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COLOUR TELEVISION

Popular interest in colour television almost rivals the intense curiosity which first welcomed radio communication and subsequently television. Many members will recall the very successful meeting held in October 1943, when John Logie Baird gave a paper on colour television and stereoscopic television, to a then record attendance of over 600 members and visitors.

Whilst not yet an accomplished production routine, however, colour television can no longer be regarded as a scientific wonder. Indeed, a practical demonstration was given at the 1949 Radiolympia, although at least one British manufacturer has stated that commercial colour television may not be available for release to the public for perhaps another decade.

Any development of this character necessitates a tremendous volume of work, study and experiment by development engineers. In Great Britain and America especially, research into the possibilities of colour television has been going on for very many years and even now may not have reached the full flood of endeavour. Much has been achieved, however, as evidenced by the technical papers now appearing more frequently on some of the more specialized aspects of colour television and reception.

There remain many complexities in the study of the subject; conflicting theories give rise to new experiments and from discussions and the ventilation of opinion will ultimately develop reliable commercial projects. Toward that end, the Institution will always welcome the publication of new work, and the papers read before its members add to the store of knowledge of radio engineers throughout the world. By virtue of its constitution, the Institution cannot, as a body, express an opinion on the merits of one theory as against another, but it is always ready to provide facilities for discussion on subjects such as colour television in which every radio engineer will inevitably be involved in the years to come.

In order to serve that purpose, the Institution depends on the co-operation of the members and others who contribute papers and who provide material for discussion meetings. Nor must we fail to recognize the good will of the manufacturers concerned in permitting information based on the results of many years' work and investigation to be released.

In this issue of the Journal appears the first of two papers on American colour television systems, published with the object of keeping British engineers *au fait* with progress on this subject across the Atlantic. During the next few years the Institution hopes to publish many other contributions, both from British and other engineers, and to hold a series of meetings on the subject of colour television, as well as on the development of high definition black and white television.

Next year's Festival of Britain will strongly feature the part played by British engineers in the development of television. In order to supplement the display and demonstration in the South Bank (London) Exhibition, the Institution is arranging a television session as part of its 1951 Convention. This will provide additional opportunity for overseas visitors to hear more of British development in this new field.

Arrangements for the Convention will be published in the Journal during the autumn; meanwhile, members are invited to offer papers suitable for inclusion in the Convention programme. It is anticipated that the television session will be spread over three days.

MEMBERS OF COUNCIL

John Leslie Thompson was born in London in 1906, and received his early technical training as a full-time student in the Engineering School of the Regent Street Polytechnic, London. Whilst there, and subsequently at the Northampton Polytechnic, Mr. Thompson secured a number of the City & Guilds Telecommunications Certificates.

His first employment in the radio industry (1927) was with A.C. Cossor, Limited, on the design of high-power triodes and the early screen grid valves. Except for a short break, he remained with that company until 1934, by which time he was Chief Designs Engineer (Receiver Department). Joining McMichael Radio, Ltd., in 1934, as Chief Designs Engineer and later as Chief Engineer, Mr. Thompson was subsequently appointed Officer-in-Charge, Radio Section, C.I.E.S.S., Ministry of Supply, but for medical reasons he had to leave that employment in 1941. Later he founded his own research and development laboratories, and in this connection he is well known to many senior members of the Institution.

Mr. Thompson holds two patents for strain gauge computors and strain gauge pick-ups.

Elected a Member of the Institution in 1942, in 1944 Mr. Thompson assisted the Technical Committee in the drafting of the Post-War Report (Part 1). After serving on the Membership Committee, Mr. Thompson rejoined the Technical Committee in 1947, and in that year was elected a member of the General Council. In 1949, he was appointed Chairman of the Technical Committee and re-elected to the Council. He was appointed Chairman of the General Council in September, 1949, and is also Chairman of the Professional Purposes Committee.

Leslie Harold Paddle was born in Mauritius on January 3rd, 1898. After serving overseas in the 1914-1918 war, during which he qualified as a pilot in the Royal Flying Corps, Mr. Paddle studied at the Regent Street Polytechnic. In addition to obtaining the Polytechnic Diploma, he secured a 1st Class Pass in the Final Electrical Engineering examination of the City and Guilds of London Institute; he also passed the Graduateship Examination of the Institution of Electrical Engineers.

For four and a half years he was with Messrs. Alfred Graham and Co., marine telephone and loudspeaker manufacturers, as an assistant engineer. In 1925 Mr. Paddle was the first engineer to give a demonstration of speech-amplifying equipment in St. Peter's Church, Rome, on the occasion of the Holy Year Celebrations. The results obtained enabled thousands of pilgrims to hear for the first time the voice of His Holiness Pope Pius XI. Before his departure from the Vatican, he was given an Audience by the Pope and received the Pontifical blessing.

Mr. Paddle was employed in the laboratories of the Igranic Electric Co. for six years, and since 1935 he has been with the Telephone Manufacturing Co. in the Telecommunication Division as the head of the Transmission Department.

In the course of Mr. Paddle's extensive experience, he has originated many British and foreign patents, including that of the common grid oscillator which was of considerable importance in the early days of radar.

Mr. Paddle was a Founder Member of the Institution and was re-elected to Council for the third time in 1948. He has assisted on a number of Committees and is now a member of both the Membership and Professional Purposes Committees.

In view of Mr. Paddle's long association with the Institution it is very appropriate that, in this Silver Jubilee year, the Council has nominated him for election as a Vice-President. This recommendation will be placed before members at the next Annual General Meeting.

CO-OPERATION with the SERVICES

It will be remembered that in 1946 meetings between the Institution and representatives of the Admiralty culminated in the recognition of certain Naval Officers' courses for the purpose of exemption from the Graduateship Examination. Since then, the courses of instruction have been revised to meet the future needs of the Service and accordingly, further meetings with representatives of the Admiralty have taken place in order to review the extent of exemption which might now be granted to certain Naval officers. It has been agreed that the Institution will now grant full exemption from the Graduateship examination to those officers who have successfully completed the radio conversion courses of either *H.M.S. Collingwood* or *H.M.S. Ariel*; this is subject to a minimum pass mark, agreed between the Institution and the Admiralty, and additionally, a satisfactory report on course work.

During the past year, meetings have also been held between the Technical Training and Education branches of the Air Ministry and the Education and Examinations Committee of the Institution. The decisions reached were published in the following Air Ministry Order which was published on March 2nd.

Student, Graduateship, Associateship and Associate Membership of the British Institution of Radio Engineers

1. The Council of the British Institution of Radio Engineers is prepared to offer to service applicants for various grades of membership, the measures of recognition given below :—

(a) Studentship

Normally, an applicant for registration as a Student of the Institution is required to have passed or been exempted from the Engineering Joint Examination Board's Common Preliminary Examination. The Council is prepared to waive this requirement in the case of an ex-aircraft apprentice (Radio) applicant who obtained not less than 70 per cent. (Class "A" pass) of the marks awarded for educational subjects in the passing-out examination at the end of his apprenticeship training.

(b) Graduateship and Associateship

(i) Partial exemption from Part I of the Graduateship examination, on a subject for subject basis may be granted to an ex-aircraft apprentice (Radio) who satisfies the conditions in 1(*a*) above; each application for such partial exemption will be considered on its merits.

(ii) Complete exemption from the Graduateship examination will be granted to an officer who has taken the Signals Officer Junior Specialist Course, at a technological standard not lower than that at present laid down, and has passed out with a score of not less than 50 per cent. in each technical education subject, and not less than 60 per cent. of the aggregate for all subjects of the course. An applicant for exemption on these grounds will be eligible for election to Graduateship *or* Associateship of the Institution.

(c) Associate Membership

(i) Satisfactory completion of the Signals Officer Senior Specialist Course, at a technological standard not lower than that at present laid down, by an officer who has been granted exemption from the Graduateship examination under the terms of 1(*b*) (ii), above will be accepted by the Council as constituting eligibility for election to Associate Membership of the Institution.

(ii) Satisfactory completion of the Signals Officer Senior Specialist Course, at a technological standard not lower than that at present laid down, by an officer who, by virtue of his experience or seniority, was not required to take the Signals Officer Junior Specialist Course will be given due weight by the Council when considering the eligibility of such an applicant for election to Associate Membership of the Institution.

(iii) The Council is prepared to consider, on its merits, an application for election to Associate Membership of the Institution submitted by an officer who, by virtue of his experience or seniority, is not required to take the Signals Officer Senior Specialist Course.

SYNCHRONIZATION FOR COLOUR DOT INTERLACE IN THE RCA COLOUR TELEVISION SYSTEM*

SUMMARY

Because the RCA colour television system is operable (although not most conveniently so) with no change in the synchronizing signal from that used for black-and-white transmission, the black-and-white synchronizing signal will first be considered briefly. The operation of the colour system with this signal will then be discussed. Next, one modification to the standard synchronizing signal, which does not affect black-and-white receiver operation, but which simplifies the construction and operation of colour receivers, will be considered.

In conclusion, the colour synchronizing problem will be discussed in more detail and the necessary additional equipment or modifications to present equipment at the transmitter will be presented.

Introduction

Complete co-operation between the transmitter and the receiver is the foundation upon which any successful television system is built. This is necessarily true because the picture is sent piecemeal by the transmitter and must be re-assembled by the receiver in the proper order and at the same relative time as the picture was dissected by the transmitter. The accuracy of timing required to assure good performance in the present-day black-and-white television system is so high as to sound almost impossible of achievement, but it offers no real problems. In the finest detail the picture can change from grey to white, back through grey to black, and to grey again in approximately one four-millionth of a second. The change from black to white or from white to black is accomplished in one eight-millionth of a second. It may be seen, then, that confusion in the system resulting in timing errors of one eight-millionth of a second would merge adjacent black and white areas of the finest detail resulting in picture degradation. This high degree of required accuracy is easily obtained from the transmitted signal in modern television receivers despite the presence of disturbing influences such as interference.

When colour is added to the picture, additional information must be transmitted and additional functions must be performed in the receiver. It becomes essential not only to have each gradation of light at the proper place on the screen, but also to make certain that it has the proper colour value.

This paper will discuss means for obtaining the proper co-ordination between transmitter and receiver in the RCA colour television system so that the received picture will have the desired characteristics.

1.0. Black-and-White Line Interlace Synchronization

In black-and-white television the synchronizing pulses are of three types, the horizontal, the equalizing, and the vertical sync pulses. Alternate equalizing and vertical sync pulses also are used for horizontal synchronizing. The FCC Standard[1] for these pulses is shown in the drawing of Fig. 1. Two drawings of the time interval preceding and following the vertical synchronizing period are shown because the time relationship between the vertical and horizontal pulses is different for alternate fields. The purpose of this is to produce an interlaced picture. Ignoring return time, the picture consists of 525 lines, 262½ of which are traced out on the screen, after which the other 262½ lying between the first ones are traced out (an odd number of lines is necessary to produce interlace). To illustrate the procedure Fig. 2 shows an 11-line picture. Zero return time for the beam is assumed because as long as it is constant it has no effect except to waste time which might better be used for transmission of picture information were it possible to do so.

Referring to Fig. 2, the horizontal and vertical scans are starting at the same time. Line 1 is first scanned, the spot moving from

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UDC No. 621.397.6.

left to right. At the completion of line 1 the spot moves back to the left and starts line 3. Lines 5, 7 and 9 are next scanned in order. Line 11 is also started at the bottom but, since only 5½ lines are to be scanned in this field (262½ lines in the actual case), it is interrupted in the middle, returned to the top of the picture and completed there, after which lines 2, 4, 6, 8 and 10 are scanned in order and fall midway between those scanned in the first field. At the end of line 10, line 1 begins a repetition of the same cycle. From this it may be seen that, if the vertical scan starts coincidentally with a line scan on the first field, it must start in the centre of a line on the second field. Fig. 1A shows the vertical blanking pedestal starting at the end of a line while Fig. 1B shows it starting in the centre of a line. The reduction in flicker because of line interlacing in the black-and-white picture is well known and it serves the same purpose in colour transmission.

2.0. Colour Dot Interlace

In colour transmission and reception it is highly desirable to use an additional type of interlacing called picture dot interlace to realize the full potentialities of the system. It provides an effective doubling of the resolution of the system[2]. If a system without dot interlace were

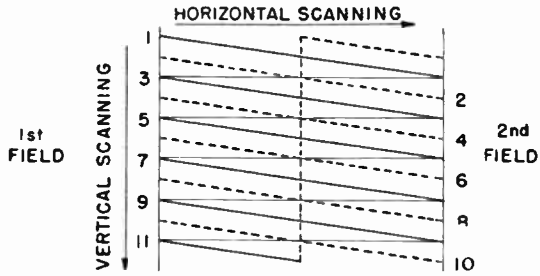


Fig. 2.—Eleven-line black-and-white interlaced scanning pattern.

used, it merely being established as a standard that the colour dot sequence be green, red and blue, the simple 11-line picture used for explanation would have the colour dot sequence shown in Fig. 3. Each of the letters G, R and B represent the centre of a picture dot area of green, red and blue. There is considerable overlap, yet it is fundamental that the highest frequency component which can be used in establishing picture detail would be a sine wave which goes from a crest to a trough in the time between two adjacent pulses of the same colour. However, by shifting the pulses by one-half picture element (half the distance between pulses of the same colour) on the next scanning of the same line, information on that colour is presented midway between those pulses for the

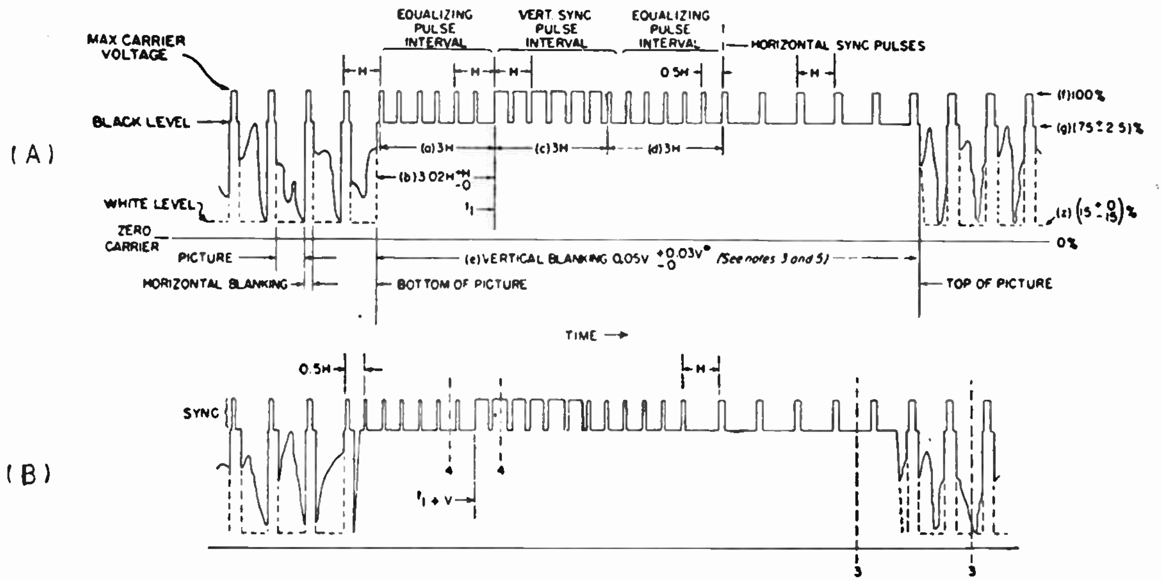


Fig. 1.—Television synchronizing waveform.

effective doubling of resolution. The overlap between colour dots is such that, at the conclusion of the fourth field (one complete colour frame), each point in the picture has been covered with picture information in each colour.

Without colour dot interlace, the transmitter would simply start its sampling oscillator in the same phase at the end of each horizontal sync pulse and the receiver would also. No more information than that contained in the black-and-white sync pulses would be required. The system requirements would be that the colour sequence be specified, and that transmitter and receiver oscillators operate at the same frequency and start in the proper phase.

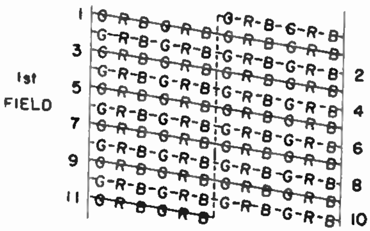


Fig. 3.—Eleven-line colour picture with line interlace but no colour dot interlace.

3.0. Colour Dot Interlace Synchronization

The colour dot interlace system can be operated without any additional transmitted synchronizing information, but the resulting receiver design does not provide the greatest economy or ease of operation. At the transmitter, the start of each alternate sampling oscillator sequence is delayed by a time equal to one-half cycle at 3·8 Mc/s (0·132 μ/sec.). At the receiver a flip-flop oscillator is included which delays the start of the receiver oscillator by the same length of time on each alternate line.

The additional circuitry for the flip-flop oscillator in the receiver would be about as complex and cost as much as that which will be described for the transmitter. It would, of course, have to be included in every television receiver, as indicated in the dotted block of Fig. 4, the receiver block diagram.

When tuning into a new programme the transmitter and receiver may be in step with each other or they may not. Because there are two possibilities, one right and one wrong, the colours would not always come out correctly, but a push-button could be provided on the receiver which would permit the user to skip one line to bring the receiver into step with the transmitter. This form of operation might be tolerable if no alternative were available, or if the alternative were prohibitive in cost or complexity.

Instead, the alternative offers no problems at the transmitter and makes the receiver simpler and less expensive by eliminating the parts necessary to create the difference in starting time of the oscillator for alternate lines.

Both the transmitter and receiver use the trailing edge of the sync pulse to determine the starting time of their sampling oscillator. By the simple expedient of increasing the length of each alternate sync pulse by 0·132 μ/sec. the transmitter and receiver are automatically made to shift the timing of the same alternate lines to effect the colour dot interlace.

As specified in Fig. 1, the length of a horizontal sync pulse is 8 per cent. H. H is the time for one horizontal line, of which there are 15,750 per second, making the length of a regular horizontal pulse 5·08 μ/sec. The alternate pulses then would be longer by 0·132 μ/sec. or 5·212 μ/sec. The lengthened horizontal sync pulse is therefore only 2·6 per cent. longer than the regular one.

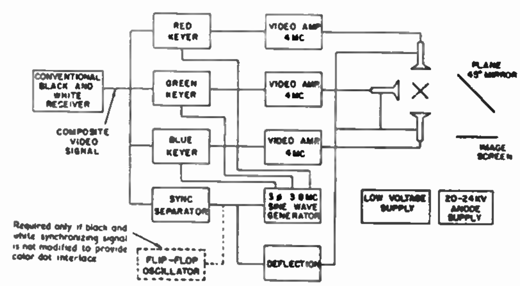


Fig. 4.—Receiver block diagram.

4.0. Effect on Black-and-White Receivers

Consideration must be given to whether or not lengthening alternate sync pulses will influence the operation of black-and-white receivers reproducing the pictures in monochrome. One answer is that the deflection circuit synchronization requirements of the colour receiver are identical with those of the black-and-white receiver so, if the colour receiver deflection circuit performance is correct, that of the black-and-white receiver must be also.

However, if the operation of deflection synchronization is considered, it can be seen that lengthening alternate sync pulses has no effect.

There are two general types of horizontal synchronizing circuits. The first, used only in the lowest priced receivers where cost is the primary consideration and performance requirements are not severe, is the so-called "triggered sync." In this circuit, the synchronizing pulses are first clipped and then differentiated, the deflection oscillator being triggered by the leading edge. In this type of circuit the performance would be the same if the pulses were either much shorter or much longer.

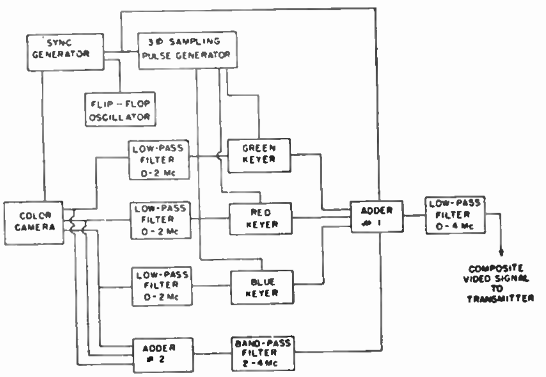


Fig. 5.—Transmitter block diagram.

Most of the current black-and-white receivers use what is called "automatic frequency control" or more simply, a.f.c. sync. In this circuit, which is relatively immune from the effects of interference or other upsetting influences, no one sync pulse affects the performance. A control voltage which is the average effect of many successive sync pulses is derived. This control voltage must be filtered to remove large amounts of 15,750-c/s energy resulting from the synchronizing pulses and it usually substantially reduces the 60-c/s component from the vertical synchronizing pulses. It may be seen, therefore, that the relatively small amount of energy at 7,875 c/s due to the 2·6 per cent. variation in length between alternate pulses will be reduced to a negligible quantity at the output of the a.f.c. detector filter.

