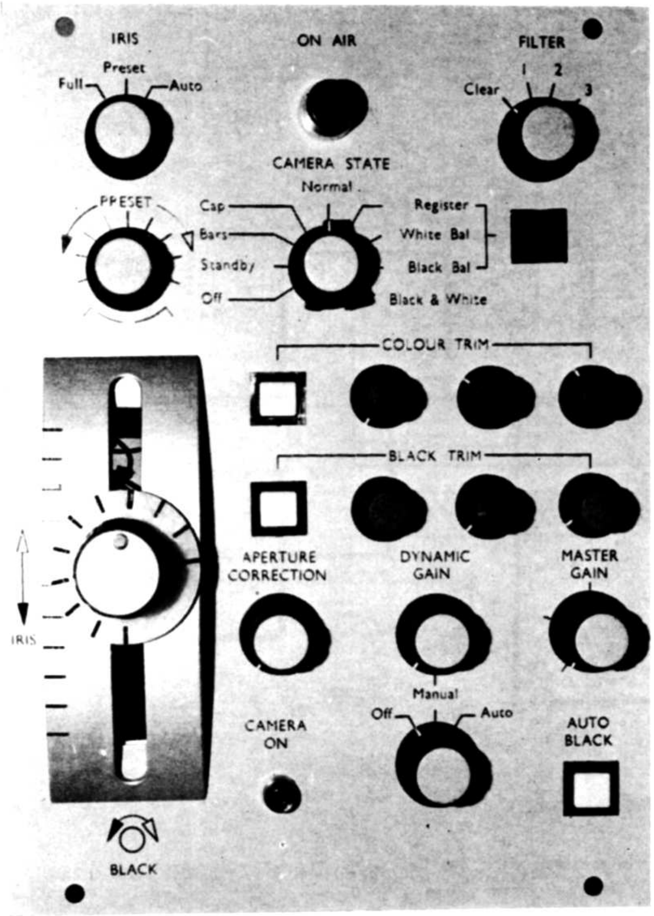

Figure 1. The Mark IX Remote Control Panel, from which the automatic systems are controlled

temperature of the diascope lamp, the amplitudes of the green, red and blue video signals being adjusted to equal pre-determined levels. These level settings are maintained independently of the main channel gain controls for the duration of the automatic sequence. Thus the operational settings of colour balance are not disturbed when registration takes place.

4. When the white balance is correct, the red channel is automatically registered, using the green channel as reference.
5. The blue channel is similarly registered.
6. The diascope test pattern is removed.
7. The camera is uncapped and returned to normal operation.

A detection system is used to ensure that each stage of the line-up sequence is correctly completed before proceeding to the next. The entire operation takes under three minutes. The sequence can be started at the camera head, as well as the CCP or RCP.

LINE-UP SEQUENCE: PORTABLE CAMERA

In the portable camera in order to reduce weight the test pattern diascope is not built in but takes the form of a detachable accessory that fits in place of the lens. The automatic line-up sequence therefore starts with item 3 above, colour balancing, and finishes with item 5, blue registration.

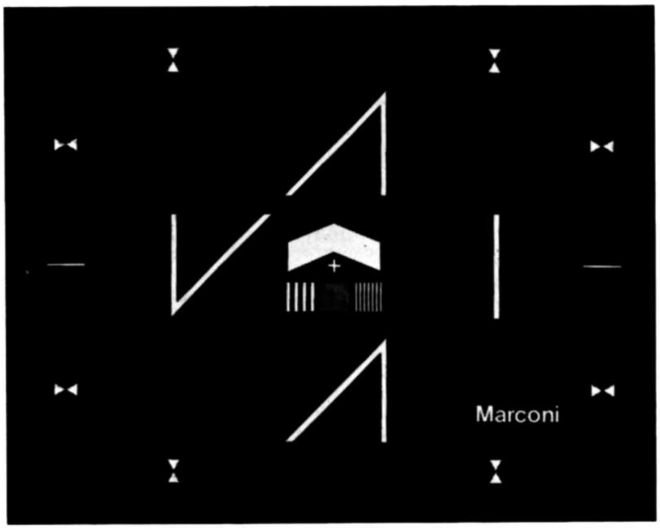

Figure 2. Diascope test pattern for automatic registration

As an alternative to the use of the diascope, the camera may be directed to an external chart bearing the same pattern.

DIASCOPE TEST PATTERN

The special test pattern used for automatic registration is shown in figure 2. In the pattern, the angular features located above and below and to left of the central area, and the vertical line to the right are used to provide information about horizontal and vertical misregistration. In the central area the small cross is used in manual beam alignment, whilst below it there are 100, 200 and 400-line resolution bars for checking the beam focus setting. Above the cross the white area is included for white balance. At the edges of the pattern eight framing 'darts' mark the limits of the picture area.

