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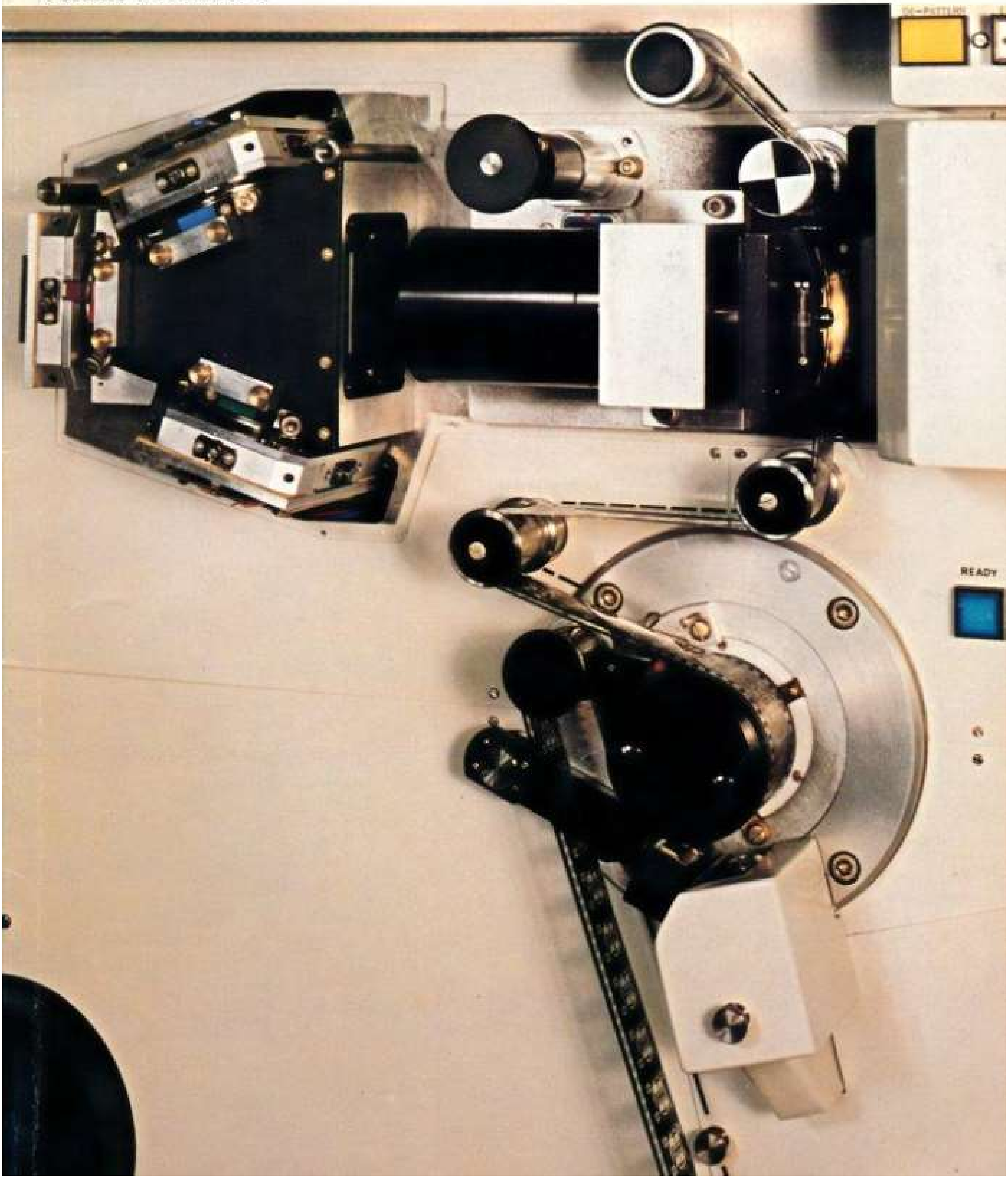

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Front cover
The first of the new generation of telecines has just been sold to VCL Video Facilities Ltd., a major London-based facilities company. This view shows the capstan area, 35mm gate assembly and optical splitter with covers removed.

The Marconi B3410 Line-array Telecine

R. Matchell, C.Eng, M.I.E.E

Summary The Marconi B3410 is a new all solid-state line-array telecine and is the first commercially produced television picture generating equipment to use completely digital signal processing. This system, which is microprocessor-controlled, is described in this article and the advantages arising from the innovation are explained. The continuous-motion, capstan-driven film transport system and other notable features are outlined and a description is given of all the major systems, including film scanning for both 625-line and 525-line operation.