For the RCA colour television system, the synchronizing signal standard for black-and-white transmission should be changed to be the same as that for colour transmissions. Doing so will permit colour television receivers to operate on black-and-white transmissions producing a black-and-white picture with full resolution. If the black-and-white standard were not changed the colour receiver would provide only half as much resolution on black-and-white pictures unless the sampler circuits were switched out when receiving such transmissions.

5.0. Sampler Circuit Principles

The transmitter and receiver samplers perform complementary operations and they must perform them at the same relative times. As may be seen from the transmitter block diagram, Fig. 5, the output of each colour from the camera is fed to a keyer in the sampler circuit and the outputs from the keyers are combined and fed to the adder to produce the composite video signal. In the receiver block diagram, Fig. 4, the complementary operation occurs, that is the signal assembled at the transmitter is dissected in the same order and relative time to obtain three outputs each of which contains the picture information pertaining to one colour, in order to modulate the appropriate kinescope. Therefore, the same relationships apply to both receiver and transmitter operation.

In each case the sampling oscillator is made to start at the trailing edge of each sync pulse and to stop at the end of the line, being quiescent for a short time. The sequence of events may be understood by referring to Fig. 6. In Fig. 6A the 3·8-Mc/s sine wave is shown starting with a certain phase difference with respect to the trailing edge of a regular sync pulse. Fig. 6B shows the same phase relationship between the sine wave and the trailing edge of the sync pulse, but the pulse is longer by a time equivalent to a half cycle at 3·8 Mc/s, resulting in a 180-degree phase delay (0·132 μ/sec.) between the two sine waves. Fig. 6C shows the vector diagram corresponding to the conditions prescribed in Fig. 6A for the sampler used in this receiver. The oscillator voltage is indicated as E_o. The voltage for keying the green keyer is obtained by advancing the phase of the oscillator voltage by 60 degrees and is shown as E_G. Similarly, the voltage for keying the red keyer shown as E_R is obtained by retarding the oscillator voltage by 60 degrees. A 180-degree phase voltage for the blue-signal keying is obtained from a winding on the transformer connected in reverse polarity. If the vector diagram of Fig. 6C is assumed to be the instantaneous phase relationships resulting from the conditions shown in Fig. 6A, which produce the scanning and interlace pattern shown in line 1 of Fig. 7, it is apparent that the vector diagram of Fig. 6D, resulting from Fig. 6B, is delayed in relative time by 180 degrees and will produce the pattern shown in line 3 of Fig. 7, first field. In Fig. 7 each letter represents the centre of a colour dot area on the screen. The colour dot areas, of course, overlap.

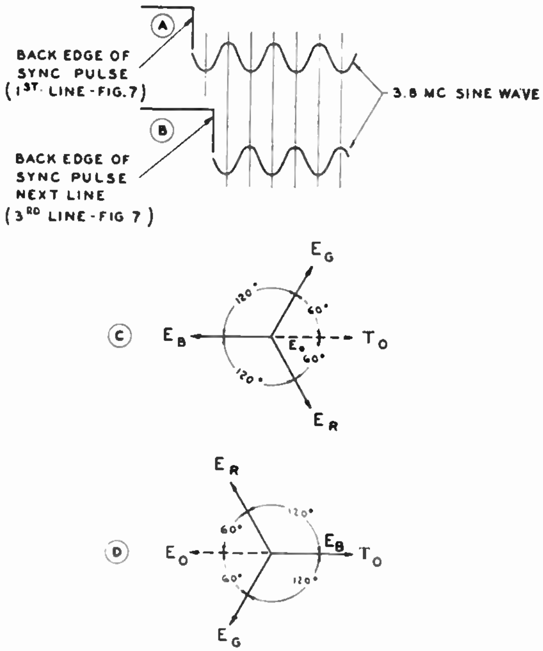


Fig. 6.—Time relationships between successive lines to obtain dot interlace.

During the first scanning field, illustrated in the upper diagram of Fig. 7, the odd-numbered lines are scanned in order. Colour dots are laid down in order along line 1 as shown. Next, line 3 is scanned with the displacement for each colour dot as shown. The remaining odd lines are scanned in order. This scanning of the first field takes place in one-sixtieth of a second.

During the second field, the even lines are scanned ; first line 2 with the colours laid down as indicated, then line 4, and so on. The dot pattern laid down during the third field is given by the lower diagram, where the odd lines are scanned in succession. During the fourth field, the even lines are again scanned in succession with the colour dot pattern shown.

6.0. Receiver Synchronizing Circuits

The sampler used in the transmitter and also in several receivers employs varistors. A vacuum tube type of sampler is also used in many cases. Both types of samplers provide adequate performance. The choice between them may be made on the basis of cost, reliability, or other factors which are difficult to evaluate at this time. For the receivers probably neither would be used in commercial production, the sampling being done in the receiver following the video amplifier owing to reduction of costs.

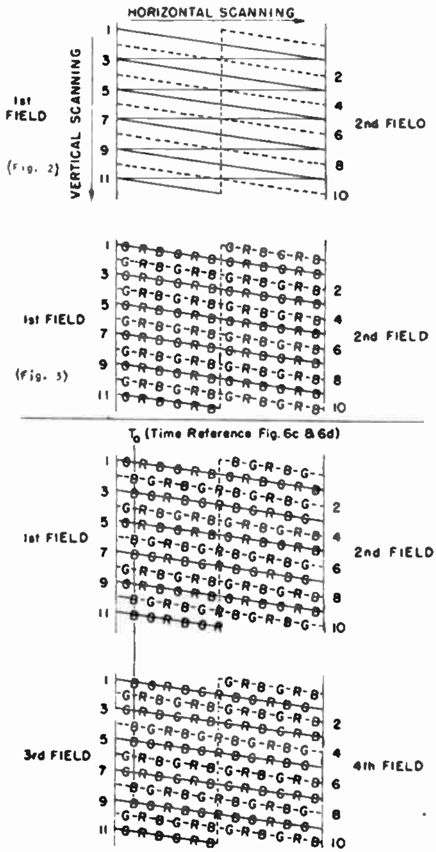


Fig. 7.—Colour dot interlace pattern (with Figs. 2 and 3 repeated for ready comparison).

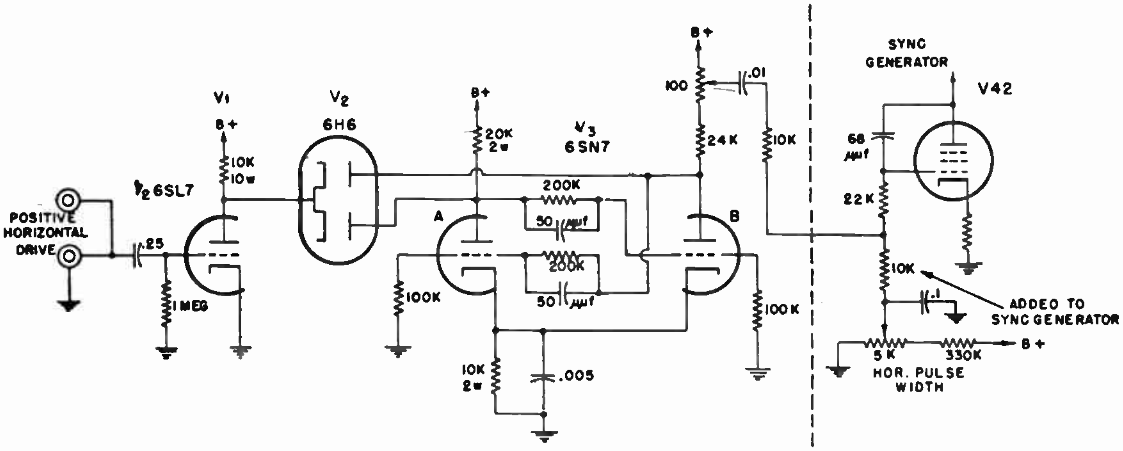


Fig. 8.—Schematic diagram of flip-flop oscillator to lengthen alternate horizontal sync pulses.

7.0. Transmitter Dot Interlace and Sampling Circuits

The sync generator at the transmitter which provides all the timing pulses used in the system is a standard RCA TG-1A unmodified except as explained below. The extra circuitry needed to vary the length of the pulses is shown in Fig. 8. Horizontal driving pulses of positive polarity are applied to the grid of V1. Amplified pulses of negative polarity are applied to the cathodes of the double diode V2, the plates of V2 being connected to the plates of V3. V3 is a flip-flop oscillator which has no natural period of its own, each triode conducting alternately and the conduction transferring from one triode to the other each time a pulse is applied. The result is a square wave of voltage across the 100-ohm potentiometer in the plate circuit. The frequency of the square wave is one half the repetition rate of the driving pulses. The 100-ohm potentiometer in the plate of V3B adjusts the amplitude of the half-frequency square wave of voltage applied at the bottom of R52. Another resistor of 10,000 ohms is connected in series with R52 across which the square wave of voltage is applied. The horizontal pulse width control still performs the same function and the amplitude of the square wave determines the difference in length between alternate sync pulses. As mentioned previously no changes were made in the TG-1A sync generator other than those shown in the grid circuit of V42 in Fig. 8.

The sequence of events is shown in Fig. 9. The sync pulse is longer when the square wave makes the voltage on the grid of V42 more negative and shorter when the grid is made more positive.

The difference in the pulse length is so slight that it is probably impossible to tell by direct observation of the pulses on most oscilloscopes when the difference between them is correct. The observation can be made with a high degree of accuracy by examining the output of the 3·8-Mc/s oscillator to see if, on alternate lines, the oscillator phase is 180 degrees different.

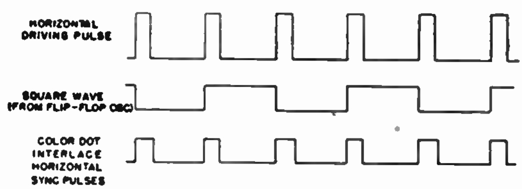


Fig. 9.—Relative timing of driving pulses, flip-flop multivibrator and sync pulses. (Note : not to scale.)

8.0. Transmitter Sampling Pulse Generator

The sampling pulse generator produce sine waves at a frequency of 3·8 Mc/s, alternate trains of which are shifted in phase by 180 degrees to produce picture dot interlace as previously explained. Fig. 10 is the schematic of this unit. Synchronizing pulses of negative polarity are fed to the grid of V11 and are amplified. The output of V11 is coupled to the grid of V12 through a small coupling condenser and the grid leak is returned to an adjustable positive voltage through the potentiometer marked "phase control." The sync pulses, which are positive in polarity at the plate of V11, are differentiated by the network in the grid of V12. The phase control varies the amount of differentiation resulting in a change in the length of the output pulses from V12. The only pulse appearing in the output of V12 comes from the trailing edge of the sync pulse. The pulse resulting from the leading edge is lost because it is positive in polarity and tends to drive the grid of V12 into grid current. However, the grid of V12 is already positive since its grid leak is returned to a positive voltage and therefore has a low impedance compared with that of the coupling capacitor. This results in little change in the grid potential or plate current. On the other hand, the differential of the trailing edge of the pulse is negative. This causes V12 to be cut off, resulting in a maximum change in plate current and a positive output pulse immediately following the trailing edge of each sync pulse. The resultant pulse is applied to a cathode follower V13.

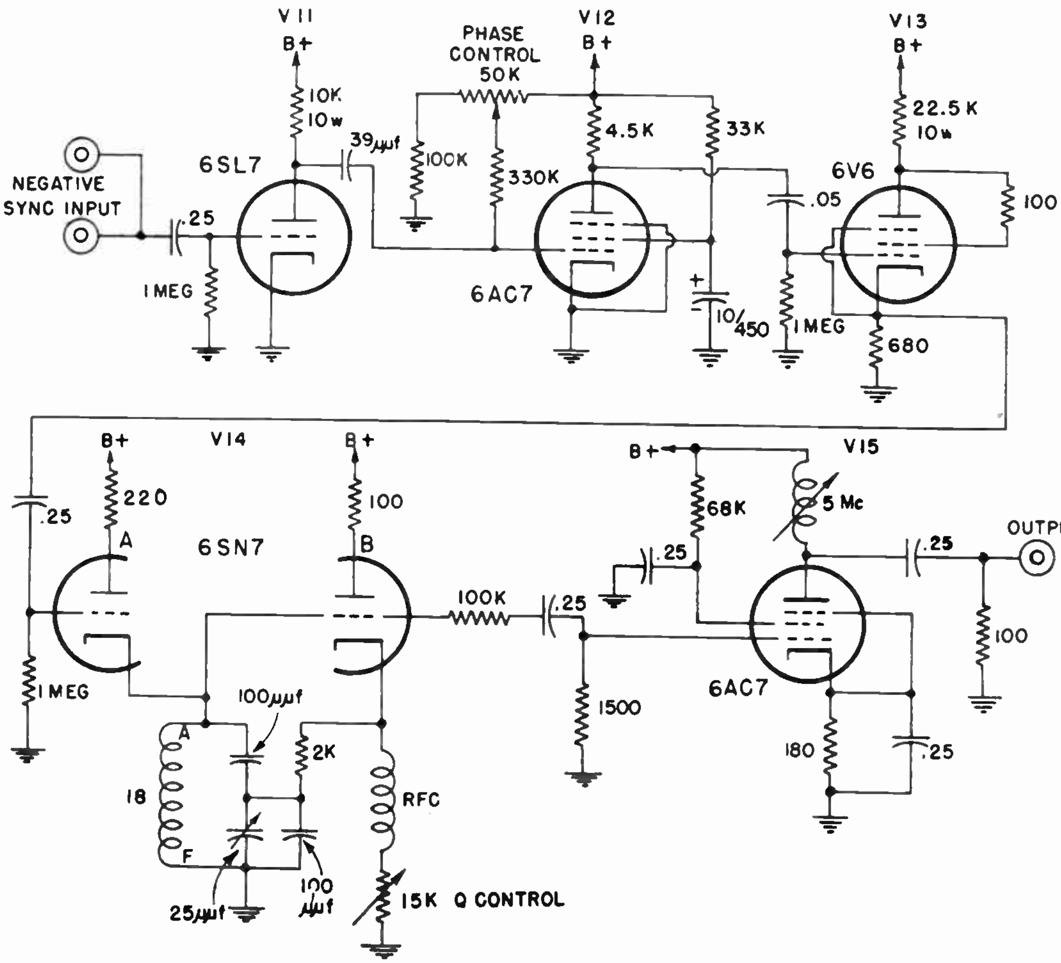


Fig. 10.—Schematic diagram of sampling pulse generator.

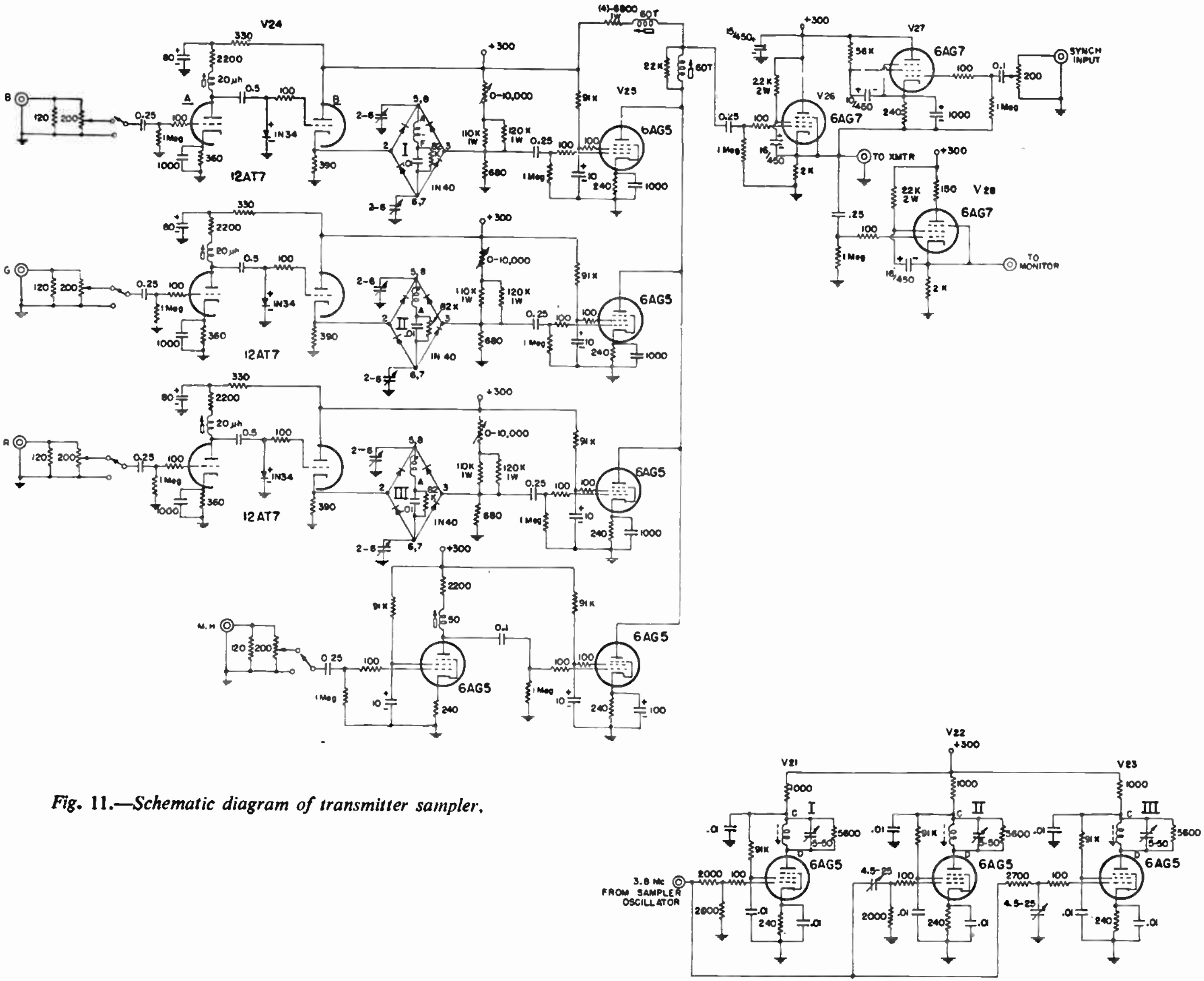


Fig. 11.—Schematic diagram of transmitter sampler.

The positive output pulse from V13 is applied to the grid of V14A which has its cathode circuit shunted across the tuned circuit of V14B (the 3·8-Mc/s oscillator). Thus, when the positive pulse is present on the grid of V14A, the oscillator circuit is shunted by a low impedance. This momentarily stops the oscillation of V14B. At the conclusion of the pulse V14B again begins to oscillate and the grid-leak bias developed in the grid circuit of V14A keeps that tube cut off between pulses. The 15,000-ohm variable resistor in the cathode of the oscillator tube marked " Q control " determines the amplitude of oscillation and influences the starting and stopping characteristics. V15 is an amplifier and buffer. Its output is fed to the sampler chassis.

9.0. Transmitter Sampler

The transmitter sampler takes the zero to 2-Mc/s portion of the output from each of the three colour camera signals, after they have passed through the filters, to remove the components above 2 Mc/s. The high frequency components by-pass the sampler as shown in Fig. 11. The outputs of the three keyers and the by-passed mixed high frequencies are then combined following which the sync pulses are added and outputs are fed to the transmitter and monitor.

The output from the sampler oscillator is fed to the grids of V21, V22 and V23. There is no phase shift in the grid of V21 ; the phase is advanced 60 degrees in the grid of V22, and retarded 60 degrees in the grid circuit of V23. Each of these tubes has the tuned primary of a transformer in its plate circuit, the secondary connection being reversed in the transformer at the plate of V21, the blue channel. These primaries are numbered I, II, III and their secondaries are similarly numbered in the varistor keying circuits.

Since all three keyer channels are identical, the blue one consisting of V24, the 1N40 varistor, and V25 will be described. Following the gain control and deactivating switch is a video amplifier V24A followed by a cathode follower V24B. A 1N34 diode is used as a clamp. There is no sync on the signal at this point, so a simple rectifier clamps accurately at the black level. As may be seen from Fig. 11, terminal 2 of the varistor is the video input terminal, terminal 3 the video output terminal and the sine-wave keying voltage is applied between terminals 5, 8 and 6, 7. The bridge must be accurately balanced for D.C. ; the 10,000-ohm variable resistor serves for this adjustment. The 2 to 6 pF variable capacitors balance the bridge for capacitance.

