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THE MARK VI-PHOTOCONDUCTIVE CAMERA FOR LIVE AND TELECINE USE

INTRODUCTION

THE INTRODUCTION of the Mark VI camera in two versions, studio and telecine, completes the Marconi range of fully transistorized cameras. In its studio version it is designed to use the Plumbicon* tube and is small in size and light in weight. It is thus complementary to the Marconi Mark V[1] camera, being intended for the smaller studio, where the use of the larger 4½-in image orthicon would not be justified. The telecine version of the Mark VI is designed to use a vidicon tube. The studio camera is so designed that without the zoom lens, lens plate, viewfinder and viewfinder mounting assembly, the camera body contains all the circuitry required for a self-contained telecine camera. The assemblies comprising the studio camera are shown in Fig. 1a, and the telecine version in Fig. 1b.

Mechanically the camera channel consists of two parts, the camera head and the camera control unit, which also incorporates the power supply and main control panel. The basic camera control unit (CCU) serves both studio and telecine versions by means of alternative plug-in modules.

TELECINE CAMERA

The telecine camera head, Fig. 2, is a small rectangular box approximately 5×9×15 in long which can readily be fitted into any form of multiplexer system either horizontal or vertical. Separate or integral mesh vidicon tubes can be used with mesh or wall potentials up to 1,000 volts. It can operate on any of the 405-, 525- or 625-line standards and no tools are required for changing standards. Power supplies for the camera head are obtained from a small plug-in power unit situated behind the pick-up tube which can readily be removed to facilitate tube changing. A small front plate is fitted which carries a standard telecine alignment ring for easy location. The telecine CCU consists of five printed board plug-in modules and a large control panel module which also is plugged into the main frame and contains the power unit for the CCU and the higher voltages for the pick-up tube. Of the five smaller modules, three are for video processing, one for pulse processing and field scan, and the fifth a shading module. The shading module would not be required if a Plumbicon were used for telecine pick-up, in which case a blanking strip would be used to fill the space left by removal of this module.

STUDIO CAMERA

The Mark VI in studio or outside broadcast form, Fig. 3, is a versatile camera of small size and light weight utilizing a tilting viewfinder. It will have particular applications in smaller studios where larger channels are difficult to accommodate, and also in news or continuity studios. The studio camera can be fitted

*Registered trademark, Philips Gloeilampenfabrieken

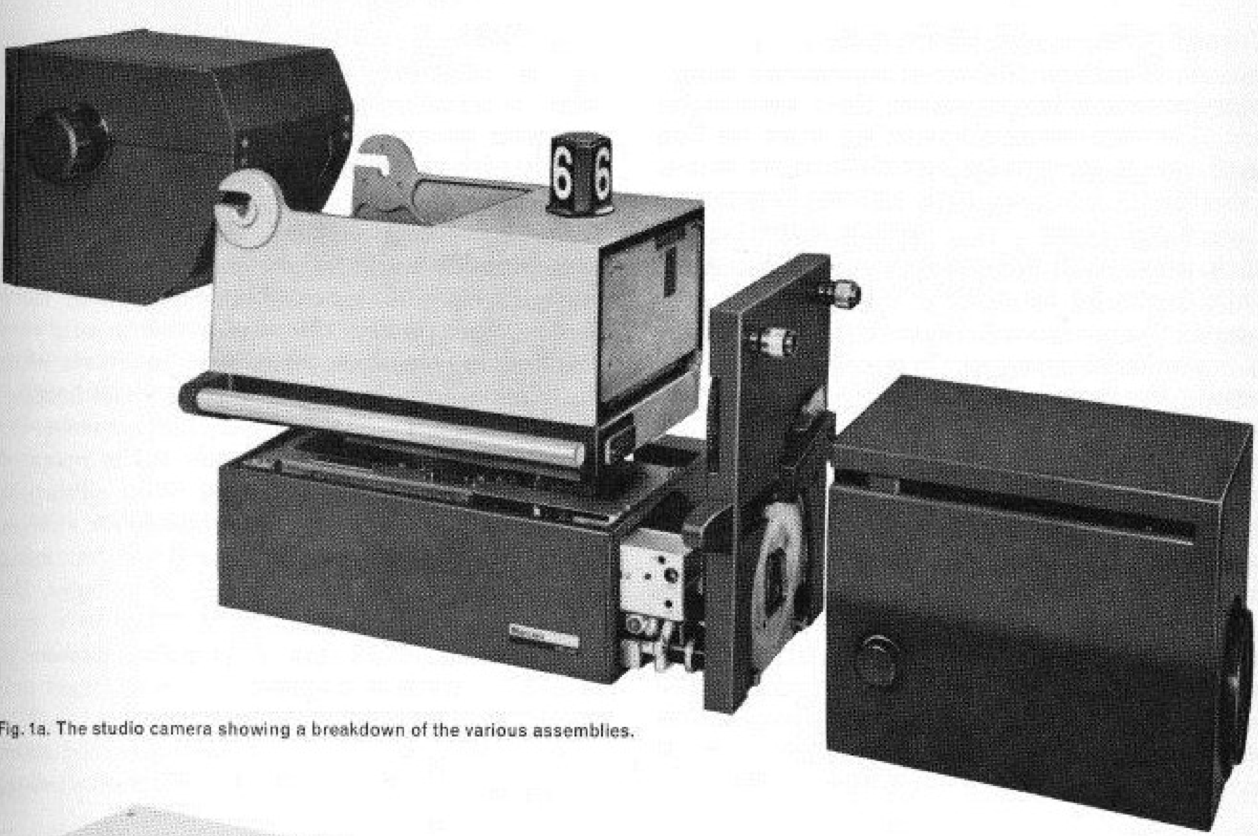

Fig. 1a. The studio camera showing a breakdown of the various assemblies.