AUTOMATIC REGISTRATION SYSTEM

Registration errors in the red and blue images are detected in terms of signal timing errors relative to the green image which is used as reference. Only the red and blue channels' scanning parameters, therefore, need to becontrolled. Scan control information is fed back to the camera head from the registration error detection system to complete the control loop. A block diagram of the system is shown in figure 3.

Using information from the green image, a line selection system gates out detection lines at the vertical centre point of each of the three diascope angular patterns. By examining relative timings of the video waveform at these points. the sense and direction of misregistration is detected. The top and bottom sloping edges provide timing information for vertical centring and height, while control of horizontal centring and width is derived from the left and right vertical bars. All these adjustments are made simultaneously, and this eliminates any possible effects due to interaction of the controls. When all the edges are in time coincidence, registration of the image is complete. The printed circuit board containing the auto registration circuits is shown in figure 4.

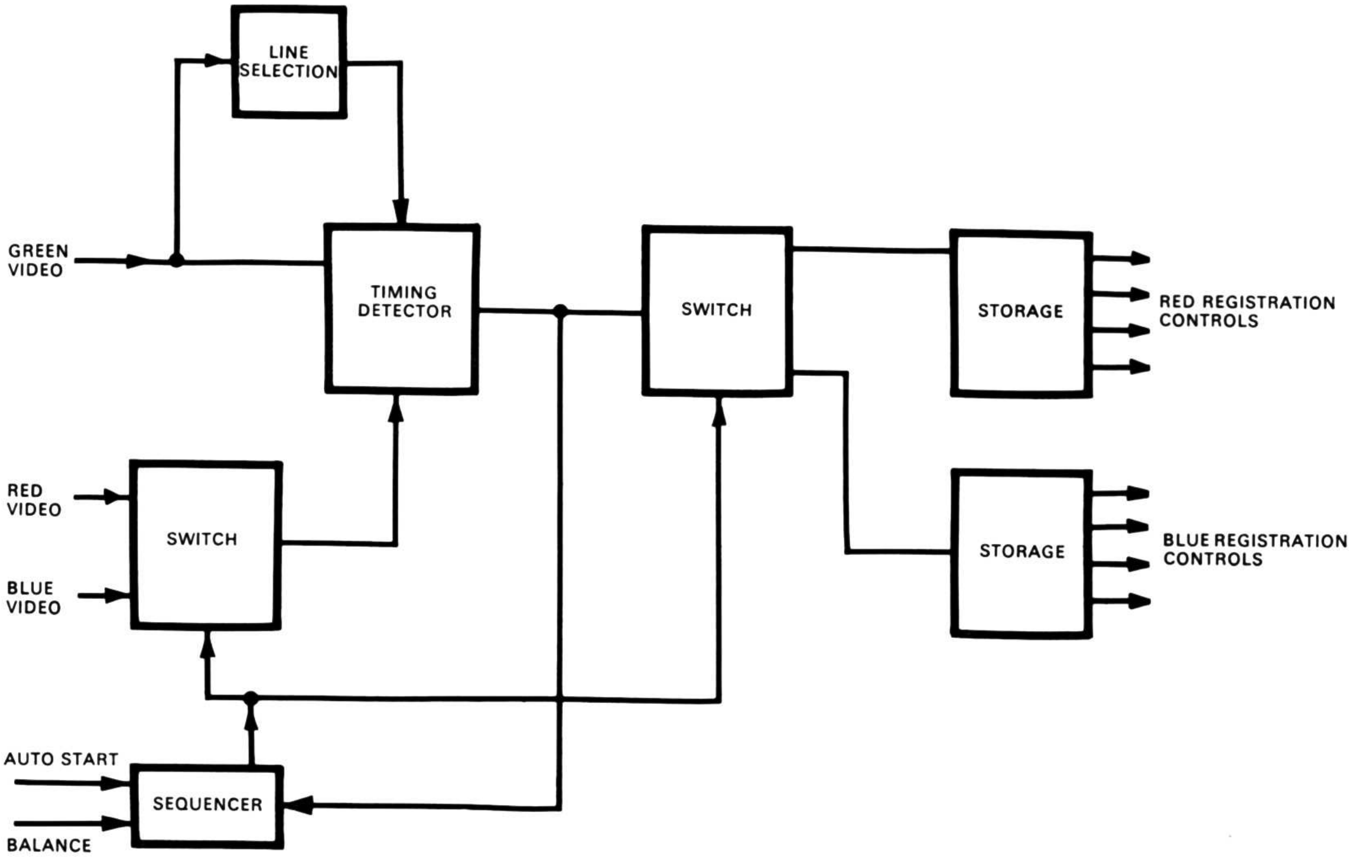

Figure 3. Automatic Registration block diagram

Black Balance

Automatic Black Balance adjusts the black level (lift) controls of the three video channels to make the black levels of red, green and blue video equal to blanking level so that neutral dark grey tones are correctly reproduced on a monitor or receiver. Three controls are provided rather than two so that the master black control, which controls the overall black level of the picture, can be calibrated by black balancing.