The video input level is of the order of 1 volt, the output being about one-quarter of the input. The D.C. developed across the 0·01-μF capacitor, 82,000-ohm load resistance combination is about 10 volts D.C. It results from rectification of the 3·8-Mc/s sine wave. The conduction angle is relatively small—of the order of 60 degrees or less. The operation of the bridge is as follows : During that portion of the 3·8-Mc/s sine wave when the rectifiers are conducting, the impedance between points 2 and 3 (Fig. 11), is very low—almost as though a switch joining those two points had been closed. During the remainder of the cycle the rectifiers are non-conducting. This effectively isolates points 2 and 3 as though the switch had been opened. Therefore, information from the camera blue-picture signal is passed through the varistor bridge for about one-sixth of the time. The signal is amplified by V25 and combined with the signals of the other two colours and the mixed high frequencies. V26 is a cathode follower feeding the transmitter. V27 inserts the synchronizing signals and V28, another cathode follower, drives the monitor.

10.0. Bibliography

1. "Standards of Good Engineering Practice Concerning Television Broadcast Stations." F.C.C. Communication, December 1945.
2. "A Six-Megacycle Compatible High Definition Color Television System." RCA Communication to the F.C.C., September 1949.

A 15 BY 20-INCH PROJECTION RECEIVER FOR THE RCA COLOUR TELEVISION SYSTEM*

SUMMARY

This paper describes two of the colour television receivers which were demonstrated by the RCA at the hearings before the FCC in Washington, D.C., on October 10th, 1949.

It deals primarily with the description of a projection receiver which produces a 15 × 20-in. picture. This unit is a modification of the receiver described in " An Experimental Simultaneous Colour Television System "[2,3] and produces pictures of equal size and detail but with greater brightness. Modifications have consisted principally in the addition of sampler circuitry to adapt it to the new system, and the substitution of reflective optics for the refractive system previously used. Of course, r.f. and i.f. circuits have also been simplified to make use of a conventional black-and-white r.f.-i.f. system in place of the three channels necessary for wide-band simultaneous colour reception.

In analysing these receivers it should be borne in mind that they are research models which were constructed for an evaluation of the potentialities of a new system.

Introduction

This receiver is one of the elements used by RCA Laboratories in research for a practical compatible colour television system. To one familiar with product design of modern black-and-white television receivers, it will be obvious that no attempt has been made to economize in these models. The use of tubes, components and power in the electrical circuits has been lavish and even a first production design could result in major cost reductions. Some of the most obvious possibilities will be mentioned in connection with the discussion of the individual circuits and others will occur to the design engineer. For example, the development of a suitable sampler to operate at higher levels would obviate the necessity for a separate video amplifier for each kinescope and thus permit the use of a single amplifier in place of the three now required.

Figure 1 is a block diagram of the receiver. The r.f., i.f. and sound circuits are those of an RCA Model 9T240 television receiver. Because no modifications have been made ahead of the picture second detector and because any other such receiver having a bandwidth of 3·8 Mc/s or more might equally well have been used, no description of the r.f., i.f. and sound circuits is included here.

* Paper submitted by R.C.A. Research Laboratories November 1949.
U.D.C. No. 621.397.62.

Receiver arrangements involving by-passed high frequencies are possible. However, this particular receiver uses the basic system without recourse to high-frequency separation.

The composite video signal is fed to the sampler and also to the sync separator chain in order to key the sampling pulse generator and to synchronize the deflection circuits as in a black-and-white receiver. The sampler provides three output voltages corresponding to the green, red and blue signals, each of which is amplified by a video amplifier and applied to the appropriate kinescope in the picture reproducer. It is the function of the sampling pulse generator to maintain order in the system and select the right information at the right time for transmission through the appropriate video amplifier. The sampling pulse generator derives its timing from the trailing edges of the horizontal sync pulses. Each alternate horizontal sync pulse is made slightly longer at the transmitter by the amount necessary to produce picture dot interlacing :—

$$\text{(i.e.,} \quad \frac{0{\cdot}5}{3{\cdot}8 \times 10^6} \quad \text{sec.)}$$

Figure 2 is a rear view of the receiver.

Because it was desired to compare the performance of the projection system with receivers using direct-view 10-in. kinescopes, another receiver was built to provide the same electrical performance with the same projection

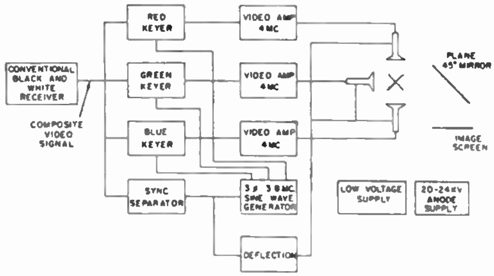


Fig. 1.—Block diagram of 3-colour projection receiver.

kinescopes but with changes in the optical system to give the appearance of a 7 × 9-in. picture. Construction of this receiver permitted direct comparisons between the two types without the necessity of making allowances for differences in picture size, viewing distance, etc.

Because the receivers are so nearly the same, the description which follows, while applying to both in most respects, will refer specifically to the one which produces the 15 × 20-in. picture.

1.0. Picture Dot Interlace Principle

As may be seen from the block diagram of Fig. 1, the composite video signal is applied to the sync clipper to derive synchronizing pulses. These are used to control the 3·8 Mc/s oscillator as well as the deflection circuits. The oscillator is made to start at the trailing edge of each horizontal sync pulse. It runs continuously for the duration of the visible portion of each scanned line, then stops briefly and is quiescent just before the next starting impulse. Since the oscillator will always start in the same phase with respect to the trailing edge of the sync pulse, it may be seen that systematic variation in the length of the synchronizing pulses can be made to produce picture dot interlacing. The system actually in use at the present time makes each alternate transmitted horizontal sync pulse longer by a time equivalent to one-half cycle at 3·8 Mc/s. This delays the start of the oscillator by 0·132 μ sec. on alternate lines and thus develops the interlaced scanning pattern illustrated in Fig. 3. The sequence of events may be understood by referring to Fig. 4. In Fig. 4A the 3·8 Mc/s sine wave is shown starting with a certain phase difference with respect to the trailing edge of a regular sync pulse. Figure 4B shows the same phase relationship between the sine wave and the trailing edge of the sync pulse, but the pulse is longer by a time equivalent to a half cycle at 3·8 Mc/s resulting in a 180° phase delay (0·132

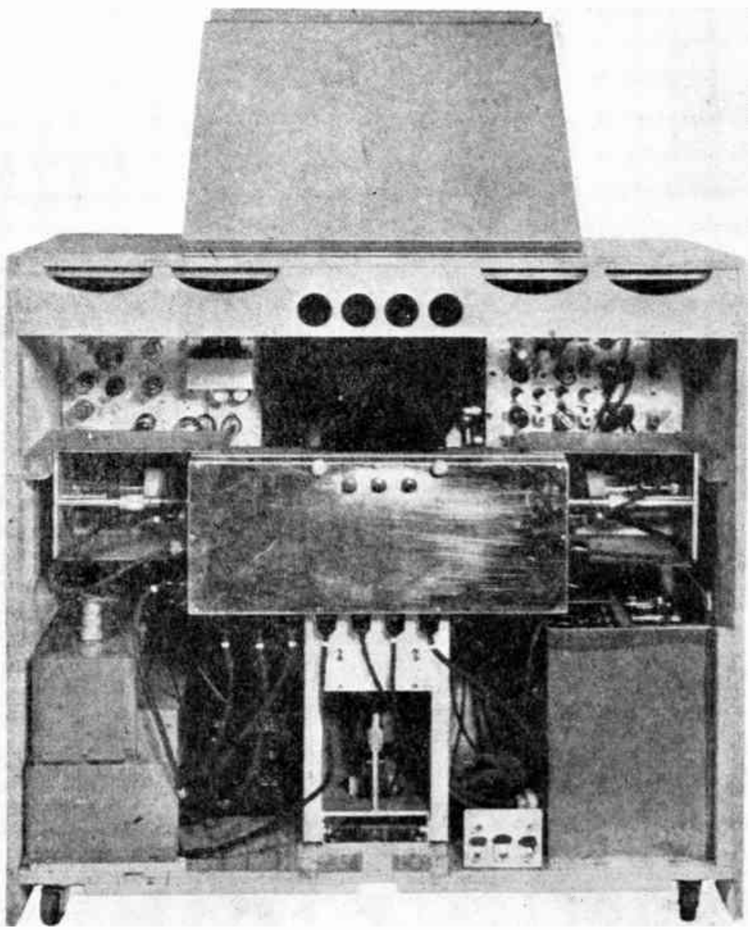


Fig. 2.—Rear view of 15 × 20-in. projection receiver.

μ sec.) between the two sine waves. Figure 4C shows the vector diagram corresponding to the conditions prescribed in Fig. 4A for the sampler used in this receiver. The oscillator voltage is indicated as E_o. The voltage for keying the green keyer is obtained by advancing the phase of the oscillator voltage by 60° and is shown as E_G. Similarly, the voltage for keying the red keyer, shown as E_R, is obtained by retarding the oscillator voltage by 60°. A 180° phase voltage for the blue-signal keying is obtained from an additional winding on the transformer connected in reverse polarity. If the vector diagram of Fig. 4C is assumed to be the instantaneous phase relationships resulting from the conditions shown in Fig. 4A, which produce the scanning and interlace pattern shown in line 1 of Fig. 3, it is apparent that the vector diagram of Fig. 4D, resulting from Fig. 4B, is delayed in relative time by 180° and will produce the pattern shown in line 3 of Fig. 3, first field. In Fig. 3, each letter represents the centre of a colour dot area on the screen. The colour dot areas, of course, overlap to a great extent.

During the first scanning field, illustrated in the upper diagram of Fig. 3, the odd-numbered lines are scanned in order. Colour dots are laid down in order along line 1 as shown. Next, line

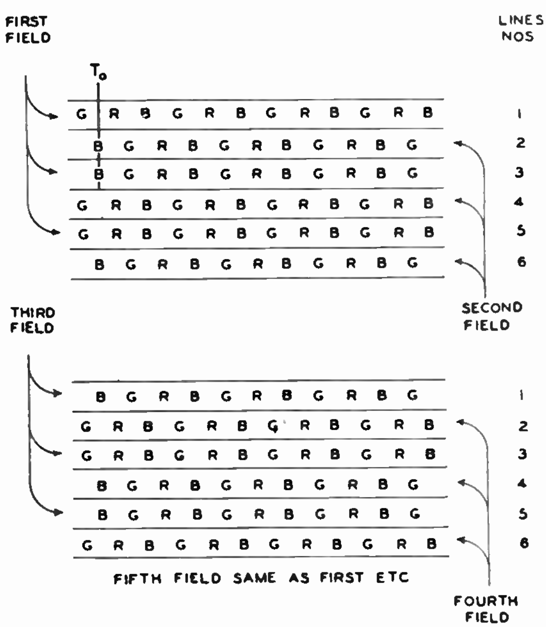


Fig. 3.—Dot interlace pattern.

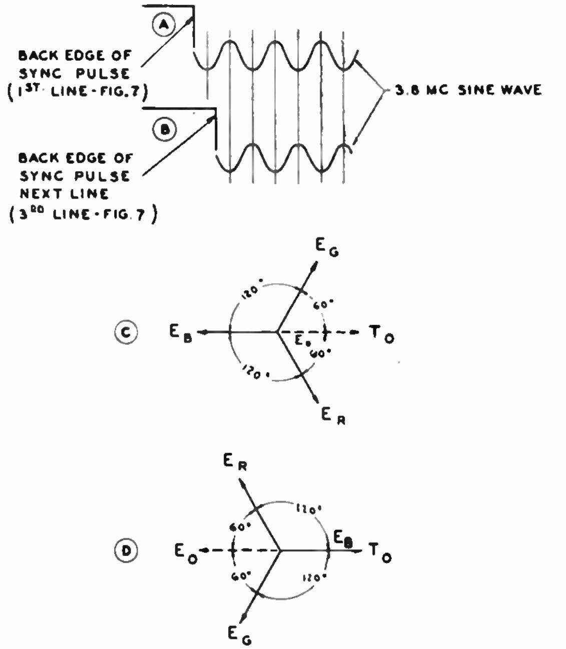


Fig. 4.—Time relationships between successive lines to obtain dot interlace.

3 is scanned with the displacement for each colour dot as shown. The remaining odd lines are scanned in order. This scanning of the first field takes place in 1/60 of a second.

During the second field, the even lines are scanned, first line 2 with the colours laid down as indicated, then line 4, and so on. The dot pattern laid down during the third field is given by the lower diagram, where the odd lines are scanned in succession. During the fourth field, the even lines are again scanned in succession with the colour dot pattern shown.

2.0. Video Amplifier, Sync Separator and Sampler Circuit Chassis

Figure 5 is a complete schematic diagram of the video amplifiers, sync separators and sampling circuits. Video output from the second detector of the black-and-white television receiver is fed to the input of this unit. The output voltages provide green, red and blue video information to the kinescopes and sync signals for the deflection unit.

The second detector video signal is applied to one-half of a 12AU7 (V1A) for amplification.

Two output voltages are taken from this tube, one for the sync separator chain via V1B, the other for the sampler circuits via the video amplifier V6.

2.1. *Sync Separators*

Tracing first the synchronizing-signal chain, it may be seen that the composite video signal is applied to V1B with sync signal positive. The sync peaks are set at zero bias and the video information is beyond cutoff on this tube which is operated at low plate voltage. In the succeeding stage the base of the sync pulses is set at zero bias and the peaks are clipped. In the third stage the sync pulses are again positive in polarity to remove any video information remaining from the first clipper V1B. The inputs of circuits V3A and V3B are connected in parallel. These tubes again clip to remove any remaining irregularities in the top of the synchronizing pulses. The trap composed of the inductance CTC5Mc and the 5 to 50 pF capacitor is tuned for series resonance at 3·8 Mc/s to remove from the sync any energy at that frequency. The output of V3B is fed to the deflection chassis for deflection synchronization. Up to this point the system is identical to that of a black-and-white receiver except that more stages are employed than are normally used when cost is a primary consideration. The output of V3A is coupled to the grid of V4 through a small coupling condenser and the grid leak is returned to an adjustable positive voltage through the potentiometer, marked " phase control."

The sync pulses, which are positive in polarity at the plate of V3A, are differentiated by the network at the grid of V4. The phase control varies the amount of differentiation resulting in a change in the length of the output pulses from V4. The only pulse appearing at the output of V4 comes from the trailing edge of the sync pulse. The pulse resulting from the leading edge is lost because it is positive in polarity and tends to drive the grid of V4 into grid current. However, the grid of V4 is already positive since its grid leak is returned to a positive voltage and therefore has a low impedance compared with that of the coupling capacitor. This results in little change in the grid potential or the plate current. On the other hand the differential of the trailing edge of the pulse is negative. This causes V4 to be cut off, resulting in a maximum change in plate current and a positive output pulse immediately following the trailing edge of each sync pulse. The resultant pulse is applied to V5 (a phase splitter) to obtain both polarities at low impedance for driving the clamp tubes, V26, V18 and V34. These clamp tubes, which are a source of considerable and perhaps unnecessary complexity, will be discussed later, but it may be seen that, since they are connected to the video output, a tube having low impedances had to be used for V5 to reduce video feedback into the sampler synchronizing circuits at this point. Use of other types of clamps or D.C. restorers would permit a smaller tube drawing less plate current for V5, or perhaps its elimination.

2.2. *Sampling Oscillator*

A positive output pulse is taken from the cathode of V5 and fed to the grid of V8A, which has its cathode circuit shunted across the tuned circuit of V8B (the 3·8 Mc/s oscillator). Thus, when the positive pulse, with an amplitude of approximately 35 V, is present on the grid of V8A the tuned circuit is loaded by the cathode impedance of V8A. This momentarily stops the oscillation of V8B. At the conclusion of the pulses, V8B again begins to oscillate and the grid-leak bias developed in the grid circuit of V8A keeps that tube cut off between pulses. Oscillation is stopped for only a relatively short time. In one receiver it was found that the 3·8 Mc/s oscillator was stopped for 1 cycle (of 3·8 Mc/s), at one end of the phase control and for 4 cycles at the other end of the control.

The 25,000-ohm variable resistor in the cathode of the oscillator tube marked " Q control " determines the amplitude of the oscillations and influences their starting and stopping characteristics. In a commercial design it might not need to be variable.

V9 is a buffer to isolate the oscillator from its load circuit. The need for it is questionable since the next amplifier (V10) should serve the purpose adequately.

V10 is a 3·8 Mc/s amplifier, the primary of the transformer in its plate circuit being tuned to that frequency. The network in the secondary of the transformer serves to provide the three phases of 3·8 Mc/s voltage required for the keyers in the sampler circuits as explained previously and shown in Fig. 4. The voltages

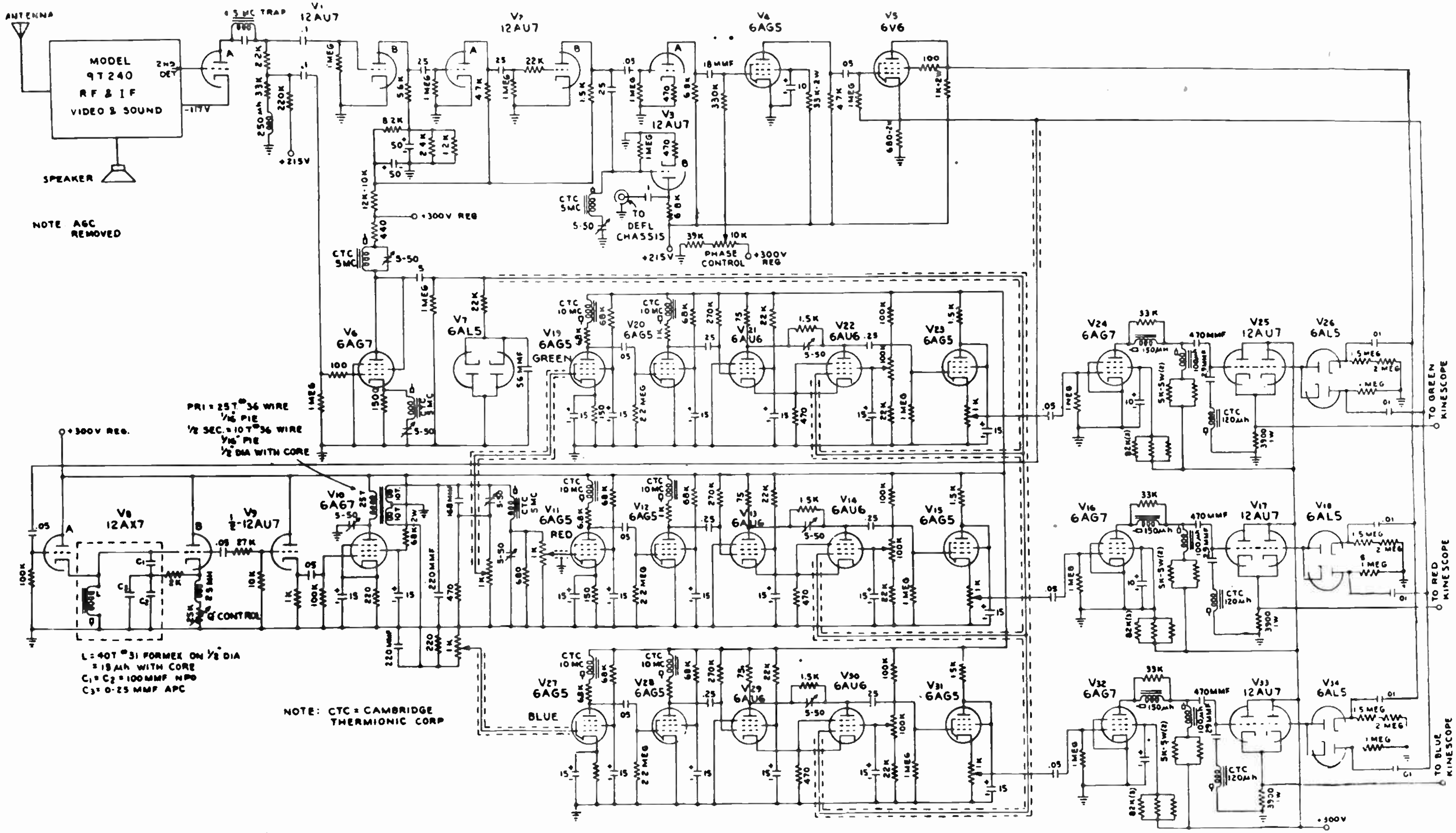


Fig. 5.—Video amplifier, sync separator and sampling circuit chassis.