Fig. 1b. The telecine camera breakdown showing the front plate and simple top cover added to the same camera body as shown in Fig. 1a.

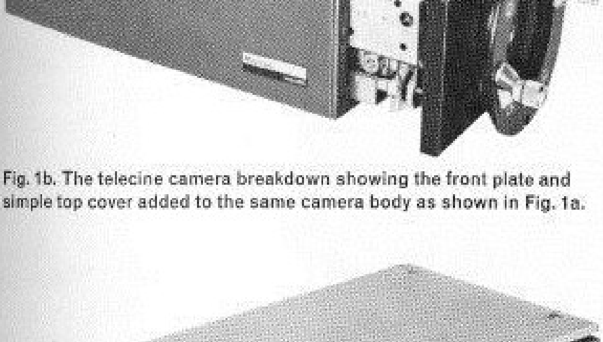

Fig. 2. The telecine camera head.

with other zoom lenses such as those existing for use on the Mark V and Mark VII cameras and these lenses are interchangeable. The format size would be wrong with these lenses, but they would provide a telephoto effect quite useful in certain applications.

Operation as a studio camera is simple, the warm-up time to rehearsal pictures being less than a minute. The use of a zoom lens has all the well-known advantages including the lack of operating noise associated with turret cameras. No fan is required in the camera. A five-way filter wheel to take two filters in each position (i.e. coloured plus neutral density) is provided. Long-term stability has been achieved to provide the 'hands-off' requirement of modern channels. To allow maintenance and testing to be carried out on the camera head, which may be over a 1,000 ft away from the CCU, there are two switches, enabling only talkback and the mains utility to be supplied to the camera when only the 'mains on' is switched. For full supplies the 'camera on' must be switched.

The camera sensitivity, when using a modern 10–1 zoom lens, is equal to any camera channel currently in production. However, the live or studio camera channel is built around the Plumbicon pick-up tube, and although vastly superior in most ways to the vidicon tube, the Plumbicon still has one or two shortcomings when compared with the modern 4½-in image orthicon, as used in a camera such as the Mark V.[1] The studio camera uses the identical camera body as described for the telecine camera, but with additions as shown in Fig. 1a and 3. An assembly is mounted on top of the camera body which is designed to accept the tilting viewfinder and its power supply. The power is taken from a transformer, the main purpose of which is to provide the requirements for the modern fully servoed lens packages now available. A bigger and more substantial front plate may be fitted which can be adapted to carry even the largest of the 10–1 zoom lenses currently used. Runners on the rear of the front plate exactly align the yoke assembly to the optical axis of the lens in use. For studio use a talkback system, with controls, is added to the basic telecine body. The talkback amplifiers are situated on a printed circuit board in the viewfinder mounting assembly. It is expected that the studio camera will be most useful when used with a lens such as the Evershed Power Optics (Angenieux) *f*/2·8 10×18F in manual (iris servo only), or fully servoed form.

THE TUBE

The lag characteristic of the Plumbicon tube is tremendously improved as compared with the vidicon and is equivalent under the proper set-up conditions to modern photo-emissive pick-up tubes. The dark current is very small and approximately 40 dB down on normal signal currents. This makes the dark current/temperature hazard, so prominent in the vidicon, negligible with this tube and consequently the black shading near perfect. The white shading is a very small percentage of the white level amplitude when the tube is scanned in a yoke with good beam landing. Shading correction is, therefore, not normally required. This is fortunate as the tube is best operated in a target voltage condition which is near saturation. This saturation means, that in contrast to the vidicon, whose signal output can be increased with increasing target voltage over a large range of voltages, the tube target becomes saturated at 30 to 40 V with respect to the cathode, Fig. 4. Very little increase in output is realized by a further increase in target voltage.

To modulate the target to cathode potential under these conditions would have little effect on shading.

Fig. 3. The studio camera complete with zoom lens attachment.

Nevertheless, even with the larger diameter target the average resolution capability of a Plumbicon is somewhat inferior to that of a good vidicon, and consequently requires a little more aperture correction to be applied. The spectral response is also different from vidicons in general, the Plumbicon having, at present, the well-known deficiency in red performance. One other major comparative difference is the near linear transfer characteristic. This is found to be between $\gamma = 0{\cdot}85$ and $\gamma = 1$. For faithful picture reproduction an increased amount of gamma correction is required for live pick-up than with the vidicon. This means more gain in the region of black.

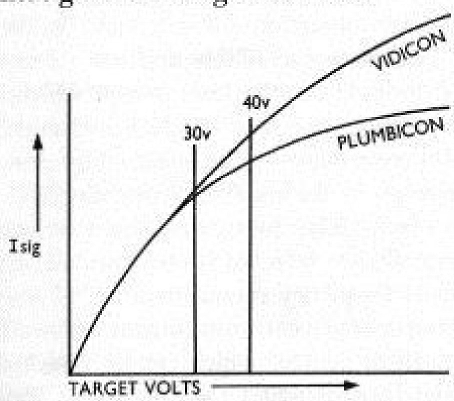

Fig. 4. Comparison of vidicon and Plumbicon outputs with increase of target voltage.