In addition to compensating for any offsets in the video circuitry, which are most significant at black level owing to the steepness of the gamma corrector characteristic, black balance controls compensate for the dark currents in the camera tubes which with light-biased tubes can amount to 17% of the video level before gamma correction.

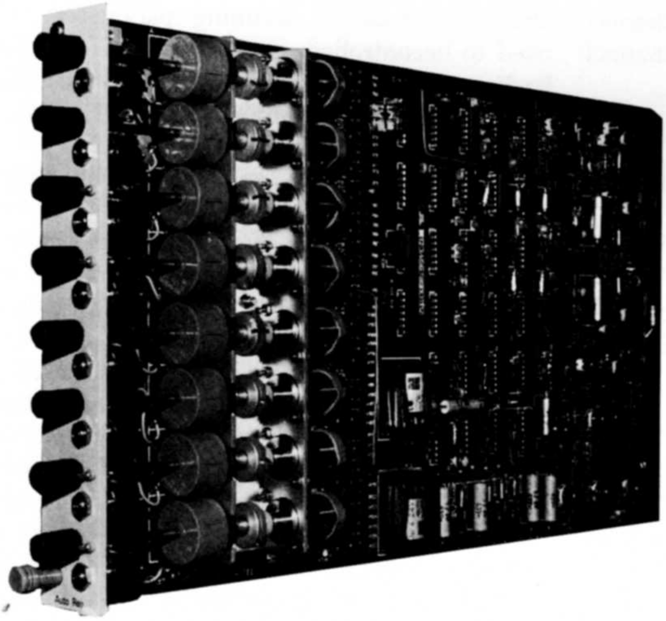

Figure 4. The Automatic Registration Module

Balancing is initiated from the CCP or RCP by turning the function switch to BLACK BALANCE, and pressing the pushbutton, which remains illuminated while balancing is in progress. The studio camera is automatically capped by a motorized shutter, and a solid white circle is displayed on the viewfinder to indicate to the cameraman that black balancing is in progress, or in the case of the portable camera, that the lens cap should be in place. A video detector circuit inhibits balancing until the camera is capped. Balancing 'capped black' allows the whole picture area to be sensed, and eliminates flare in the optical system which in normal operation is corrected elsewhere in the video circuitry.

Video is coupled to the Automatic Balance Module from immediately prior to the black clipper stages, where the d.c levels are well defined relative to the blanking levels at the channel outputs. The same feed is used for White Balance and Auto Master Black. A severe bandwidth restriction, provided by R and C in figure 5, permits precise balancing in the presence of the relatively high noise level at black level, corresponding typically to a signal-to-noise ratio of only 20dB. This is caused by the steep gamma corrector characteristic and the need to balance at the maximum video