R. Matchell
Born in 1925, Ray Matchell was educated at Otley, Prince Henry's Grammar School, and at Leeds University where he was a laboratory assistant/student in the physics department. He then gained experience in the development of television studio equipment with the BBC, EMI, Rank Cintel and Marconi. From 1963 to 1968 he was Section Leader in Marconi's Studio Equipment Development Group. After ten years with Rank Cintel, first as Technical Manager and then as Product Group Manager, he rejoined Marconi in February, 1979 as Engineering Manager of the Camera and Telecine Department.

Introduction

The Marconi Line-array Telecine is a completely new, all solid-state design incorporating totally digital signal processing. It will produce high-quality pictures from 16mm, 35mm or Super 8mm film, either positive or negative, and the change between film gauges can be made in a few seconds by means of interchangeable, plug-in film gates. The telecine will operate equally well on either the 625-line or 525-line television system and the same printed-circuit boards are used for both. In addition to the normal standard speeds, it will produce coherent pictures at all speeds between $\frac{1}{5}$ and ten times normal speed, both forward and reverse.

This telecine is the first commercially produced television picture generating equipment to use completely digital signal processing. The benefits obtained from this are freedom from time consuming setting-up procedures, increased reliability and predictable drift-free performance. The signal processing (which is microprocessor controlled) provides fully variable gamma correction, logarithmic masking and differential adjustment of gain, lift and gamma. Vertical and horizontal aperture correction and coring are also provided.

Unlike most other telecine equipment available, this design uses no vacuum tube devices other than conventional quartz-halogen lamps. Consequently there are none of the high-voltage or scanning requirements needed by camera tubes, cathode-ray tubes or photo-multipliers. The image sensors used in the telecine are 1024-element linear charge-coupled devices (line arrays). The type used measures 30mm (1·2in) by 6mm (0·25in) approximately, and is illustrated in figure 2. Three devices are used to sense the red, green and blue signal components. The life of the sensors is virtually infinite, thus the combination of solid-state sensing and digital signal processing greatly reduces off-line operator and maintenance time and makes the equipment economically attractive to run.

In addition to the new design features described in this article, the telecine incorporates all the comprehensive facilities which are essential for effective operational use in broadcasting.

The film scanning system

Methods of scanning film

Three principal methods of deriving television pictures from colour film are in current use. The most obvious method uses a colour television camera arrangement into which the film is projected. The whole of each film frame is imaged on the camera tubes which, being storage devices, retain the image until it has been scanned. Consequently a fairly conventional intermittent motion projector may be used.

The second method is the flying spot system in which the raster on the face of a special cathode-ray tube is imaged on the film. The light passing through the film is collected by red, green and blue photomultiplier tubes after suitable beam-splitting. This is a non-storage method and the film has to be effectively immobilized for all but approximately 1ms in each television field. A variety of arrangements including high-speed pneumatic pull-down, rotating prisms, twin-lens and 'hopping patch' or 'jump-scan' systems have been devised to achieve the required effective immobilization of the film.

The third method, which is used in the new Marconi telecine, involves the use of a linear sensor which can produce only a single horizontal line of picture from a stationary object. Thus when the film is stationary a signal corresponding to the single line imaged on the line array appears on all lines of the television picture. However, by moving the film at the correct velocity

Fig. 1. The Marconi B3410 Line-array Telecine

and by employing a little electronic manipulation, a normal picture can be produced.

625-line operation

The simplest case to consider is that of operation on a 625-line, 50 field per second television system. In this case the film is run normally at 25 frames per second. While the television system has 50 fields per second, each field has only $312\frac{1}{2}$ lines. It requires two fields interlaced to produce a complete picture or frame which is repeated 25 times per second (in fact only 575 lines are used by the picture, as 25 lines of each field are occupied by blanking, etc).

Thus, if the film is moved continuously through the projector at a constant velocity of 25 frames per second, and the line-array signals are read out at the normal television line rate, a complete television frame of 625 lines will be received during the passage of one film frame through the projector. Unfortunately the lines will appear in one sequential stream rather than in the two interlaced fields required by the television system. This problem may be overcome by the use of digital storage devices in a 'sequential to interlace' converter. The signals from the arrays are not used directly, but are written into stores instead. To reproduce the picture correctly, all the odd-numbered lines are read out in succession in a period of $\frac{1}{50}$th second to produce the first television field. The even-numbered lines are then read out in the next $\frac{1}{50}$th of a second to produce the second or interlaced field. As a result, 25 normal television frames or pictures are produced each second.