CAMERA VIDEO SYSTEM

The signal current from the pick-up tube is amplified by a low-noise head amplifier Fig. 5 which is mounted onto the scanning yoke assembly. When the yoke is required to be moved for focusing purposes the head amplifier moves with it to ensure extra mechanical stability of the signal current lead into the head amplifier from the tube target ring. The input stage of the head amplifier uses a Nuvistor to ensure very low-noise operation. The signal current passes through a peaking circuit sometimes known as a Percival coil into the Nuvistor feedback circuit, where it is amplified to a level high enough to be passed through a flexible lead into the vision amplifier. The vision amplifier input stage has a notching or anti-Percival circuit which removes the resonant peak introduced by the Percival coil. The next stage is a high peaker circuit which corrects for the loss of high-frequency response due to the head amplifier input circuit.

The signal passes through two high-gain thin-film feedback amplifiers which increase the level to give 0·7-V peak-to-peak video from the 75-Ω output stage into the camera cable and thence to the CCU.

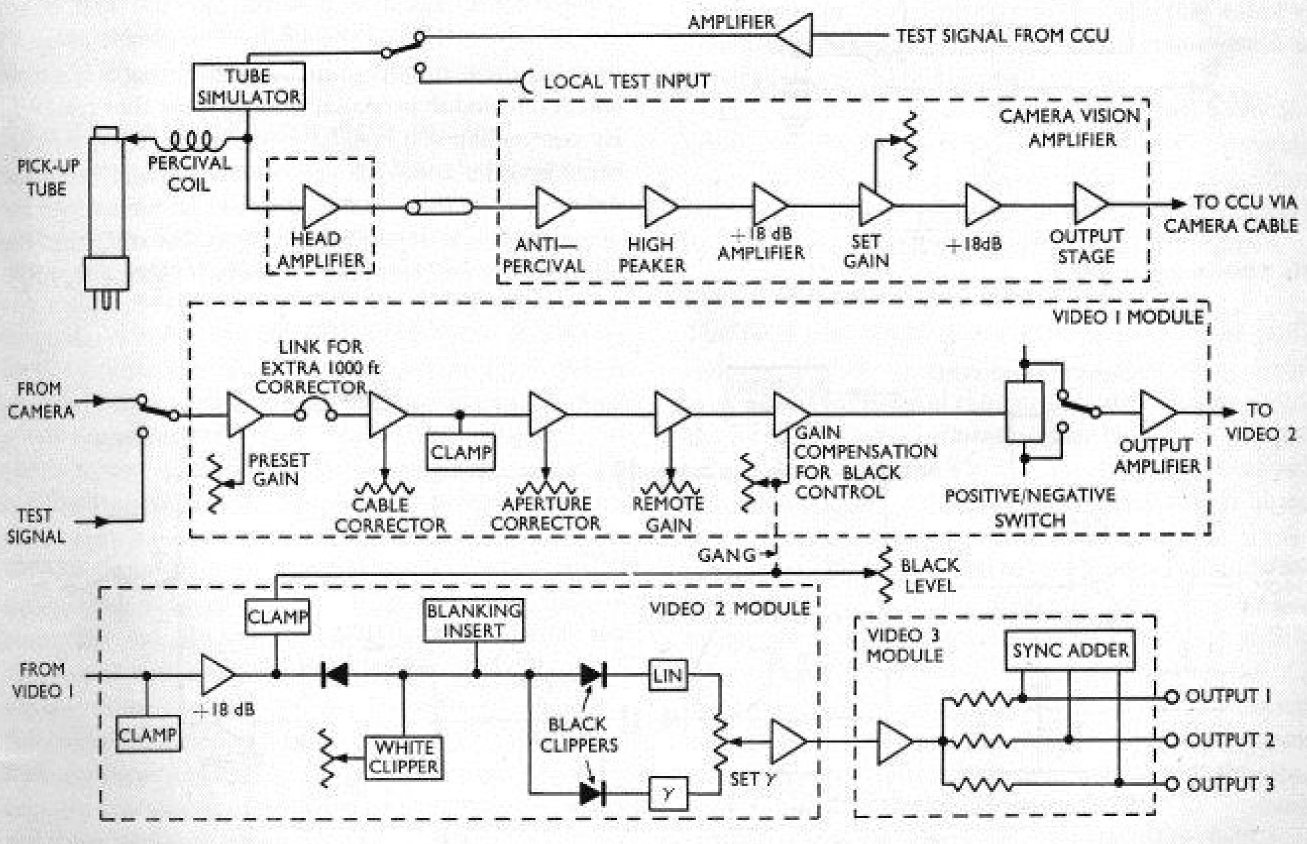

Fig. 5. Video system: live camera.