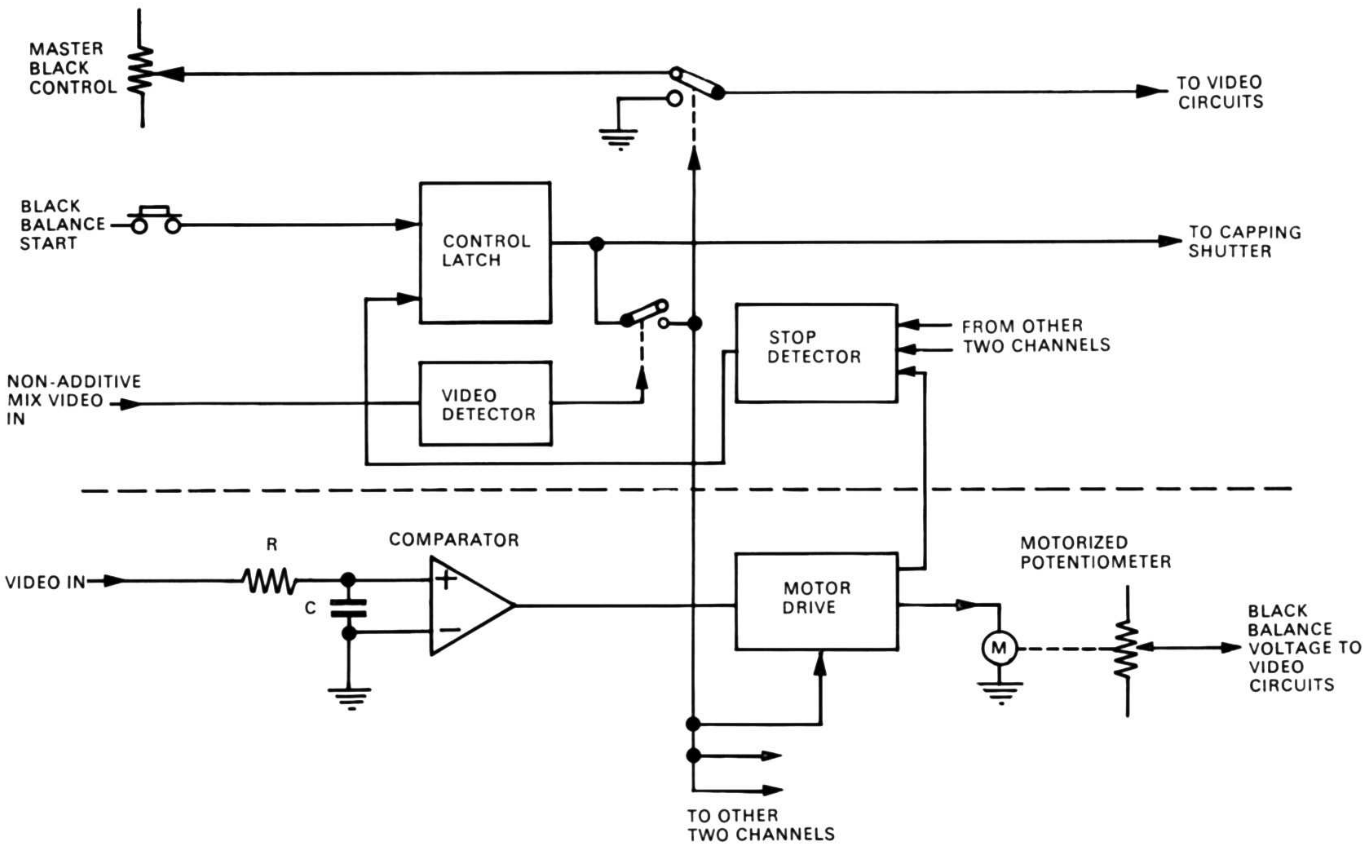

Figure 5. Automatic Black Balance block diagram

gain setting (+12dB) so that residual balance errors are not amplified by any subsequent increase in gain setting. The time constant introduces a significant delay into the servo loop but fortunately speed is of secondary importance in black balancing since large adjustments are only rarely required, such as after changing camera tubes.

A stop detector circuit cancels the function when

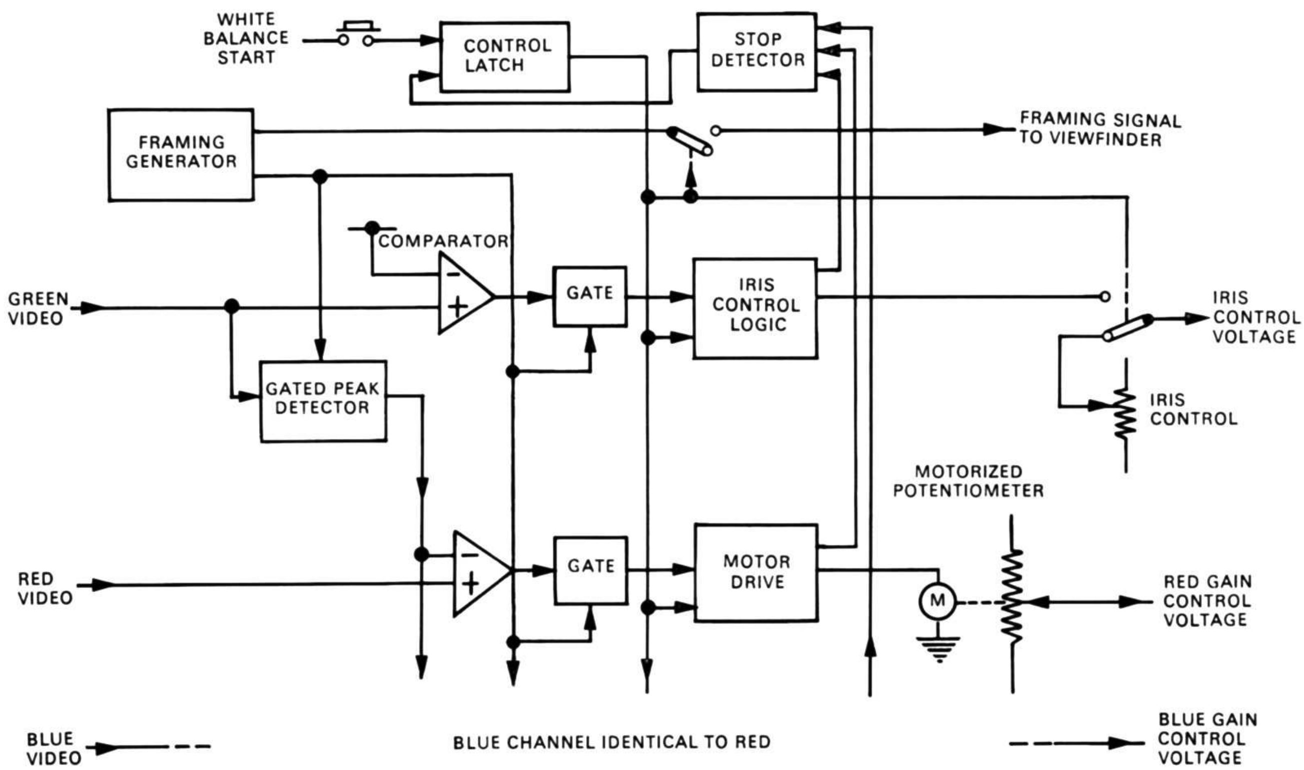

Figure 6. Automatic White Balance block diagram

balancing is complete, and returns the camera to normal operation.