The signals obtained from the array are of normal television active line length, that is $52\mu s$, but in order to make the active or picture-bearing portion of the film frame fit the active television picture, the 'wait' period between lines is adjusted. Consequently, the lines are written into the stores with the correct active length, but the incorrect total length. The read-out timing is arranged to correct for this and to produce standard line length and spacing.

525-line operation

For 525-line operation the system is more complicated because there are 60 television fields or 30 complete television pictures per second. For this system the film is run at the standard 24 frames per second and consequently there are five television fields for each two film frames. A 3, 2, 3 sequence of television fields obtained from consecutive film frames stored in the sequential-to-interlace converter is used to overcome this problem.

Still frame

The telecine produces a still frame when stationary and whilst running up to speed. In order to be able to see any full film frame it is necessary first to have moved the whole of that frame through the film gate and to have stored the information from each line. Furthermore, if the movement was not at constant velocity, positional information would be required to ensure that each line was written at the correct time so as not to create vertical linearity errors. Such positional information is available from sprocket pulses and the capstan tachometer. Once the required information has been written into the stores it can be read out in the form of a still picture for as long as required.

For the normal running system to operate correctly, the velocity and position of the film must be synchronized to the television system and precisely controlled. This is because the whole of the vertical scanning of the picture is provided by the film movement alone.

The film transport system

A diagram of the film deck is shown in figure 3 and a photograph in figures 4

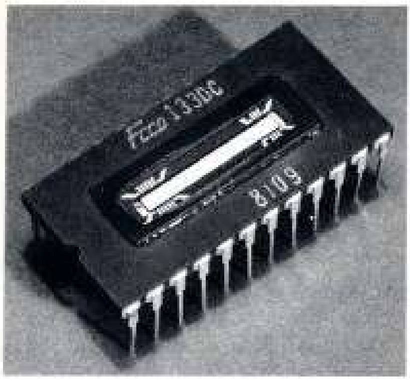

Fig. 2. The line-array image sensor, a 1024-element charge-coupled device

and 5. In addition to the need to operate correctly the design was influenced by the following factors:

i) the film spool position should be at a comfortable height for loading large spools;

ii) the film gate should be near eye level and be vertical;

iii) the hottest part of the equipment, namely the video lamp house, should be at the top so that hot air could be directly evacuated and not warm the rest of the machine.

Capstan system

The motion of the film is achieved by the use of a synthetic-rubber coated capstan of approximately 50mm diameter around which the film is wrapped under controlled tension. There is no pinch roller (figure 5). The capstan velocity is controlled by a digital servo, incorporating a microprocessor which compares pulses generated by the 5000-line capstan tachometer disc with the master clock. Positional control is achieved by the use of pulses generated by the sprocket pulse generator, which consists of a sprocket which is driven by the film, fixed to a shaft carrying an optical generator. The optical generator produces a pair of pulses phased 90° apart for each film frame. These pulses are used for framing, for film counting and also to provide instructions to the sequential-to-interlace converter.

As the capstan provides the movement of the film and, consequently, the vertical scanning of the picture, the capstan must be extremely precise mechanically and the motor must be free from 'cogging' and other undesirable effects. The whole capstan assembly was therefore designed and is manufactured by Marconi.

Sound

Optical and magnetic sound are picked off at the capstan, as at this point the velocity of the film is under greatest control and 'wow' is at a minimum. For 35mm film only, two additional rollers are interposed in the film-lacing path between the film gate and the capstan. This is to allow for the difference in picture-to-sound spacing between 16mm and 35mm film. The optical sound sensors are mounted on curved arms which lie in slots cut in the capstan. Light for the optical sound system is brought through the deck plate by transparent light guides and falls on slots which are focused on to the film.

The magnetic sound head is mounted on a pivoted arm which brings it into contact with the film when required. The sprocket for the sprocket pulse generator, and all the film rollers apart from the two special 35mm rollers are of the triple-gauge type to permit the use of the three film gauges.