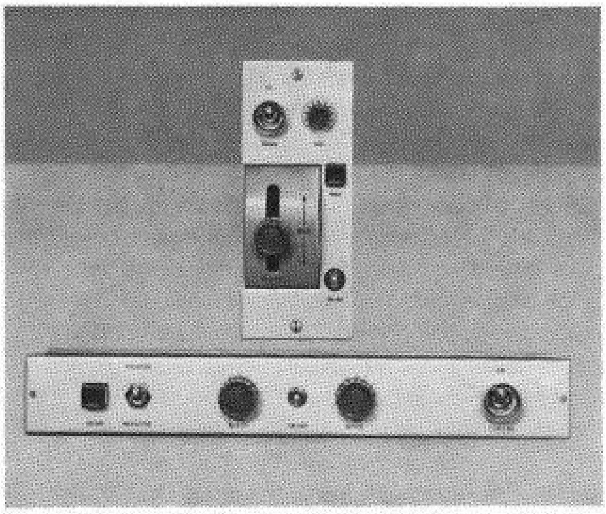

Fig. 6. Above the studio camera OCP and below the telecine OCP.

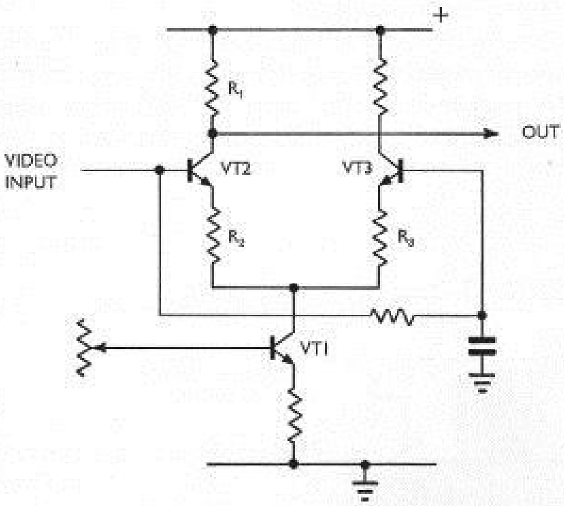

Fig. 7. Remote gain circuit.

CCU VIDEO SYSTEM

A preset gain control is provided at the input to the video 1 module of the CCU, and this control allows the range of the remote gain controls and the signal level in the CCU generally to be set. The first stage after preset gain is the camera cable corrector which corrects for distortion introduced by the cable and is adjustable to correct for up to 1,000 ft of cable. Provision is also made in the case of the live camera channel to allow for correction of a further 1,000 ft. This stage is followed by an aperture-loss corrector capable of providing substantially phaseless h.f correction needed to compensate for the finite scanning aperture of the pick-up tube. Two correction characteristics in the case of the live channel are available and are selected easily on to the module for the line system which is being employed. In the case of the telecine channel, appropriate film correction can be selected by remote control of a relay in the module, from, say, the telecine machine room. The particular characteristic to be relay controlled is selected on the module, according to the boost frequency requirements.

Two stages of remote gain control follow. The first gives ±3 dB of control which can be remoted to the operational control panel OCP, Fig. 6. The second gain stage provides 6 dB compensation for the black level control, and this control, like the first stage, can be adjusted from the OCP. The circuit (Fig. 7) used for these remote-controlled gain stages is simple and stable and depends on the principle that $r_e \simeq 25/I_e$. By controlling the standing current in VT1, the currents in VT2 and VT3 are controlled, and hence the value of r_e in these transistors can be varied. As the degeneration is dependent on this value of r_e, then the gain of VT2 will be approximately $R1/(2r_e+R_2+R_3)$.

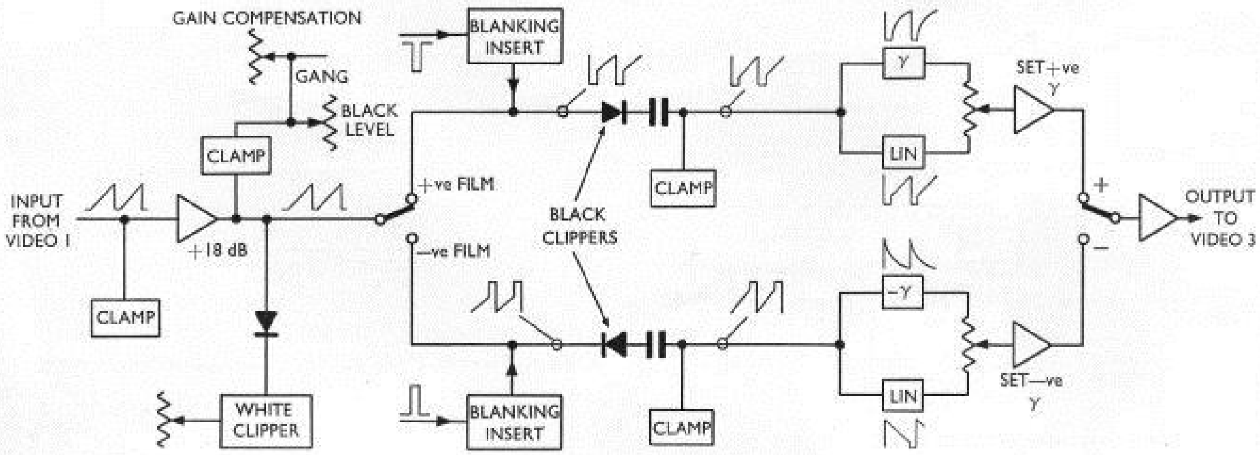

Fig. 8. Telecine Video 2 module schematic showing positive and negative film gamma correction.