White Balance

White balance (gain) controls are provided in the red and blue channels to balance their signal levels to that of green. This compensates for the colour temperature of scene illumination to give neutral white on a receiver or monitor. Although studio lighting can be accurately controlled, a wide gain range is needed because the colour temperature of daylight can vary widely (typically 3 000–10 000°K).

White balance is initiated by turning the function switch on the CCP (or RCP) to WHITE BALANCE and pressing the pushbutton, which lights during balancing. The arrangement used is shown in figure 6. As the noise level at white is much lower than at black the peak levels of red and blue video can be balanced to that of green. The picture area used is restricted to a central framed portion. This allows the operator to isolate a suitable area of white in the scene. The lens iris is adjusted by a servo system to bring the peak level of green video, within the framed area, to 90% of peak white (safely below the clipping level). The peak level of green video is used as a reference with which red and blue peak levels are compared, over the framed area, and the red and blue motorized gain potentiometers are driven to balance them. When balance is achieved, the function is automatically cancelled.

The framed area of the picture is a circle with diameter approximately equal to half the picture height. This is easily generated by level-detecting a suitable mixture of line- and field-rate parabolic waveforms. This technique is commonly employed in analogue pattern generators for television special effects, and was used here because the parabolic waveforms are readily available from the shading correction circuitry. To assist the cameramen during balancing a white outline indicating the framed area is superimposed on the viewfinder picture.

Both white and black balance circuits, together with the automatic master black and iris circuits are contained on one module illustrated in figure 7.

Automatic Master Black

In principle, since black is absolute, *i.e* absence of light, no black level control is needed in a television camera. However, the television system has a limited contrast range which can be more effectively utilized if a black level control is available. The automatic system adjusts the black level to bring the most negative excursion of whichever primary colour signal is most negative to blanking level. Thus the whole dynamic range is used down to black level, without any information being lost in the black clippers. The process is illustrated in the block diagram, figure 8.

It was found to be advantageous to set a minimum size for the black area to which the system responds. This ensures that the black level is not raised because of negative peaks of noise or because of aperture correction. If the correction control is excessively advanced, pre- and over-shoots arise at sharp black-to-white or white-to-black transitions. The minimum area to which the circuit is sensitive is approximately 1/25 of picture width by 1/35 of picture height.

The automatic system raises the black level much more rapidly than it is lowered. This avoids visually disturbing oscillations of the black level when the picture content is rapidly changing (*e.g* when the camera is panned). A time-wise peak detection of the black level takes place, so that the darkest parts of the scene are lifted to near black level.

Automatic Master Black is selected by an illuminated binary pushbutton on the CCP (or RCP). Occasionally the operator may wish to return to