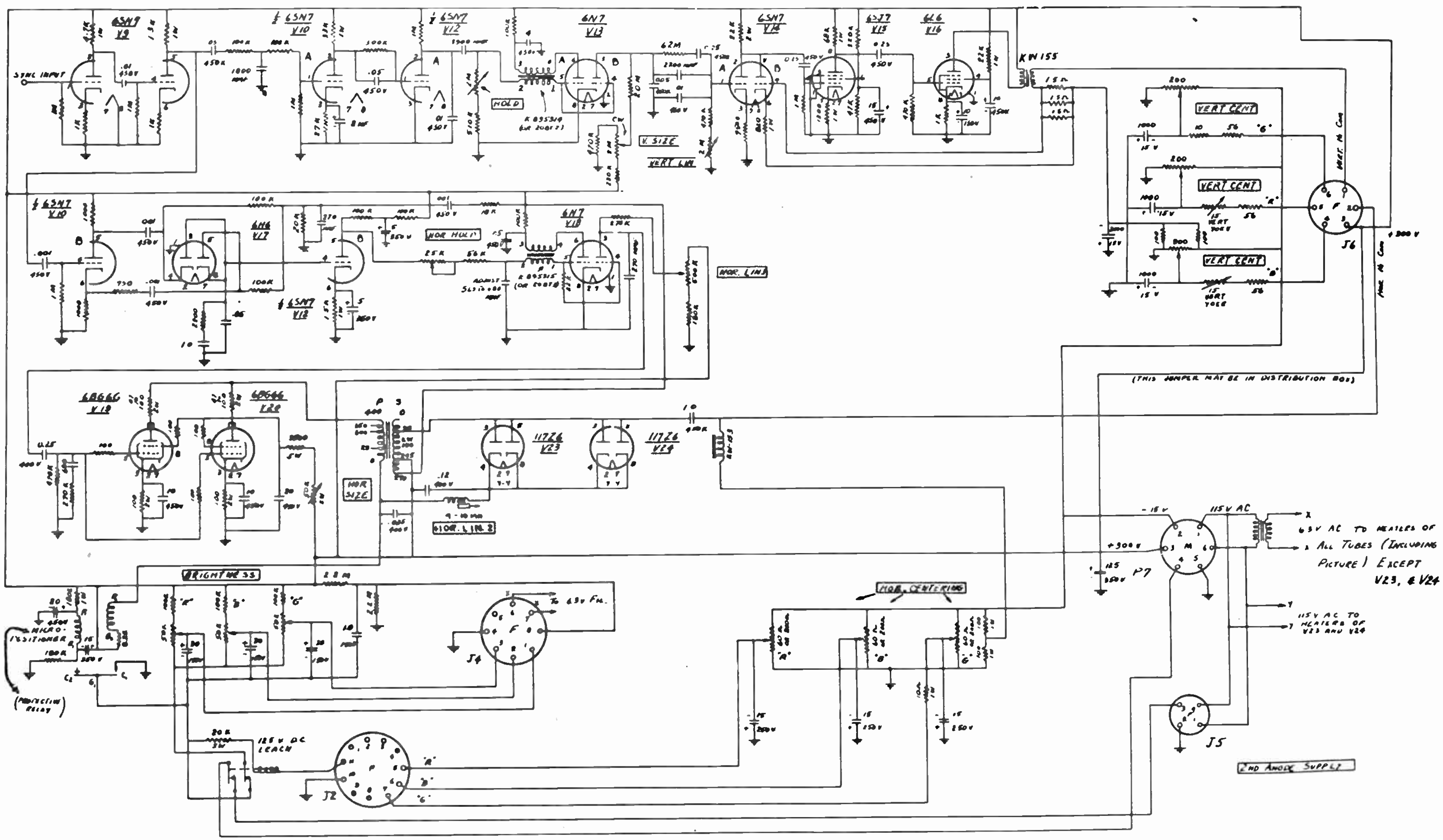


Fig. 6.—*Deflection chassis.*

controls for each colour accessible from the front panel. A cathode follower was necessary to obtain the low impedance required of a remote control with its associated capacitance if the frequency response were to be retained. In a commercial design the cathode follower may be omitted, although individual controls will probably be necessary in the original design of a receiver owing to tube and circuit component tolerances.

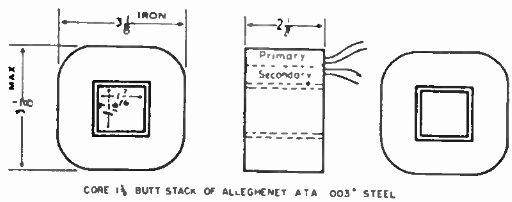
Following the original circuit, one master gain control should suffice. In this receiver, the changes made in the video and sync circuits resulted in a loss of the original A.G.C. circuits. Therefore, a manual bias control on the r.f. and i.f. stages was installed and used as the master contrast control. A good commercial design would incorporate A.G.C. and include a contrast control to vary the gain through V6. The cathode follower V31 drives a video-amplifier stage V32 which is conventional except for the inclusion of the 29 p.F. capacitor and variable inductor marked CTC120 μH which, in combination with the peaking circuits, is adjusted to attenuate frequencies above 4·2 Mc/s. The output of the video stage feeds a cathode follower V33 which is no more necessary in a colour receiver than in its black-and-white counterpart, but it was convenient for research work to have the video response unaffected by variations in capacitance of the kinescope grid lead. The output of the cathode follower is 40 to 50 V peak to peak which drives the kinescope.

Connected to the grid of the cathode follower is V34, a double diode used as a line-by-line clamp. When the pulses, which immediately follow the back edge of the sync pulse, are applied to the clamp from V5 the D.C. level is established at the black level. A complete discussion of this type of clamp circuit is contained elsewhere.[4] It is important in a colour television receiver that the D.C. levels be maintained for proper colour balance but it is problematical whether or not elaborate clamp circuits of this type are necessary. It is quite possible that simple diode D.C. restorers of the type used in black-and-white receivers will suffice.

3.0. Deflection Chassis

Figure 6 (facing page 141) shows the circuit diagram of the deflection chassis. Sync input to this unit comes from the sync output terminal on the video-amplifier chassis (marked TO DEFL. CHASSIS on Fig. 5). The level is approximately 40 V peak to peak and the polarity is sync positive. At the output of the first 6SN7 (V9), the sync signal is integrated for the vertical and fed to V10A and is also fed to the other half of the same tube used as a phase splitter for the horizontal a.f.c. sync circuit.

The vertical circuit as shown is quite complex even though the vertical synchronization and linearity requirements are no more stringent that those for a monochrome receiver of the same type. Since all three kinescopes are deflected by the same source, they are affected identically by any non-linearity of the deflection currents. Therefore, registration is not a function of linearity. However, this receiver was built to provide the best possible vertical linearity by the inclusion of a degenerative feed-back network in the vertical deflection circuit. The network in the plate circuit of the discharge section of the 6N7 (V13A) is designed to produce a linear saw-tooth voltage which is amplified by V14A, V15 and the vertical output tube V16. The output-transformer secondary current which flows through the deflection yokes is passed through a resistance composed of the three 1·5-ohm resistors in parallel. The voltage developed across these is applied to V14B to furnish the degeneration which assures that the yoke current is essentially as linear as the original saw-tooth voltage generated by the discharge tube.



CONDUCTOR MATERIAL & SIZE		ORDER OF WINDING	WOUND OVER	TURNS	LAYERS	T/L	WIRE TRAV	BETWEEN LAYERS	OVER COIL	D.C. RESIST AT 25°C OHMS	COIL BUILD
005	KRAFT PAPER			FOUR	LAYERS						
# 18	HEAVY FORMEX	SEC	SPOOL	308	8	39	1 7/8	1 - 002"	3 - 005"	1·68 Ω	410"
# 31	HEAVY FORMEX	PRI	SEC	5040	30	168	1 7/8	1 - 002"	5 - 005"	598 Ω	420"

Fig. 7.—Vertical output transformer.

The three vertical deflection yokes are connected in parallel but each is provided with its own centring control. In addition, two of the yokes are provided with incremental size controls to permit their respective deflections to be made the same as that of the third. In a commercial which lead or lag by 60° are derived from the top end of the secondary. The inductance marked CTC5Mc in combination with the 5 to 50 p.F. capacitor provides a phase delay of 60° for the red channel. The 168 p.F. capacitor in parallel with the 5 to 50 pF capacitor and in series with the combination of 470 ohms and 1,000 ohms in parallel provide the 60° phase advance for the green channel. The blue channel voltage is taken from the bottom end of the secondary to obtain the requisite 180° phase reversal. The potentiometers which vary these output voltages do not appear to be essential. There is a critical value of voltage at which the system starts to operate and the operation continues unchanged above that level. In a commercial receiver it should suffice to provide adequate output voltage with most adverse component tolerances.

2.3. *Sampler Circuits*

Since the 3 keyers, one for each colour, which compose the sampler are identical, only one need be examined. The blue chain, for example, is composed of V27, V28, V29 and V30.

The 3·8 Mc/s sine wave of the phase is applied to the grid of V27 which serves as an amplifier. The inductance in the plate circuit is set for maximum 3·8 Mc/s gain. The electrolytic capacitors, shown as by-passes, should not be necessary in the circuits of V27, V28 and V29. V30, however, has a video signal applied and adequate by-passing for low frequencies is necessary. The output of V27 is a 3·8 Mc/s sine wave of relatively large amplitude. V28 is grid-leak biased so the positive tips of the sine wave set at zero bias and the negative portions of the cycle swing beyond cutoff. This produces clipped sine waves of negative polarity in the plate circuit. These are applied to the grid of V29. V29 and V30 have a common cathode resistor. The grid leak of V29 is returned to + B. This causes V29 to draw sufficient plate current to keep V30 at cutoff except when the grid of V29 is supplied with a negative cutoff pulse from V28. Thus, when V29 is cut off, V30 amplifies the video signal applied to its grid. This signal contains the information to be reproduced by the blue kinescope. During the remainder of the time, when information to be reproduced by the red and green kinescopes is present in the video signal, V30 is cut off, but, due to the difference in phases of keying voltages applied to the other two chains, one of them is operative. The arrangement of the 1·5 kΩ load resistor returning to the small load resistor in the plate of V29 and shunted by the 5 to 50 pF capacitor is to obtain neutralization so that a minimum of the keying signal appears in the output of V30. The 100,000-ohm potentiometer in the screen of V30 is effectively a D.C. balance control. It should be set for minimum gating transient in the output.

It may be of interest to note that an experimental keyer using triodes in place of pentodes for V27, V28, V29, V30 and V31 has been assembled. Preliminary tests indicate that the performance characteristics will be satisfactory.

It should again be mentioned that the development of a high-signal-level sampler would simplify some of the circuitry shown in Fig. 5, (facing page 140).

2.4. *Video Amplifiers*

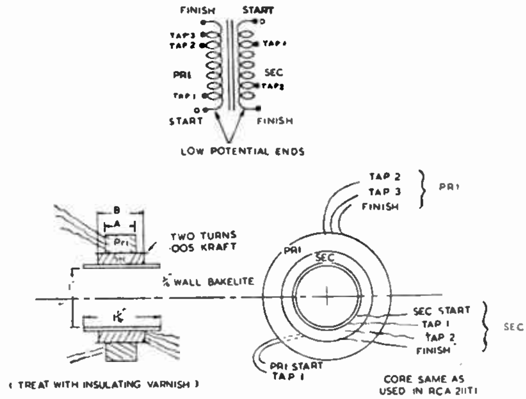
Following V1A, which amplifies both the sync and video signals, is V6. The gain of this stage is less than unity for most of the video range as may be seen from the fact that the degenerative cathode resistor is larger than the plate load resistor. However, it does have considerable gain at 3·8 Mc/s to boost this frequency. Relatively higher gain for 3·8 Mc/s has been found to be a desirable attribute of the video system. The LC network in the cathode of V6 is series resonant removing the degeneration and the parallel LC combination in the plate is parallel resonant increasing the plate load at that frequency.

The output of V6 is capacitance coupled to the three keyed tubes of the sampler, V30, V14 and V22. In order to restore the D.C. component at this point, V7 is connected from the grid of these tubes to earth in customary D.C. restorer fashion.

From this point to the kinescopes there are three video amplifiers, each amplifying the picture information for green, red and blue for application to the appropriate kinescope. Since all are identical, only one need be discussed. To return to the blue channel, pulses of information corresponding to the blue picture content at a 3·8 Mc/s rate were obtained at the output of V30. These are fed into a triode-connected 6AG5 (V31) as a cathode follower. In the research stage it has been essential to have separate gain design it seems probable that V9 would not be required and that the tubes in the vertical chain, V10A, V12A, V13, V14, V15 and V16 could be replaced by one triode as a blocking oscillator-discharge tube and a power triode output tube. Details of the vertical output transformer are shown in Fig. 7.

The horizontal a.f.c. sync circuitry is conventional and is of the blocking-oscillator type.[5] The two 6BG6G deflection tubes are coupled to the damper diodes by the output transformer KW154, details of which are shown in Fig. 8. No attempt has been made to apply recent developments in deflection circuits which provide increased efficiency. Since the deflection angle of the kinescope is only about 40° the deflection power requirements are not severe.

The horizontal deflection yokes are isolated for D.C. from the output transformer by a 1-μF condenser and a choke KW153 (also shown in Fig. 8) is used to provide a D.C. path for the centring currents. As with the vertical yokes, the three horizontal deflection yokes are connected in parallel and each is provided with a separate centring control for registration. Individual adjustment of width is made by adjustment of the deflection yoke position on the tube neck.



TRANSFORMER WINDING

DESIGN NUMBER	PRIMARY COIL						SECONDARY COIL						DIMENSIONS	
	WIRE	TAP 1	TAP 2	TAP 3	TOTAL TURNS	WINDING SET-UP	WIRE	TAP 1	TAP 2	TAP 3	TOTAL TURNS	WINDING SET-UP	A	B
KW153	CHOKE						#30 SSE OR DSE	—	—	—	1500	70/71, G 35	—	1"
KW154	#30 DSE	25	300	350	400	GEAR RED 110/60 G 15	#20 DSE	90	245	—	270	70/71, G 10	1/2"	3/4"

Fig. 8.—Horizontal output transformer and choke.

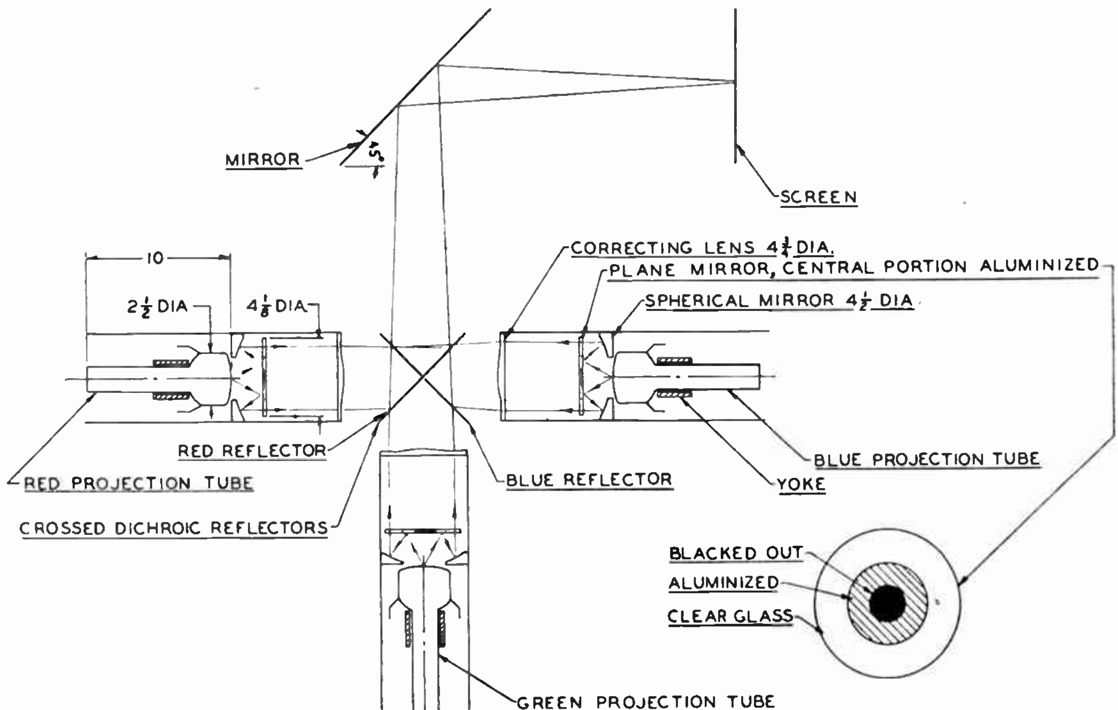


Fig. 9.—Diagram of bi-reflective projection optical system.

The "Micro-positioner" protective relay together with the Leach 125-V D.C. relay provide protection for the cathode ray tubes in the event of horizontal deflection failure.

The deflection yokes are conventional in design but, if good registration is to result, it is important that they be uniform in characteristics. In their assembly a signal should be applied to one set of windings and the other adjusted until the induced voltage is zero. This ensures that the fields from the two windings are at 90°. Unless this is done it is possible to obtain registration in either the vertical or horizontal direction but not both simultaneously without skew circuits to correct for yoke differences. The horizontal yoke inductance is 17 mH and the vertical 22 mH.

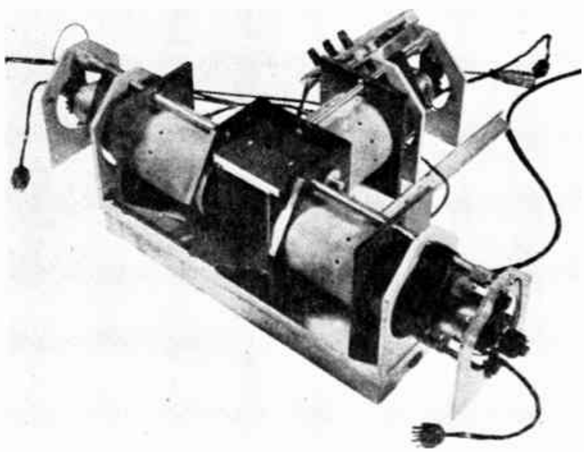


Fig. 10.—*Close-up view of optical assembly.*

In a black-and-white television receiver a small amount of deflection from stray power line frequency fields is not objectionable. The same would be true in a colour receiver using more than one kinescope if the stray fields acted similarly on all kinescopes. However, the difference in orientation of the tubes almost certainly precludes this possibility. In order to maintain registration it has been found desirable to place magnetic shields around the necks of the kinescopes.

4.0. The Bi-reflective Optical System

Viewed as a complete unit, the bi-reflective projection optical system, which reproduces the colour picture, consists of the green, red and blue kinescopes each mounted in conjunction with its own reflective optics, a pair of crossed dichroic selective reflectors, a 45° plane mirror, and a viewing screen. Their relative positions in the entire assembly are shown diagrammatically in Fig. 9 and Plate D (p. 151). In operation the whole unit is positioned vertically in the rear of the cabinet as in Fig. 2, thus permitting the projected image to reflect from the plane mirror in the hinged cover on to the screen. For a close-up view of the optical assembly, reference is made to Fig 10 which shows the three optical barrels, the dichroic mirrors, and some of the adjusting controls.

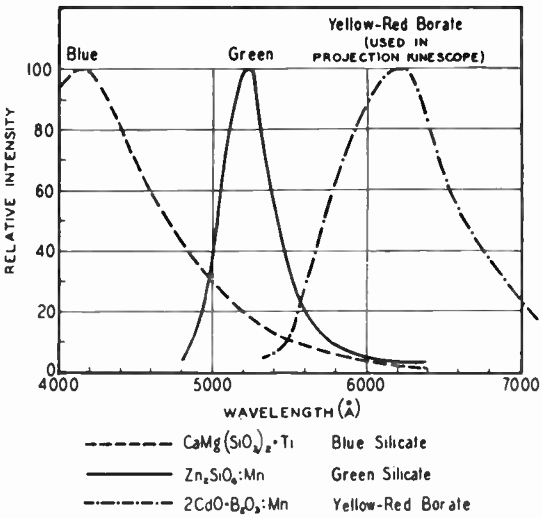


Fig. 11.—Approximate spectral characteristic of colour phosphors.

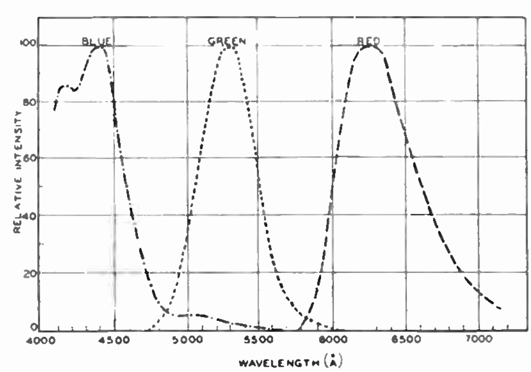


Fig. 12.—Spectral distributions of green, red and blue colours on the viewing screen.

Laboratory-model 2½-in. colour kinescopes provide the green, red and blue images for the picture. Their electron guns are of the type used in the 5TP4 projection kinescope. Approximate spectral characteristics for the different colour phosphors are plotted in Fig. 11, the peak intensity being arbitrarily set at 100. Note should be taken of the fact that while the green and blue phosphors have good chroma, the output of the yellow-red phosphor of the red kinescope requires the use of a red filter, such as the Wratten No. 26, to provide better chroma.