The value of r_e can be controlled by varying the constant current from the VT1 collector and thus the gain can be controlled by d.c from a remote point. A simple positive negative switching circuit is then provided in the live channel before the output circuit of the video 1 module.

Once into video 2 module the signal is clamped to establish the d.c level required for correct signal handling of the following 18-dB amplifier which provides the higher level signal required for the white clipper, the blanking insertion, black clipper and gamma correction. After this amplification the video is reclamped and the d.c clamp reference taken away as the black level control. After black clipping the signal is fed to two circuits, one with a fixed gamma law of $\gamma=0{\cdot}4$ followed by an emitter follower. The other circuit has a linear characteristic of similar overall gain and a signal from it is fed into a similar emitter follower stage, as shown in the block diagram, Fig. 5. A single knob variable gamma control is arranged by fitting a potentiometer between the two emitter followers and taking the final output from the slider. An output stage employing considerable feedback, to reduce the output impedance to fractions of an ohm, is used to provide three outputs with a high degree of separation at 5 MHz. Synchronizing pulses may be added resistively as required at the output, ensuring constant amplitude synchronizing information regardless of picture content.

GAMMA CORRECTION FOR FILM

Unlike the gamma correction applied to the signal in the live or studio camera channel, the correction required, when film is the picture source, becomes far more complicated. In the live camera, when a Plumbicon with its near linear transfer characteristic is used, any gamma correction applied is purely to precorrect for the gamma law of the receiver picture tube. When positive film is being scanned, using a vidicon, the final gamma required is the same as for the live camera, i.e. $\gamma=0{\cdot}4$ to $0{\cdot}5$, but as the vidicon transfer characteristic has itself a gamma of about 0·7, correction of about $\gamma=0{\cdot}7$ only is needed for an overall figure of $\gamma=0{\cdot}49$ to be transmitted. However, when negative film is to be scanned the vidicon transfer characteristic no longer assists the overall system gamma, but instead quite the contrary is true and additional correction is required for the vidicon as well as that required for the film. Adequate correction is therefore provided for negative film. As shown in Fig. 8, the telecine video 2 module contains two gamma laws both of which can be preset and the selection of which is relay operated. This relay is usually controlled from the positive negative switch on the telecine OCP, Fig. 6.

SHADING CORRECTION

It is well known that the vidicon, while exhibiting poor shading qualities under adverse lighting and target voltage conditions, is capable of shading correction. If the target to cathode potential is modulated with a line-frequency waveform, a variation of output will occur depending on whether the waveform adds to, or subtracts from, the target voltage. In the shading module supplied, line and field sawtooth and parabola waveforms are available which are continuously variable from 10-V amplitude positive going through zero amplitude to 10-V negative. This amount of correction is more than adequate for most vidicons.

VIEWFINDER

The 7-in viewfinder which is fitted to the Mark VI live camera channel is of the type used on the Mark V and Mark VII cameras. It can be fully tilted to allow the most convenient viewing angle even when the camera is tilted to extreme angles. It can be run detached from the camera on up to 30 ft of extension cable and has a highlight brightness of 200–ft lambert. The viewfinder is normally supplied with picture information processed in the CCU, but the cameraman may switch his viewfinder to a picture source fed into the 'external viewfinder' socket on the CCU. This requirement is generally used only for special effects.

The viewfinder video input is obtained from the printed circuit board in the viewfinder mounting assembly. An extra output of video from the viewfinder assembly is provided at a socket at the base of the camera to drive a monitor if one is required.

FIELD SCAN

The field scan circuitary is all contained in the pulse and scan module in the CCU. A field drive delay circuit of at least two lines is required to prevent the photoconductive tube 'bright-up' at the bottom of the picture, visible when the leading edges of field drive and field blanking are coincident. The delay circuit in the Mark VI uses a ramp waveform driving a Schmitt trigger circuit. The firing point of the Schmitt circuit is set by the delay control. The Schmitt output pulse is used to trigger a pulse generator to form the delayed field drive. The field sawtooth is generated by means of a capacitor charged from a constant current generator. This process is reset at the end of each field by means of a transistor which is switched to discharge the capacitor; linearity correction is by means of feedback applied across the charging capacitor. The field scan output stage in the Mark VI couples directly into scanning coils and thus the need for a bulky output transformer is eliminated. Since this is a d.c coupling, centring can be applied directly. Considerable current-derived feedback across the output stage ensures the very good linearity of less than ½% of the overall field scan.

LINE SCAN

Processed and inverted line drive from the CCU is fed to the line-scan generator in the camera. The pulses are cleaned to remove any pickup which could occur along 2,000 ft of camera cable. The line-scan output stage employs a switching transistor and recovery diode in a conventional circuit. Inherent in the use of a switching transistor is the hole-storage problem. Since this varies with temperature, a variable displacement in time occurs, resulting in picture shift, unless special precautions are taken:

(i) Reduction of hole-storage effect by special circuit design;
(ii) Temperature-dependent base drive.

These measures have been taken in the Mark VI design and result in a comparatively simple line output stage of very high stability and reliability.

Of special interest in the line time base circuit is the small linearity corrector. A saturable reactor is used in which the scan current drives the core into saturation, the point of operation being determined by the d.c flowing in a control winding on the same core. Thus by adjustment of a potentiometer on the printed board adequate variation of linearity can be obtained.