Film tension control

Correct tension in the film is maintained by the use of the compliance arm mechanisms which are pivoted and sprung so that the correct tension is applied to the film when the arms are in their central positions. Optical sensors, attached to the compliance arms, detect departure from the correct position and apply correcting signals to the

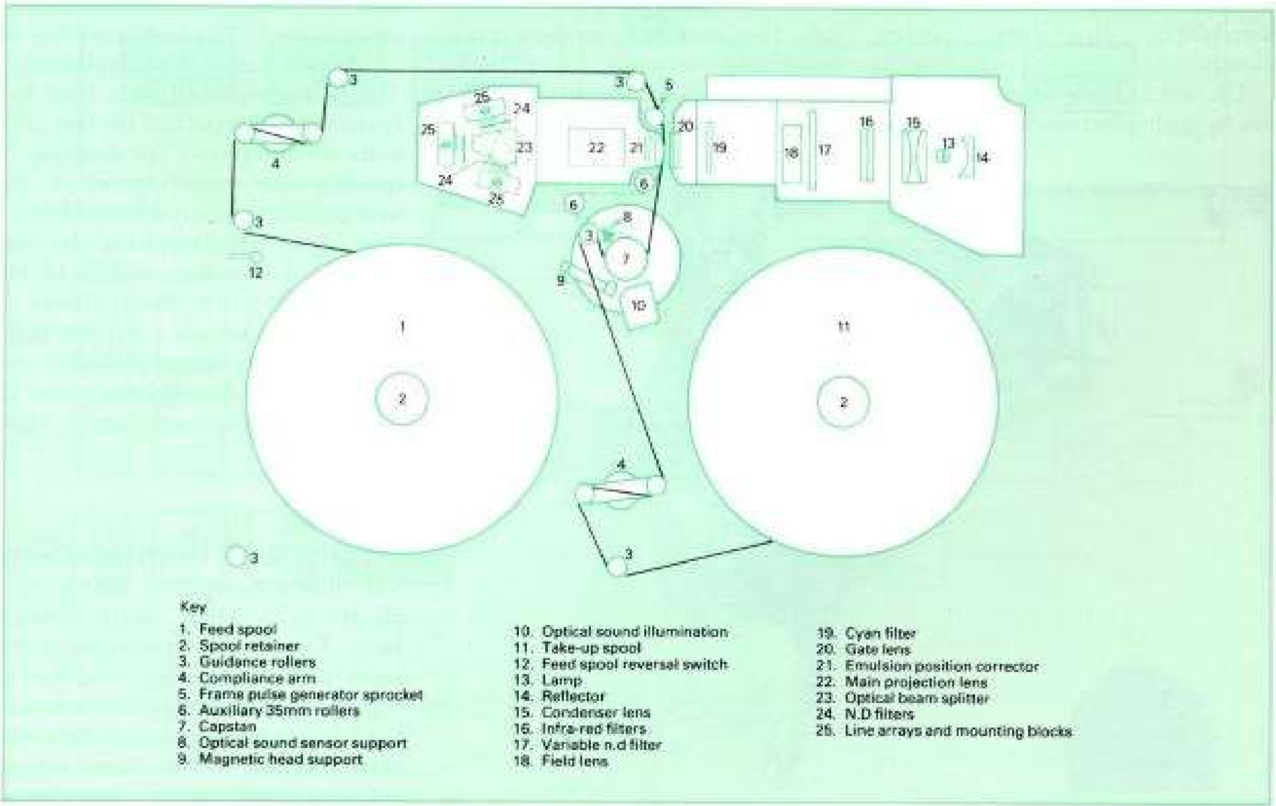

Fig. 3. Details of the film transport deck

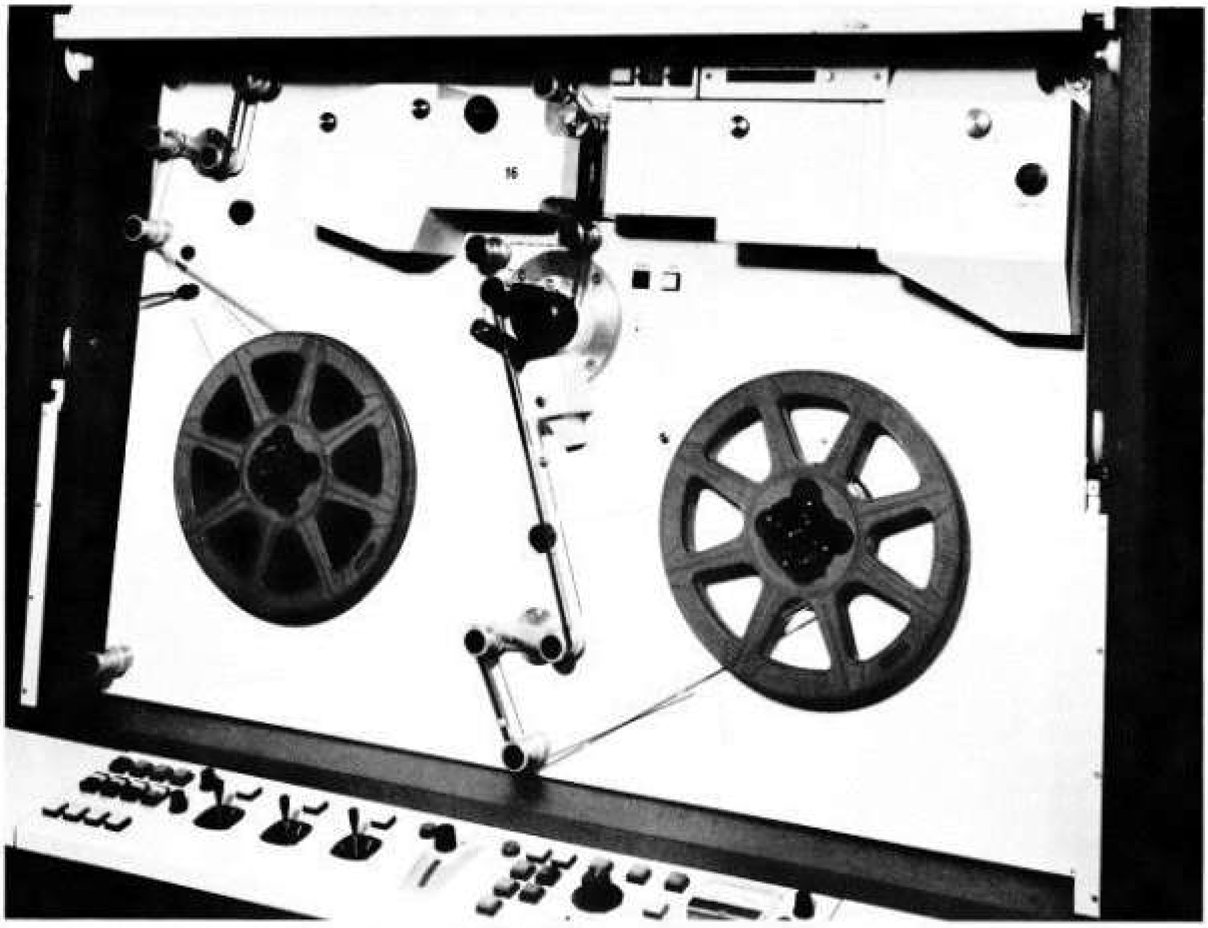

Fig. 4. The film transport deck, shown here loaded with 16mm film

high-torque, direct-drive spooling motors.

The feed and take-up spools are driven by sprung friction discs on the rear side. They are held by push-on retainers which are reversible to keep the film central with both 16mm and 35mm film. For Super 8 film additional adaptors are used. The feed spool has to handle film wound in either direction. This is accomplished by a lever between the feed spool and the first idler roller which reverses the direction of spooling and cannot be set in the wrong position as it is designed to prevent lacing by obstructing the film path. An intermediate position of this lever is used for running test loops of film and in this mode a warning lamp lights up. In the interests of safety and cleanliness, the film deck is covered by a tinted transparent cover when operating.