By way of comparison, Fig. 12 shows the final spectral distribution of the three colours as viewed on the screen after passing through the optical system and dichroics. Fig. 13 gives the location of these green, red and blue colours on the I.C.I.* colour diagram. From this it is evident that practically all of the ordinarily useful colours are included in the triangle.

Before taking up the other elements of the optical system it might be well to mention that the deflection yoke on each kinescope is so mounted mechanically within the housing that it may be both rotated and moved axially for adjustment of picture size and to assure proper registration even though there may be slight differences in tubes and yokes. Furthermore, the tubes are supported by the necks and tube-face corona shields in such a manner that when pushed up against the shields and clamped by the neck, they are automatically aligned with the optical system.

Situated in front of each kinescope are the spherical mirror, the plane glass disc and the correcting lens which, together with the crossed dichroic mirrors, complete the optics of the system. The plane glass disk has its centre blacked out, a portion around the centre aluminized, and the outer section clear, as shown in Fig. 9. Light from the faces of the red and blue tubes is reflected from the aluminized portion of the plane disc to the spherical mirrors, back through the clear outer section of the disc, through the correcting lens which serves to correct for the aberrations of the spherical mirror, and thence is reflected by the red or blue dichroic mirrors. Light from the green tube takes much the same course, except that it passes directly through the dichroics without reflection.

* International Commission on Illumination.

A more complete description of the principle of these reflective optics has been published elsewhere.[6]

An excellent discussion of the theory and principles of operation of dichroic reflectors has also been given.[7] As used in the present system, the arrangement consists of two crossed dichroic mirrors, or, more accurately, three, because one of the plates is divided in half at the line of junction. One dichroic reflects red and passes blue and green, while the other reflects blue and passes red and green. Such mirrors are made by vacuum deposition of multiple metallic films on glass, arranged in alternate layers having different indices of refraction. They operate at high efficiency and at the same time have a desirable filtering action which improves the chroma of the light from the three kinescopes.

From the dichroic mirrors, the light travels to a front-surface plane mirror located in the hinged cover of the cabinet and oriented at a 45° angle to reflect the picture to the rear-projection viewing screen of the type described by R. R. Law and I. G. Maloff.[8]

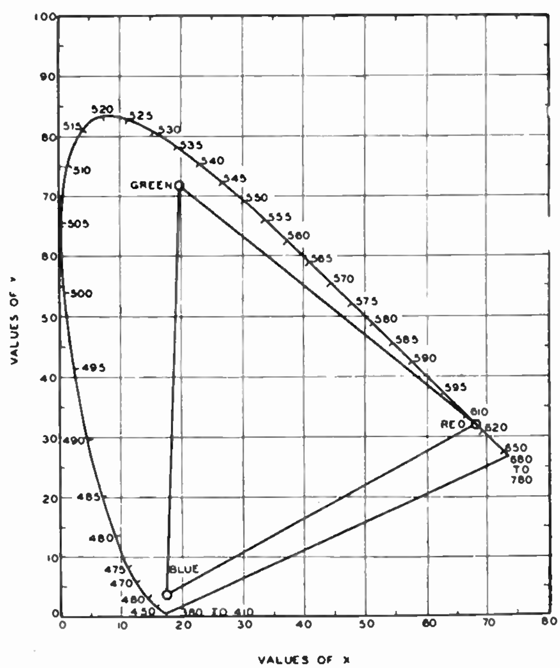


Fig. 13.—Co-ordinates of green, red and blue colours as seen on the viewing screen.

5.0. Kinescope Anode Supply

The circuit diagram of the kinescope anode supply is shown in Fig. 17. Construction details of the oscillator coil are given in Figs. 14 and 16 and of the filament transformers in Fig. 15.

As may be seen, this is a laboratory-type regulated supply which, with appropriate changes in the filament transformer capacitors, will provide voltages between 20 and 40 kV. For the 20 to 24 kV operating potential range the values as shown are used.

This particular receiver was built with a regulated r.f. power supply. However, there is no reason for believing that a flyback power supply, deriving the anode potential from the horizontal-deflection circuits might not be just as satisfactory here as in a monochrome receiver even though the current required is higher. For example, the combined anode currents of the three kinescopes may be as much as 1 mA on a maximum brightness white picture.

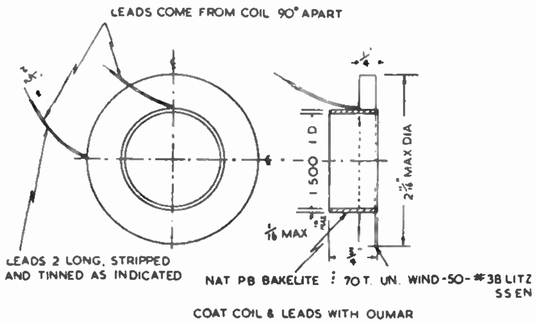


Fig. 14.—Primary of r.f. high voltage oscillator.

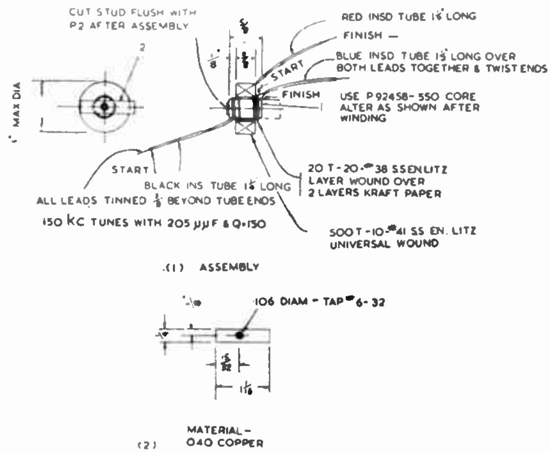


Fig. 15.—Rectifier filament transformer.

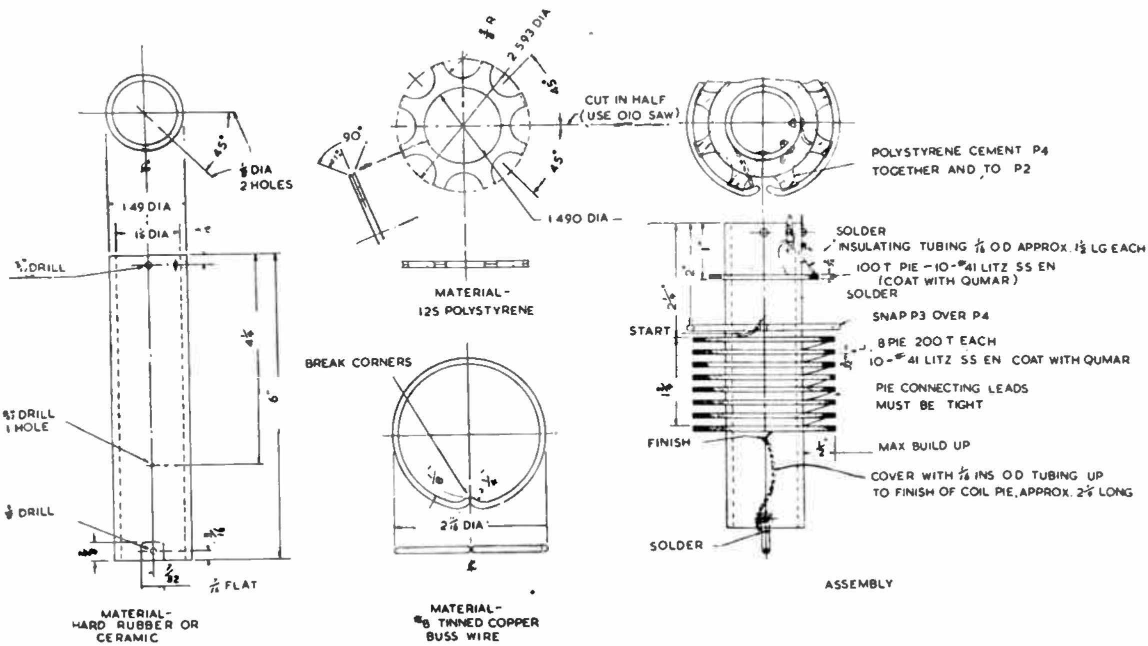


Fig. 16.—R.f. power supply coil.

The general subject of r.f. power supplies has been covered by R. S. Mautner and O. H. Schade.[9] In the present source the regulation is accomplished by applying some of the r.f. potential across the oscillator coil to a 6AL5 rectifier. A selected portion of the diode-developed D.C. voltage is applied to the grid of a 6AK5 voltage amplifier, the output of which is connected to the grid of a 6L6 which controls the screen voltage of the oscillator tubes. The system is degenerative in that an increase in oscillator voltage results in a decrease in oscillator screen voltage to augment the effect.

6.0. Low-voltage Power Supplies

The portion of this receiver in the block marked " R.F. & I.F. VIDEO & SOUND " in Fig. 5 is operated from the original power supply of the Model 9T240 chassis. This unit is less heavily loaded than it was originally because of the removal of the video and deflection circuits.

Three other low-voltage supplies furnish the power for the balance of the receiver. The principal source is an RCA commercial regulated unit WP33A which is rated at 600 mA maximum. It operates at close to its maximum rating in supplying current to all the circuits except those of the output video stages and the r.f. power supply. The three output video stages are fed from an unregulated power supply delivering approximately 45 mA at 300 V D.C. A third unregulated power supply was designed to operate the laboratory-type regulated second-anode potential source. Its output is 400 V D.C. and the current drain is about 200 mA with a maximum brightness white picture.

No attempt has been made to replace the regulated supply with an unregulated one as a

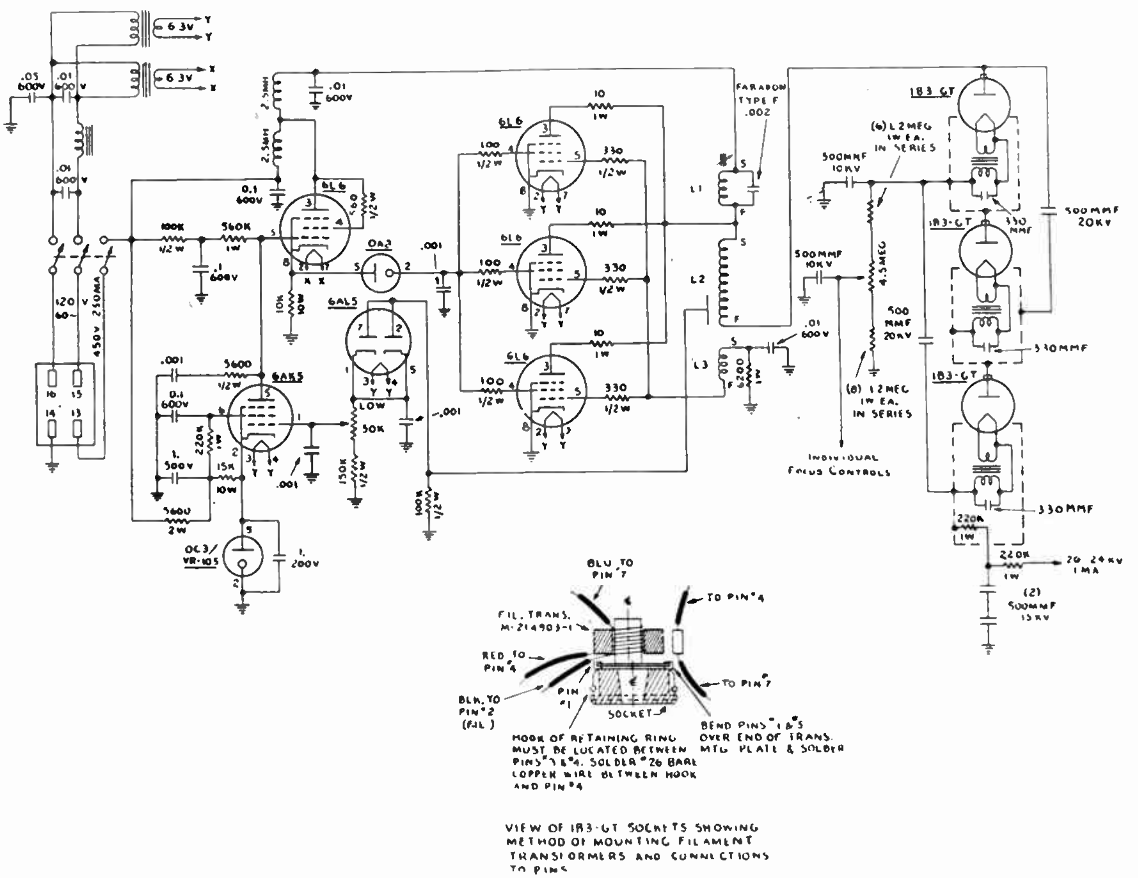


Fig. 17.—Regulated r.f. power supply.

cost reduction measure. However, the gains at low frequency are about the same as in as conventional monochrome receiver. It seem reasonable to assume that the techniques which minimize the effects on line-voltage variation in a well-designed black-and-white receiver would yield equally good results here.

7.0. Power Distribution Panel

Across the back of the receiver shown in Fig. 2 may be seen the power distribution panel. Its function is obvious, and would need no comment except for the fact that the focus controls, one for each kinescope, are mounted on this panel. Focus voltage is obtained from the potentiometer as shown in the r.f. power supply diagram, Fig. 14. The top ends of the 2-megohm focus controls are connected to this point and the bottom end of each is connected to earth through 22 megohms.

8.0. Bibliography

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9. Mautner, R. S. and Schade, O. H. " Television High Voltage R.F. Supplies." *R.C.A. Review*, Vol. VIII, No. 1, 1947, pp. 43-81.

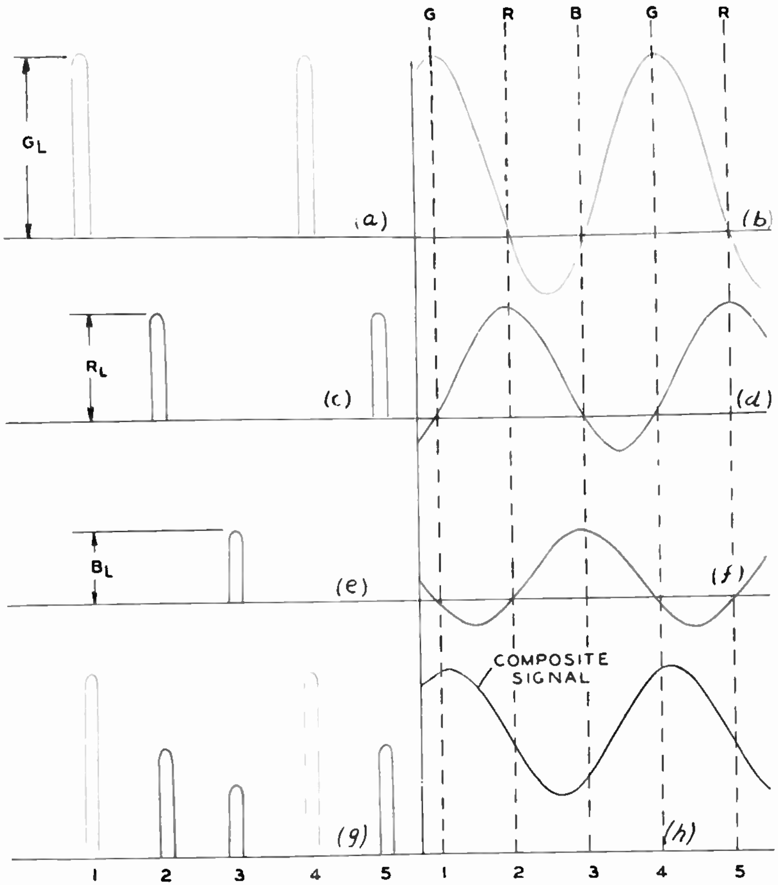

Fig. 18. *Functioning of the sampling system at the transmitting end in the pick up of large uniform polychromatic areas. Figs. (a), (c) and (e) show the output of the sampler due to the green, red and blue signals respectively. Each channel is sampled every 0·263 microseconds. The composite output of the sampler is shown in (g). The narrow pulses in (a), (c) and (e) are smoothed by low pass filters to give the results shown in (b), (d) and (f). (h) illustrates the composite signal.*

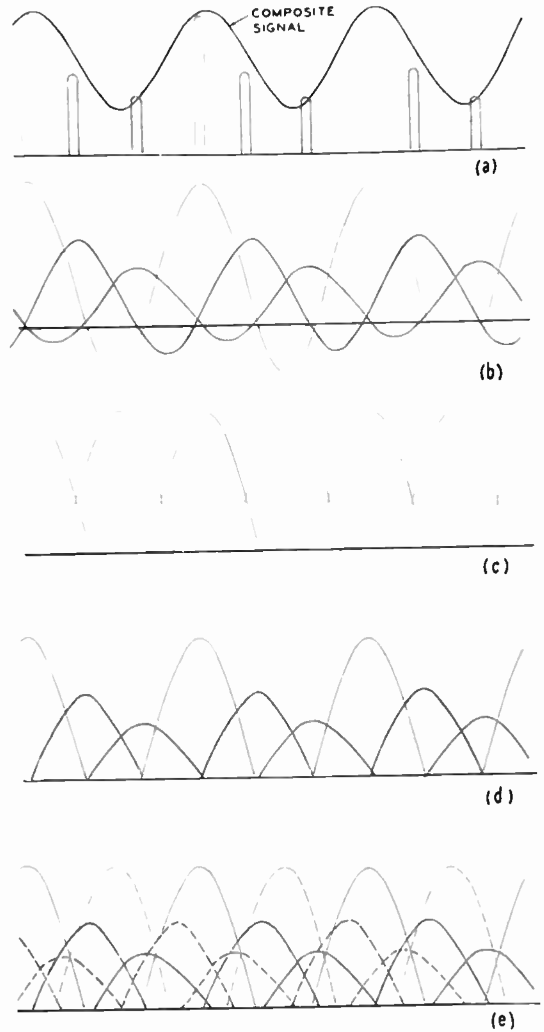

Fig. 19. *Functioning of the sampling system at the receiving end. The signal from the second detector enters the sampler and it has the form of (a). The electronic commutator samples the composite signal every 0·0877 microseconds. Each separate colour, however, is sampled every 0·263 microseconds. The resultant smoothed signals after passing through the video amplifiers are shown in (b). The solid lines in (c) may be regarded as the effective light intensity along one line scan in green, (d) shows that, while a single scan lays down a series of green dots on the screen with spaces between dots, this space is filled at the same time by the red and blue dots with great overlapping of the dots. The effects of the successive scans of a single line (e) shows the complete covering of the line area with picture dots of three colours.*

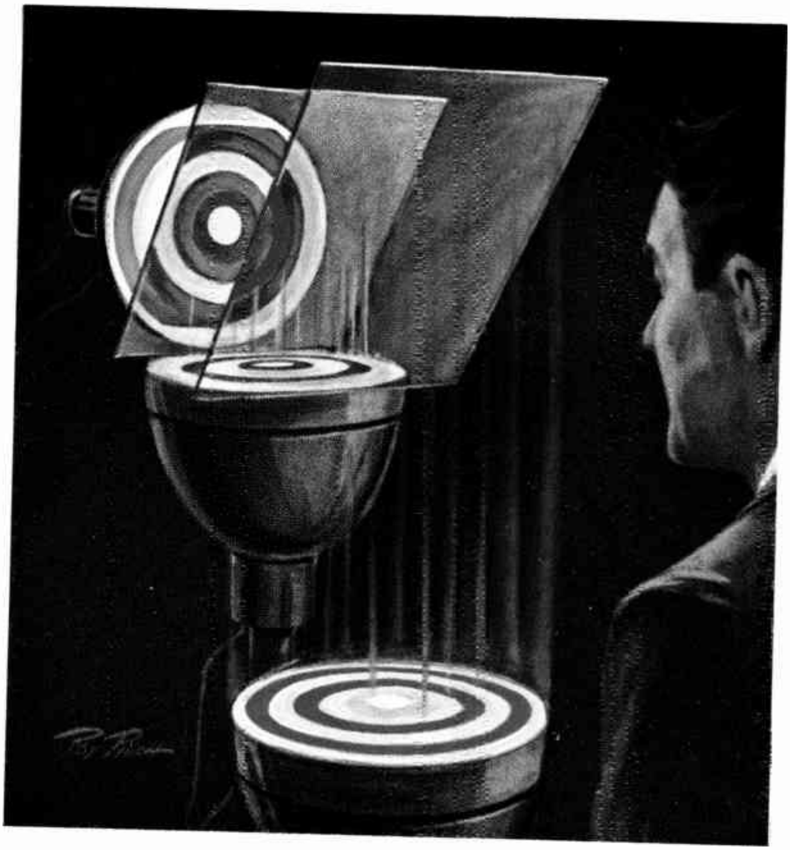

Plate A. *Direct-view picture-reproducing system using three kinescopes and a pair of dichroic mirrors. The three kinescopes are standard in every respect except that the phosphors are green, red and blue respectively. The deflecting yokes of the three tubes are connected in parallel so that the rasters produced on the screen are identical. The tubes are viewed through dichroic mirrors. The red dichroic mirror reflects the red image and the blue dichroic mirror reflects the blue image, while both mirrors are transparent to green light, so that the green tube can be viewed directly through both dichroic mirrors. The red dichroic mirror is also transparent to blue light, so that it does not interfere with the blue image.*