The flyback time of the line sawtooth has been reduced so as to allow operation on more than 1,000 ft of camera cable, before the video received at the CCU is mistimed with respect to line blanking, while normal pulse timings are being used. When up to 2,000 ft is required the line drive sent to camera will need a few μs advance; alternatively, delay can be applied to system sync and blanking pulses for the same effect.

CAMERA POWER SUPPLIES

In order to achieve good long-term stability in the channel it was essential that special attention be given to power supplies. Because of the versatility of the Mark VI and the necessity that each major removable unit at the camera should have a self-contained power supply, a 50/60 Hz transformer system was chosen. In the camera body of the telecine form, a compact plug-in power unit is situated behind the pickup tube. This unit supplies all the requirements of the camera body which are not brought up the camera cable.

When the live version is required, the lens, viewfinder mounting and viewfinder are added. In this case the power requirement is provided by a transformer, rectifier and regulating circuitry in the viewfinder mount. To accommodate camera cable length variations up to 2,000 ft, and to ensure a small power dissipation in the cable, it was decided to supply the transformer primaries in the camera with 440 V derived from a secondary winding of the CCU mains transformer. Even when working with long lengths of camera cable the low current flow gives rise to quite small voltage losses. This allows for easier design of regulators in the camera and results in greater efficiency when using short cable lengths. In both camera power supplies, the series regulator transitors are mounted so as to use external camera panels as heat sinks and thus reduce internal camera heating.

CCU POWER SUPPLIES

All the power requirements for the CCU are generated by the large plug-in module which also contains the main control panel. A 20-V and 30-V positive rail system is used, and for maximum stability the reference components are held at constant temperature in a 65°C oven. In addition to the low-voltage requirements of the CCU the higher voltages for the camera are also provided. The 1,000-V generator, the 180-V rails required for the head amplifier, and the +300-V supply for the tube accelerator anode (for which a simple zener diode regulator is used) are plugged on to the rear surface of the module.

The series regulator power transistors are mounted on the outer surface of the rear panel to keep heating in the CCU to a minimum.

HIGH-VOLTAGE SUPPLY AND FOCUS CURRENT

The high voltage required by the pick-up tube wall and mesh electrodes is obtained from a circuit providing excellent regulation against load current variations. A voltage square wave at half-line frequency driven by line drive is applied to the primary of a small ferrite-cored transformer, across the secondary of which the required high voltage is developed. After rectification the d.c is applied to a conventional 1,000-V corona stabilizer. The corona stabilizer current is sampled and the voltage produced used to control the amplitude of the transformer primary voltage square wave. The

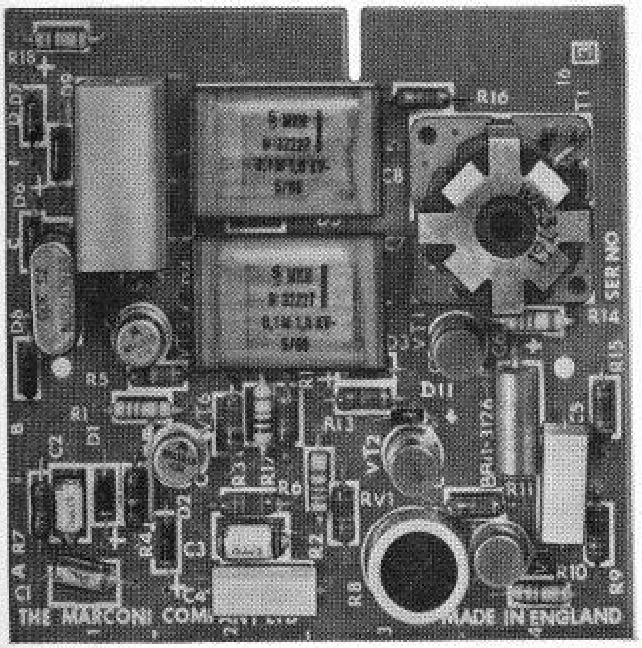

Fig. 9. The 1,000-V generator printed board.

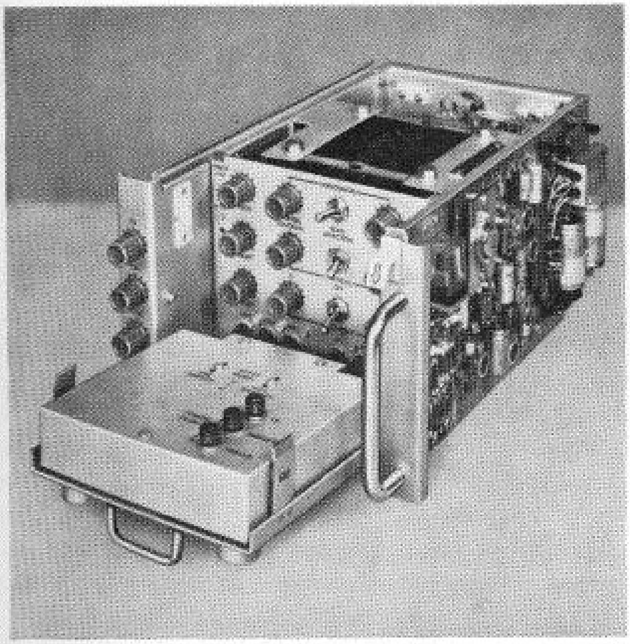

Fig. 10. The control panel and power supply units showing the secondary control panels and the power supply printed board.

corona stabilizer is made to operate substantially in a constant current mode, and therefore, at a constant voltage.