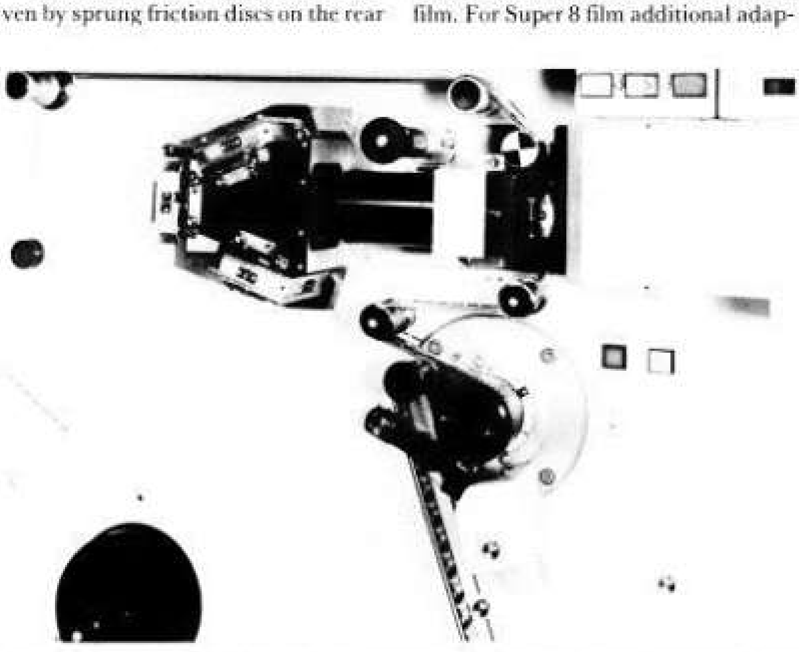

Fig. 5. A view of the transport deck showing the capstan, the optical splitter block and the 35mm gate assembly, both with covers removed

Optics and illumination

The illumination source used for the picture is a 250W quartz-halogen lamp. Two lamps are mounted in the lamp house. The one not being used is kept on stand-by voltage and automatic changeover takes place in the event of lamp failure. A conventional mirror and condenser system, with heavy infra-red filtering, is used to produce a filament image in a field lens. This image is then focused into the projector lens by a gate lens which is close to the film. Both the projection lens and the gate lens are part of the interchangeable film gate. On the lamp side of the field lens there is a servo-controlled, variable neutral-density filter used for light control, and on the other side there is a colour-balancing filter for use with negative film.

The projection lens produces images of the film, via a conventional beam-splitting block as used in a colour camera, on to the red, green and blue sensors. Neutral-density filters are used in the red and green exits of the splitter block to balance the sensitivities to that in blue.

The arrays are mounted on mechanisms which provide four degrees of freedom to permit initial registration of the three images. The adjustments are locked after the sensors have been registered and do not require further adjustment unless a sensor is removed for some reason.

Illumination for the optical sound is provided by a 20W quartz-halogen lamp and again there is automatic changeover in the event of lamp failure.

Electronic systems

The electronic systems include the following parts, some of which will be covered in detail in subsequent articles.

Signal processing

A simplified block diagram of the video signal processing appears in figure 6.

The signals from the three line-array sensors are filtered to remove the 1024-element sampling component and are then digitized into an 11-bit digital code. The following operations follow in sequence: logarithmic amplification, matrixing of the log signals and exponential amplification. The signals obtained at the output of the exponential amplifiers have been gamma corrected and have had masking for the film dyes applied. They still require to be put into interlaced form and to have vertical and horizontal aperture correction added.

After gamma correction only eight bits are necessary for digitization because the contrast range to be handled has been reduced. The less-significant bits are discarded and the sequential-to-interlace converter operates on eight bits. Four full fields of storage, that is two for luminance and two for chroma, are used in the sequential-to-interlace converter, the storage devices being 16K RAMs. The sequential-to-interlace converter operates on the Y or luminance signal at full bandwidth and on the R–Y and B–Y colour difference signals at half bandwidth. The Y, R–Y and B–Y signals are obtained digitally from red (R), green (G) and blue (B). Vertical and horizontal aperture correction are applied to the luminance component of the interlaced signal. For convenience in monitoring and encoding into different colour television standards, the signals are converted back to analogue R, G, B form after aperture correction. The whole of the video processing is controlled by the main microprocessor system.

Servo systems

The capstan servo system consists of a velocity servo which maintains the capstan velocity at the correct value by comparing the 5000-line-per-revolution capstan tachometer pulses with the video master clock pulses. In addition, pulses from the sprocket pulse generator are received once per