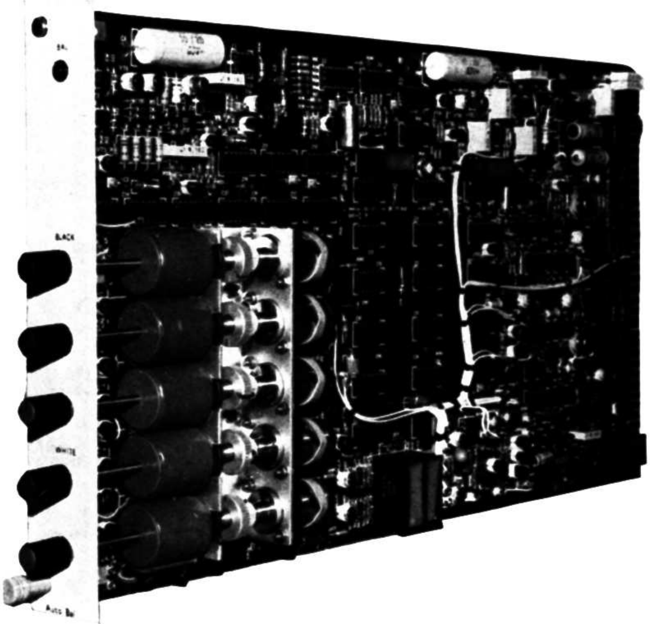

Figure 7. The Automatic Balance Module

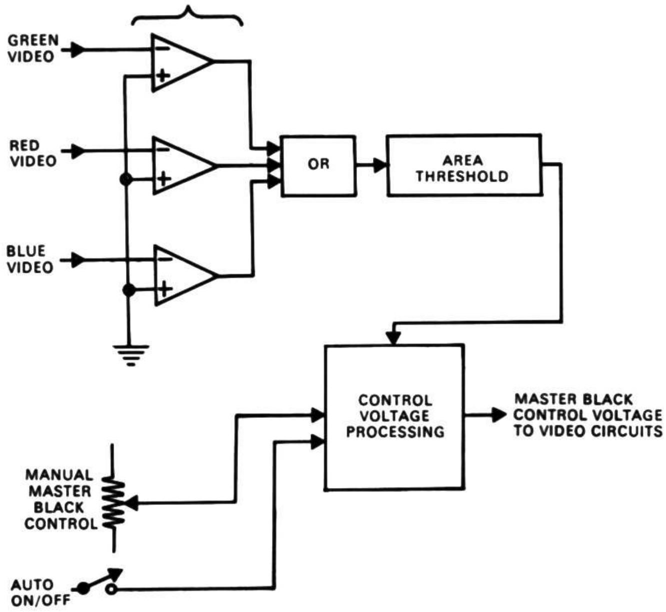

Figure 8. Automatic Master Black block diagram

manual control while the camera is on-air, and it was considered important to ensure that a visually disturbing jump in black level does not occur when the function is switched off. This is achieved by ramping the master black control voltage smoothly from the automatic to the manual setting. The manual setting required is easily predicted since the nominal setting of the control will have been calibrated by black balancing.

Automatic iris

The lens iris in a colour television camera is probably the control having the most marked effect on the picture produced, and at the same time is the most subjective in its setting. Consequently, considerable experiment was needed to optimize the criteria for an automatic iris system.

The Auto Iris system is illustrated in figure 9. Video from a point in the chain preceding the gamma correctors is used to determine the exposure required, because the video at this point has already been white balanced but has a greater overload margin than later in the video chain. In addition, the true brightness of the picture can be assessed at this point, since the gamma value is close to unity.

Various methods of combining red, green and blue video prior to level detection were evaluated and at first different additive mixes were tried. While an equal mixture of red, green and blue was best, all combinations gave over-exposure of scenes containing a preponderance of saturated colours. Non-additive mixing (in which the signal having the highest amplitude at any instant appears at the output) using silicon diodes overcame this problem.

For level detection, systems sensitive to peak video level and to mean level were evaluated and both found wanting. Peak level detection gave insufficient exposure when the scene contained bright highlights. Mean level detection was generally satisfactory, but caused over-exposure of low-key scenes such as people against a dark background. A detector sensitive to both peak and mean was finally chosen; just sufficient peak sensitivity was used to prevent over-exposure of flesh tones against a dark background. This gives slight under-exposure of back-lit scenes but is much less objectionable than 'burnt-out' flesh tones.

Since the part of the scene of greatest interest is normally at the centre of the picture, the Automatic Iris system was arranged to take more account of the centre of the picture than the edges. This is done by weighting the video with line and field rate parabolic waveforms which are available from the shading circuits.

It was found to be advantageous to open the lens iris relatively slowly in the event of under-exposure but to close it more quickly when over-exposure, which is more visually objectionable and potentially hazardous to pick-up tubes, is detected. This also has a peak detection effect (similar to that in Automatic Master Black) when the picture content is rapidly changing, which avoids over-exposure of brighter images. A small amount of hysteresis in the control is provided so that the exposure is not affected by very small changes in brightness. The resulting system is smooth and unobtrusive in operation and does not overshoot after making large corrections, even at maximum channel gain setting.

Specular reflections give rise to small, very bright areas in the picture which the Automatic Iris system must ignore. A minimum area which will cause the exposure to be reduced is set by an identical circuit to that used in Automatic Master Black for rejecting small black areas.

Automatic Iris is selected by an illuminated binary pushbutton on the CCP or a rotary switch on the RCP. Much consideration was given to the best method of providing smooth but quick transitions from automatic to manual iris control. Clearly a ramping arrangement of the type used for Automatic Master Black would be unsatisfactory because of the critical nature of the iris setting.

The solution adopted was to motorize the iris control potentiometer, via a slipping clutch, so that it rotates to follow automatic adjustments. This eliminates discontinuities in iris setting when switching between auto and manual. The control voltage to the iris servo is generated electronically and the potentiometer