The whole circuit except the corona stabilizer is contained on a small printed board, Fig. 9, and provides a very compact and stable high-voltage supply, with a stability better than $\pm 0{\cdot}1\%$ for a load current change of 50%.

In order to maintain the optimum tube resolution it is also essential that the focus current remains absolutely constant. A d.c amplifier, employing a stable reference source and a high degree of negative feedback, ensures that the picture resolution is not visibly degraded for a temperature change of $\pm 10^\circ$C.

CONTROLS

The CCU contains the main controls on the front of a pull-down panel. A secondary control surface behind this panel, Fig. 10, contains controls required less frequently, such as centring, shifts, alignment, etc. Where an operation requirement originates from the video or pulse modules, the control has been brought to the front of the module as in the case of aperture corrector, white clipper, sync amplitude and so on. The CCU front panel layouts of the studio and telecine versions are shown in Figs. 11a and 11b.

The main panel contains all of the controls which are required for adjustment during transmission and the channel can be operated from this panel. Usually the channel would operate using the smaller OCP.

OPERATIONAL CONTROL PANELS

The control panel, in case of the live studio camera, takes the form of the standard Marconi joy-stick control shown in Fig. 6. Control of gain, black level, iris, beam on/off, camera on/off are provided. An 'on air' cue light is also fitted.

The telecine OCP, Fig. 6, measures 14 in$\times$2 in and will fit into the standard Marconi Picture and Waveform monitor console. The controls are similar to the live camera, but also include a positive/negative switch, as required for negative film working. Both OCP's can be operated with up to 500 ft of cable.

PERFORMANCE

The sensitivity of a television camera can be defined in terms of the amount of light required at a given depth of focus to produce an output signal of a certain signal/noise ratio.[2]

At a lens aperture of *f*/4, corresponding in depth of focus to *f*/8 using an Imagine Orthicon format, a peak signal to rms noise ratio of 40 dB in a 5·5 MHz bandwidth may be obtained using a scene illumination of 30 foot candles, assuming a peak scene reflectance of 60%. These figures assume gamma correction of 0·5 and aperture correction sufficient to provide 100% depth of modulation at 400 lines per picture height. At least 46-dB signal to noise is obtainable when a

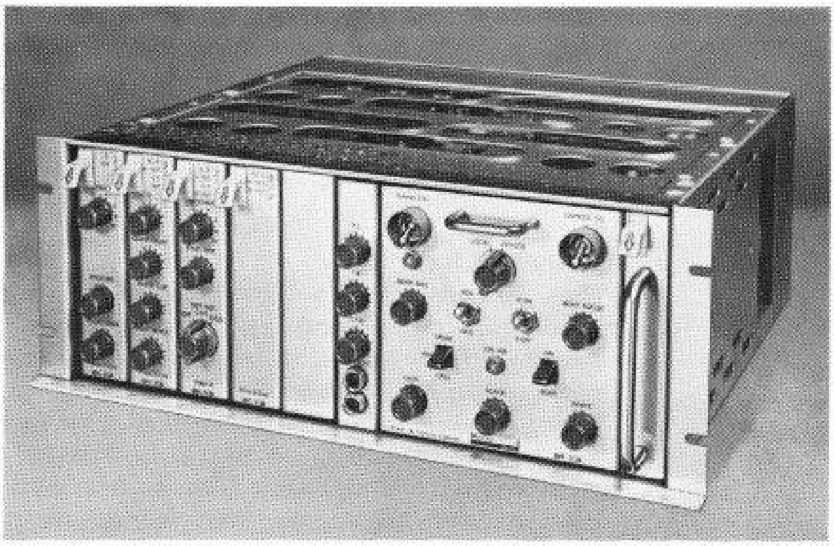

Fig. 11a. The studio camera control unit.

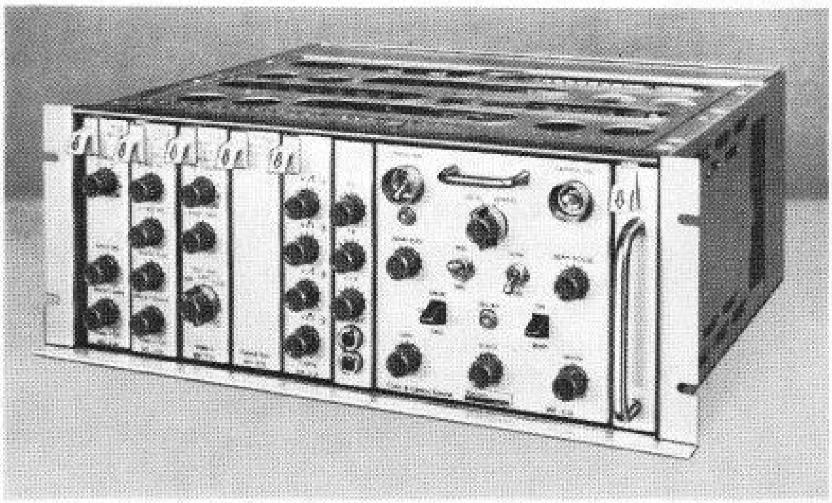

Fig. 11b. The telecine CCU showing the shading module.

signal current of 0·3 μA is supplied and the CCU corrective circuits are switched out.