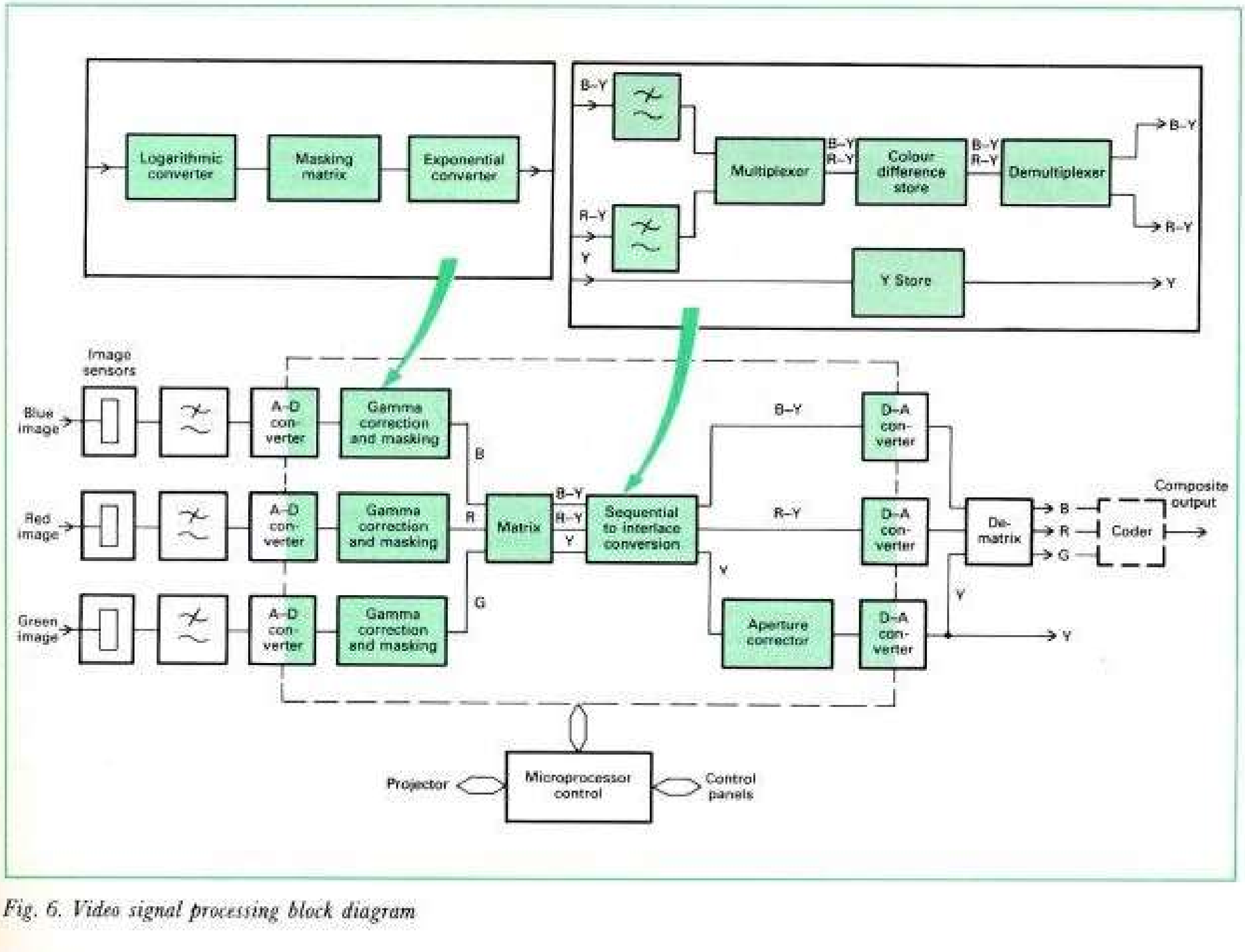

Fig. 6. Video signal processing block diagram

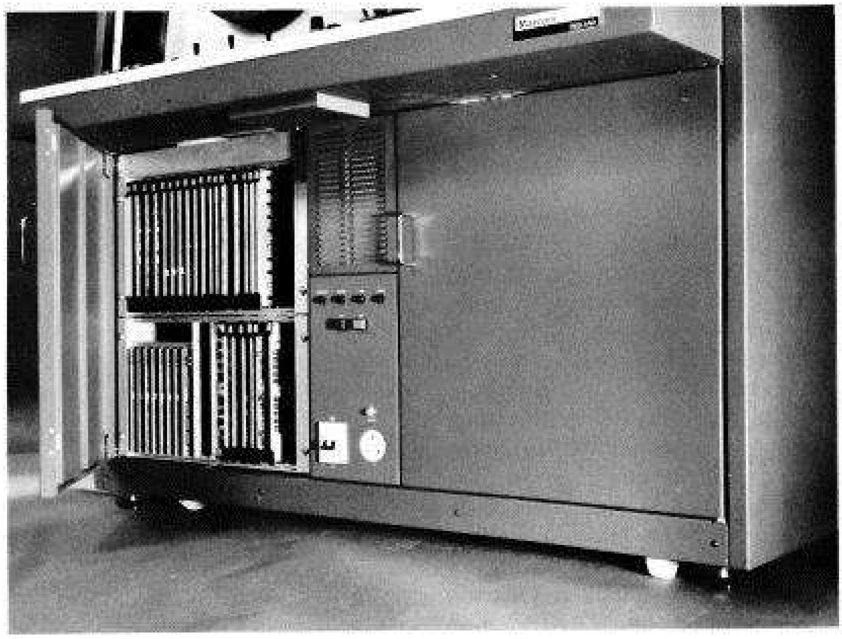

Fig. 7. The main electronics are housed in the telecine base. The modules seen here include the video processing

film frame and are used to provide positional lock or 'framing'. The spooling servos provide forward or reverse drive to the spooling torque motors as the compliance arms move from their correct central positions. A light-control servo operates the variable neutral-density disc for control of film illumination.

Other systems

Sound systems

These consist of pre-amplifiers for 16mm and 35mm optical sound and for 35mm magnetic sound, followed by switching, output amplifiers and monitoring.

Microprocessor control system

This controls the video processing and the interaction between the film transport and the electronic storage system.

Film transport control logic

This controls all functions connected with the film transport and interfaces with the microprocessors.

Pulse and master clock generation

All pulses required for the line-array devices and for the digital signal processing are supplied by this system.

The main electronics are housed in racks in the lower half of the telecine, as can be seen in figure 7. The left-hand racks contain the video processing principally and the right-hand rack contains the servos, film transport control logic and the sound amplifiers.

Conclusion

The B3410 Telecine has been designed using the most modern techniques available. The combination of solid-state image sensing, microprocessor-controlled digital signal processing and a continuous-motion capstan-driven film transport system is unique. It offers a new concept in versatility, reliability and predictability of performance in the production of high-quality television pictures from film. In addition, time-consuming regular line-up procedures have been eliminated.

The image sensing devices are not expendable like camera tubes or cathode-ray tubes, consequently no down-time is required for their replacement and the subsequent realignment of the equipment.