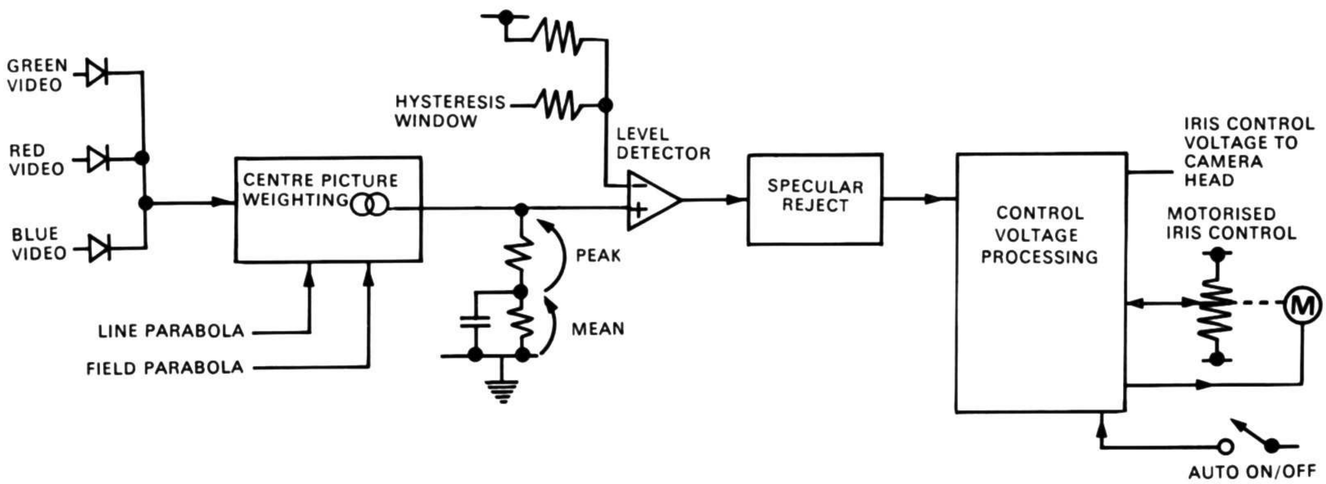

Figure 9. Automatic Iris block diagram

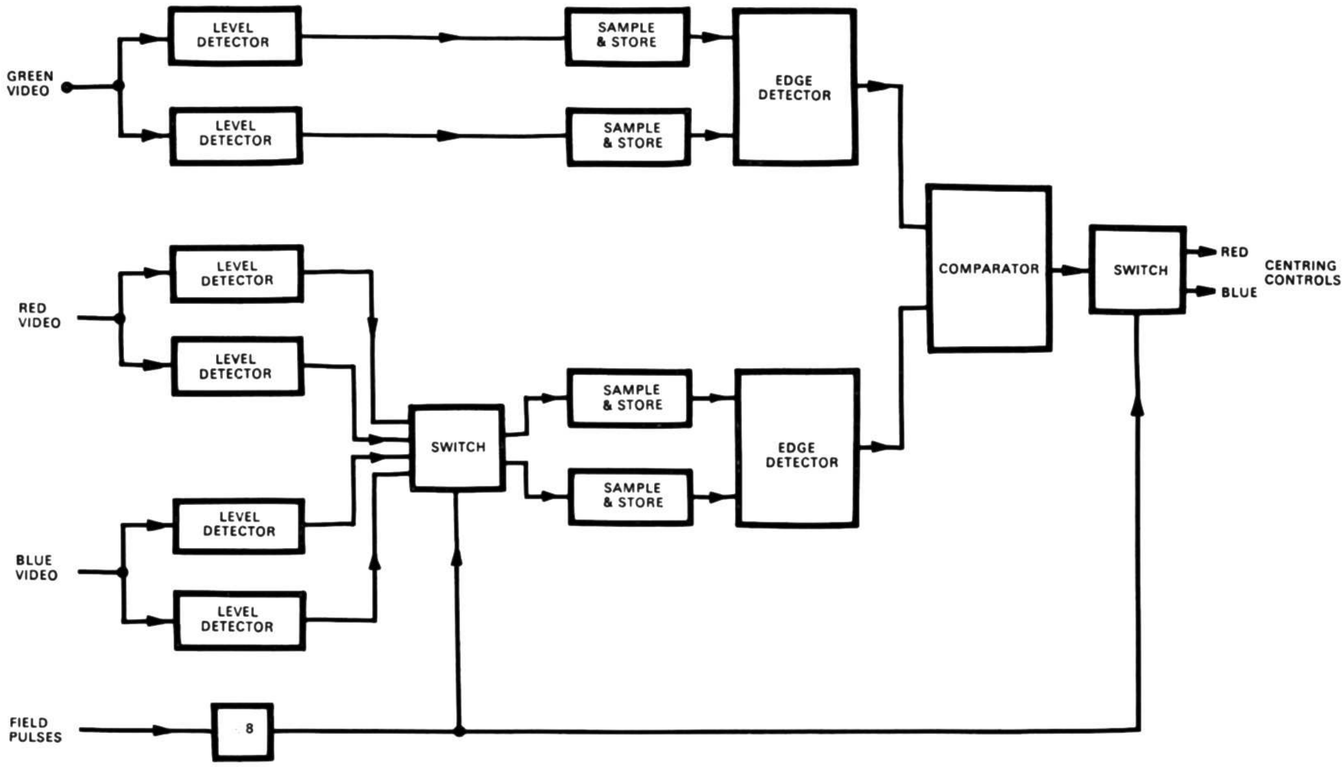

Figure 10. Automatic Centring block diagram

merely slaved to it. This arrangement is superior to the alternative in which the iris servo is controlled from the motorized potentiometer, since it eliminates the delay of the motorized potentiometer from the control loop. Incidentally, it also prevents the automatic system being defeated by the operator resting his script on the control panel!