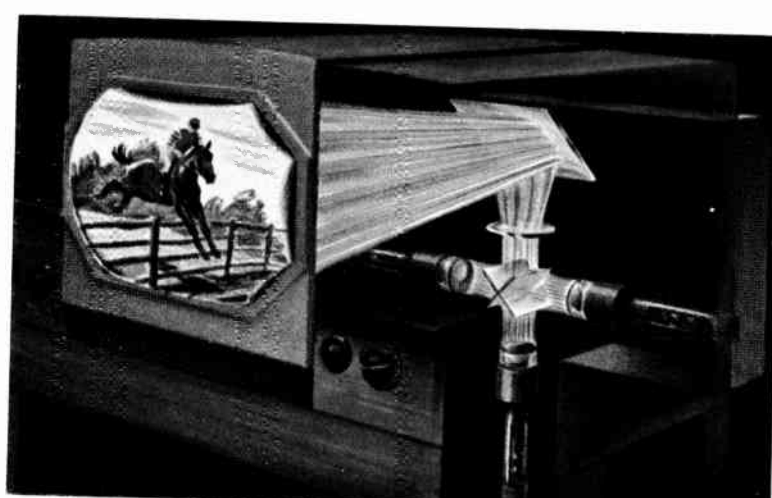

Plate C. *Colour converter using small projection kinescopes and refractive optics. The complete kinescope and optical assembly is mounted on the back of a standard television receiver. An additional chassis containing the sampling circuits deflecting circuits and power supplies is mounted under or at the back of the television receiver.*

Plate B. *The two-colour picture-reproducing system. Two kinescopes are used with the appropriate colour phosphors, and no filters are required.*

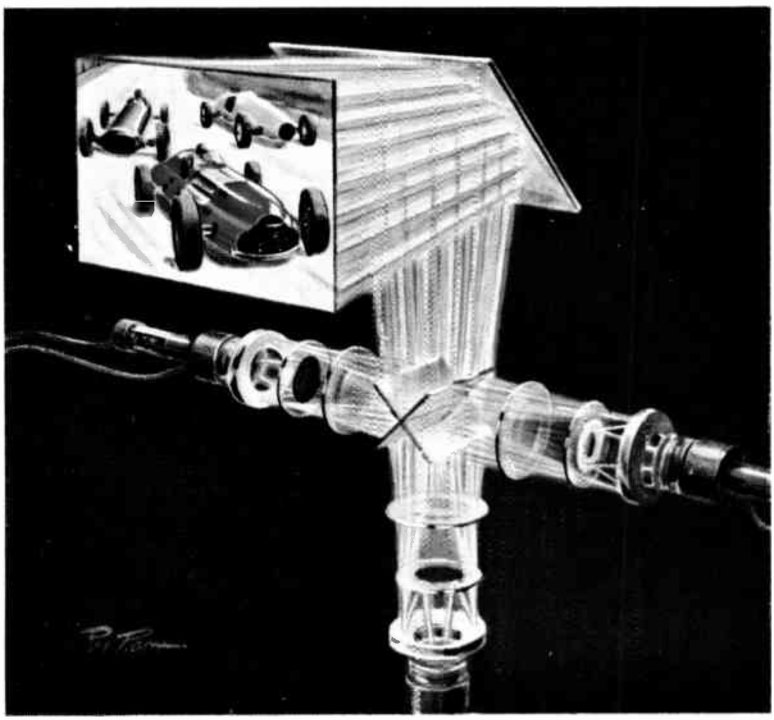

Plate D. *Projection picture-reproducing system using three projection kinescopes, reflective optics and a pair of dichroic mirrors. The light rays from each tube first strike a plane mirror from which they are reflected to a spherical mirror of the proper focal length to produce an image on the screen. Beyond the spherical mirror the rays pass through a correcting lens and thence via a plane-reflecting mirror to the projection screen. The green image passes through the red and blue dichroic mirrors while the red and blue images are reflected by the red and blue deflecting dichroic mirrors respectively. The images are superimposed and register in focus on the projection screen.*

C.B.S. COLOUR TELEVISION SYSTEM

The brief description of the C.B.S. Colour Television system which appears on pages 154-155 was received from Dr. Peter Goldmark, of the Columbia Broadcasting System Incorporated of America. In addition, two other papers by Dr. Goldmark himself have been received, " Flicker and Colour Fringing Phenomena in Colour Television " (an extract of his book to be published shortly by Harpers), and " Brightness and Contrast in Television." It is hoped that both these papers will be published in the May Journal.

The following figure is an illustration of the scanning pattern of the C.B.S. colour television system described on page 154.

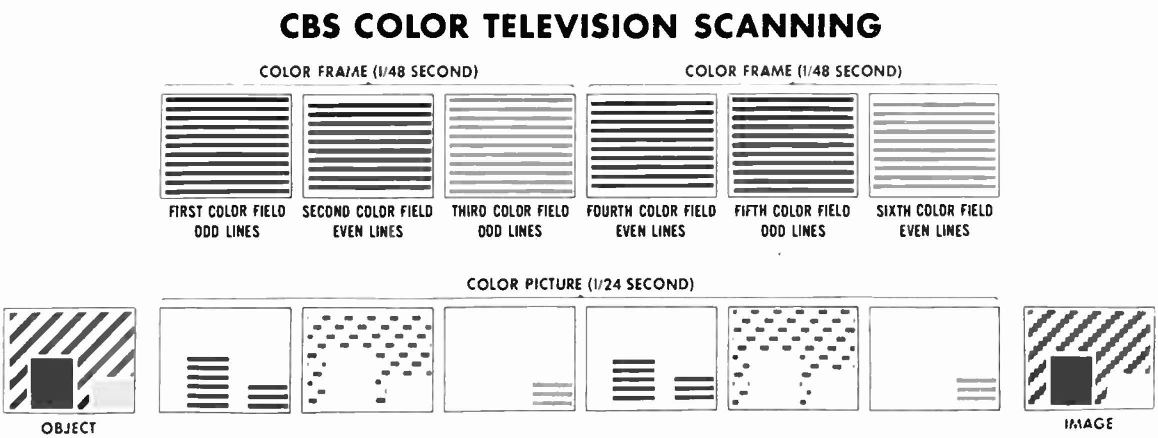

Fig. 1 (see page 154).

A Report from the Education and Examinations Committee

Mathematics

As announced in the editorial of the March issue of the Journal, the Council has now given approval to the inclusion of mathematics as a compulsory subject of the Graduateship Examination with effect from May 1951. This subject will be designated Part IIIA, whilst Advanced Radio Engineering becomes Part IIIB.

It will be noticed that the Mathematics has been incorporated in Part III and will, therefore, normally be taken at the same time as the Advanced Radio Engineering paper. (Those candidates who have already passed or been exempt from Part III of the Graduateship Examination on April 1st, 1951, will not be required to pass the Mathematics.)

The exempting qualifications which are at present listed in the regulations as exempting from Part III all include an examination in Mathematics of a sufficient standard to exempt a candidate from sitting this paper. However, for those candidates who do not hold qualifications already listed in the regulations, the following examinations will be accepted as exempting from the Mathematics :—

City and Guilds of London Institute, Mathematics for Telecommunications (Principles) III.

Higher School Certificate. Pure Mathematics as a principal subject. (General Certificate of Education Pure Mathematics at advanced standard.)

Intermediate Science, Pure Mathematics Examination, of a British University approved for the purpose.

Science degrees, in which mathematics was taken as a subject, of Universities approved by the Council for the purpose.

Final Mathematics for Higher National Certificate.

Pure Mathematics of the Joint Section "A" examination of :

Institution of Civil Engineers,
Institution of Mechanical Engineers,
Institution of Electrical Engineers.

New Examiner in Radio Transmission

Mr. F. Butler, B.Sc.(Hons.), (Member), has recently been appointed as the Institution's Examiner in Radio Transmission with effect from the November 1950 examination. Mr. J. W. Whitehead (Member), the present examiner, has held this appointment since November 1946, and the Committee takes this opportunity of thanking him for his valuable assistance.

May 1950 Examination

Although final figures are not yet complete, entries for the May 1950 Graduateship Examination are in excess of 290 which, once again, is a record number. In addition to the increase in the number of entries from home candidates overseas entries are much larger than in previous years. As an example, Bombay centre with 51 candidates will be the largest centre with the exception of London. This large increase in examination entries—the final number is expected to be much greater than 300—is very encouraging.

Applications for exemption from the Graduateship Examination have again reached a new level, the Committee having already considered 301 applications since April 1st 1949. Of these, only 39 were granted exemption from the entire examination.

New Edition of the Regulations

The sixteenth edition of the Membership and Examination Regulations has recently been published, and this includes the syllabus of the Mathematics to be included as a compulsory subject of the Graduateship Examination with effect from the May 1951 examination. The regulations have, in addition, been revised to make a more attractive layout.

Examiner in Mathematics

Mr. E. T. A. Rapson, M.Sc. (Member) has been appointed the first examiner in Mathematics. Details of Mr. Rapson's career appeared in the January issue of the Journal as a Member of Council.

CONTRIBUTIONS

Written comment on papers published in the Journal as well as brief papers are now invited for this section of the Journal.

DESCRIPTION OF CBS COLOUR TELEVISION SYSTEM*

1.0. The System

1.1. *Type of Colour Television System*

The CBS colour television system is not inherently a mechanical system or an all-electronic system. It may be either, or it may be a combination of both, depending on the apparatus which it is found most desirable to use. Up to now, it has been found more desirable and economical to use the disc at the camera and at the receiver, on the grounds of performance, cost, simplicity and reliability.

1.2. *Type of Colour Switching*

In a sequential system, as contrasted with a simultaneous system, the colour components have to be transmitted to the receiver one after the other. This process of creating the sequence is called colour switching, while the rate at which the sequence occurs is called the switching rate.

The CBS colour television system switches colours after each field, that is, after all the odd lines or even lines have been scanned. The colour switching rate is 144 per sec.

On the basis of present known facts it can be stated that the higher the colour switching rate the greater the complexity, cost and instability of the overall apparatus required. In addition the CBS system can use any of the specific types of apparatus required with other American systems.

1.3. *Scanning Pattern*

The scanning pattern of the CBS colour television system is shown in Fig. 1 (p. 152) and is described below :—

	Lines	*Primary Colour*
Field No. 1	Odd	Red
Field No. 2	Even	Blue
Field No. 3	Odd	Green

At this point a "colour frame" has been completed because the subject has been scanned in all three primaries, although not yet on both odd and even lines in all three primaries. Now to continue with the field sequence :—

	Lines	*Primary Colour*
Field No. 4	Even	Red
Field No. 5	Odd	Blue
Field No. 6	Even	Green

At this point a "colour picture" has been completed because the subject has been scanned in all three primaries on both the odd *and* the even lines.

The field scanning period, that is, the time required for one set of lines either even or odd, to be scanned from top to bottom is 1/144th of a second.

The colour frame rate, that is, the time required for all three primary colours to have scanned the screen once is 1/48th of a second.

The colour picture rate, that is, the time required for two colour frame periods, or the time required for all areas to be scanned in all primary colours, is 1/24th of a second.

1.4. *Basic Outline of Colour Production*

The reason the pictures appear in colour is this : the camera, with a single pick-up tube and image, through a set of colour filters, extracts the red, blue or green components of the scene. These are transmitted in sequence. At the receiver they are reproduced, through colour filters or by different coloured phosphors, in the same sequence, and the retentive capability of the eye synthesizes the three primary colours, so that they reproduce the colours of the original scene. All colours are composed of mixtures of varying amounts of the three primaries, red, blue, and green. For instance, yellow is reproduced by a mixture of red and green ; purple by a mixture of red and blue. In a two-colour system or two-colour receiver, however, instead of a vast number of colour hues, only two can be produced.

It is essential in any colour television system, of course, that the receiver should reproduce the

* Manuscript received from Dr. P. Goldmark of CBS Inc., January, 1950.
U.D.C. No. 621.397.6

green component, when the camera is seeing that component, and the blue and red components, respectively when the camera is seeing those components. In order to accomplish this, it is necessary to synchronize the camera and receiver not only for the rate of colour switching but also for the position of their respective discs, this latter being called " phasing."

1.5. *Standards for CBS Colour Television System*

The CBS colour standards of broadest interest are the following :—

(*a*) The number of lines per picture is 405, as compared with the black-and-white U.S.A. standard of 525.

(*b*) The field frequency is 144 per sec., as compared with the black-and-white U.S.A. standard of 60.

(*c*) CBS also suggests that the standards should include a colour sequence phasing pulse to permit, in addition to manual locking, automatic locking of the respective colours of the cameras and receivers together, so that when the camera sees one colour, the viewer also sees the same colour.

(*d*) The standards also include specifications for the colour primaries.

2.0. The Apparatus Used and Usable in the CBS Colour Television System

2.1. For the most part, the design and electronic principles of the equipment now used in the CBS colour television system are conventional. In so far as can be determined from available information, all other types of colour camera and receiving apparatus could be employed in the CBS colour television system by the simple means of slowing down the colour switching rate to 144 times per sec.

2.2. The camera apparatus developed for the CBS colour television system consists of :—

(*a*) Single-image orthicon tube cameras with 12 segment colour discs revolving at 720 revolutions per minute. It uses a standard black-and-white image orthicon with a single image and can be used for live, film and slide pick-up.

(*b*) A single-image dissector tube camera which has a single image and is used for film and slide pick-up.

2.3. The colour receiving apparatus which has been developed for the CBS colour television consists of :—

(*a*) Colour disc-type direct-view receivers with a single tube having a single gun. These receivers use standard black-and-white cathode ray tubes and produce a single image which is viewed directly.

(*d*) Colour disc-type projection receiver with a single tube, single gun and single image. This type of receiver has a single image.

2.4. The scanning adaptor used in this system to permit viewing of black-and-white pictures from colour signals on existing and future black-and-white receivers, consists of the necessary circuits and a switch to permit converting from the standard black-and-white scanning frequencies to the colour scanning frequencies and vice versa.

2.5. The colour converter now used in the CBS system to produce colour pictures on adapted, existing or future black-and-white receivers is of the colour disc type, and is placed in front of the receiver picture tube between the face of the tube and the eye of the viewer.

2.6. The CBS system employs standard broadcast transmitters without modification.

2.7. The CBS colour television system employs standard relay transmitters without modification.

2.8. Standard RMA-type of synchronizing signal generator is used, modified to produce a line scanning frequency of 29 or 160 per sec., a field scanning frequency of 144 per sec. and to inject a colour sequence phasing pulse each 1/48th of a second for automatic colour phasing.

2.9. The colour monitors used in the studio equipment are of the colour disc type and are single-tube, single-gun, single-image, and direct view.

2.10. The colour mixer is an item of apparatus additional to the studio complement of a standard monchrome station. Its purpose is to control the individual intensities of the respective primary colours to permit correction of colour deficiencies occasioned by pick-up tubes of varying colour response, colour distortion in films, colour of lights in live pick-up, or to produce dramatic effects.

TRANSFERS AND ELECTIONS TO MEMBERSHIP

Subsequent to the publication of elections to membership which appeared in the February issue of the Journal, a meeting of the Membership Committee was held on February 28th, 1950. Thirteen proposals for direct election to Graduate or higher grade of membership were considered and fourteen proposals for transfer to Graduate or higher grade of membership.

The following list of elections has been approved by the General Council. Eleven for direct election to Graduate or higher grade of membership, and fourteen for transfer to Graduate or higher grade of membership.

Direct Election to Associate Member

Pember, Arthur Lawrence	Berlin, Germany
Richardson, John T.	Treforest, Glam.
Varcoe, Kingsley John	Rochford, Essex

Direct Election to Associate

Davis, Norman	Sleaford, Lincs.
*George, Anthony Edward Colin	Cambridge
*Handley, George Frederick	Bromley, Kent
Kitchin, Richard	Dalton-in-Furness, Lancs.
Nanda, Chandarmukh, Major, B.A.	Mhow, India

Transfer from Associate to Associate Member

Martin, Albert Victor Jean	Paris, France

*Reinstatement

Transfer from Student to Associate Member

Hinton, Maitland Joseph Gresley	London, S.W.1

Transfer from Student to Associate

Balderston, Robert Walter	Thetford, Norfolk
Wright, Charles Alfred	Sutton Courtenay, Berks.

Transfer from Student to Graduate

Aldred, Arthur Bernard	Gt. Yarmouth, Norfolk
Forbes, Frank	W. Croydon, Surrey
Pearce, Richard John	Shrewsbury, Shropshire
Quirk, William James	London, S.W.13

The above numbers are in addition to the list of direct elections to Graduate, and Student to Graduate which appeared in the February issue of the Journal.

STUDENTSHIP REGISTRATIONS

In addition to the list of Studentship Registrations published in the February issue of the Journal, the following sixteen studentship proposals were dealt with at the meeting of the Membership Committee held on February 28th, 1950, and these have now been approved by Council.

Ead, Harold William	London, S.E.26
George, P. M., B.A.	Travancore, India
Ghosh, Jyolirmay	Benares, S. India
Hanumantha Rao, M. V.	Narsapatnam, S. India
Kutumba Rao, M.	Vizayawada, India
Lakshmanaswamy, V.	Vellore, India
Lodder, Albert Stanley	Carshalton, Surrey
Longman, Charles Robert	Hull, Yorks.
McDonald, George Watt	Elgin, Morayshire
Marns, Joseph Henry Ronald	London, E.3
Rajeswara Rao, M. K.	Buckinghampet, India
Rangarajan, K. S., B.Sc.	Devakotta, India
Sherry, Malcolm Godfrey	Southall, Middlesex
Siromani, Abraham, B.Sc.	Coimbatore, India
Tejuja, Mohonlal M.	Bombay, India
Venkateswara Rao, Ch.	Madira, India

NOTICES

Obituaries

On behalf of the membership, the Council has expressed sympathy with the Australian Institution of Radio Engineers and with the family of Mr. Norman W. V. HAYES, who died suddenly in Melbourne on February 12th.

Mr. Hayes was elected President of the Australian Institution of Radio Engineers in May 1949, having first become a member of that Institution in 1933, and elected a Fellow in 1940. Mr. Hayes was for many years an active member of the Australian Institution and in his various offices had been responsible for a great deal of liaison work with the Brit.I.R.E.

At the time of his death Mr. Hayes was Deputy-Chief Engineer of the Australian Postmaster-General's Department, having first joined the Department in 1907. Mr. Hayes became well known to many engineers who had connections in Australia, particularly during the recent war, when he was responsible for many communication developments.

Older members of the Institution, especially, will regret to learn of the death, after a lengthy illness, of William Dean SELL (Member). Mr. Sell passed away on March 28th last at the age of 67 years.

Mr. Sell enlisted in the Royal Navy in 1899 and was one of the first holders of a P.M.G. certificate of Proficiency in Radio Telegraphy. In 1910, he was a Chief Petty Officer (Instructor) in the Wireless Branch of the Royal Navy, and after leaving the Service at the end of the First World War, he joined the Sterling Wireless Company of Dagenham. In 1928, he was appointed Principal of the London Radio College (subsequently taken over by E.M.I. Institutes), where he remained until August 1941. He then joined the teaching staff of the Chelsea Polytechnic, his work there being mainly in connection with Navy war-time training. Mr. Sell retired from professional life in 1946 owing to ill-health.

Mr. Sell was first elected an Associate Member of the Institution in 1937 and was elected a member of the Council the following year. He was transferred to full Membership in 1939 and in the subsequent years he served the Institution for a second period as a member of Council and the Membership Committee.

1951 Exhibitions

The Festival of Britain office and the Council of Industrial Design have recently published a booklet entitled "Notes for Industry on the 1951 Exhibitions."

This booklet, after giving brief details of the six exhibitions, goes on to give full details of the Centre-Piece, i.e., the South Bank Exhibition. The methods of organization and selection of exhibits are explained, and the principal exhibits of the Upstream and Downstream sequences are listed.

The booklet finally lists industries and categories of manufacturers which are to be represented. Manufacturers are requested to submit products for the Exhibition. All enquiries should be addressed to Mr. Mark Hartland Thomas, Chief Industrial Officer, Council of Industrial Design, Tilbury House, Petty France, S.W.1.