The lens can still be opened to *f*/2·8 and at least 6 dB more gain is available to allow the above illumination to be divided by 4 but with the signal/noise ratio reduced appropriately. These conditions are for an average pick-up tube sensitivity, and have been found in practice to vary no more than ±3 dB.

If extreme sensitivity is required an *f*/2·2 lens, such as the Angenieux 10×18H, can be fitted with only slight modification to the camera baseplate.

Errors in geometry in the Mark VI camera are such that over the greater part of the picture area, the location of picture points is within 1% of picture height of their correct positions.

To achieve this has required detailed study of many factors including shape, length and position of the deflexion coils, and the distribution of the focus field.

SCANNING YOKE

To enable the camera to accommodate either a vidicon or a Plumbicon it was necessary that the design should allow the scanning and alignment coils to move inside the focus coil windings as correct positioning for each tube is essential to ensure good beam landing. To obtain correct skew, or uniform non-rectilinearity of the raster, the position of the line coils, with respect to field coils, has been made adjustable. The rectangular defining mask is also changed to provide the correct aperture for the tube faceplate. An adaptor is

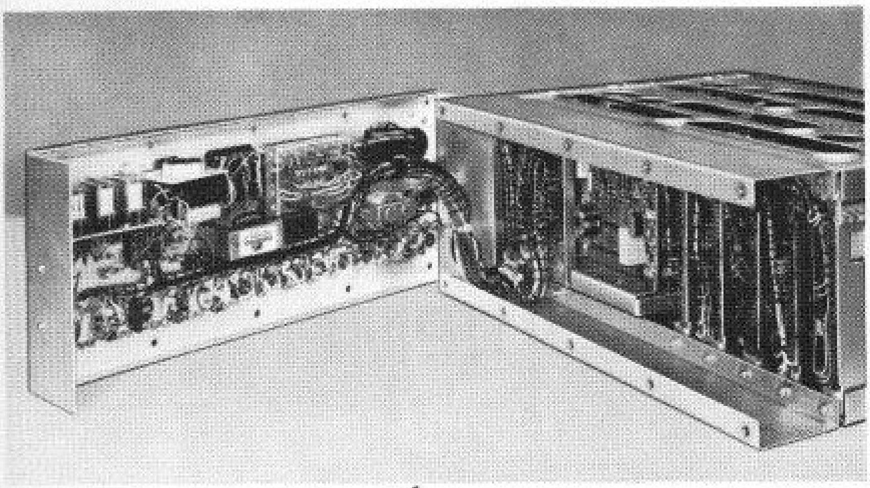

Fig. 12. Rear view of the CCU showing connector panel open.

fitted on to the pins of the vidicon when this tube is to be used. This adaptor not only plugs into the Plumbicon-type socket wired into the camera, but also increases the effective length and diameter of the vidicon up to Plumbicon dimensions, allowing correct axial alignment. The yoke is fully screened, being encased in a mu-metal shield.

CONSTRUCTION

Camera

The camera body consists of a thin-gauge steel framework screwed to a baseplate which is machined to shape from solid aluminium alloy plate. In either camera form, the yoke assembly is mounted on large-diameter anodized runners which are locked to the aluminium alloy camera front plate. The front plate in turn is held with captive screws to the front of the steel framework. The whole assembly offers maximum strength together with light weight. The side flaps, and a rear flap hinged to the baseplate, allow maximum access to the power supply and printed boards which are mounted close to the outside surfaces.

The two side-members of the viewfinder mounting assembly are also made from aluminium alloy plate, and an aluminium chassis, built between them, houses the mains transformer and other components. When this assembly is mounted on top of the camera body, and with the zoom lens front plate offered up, the whole camera is screwed firmly together with socket-headed captive screws, giving extra rigidity. To attach the zoom lens and viewfinder to complete the camera is then a simple operation. The whole camera is finished in a two-tone Organosol paint of attractive appearance and having hard-wearing properties.

CCU

The CCU is constructed from a Marconi 7-in high standard 19-in rack mounting frame. On the back of the frame, is fitted a rear panel onto which all the plugs and sockets, including the camera cable socket, are mounted, Fig. 12. The main frame is well ventilated, yet still retains extreme rigidity and can also be fitted into mobile cases.

TEST POINTS

To assist quick maintenance and the setting up of signal level, test points are provided on the front of the modules. Other test points are on the printed boards and these can be used when the module is connected to an extension test jig. Voltage test points are available on the secondary control panel of the CCU power supply module, and this unit can also be extended by flexible leads to allow operation outside the main CCU frame.

TEST WAVEFORM INSERTION

Input sockets on the CCU rear panel are fitted to accept test signals. A switch on the front of the video 3 module can be used to connect the test signal either into the camera head amplifier or into the CCU in place of the camera video signal. A socket is also provided on the camera head amplifier to permit the direct injection of test signals when it is desirable not to pass the signal through the camera cable.

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1 D. Pay: Marconi Mark V; *Sound and Vision broadcasting*, Vol. 6, No. 1, Spring 1965, p. 1.

2 A. N. Heightman and W. T. Underhill: A New Four-tube Colour Television Camera; *Sound and Vision broadcasting*, Vol. 7, No. 1, Spring 1966, p. 8.