Automatic centring

Despite careful design aimed at eliminating all causes of registration drift over extended periods, residual drift errors can exist. The error most apparent is in relative image positions, and to compensate for this, Automatic Centring detects registration errors from picture detail in the three images and adjusts the appropriate image centring controls in a direction to reduce the errors. The detection of errors is carried out along horizontal and vertical search lines. The search lines scan the central picture area, where the scanning sequence is controlled by a pre-programmed digital memory.

The block diagram of the system is shown in figure 10.

Each level detector produces a digital output the state of which depends on whether the video waveform is above or below a reference level. Each tube has two level detectors and the two reference levels are close to, and symmetrically displaced about, the half-amplitude of the video signal. The outputs of the level detectors are sampled at line frequency for the duration of the vertical search line, at 5.5MHz for the duration of the horizontal search line, and stored for the period of one sampling pulse. The horizontal sampling frequency is chosen to give the same resolution in the horizontal as in the vertical direction.

The sampled signals then pass to the edge detector stages where they are examined for patterns representing video transitions suitable for error correction. The green signal is used as a reference and the red and blue signals are arranged to time-share the second edge detector circuit by passing them through an electronic switch, the switching frequency of which is chosen to include both an even and an odd field in order to achieve better vertical resolution. The edge detection is carried out by a synchronous sequential logic system synchronized to the sampling waveform. The edge detector circuit recognizes positive- or negative-going transitions where the video waveform passes through both reference levels within the duration of one or two sampling pulses. Slower edges are rejected.

The outputs of the two edge-detector circuits are fed into the comparator. This produces an output signal when it receives information from both edge-detector circuits indicating that suitable transitions have occurred in both video inputs which are of the same sense (that is, either both positive going or both negative going), followed by a second set of transitions of opposite sense, and which are separated by at least seven sampling pulse periods, with both sets of transitions displaced in the same direction by not more than two sampling pulses.

In common with any automatic registration system working on picture information, there is a danger of operating from a luminance detail un-accompanied by a chrominance detail and a chrominance detail un-accompanied by a luminance detail, which are in close proximity in the picture area. Had the comparator worked on a single transition only, the chances of malfunction for this reason would have been significant.

In the present design, where both senses of transition are required, this has been reduced to statistically negligible proportions. The maximum displacement of transitions for operation of the comparator is limited to two sampling pulse periods to prevent the system operating on picture information in which there are adjacent edges which could be misinterpreted as registration errors.

The outputs of the comparator are in digital form and consist of signals that are present for one field period whenever an error is detected. These outputs are fed to the centring controls of the red and blue tubes via a second electronic switch, synchronized to the first, thereby separating the red and blue controls. The same motor-driven centring potentiometers are used as for the automatic registration system so that dynamic centring continually up-dates the registration of the camera channel. Figure 11 shows the printed circuit board used for the automatic centring system. A fully digital system has the advantage, that as the operation is frequency independent, the same circuits may be time-shared for horizontal and vertical registration error detection.

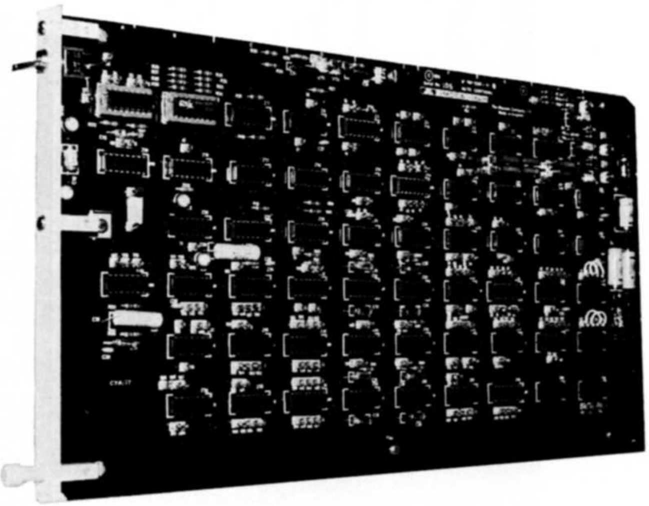

Figure 11. The Automatic Centring Module

Conclusion

The extensive use of digital circuitry and the sharing of circuit blocks between various functions has permitted a very comprehensive and at the same time effective and reliable set of automatic facilities to be provided for the Mark IX family of cameras. Only 0.2 square metre of printed board space is used, including thirteen motorized potentiometers, and a maximum total power of 9W is used with motors running.

References

[1] N. N. PARKER-SMITH: 'The Mark IX – A camera system for the 80s', *Communication & Broadcasting*, Vol.4, No.2, pp.4–9 (Spring, 1978).

[2] J. K. CROOK and I. E. GIBSON: 'A new studio outside broadcast camera channel', *Communication & Broadcasting*, Vol.4, No.2, pp.10–15 (Spring, 1978).