Meetings of Interest to Members

In association with the Institute of Industrial Administration, the British Institute of Management is holding its next Conference at Cliftonville from May 18th to 21st next.

Quality Control and Time Study Methods are subjects of special meetings. Further information can be obtained from the Director, the British Institute of Management, 8 Hill Street, London, W.1.

E.B.U. Wavelength Tests

The B.B.C. high-power, long-wave transmitter at Droitwich was placed at the disposal of the European Broadcasting Union on March 19th.

Throughout the day the wavelength-measuring station of the E.B.U. at Brussels and the B.B.C. measuring station at Tatsfield, with the collaboration of other similar stations in Europe, measured the actual wavelengths of all European broadcasting stations. These details were broadcast throughout the early hours of the next morning in English, French and Russian from Droitwich and also from Brussels and Paris, to assist the broadcasting stations to adjust their carrier-waves exactly to the new wavelengths allotted to them in the Copenhagen Wavelength Plan.

A measuring station at Prague was performing a similar service for broadcasting stations in Eastern Europe.

HIGH PERFORMANCE TELEVISION MONITORS*

by

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A paper read before the London Section on March 23rd, 1950

SUMMARY

This paper outlines the performance specification which should be met by a high performance Vision Monitor intended for use in television transmission stations.

Particular emphasis is laid on the importance of utilizing the correct type of geometric projection to produce a picture on a spherical surface from the ideal picture on a plane surface with the least objectionable type of distortion.

Means are indicated whereby the type of projection chosen, namely, stereographic, can be realized in practice. A method called " Spot Wobbling " by which the line structure of a television picture can be rendered less visible is described. A monitor which incorporates most of the desirable features discussed in the first part of the paper is described in some detail. Some indication is also given of methods by which its performance can be checked without having recourse to a picture.

1.0. Introduction

It has long been the practice in sound broadcasting to provide high-quality reproducing equipment specifically designed for monitoring the transmitted signal. Little or nothing has been published so far in this connection in the television field, though there is evidence in the current literature[1] of the need for vision monitors specially designed for the purpose. Television broadcasting is now growing rapidly and the need for suitable monitors will become more and more apparent as more stations come into operation, especially if the home viewer has the choice of a number of different programmes from different stations and so is able to make comparisons between them.

The station vision monitoring equipment should be designed to furnish the quality-checking engineer with the best picture obtainable for the particular television system in use. The equipment should, therefore, use the best of current design techniques and be of considerably higher quality than any likely to be in the possession of home viewers. The ideal to be aimed at is that the engineer should be able to detect and rectify any small loss of picture quality long before the ordinary viewer becomes aware of it at all. This particularly applies to a gradual deterioration of quality over a period of time such as, for example, may be caused by slow changes taking place in a camera tube during its life.

The monitor should preferably receive the radio frequency output of the transmitter in the normal way so as to check the overall performance of the station, but if this is not convenient it should be connected to a point in the transmitting chain as near to the aerial as possible.

It is suggested, therefore, that every television station should have at least one high performance vision monitor capable of doing full justice to the picture transmitted ; and designed solely for picture quality checking. Monitors of the picture type can be used for purposes other than quality checking. They are convenient, for example, for observing certain features of the transmitted waveform. It seems preferable, however, that this work should be done by a monitor specifically designed for the purpose rather than by increasing the complexity of the already complicated quality monitor to make it perform adequately more than one function.

This paper outlines essential features in the design of a picture-quality checking monitor and describes one recently supplied to the British Broadcasting Corporation which incorporates most of these features.

It is important that means should be available for checking the performance of the monitor independently of the picture. Some indication is given of suitable methods which may be employed for this purpose.

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2.0 Design Considerations

2.1. *The Cathode Ray Tube*

The cathode ray tube used in a high performance monitor is perhaps the most important single component. The ability of the monitor as a whole to reproduce the required quality picture depends on the tube quite independently of the quality of the electrical circuits, provided they achieve a sufficiently good performance.

The tube must meet an exacting electrical and mechanical specification and be capable of the very high performance required with a reasonable life.

The magnetically focused and deflected tube, when designed for the purpose, is eminently suitable for this particular use. The desirable features of the tube outlined below have been compiled with the all-magnetic type of tube in mind though, of course, they could be met by other types.

2.1.1. *The Size of Bulb*

A tube having a flat screen is to be preferred on theoretical grounds as discussed later, but practical consideration of the mechanical strength of the bulb makes it necessary to use a spherical screen in tubes of greater diameter than approximately 10 in. (25 cm). The design of the bulb should be such as to provide a screen of the largest possible uniform radius for its overall diameter.

If the monitor is to be used for observing the quality of the picture, the optical mask fitted to the tube should have square corners and the picture size should be adjusted so that the whole of the picture is visible. This requirement, together with the fact that only the uniform radius part of the screen should be used, severely restricts the size of picture obtainable on a given diameter of bulb.

The dimensions of the monitor picture, however, must be such that it can be examined in sufficient detail at a reasonable viewing distance. It is particularly necessary to meet this requirement when an interlaced picture from a continuous film motion, flying spot film scanner is being observed. Each frame of the film is scanned twice and the machine must be adjusted so that the two television frames are properly interlaced over the whole area of the picture.

Experience has shown that for a 400-line system a 12 in. (30 cm) diameter tube is just adequate, though a 15-in (38-cm) tube is to be preferred. It is perhaps worth noting that, unless some form of optical magnification is employed, higher definition systems will require larger tubes and that the minimum tube diameter for a given aspect ratio is directly proportional to the number of lines in the picture. On this basis a 625-line picture would require a tube of at least 18 in. (46 cm) diameter and an 800-line picture one of 24 in. (60 cm) diameter.

2.1.2. *The Fluorescent Screen*

The tube should be fitted with a fluorescent screen of the normal white colour with a short afterglow and should be capable, when operated with suitable values of voltage and current, of a brightness of approximately 25 foot lamberts in the picture highlights without saturation effects being noticeable. The maximum contrast range obtainable with the screen should be large ; at least 100 : 1 and higher if possible.

It is probable that the monitor would be used in a place where the ambient lighting is relatively high. It would then be necessary to operate the screen at a considerably higher brightness level if a reasonable contrast range were to be maintained. Unfortunately, with television systems having their frame frequency synchronized to a mains frequency of 50 c/s, this results in a reduction in the smoothing effect of persistence of vision, and flicker becomes apparent.[2] A solution to this difficulty is to operate the phosphor at the higher brightness and to interpose between it and the viewer and the ambient light source a neutral filter of suitable density so that the highlight brightness is of the same order as before. The contrast of the picture will be improved, however, since in the blacks the ambient light reflected by the phosphor as seen by the viewer will be twice attenuated by the filter whereas the light emitted by the phosphor in the highlights will be attenuated only once.

Aluminized screens are particularly satisfactory for the purpose and have the additional advantages of preventing negative ion burn and avoiding " sticking " of the screen potential due to secondary emission effects. The contrast performance could be still further improved by blooming the outside face of the bulb to reduce halation effects from the spot. Unfortunately this cannot be done at present since blooming equipment capable of handling large bulbs is not available. Incidentally, a neutral filter would also require blooming for best results.

2.1.3. *The Electron Gun*

The design of the electron gun must be such that it meets the following requirements :

(1) It must be capable of providing the beam power necessary to excite the fluorescent screen to the required brightness; and at the same time the focused spot size must be such that, in relation to the picture size, the full definition of the picture can be reproduced.

The gun must meet these requirements with a reasonable expectation of tube life, since the monitor, if installed in a transmitting station, is likely to be running all the time the station is working. This condition will be more difficult to meet in tubes intended for operation on higher definition systems, since a higher performance will be demanded of them.

(2) The gamma of the tube, which may be defined as the slope of the curve connecting the logarithm of the brightness with the logarithm of the driving voltage (as measured from the beam current cut-off point), should be of the same order as that of the average picture tubes in home receivers.

This factor is of considerable importance since, if the monitor tube has a gamma markedly different from the average, the picture quality checking engineer at the transmitting station will gain a false impression of the tone quality of the picture as it appears in the average home.

The majority of current tubes designed for use in the home have a gamma which lies between 2 and 3, and a good average value is 2·5.

2.1.4. *The Electron Lens*

The divergent beam of electrons emanating from the cathode of the tube must be focused by a suitable electron lens which may be either electrostatic or magnetic. The beam diameter in the lens will be quite large compared with the diameter of the lens, due to the high peak beam current, of the order of 200-300 μA, required to excite the screen to the necessary brightness and due to the fact that the magnification of the system must be such as to produce the required size of spot at the screen.

The lens must be designed to focus the beam without introducing appreciable spherical aberration. One of the necessary conditions to achieve this object is that the beam should pass centrally through the lens and subsequently the deflector. Means must be provided, therefore, should the gun be misaligned in the tube, to deflect the beam before it is focused or deflected so that it passes along the common axis of the lens and deflector.

In the monitor described later, the lens and deflector are mounted coaxially with the tube neck and the beam is deflected, if necessary, to pass along the axis of the neck by means of a small magnet near the cathode of the tube. The field required is very weak and the aberrations introduced by this method are negligible.

An additional desirable feature in the design of the lens is that it shall be so constructed as to enable its power to be varied in a suitable manner in synchronism with the line and frame scanning waveforms.

2.2. *Picture Scanning*

2.2.1. *Projection of Flat Pictures on to Spherical Surfaces*

All pictures would ideally be presented on flat surfaces. The visual training which we have been receiving since early childhood has given us the ability to appreciate perspective in a flat representation of a three-dimensional scene. We have acquired the remarkable facility of making, quite unconsciously, the complicated mental corrections for changed viewing distance and even for oblique viewing of a flat picture. If we had the choice, therefore, we should always use a flat screen for our pictures so that the viewers would not be called upon to use more than their normal subconscious powers of interpretation.

In practice, as described above, we have frequently to use a screen which approximates to a portion of a sphere. The problem then arises of finding the least objectionable way of distorting the ideal flat picture to fit the practical curved screen.

It is clear that some kind of distortion is bound to occur if it is attempted to put a flat picture on to a spherical surface. This is quite independent of the actual mechanism used for producing the picture and arises from the different geometry of plane and spherical surfaces.

The problem is the same, though in reverse, to that involved in map-making, when it is realized that a map drawn on a flat surface cannot be a distortionless representation of a portion of the earth's surface which is essentially spherical. The map-maker has the choice of a number of different projections in drawing a map, and his choice will be governed by the use to which the map is to be put. He may choose a projection which shows all areas in their correct relation or one which preserves the shapes of objects all over the map. Thus it is possible to get correct relative areas, or correct shapes, but not both simultaneously. Although distortion, cannot be avoided, it can be arranged to occur in that form, which is, for a specified purpose, the least important. The same is true of the television picture on a curved screen, but here there is some difficulty in deciding what will be the least objectionable form of distortion since it must be assumed that the viewers will be aware that the screen is curved and will use this information (subconsciously, of course) when interpreting the shapes of objects presented in the picture.

The practical curved picture will be related to the ideal flat picture by some form of projection. If the spherical surface and the flat surface are imagined to be in contact at the centre of the picture and corresponding points in the two pictures are joined by projection lines, there are three well-known cases to consider. The projection lines may be parallel, they may pass through the centre of the sphere or they may pass through the opposite pole of the sphere.

Parallel projection produces a picture suffering from " pin cushion " distortion and projection through the centre of the sphere causes it to have " barrel " distortion.

The third class of projection in which the projection lines pass through the pole of the sphere opposite the centre of the picture is known as " stereographic " projection. The projection lines make equal angles with the sphere and the plane. The unique feature of this projection is the accuracy with which shapes are reproduced all over the picture. An object moving outwards from the centre of the picture will become slightly smaller in size, but its shape will be accurately maintained. The corner angles, and indeed the angles all over the picture, are correctly reproduced. The correct reproduction of the shape of a moving object appears to be an overwhelming recommendation for this type of projection.

It was, therefore, decided to regard stereographic projection as the most desirable relation between the practical curved picture and the ideal flat picture. The main implications of this choice are :

(i) The deflection yokes, scan generators, etc., should, as far as possible, be designed to give a picture shape which is a stereographic projection of the ideal flat picture.

(ii) The shape of an optical mask, if fitted to the cathode ray tube should conform to a stereographic projection of the ideal flat shape.

(iii) Measurement and specification of performance (e.g., linearity of scans) should always be referred to the ideal flat picture by means of stereographic projection.

2.2.2. *Wide Angle Deflection*

Modern cathode ray tubes employ wide angles of deflection with the result that the spot displacement from the centre of the screen cannot be considered proportional to the angle of deflection since the centre of curvature of the screen is not coincident with the centre of deflection. This effect will cause distortion of the picture shape which will vary in amount depending on the distance between the centres of the screen and deflection.

In the case of the flat-faced tube, which is merely the limiting case corresponding to a screen of infinite radius, the displacement of the spot is proportional to the tangent of the deflection angle, so that, with increasing deflection angle, the displacement increases more rapidly than it should for an accurately proportional relation between deflection and angle of deflection.

The increasing deflection sensitivity as the spot moves away from the centre of the screen affects the position of all points in the picture, and is not confined to the line and frame directions. Every point in the picture is moved radially outwards from its correct position by an amount proportional (as a first approximation) to the cube of the radius. The most obvious result of this is that the corners of the picture are moved outwards much more than the centre of the sides of the picture, and "pin cushion" distortion occurs.

To correct for this condition solely by modifications to the scan generators would call for a most complicated arrangement involving cross-modulation of line and frame scanning waveforms,[3] which can be ruled out as impracticable for most purposes.

Correction can be obtained empirically by modifications to the scanning yoke. Such methods can only operate by virtue of the non-uniformity of the deflection field so that they are certain to introduce deflection astigmatism. The amount of astigmatism will be proportional to the beam diameter. In this case, the beam diameter is relatively large and, since it is required to reduce the deflection astigmatism as much as possible, the deflection fields must be uniform and some other means of correction must be employed.

A solution to the problem which is both effective and practical involves the use of an eight-pole magnetic field. At the centre of the system the field is zero, and in any direction away from the centre, the field strength varies with the cube of the radius. The field at any fixed radius is constant in magnitude, but variable in direction round the circle. At four equidistant points round the circle, the field will deflect an electron beam outwards, while at four intermediate points it will deflect the beam inwards. Applied to a cathode ray tube the field is arranged to pull out the edges of the picture in the horizontal and vertical directions and to compress the picture in the intermediate 45° directions. It is clear that this will serve to remove the pin-cushion shape from the edges of the picture, and, since the field varies with radius in the required manner, the correction will hold good for all vertical and horizontal lines in the picture.

The eight-pole field is only a part of the complete solution. It reduces the distortion in the 45° direction, but increases it in the horizontal and vertical directions. The usefulness of the eight-pole field arises from the fact that this redistribution converts all the distortion into a form in which it can be corrected by simple changes in the linearity of the scan generators without the necessity for intermodulating the two waveforms.

The eight-pole field, being non-uniform, might be expected to produce astigmatism. However, the field operates on the beam where it is displaced from the axis by a distance which is large compared with its diameter, so that for most purposes the astigmatism is negligible.

The scan generators must be designed to produce scanning currents or voltages of the correct waveform so that when used in conjunction with the pin cushion corrector the picture is a stereographic projection of the ideal flat picture. The waveforms should be correct to within ± 2 per cent. since a 10 per cent. error is objectionable and 5 per cent. is still noticeable.

In addition, where an interlaced system is in use, the frame scan generator must be designed to interlace accurately under all normal conditions of service.

2.2.3. *Focus Modulation*

Assuming that all the conditions outlined above have been met, there remains to be made one further correction to achieve the best overall result. The throw distance between the centre of deflection and the screen varies with the displacement of the spot from the centre of the picture. The electron lens, due to the relatively wide aperture required, will have inadequate depth of focus, and, as a result, the spot will not be in focus in the corners of the picture. This effect can be overcome by modulating the focusing current or voltage, and hence the power of the lens, in a suitable manner as the spot moves over the screen. What is required, for example, in the case of a magnetic lens, is that there should be added to the D.C. component two small alternating components of parabolic waveform repeating at the line and frame frequencies respectively.

It is essential in order to use this refinement successfully, apart from other reasons, that the astigmatism introduced by the deflection yoke be as small as possible and the latter must be designed with this object in view.

2.3. *Suppression of the Line Structure*

A cathode ray tube which is designed, focused and scanned in accordance with the principles outlined above, should with suitable driving circuits produce a very high-quality picture. The picture will be of very uniform focus and, in the case of a 405-line interlaced television system, the line structure will be clearly visible over the whole picture at the normal viewing distance. Vertical panning of the pick-up camera or vertical movement of the observer's eyes will cause the interlace to break up due to stroboscopic effects, and while this effect will not trouble the television engineer very much, it may well cause considerable irritation to the non-technical viewer.

This undesirable effect can be virtually eliminated by what is called, for want of a better name, " spot wobbling." An additional pair of coils is fitted to the deflection yoke and arranged to deflect the spot vertically. A sine wave current of small amplitude is passed through them, the frequency of which is high enough not to be resolved by the tube (some three to four times the maximum video frequency in the signal).

The wobbled spot approximates to a rectangular spot in which the vertical dimension is larger than the horizontal and the correct amplitude of wobble completely elides the fundamental component of the line structure. The line structure could be elided, of course, by using a circular spot of sufficient size, but this results in such a large overall loss of definition as to make the method unusable. The advantage of the spot wobbler lies in the fact that the suppression of the line structure can be achieved with the use of a very much smaller spot than could be used without it. The use of the wobbler necessarily produces some loss of definition across the line, but this loss is more than balanced by the ability to use a smaller spot than normal, thus improving the definition along the line, and by the suppression of the line structure.

The picture, viewed at the normal distance, appears to be quite smooth, the reproduction of fine detail is improved, the line structure is invisible, and stroboscopic effects are virtually absent. In general the picture approximates to one produced by a television system of considerably higher definition without the latter's practical and economic disadvantages.

A further advantage to be gained by using a spot wobbler, is the fact that the beam energy is spread over a larger area of fluorescent material, thus reducing current saturation effects.

The spot wobbler should be arranged so that it can be switched off when it is necessary to examine closely the line structure of the picture.

2.4. *The Video Amplifier*

The video amplifier fitted to the monitor must raise the level of the input signal with the proper frequency, phase and amplitude response to that required to modulate the tube.

The frequency response of the amplifier should be uniform from zero to a frequency just above the maximum useful value radiated by the station, followed by a rapid cut-off.

No useful purpose is served by extending the bandwidth beyond this value, as the home viewer cannot receive it and it means that the monitor picture may have an undesirably high noise level. The phase errors[4] introduced by the amplifier should be corrected. This, together with the sharp cut-off, will result in ripples being observable, both before and after short pulses and sharp edges, on close examination of the picture ; but they are of small amplitude and do not detract from the quality of the picture at the normal viewing distance.

It is suggested that the level of the input signal should be the internationally agreed standard of 1 V peak-to-peak picture and synchronizing signal with a variation of level of not more than $\pm$ 6 db. If it is known that the signal may contain impulse interference, owing to its origination some considerable distance from the main transmitter, and being coupled thereto by means of a radio link, or some other cause, the amplifier should be fitted with some form of interference limiter.

If the input signal is of the order of 1 V overall, and even though the D.C. component may be present, it is not practicable to use a directly-coupled amplifier. The gain of the amplifier will necessarily be of such a value that drift in the amplifier is likely to be troublesome.

Consequently it is preferable to use A.C. coupling at the input and to include some precise form of D.C. insertion in the design. The amplifier must, of course, be fitted with a gain control which should be arranged so that the black level of the picture does not change as the gain is varied.

The amplitude distortion introduced by the amplifier should be small in order to avoid modifying the gamma of the picture to any appreciable extent.

2.5. *Synchronizing Signal Separation*

The monitor should be fitted with a high performance Synchronizing Signal Separator capable of completely separating the synchronizing signals from the vision signals, and the line and frame signals from each other, so that, if an interlaced system is used, proper interlacing can be secured. If impulse interference is liable to be present, the design of the circuits must be such as to afford as much protection as possible from its disturbing effects.

2.6. *Power Supplies*

The power supply to the monitor will normally be obtained from the single phase A.C. mains. All the D.C. supplies, including the E.H.T. supply for the cathode ray tube, should be stabilized against fluctuations of the mains input voltage and the D.C. load current. In addition, the magnetic lens current must be stabilized against variation of the coil resistance with temperature.

The physical layout of the power pack, if it is in the same cabinet as the rest of the monitor, must be carefully considered in order to avoid appreciable stray alternating magnetic fields in the volume occupied by the cathode ray tube. It is impracticable to screen large tubes magnetically, and, if the cabinet is to be of a reasonable size, it is impossible to place the transformers and smoothing chokes any great distance away. The transformers, etc., should be orientated so that the resultant stray field in the space occupied by the tube is small and parallel to its longitudinal axis. This procedure will result in the picture varying slightly in focus and will reduce to a minimum any deflection effects.