RÉSUMÉ

Le Marconi B3410 est un nouveau télécinéma à réseau de lignes tout en semi-conducteurs et constitue le premier matériel générateur d'images de télévision produit commercialement qui utilise le traitement de signal entièrement numérique. Ce système, qui est commandé par micro-processeur, est décrit dans cet article et les avantages qui découlent de cette innovation y sont expliqués. Le système de mouvement continu, le dispositif d'entraînement du film par cabestan ainsi que d'autres particularités notables y sont exposés et les principaux systèmes y sont décrits, notamment celui du télécinéma avec fonctionnement de lignes 625 et 525.

ZUSAMMENFASSUNG

Der Marconi B3410 ist ein neuer Filmabtaster, in Festkörperschaltung und linearer Anordnung sowie die erste auf kommerzieller Basis hergestellte Ausrüstung zur Fernsehbild-Erzeugung unter Anwendung einer vollständig digitalen Signalverarbeitung. Der vorliegende Artikel befasst sich mit diesem mikroprozessor-gesteuerten System und nennt die Vorteile, die sich aus dieser Neuerung ergeben. Neben anderen bemerkenswerten Kennzeichen wird das Dauerlauf-Filmtransportsystem mit Rollenantrieb besprochen, und es folgt eine Beschreibung aller bedeutenden Systeme, einschliesslich der Filmabtastung für sowohl 625 als auch 525 Zeilen.

RESUMEN

El Marconi B3410 es un nuevo telecine con red directiva lineal de antenas totalmente de estado sólido, y constituye el primer equipo generador de imágenes de televisión producido comercialmente que hace uso del proceso de señal completamente digital. Este sistema, el cual es controlado por microprocesador, se describe en este artículo y se explican las ventajas que surgen de la innovación. Se expone a grandes rasgos el sistema del transporte de películas accionado por torno revólver de movimiento continuo y otras características notables, y se da una descripción de todos los sistemas principales, incluso la exploración de películas tanto para el functionamiento de 625 líneas como para el de 525 líneas.