2.7. *Screening*

The monitor as a whole must be well screened electrically. It may have to operate in the same building as the main sound and vision transmitters and no interference at radio and video frequencies from these sources must be visible on the picture. In addition the monitor itself must not produce any external interference from its own circuits such as can arise from the line scan generator, radio frequency-operated E.H.T. supply or spot wobbler.

Since it is impracticable to screen the whole monitor magnetically, care must be taken to see that it is not operated in such a position that it may be in the stray magnetic field of larger power transformers.

The television system for which the monitor is designed may have its line frequency in the audible range and acoustic interference can be produced by magnetostriction effects in the line scan output transformer. In such cases the transformer should be enclosed in a box lined with sound-absorbing material.

2.8. *Sound Equipment*

The monitor may or may not be required to reproduce the sound accompanying the picture. If the sound is required, the design of the reproducing equipment, the quality of which should be in keeping with the rest of the monitor, calls for no comment here. All the usual precautions called for in the design of home television receivers must be taken to avoid the effect of stray magnetic field from the speaker distorting the picture, mechanical resonances due to the cabinet and its fittings, and acoustic and microphonic pick-up by the video and scanning circuits.

2.9. *Radio Frequency Operation*

So far, the monitor has been considered as operating from a "line" signal only, but, of course, it can equally well obtain its input signals from a radio receiver. The design of a suitable receiver cannot be dealt with here in detail, but it is sufficient to note that it must exploit to the full the quality of the transmission. Extra attention may have to be given to the design of the synchronizing signal circuits to avoid the disturbing effects of C.W. interference such as is produced by diathermy equipment and the like. Additional phase correction will also be needed to correct the distortion introduced by the radio-frequency amplifier and detector circuit filter.

3.0. A 20-in. Sound and Vision Monitor

3.1. *Brief Specification*

A sound and vision monitor has been designed for the British Broadcasting Corporation which complies with most of the requirements stipulated in section 2 of this paper.

The clauses in the specification which virtually determined the design of the monitor were as follows :

(*a*) The cathode ray tube to be 20 in. (51 cm) in diameter, capable of providing a high-light brightness of 25 foot lamberts in a picture of the largest size which could be accommodated on the bulb, together with good contrast and focus.

(*b*) The sound and vision signals to be line-fed. The vision signal to be of standard B.B.C. waveform and at either of two levels, namely : 10-V overall, white positive, with a possible variation of $\pm$ 6 db or 1-V overall, white positive, with a possible variation of $\pm$6 db, each with a "picture-sync" ratio of 70 : 30 and without the D.C. component. In addition the signals might be subject to impulse interference and also might have superimposed on them a sine wave signal of 50 c/s and peak-to-peak amplitude not exceeding 50 per cent. of the synchronizing signal amplitude.

The sound signal to be zero level in 600 ohms, i.e. 1 mW.

(*c*) The D.C. component to be inserted by a circuit which monitors the black level after the synchronizing impulses (i.e., the "back porch") and to be insensitive to the disturbing effects of impulse interference mixed with the vision signal.

(*d*) The scanning to be of good linearity and to produce a proper interlace free from pairing, "jitter" or "bounce."

(*e*) The monitor to be self-contained in a cabinet mounted on castors and driven from a single-phase 50 c/s A.C. supply.

(*f*) The equipment to be capable of operating from supply mains not synchronized with the frame synchronizing pulses with negligible effect on the picture.

A block schematic diagram of the monitor is shown in Fig. 1, in which it will be seen that the electrical equipment is divided into nine main units, namely :—

Video Amplifier
Black Level Control
Synchronizing Signal Separator
Line Scan Generator
Frame Scan Generator
Protection Unit
Radio Frequency Operated E.H.T. Supply
Main Power Supply Unit
Sound Amplifier

A brief description of the electrical equipment is given in the following sections.

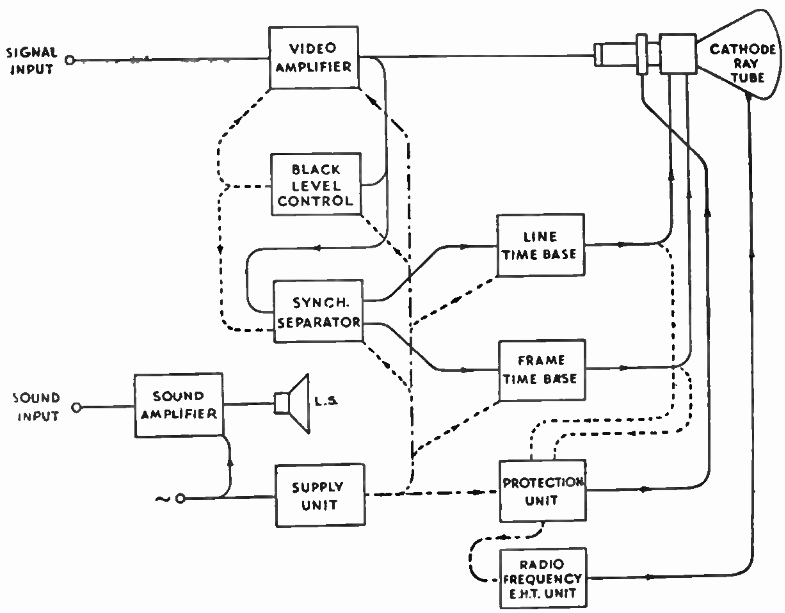

Fig. 1.—Block diagram of the 20-in. Monitor

3.2. *The Cathode Ray Tube*

The cathode ray tube is 20 in. (51 cm) in diameter by some 32 in. (81 cm) long and is of the magnetically-focused and deflected type. It has a white, aluminized fluorescent screen of large radius of curvature which, when operated at 13 kV and approximately 200-300 microamps beam current, has a highlight brightness of the order of 25 foot lamberts and is capable of a contrast range rather better than 100 : 1.

The optical mask fitted to the tube can, in this case, have rounded corners since the equipment is not intended to be used strictly as a monitor, but more as a high-class viewing unit. A picture having the dimensions of 16 in. (40 cm) by 12·8 in. (32 cm) can, therefore, be accommodated on the tube.

The tube has a triode gun and the overall gamma is approximately 2·5 which is very suitable for its purpose.

3.3. *Video Amplifier*

The video amplifier, a basic circuit diagram of which is shown in Fig. 2, is divided into three main sections; a pre-amplifier comprising valves V_1, V_2 and V_3, a gain control stage V_5 and the main amplifier V_7 to V_{11}.

The pre-amplifier is brought into use by a switch when the low-level signal is being received. It consists of a cathode-coupled pair of pentode valves, coupled to a cathode follower output stage. The anode coupling impedance of V_2 is a low-pass filter network with a cut-off frequency of 4 Mc/s.[5] The phase distortion introduced by the filter is corrected with a suitable all-pass network inserted between the cathodes of V_1 and V_2 so that when the pre-amplifier is switched into the circuit no additional correction is required in the main amplifier. The amplifier has a gain of approximately 10 times and raises the level of the input signal to that of the high-level signal.

The gain control stage comprises a cathode follower valve, V_5, which has, as part of its cathode load, a low-resistance non-inductive potentiometer used as the gain or contrast control. The valve takes its signal either from the pre-amplifier or from the incoming high-level line.

The output of V_5 is fed to two further cathode-coupled stages, V_7, V_8 and V_9, V_{10}, and thence via a cathode follower, V_{11}, to the cathode ray tube. The anode coupling impedances of V_8 and V_{10} are low-pass filters with cut-off frequencies of 4·4 and 3·9 Mc/s respectively. The phase correction for both of these filters is placed between the cathodes of V_9 and V_{10}. The amplifier is D.C. coupled from the grid of V_5 to the cathode of V_{11} and part of the output of V_{11} is fed to the black level control unit which feeds its controlling signal back to the grid V_5.

A conventional inductively compensated coupling, A, is placed in the anode circuit of V_9, which serves to feed a signal to the synchronizing signal separator. In this anode

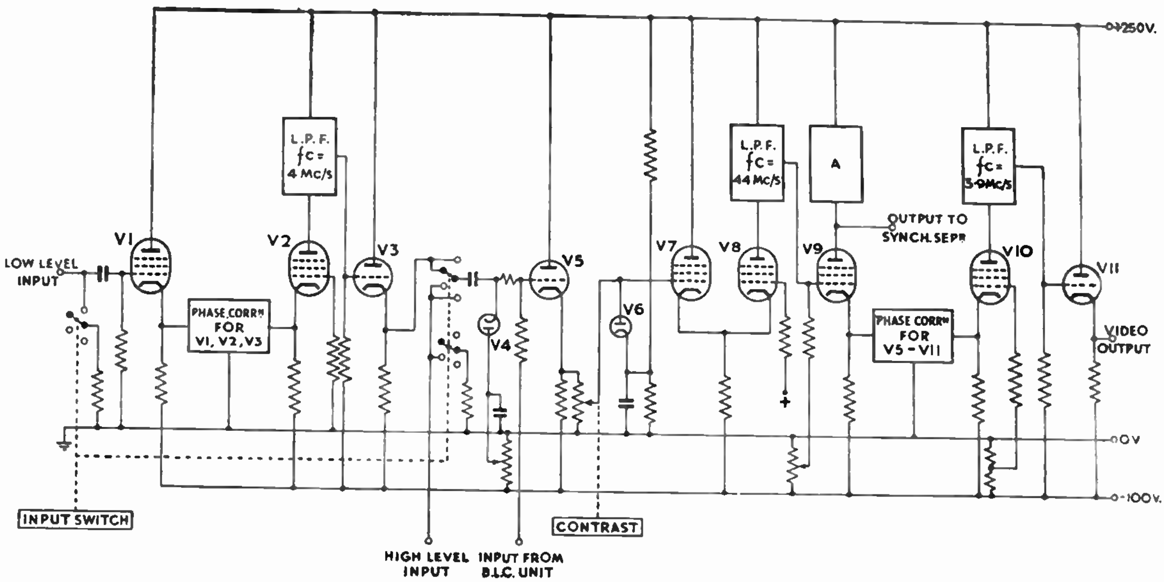

Fig. 2.—Basic circuit diagram of the Video Amplifier.

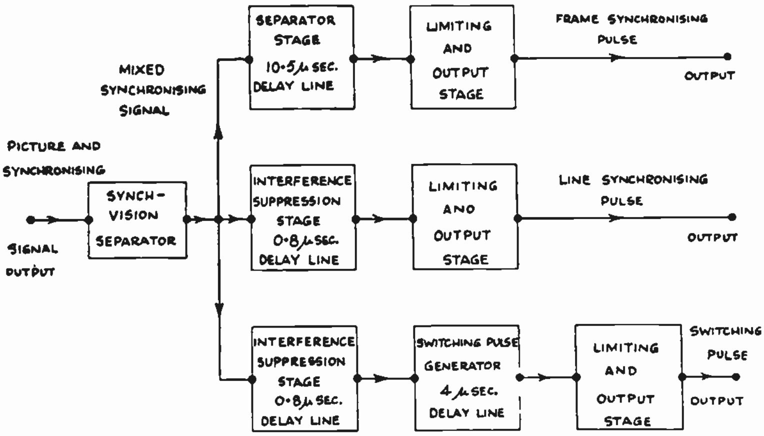

Fig. 3.—Block diagram of the Synchronizing Signal Separator.

circuit the signal is inverted, the white being negative going and the synchronizing signals positive going. All the circuits carrying the synchronizing signals up to and including the synchronizing signal-vision separators have a band-width of not less than 2 Mc/s to avoid the picture " pulling the synchs."*

The amplifier is designed to deliver a maximum of 50 V of vision signal, white positive, to the cathode ray tube. Its overall frequency response in conjunction with the black level control is level to within 0·2 db from zero to 3 Mc/s, followed by a sharp cut-off.

All the filter networks are designed so that the capacitances required at the points where the grid and anode connections are made are in excess of those provided by the valves and the wiring. Trimmer capacitors are used to pad the capacitances up to the required values. This means that the full efficiency of the circuit is not realized, but, the ease with which the filters can be adjusted is well worth the loss of efficiency. In fact, with suitable test equipment, it is a matter of only a few minutes' work to adjust each filter network to operate correctly.

A signal limiter, the diode V_6, is incorporated in the amplifier, which is adjusted to restrict the amplitude of interference pulses to a level approximately 20 per cent. above the normal value of the signal representing peak white at that point. This device does not render the pulses invisible, but reduces their visibility, as they are only the approximate size of a picture point instead of being very much larger due to the cathode ray tube spot swelling, caused by the severe over-load which would otherwise be present.

3.4. *Control of the Black Level*

The control of the black level in the picture is accomplished in the following manner. The output vision signal from the video amplifier is fed into a circuit which compares its voltage level, during the period of black immediately after the line synchronizing pulse, with a reference voltage. The signal arising from the difference, if any, between the black level and the reference is fed back to the input stage of the main video amplifier, the grid of V_5 (Fig. 2) with the required polarity to correct the error at that point.[4]

By means of this arrangement the black level in the picture can be maintained constant to a high degree of accuracy despite sudden changes in the picture content or the addition of a relatively large amplitude, low-frequency sine wave to the signal. Since this is a feedback circuit, with appreciable loop gain, any drifting of the black level due to the D.C. coupling in the amplifier is automatically reduced to a very small amount.

The feedback circuit is only complete during the specified period and is brought into operation by a switching pulse, of 4 microseconds duration, derived from the synchronizing signal.

When the equipment is required to operate on signals subject to impulse interference, the performance of the circuit must be degraded somewhat due to the fact that spurious switching pulses can, on occasion, be generated during the picture interval. If, for example, a spurious switching pulse occurs when the picture signal is at peak white, so that during the pulse this voltage is set to the level which corresponds to black, the picture signal during the remainder of the line lies at a voltage level which is beyond the cut-off voltage of the cathode ray tube. The effect on the picture is that, after the inter-

* Variation of the line scan generator triggering point with the picture content at the right-hand edge of the picture.

ference pulse, the remainder of the line appears to have been removed from the picture. The next correct switching pulse restores the situation.

The performance of the unit must be degraded, therefore, just sufficiently to avoid this undesirable effect. In spite of this being done the circuit is still capable of controlling the black level to a high degree of accuracy.

It will be observed in Fig. 2 that the video gain control is situated in the loop formed by the video amplifier and the black level control unit, and when the gain is reduced to zero, the loop is broken. In the event of certain types of test pattern being observed, for example one consisting of vertical black and white bars, the condition can arise that, as the gain is increased from zero, the peak white part of the signal is established as the black level, due to the synchronizing signal-vision separator having insufficient signal of the proper waveform on which to operate. This fault condition can persist, since the synchronizing signals proper may well lie beyond the grid cut-off point of V_5, and the monitor becomes unusable. A diode valve V_4, which under normal conditions is so biased as to be inoperative, is added to the circuit. Under fault conditions, however, the signal voltage excursion on the grid of V_5 will be more negative than normal and the diode will conduct on the tips of the synchronizing pulses and charge the grid of V_5 positively. This action overrides the control exercised by the black level unit and brings the correct synchronizing signals into the conducting region of the valve characteristic. The synchronizing signal-vision separator then commences to operate correctly and the black level in the picture is established at the proper level.

3.5. The Synchronizing Signal Separator

3.5.1. *The Synchronizing Signal-Vision Separator*

The unit, the block diagram of which is shown in Fig. 3, is fed with mixed picture and synchronizing signals (picture negative and synchronizing signals positive) from the anode circuit of V_9 in the video amplifier. This signal is applied to the grid of a valve with the result that, by means of the well-known method of grid rectification on the tips of the synchronizing pulses, the picture signal is biased beyond the cathode current cut-off point of the valve and only mixed synchronizing pulses (Fig. 4*a*)

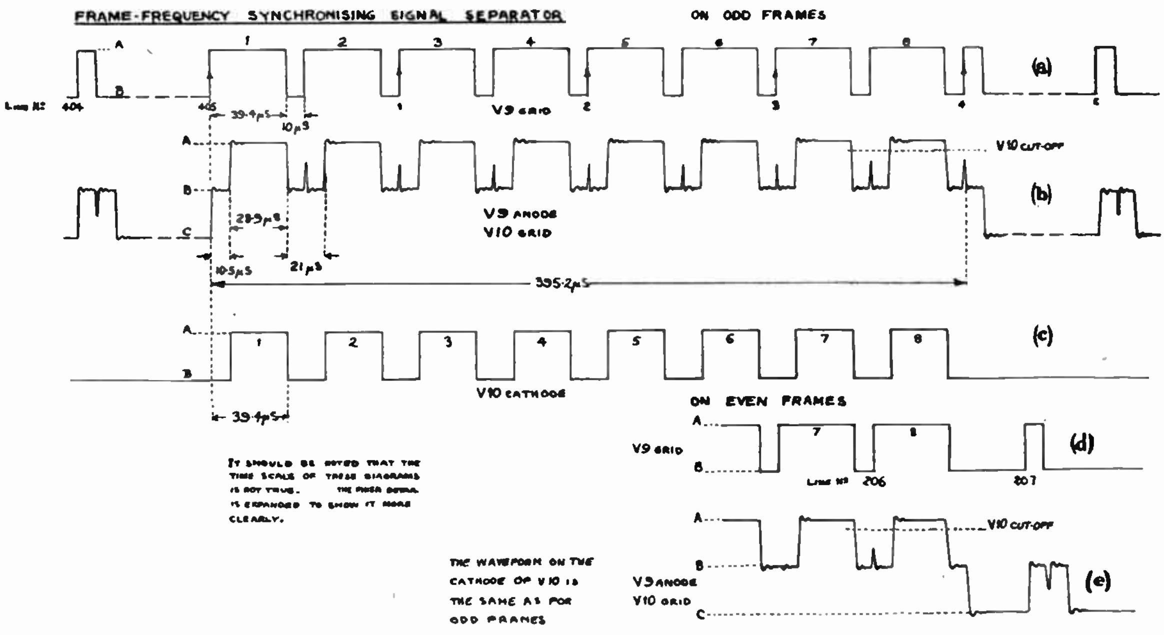

Fig. 4.—Waveforms appearing in the Frame Synchronizing Signal Separator.

appear in the anode circuit. The mixed synchronizing signal is fed to three independent sections giving the following outputs.

(1) Frame-frequency synchronizing pulses for the Frame Scan Generator.

(2) Line-frequency synchronizing pulses for the Line Scan Generator.

(3) A 4-microsecond switching pulse for the Black Level Control Unit.

3.5.2. *Frame Synchronizing Pulses*

The mixed synchronizing signal is fed to the grid of a valve, which has in its anode circuit an artificial delay line[6] open circuited at the end remote from the valve. The total time taken for a signal to travel to the end of the line, suffer a reflection and return to the sending end is adjusted to be slightly longer than the duration of the line synchronizing pulses. In this case they are 10 microseconds long and the delay time is 10·5 microseconds. The effect of this arrangement is that, as the reflected signal is of the same polarity as the original, the line synchronizing pulses appear side by side with their reflections. In the case of the frame synchronizing pulses, however, which are of considerably longer duration than the " echo " time of the line, the reflected signal adds to the original signal and produces a total voltage excursion at the anode of approximately twice the original signal. This effect is illustrated in Fig. 4*b*.

The modified signal, Fig. 4*b*, is then fed to a limiter valve adjusted to pass only signals in excess of the amplitude of the original pulses applied to the delay line, with the result that only those parts of the waveform in which the pulse duration is longer than the echo time of the line appear at the output as shown in Fig. 4*c*.

The advantages of this type of frame synchronizing signal separator are that, although the leading edge of the pulse is delayed by several microseconds, the delay is caused by a passive network and the timing of successive pulses is as accurate as in the original waveform. Moreover, equalizing pulses are not required to obtain accurate interlacing, as the leading edge is identical on odd and even frames. In addition, a large proportion of the impulse interference which may be mixed with the original signal will be suppressed, since the great majority of interference pulses will be short compared with the echo time of the line. They will only appear in the output if they occur during a frame synchronizing pulse or if a second interference pulse occurs at the instant the echo of a proceeding pulse returns to the anode of the valve.

3.5.3. *Line Frequency Synchronizing Pulses*

The line scan generator operates on the mixed synchronizing waveform and is designed to ignore alternate twice line-frequency pulses which occur during the frame synchronizing interval.

The waveform is passed through an exactly similar circuit to that used for the frame synchronizing pulses in order to suppress impulse interference, except that the echo time of the delay line is reduced to 0·8 microsecond, and the pulse appears as in Fig. 5*b*. The width of the majority of interference pulses at the synchronizing signal take-off point is determined by the bandwidth of the video amplifier. The bandwidth is 3 Mc/s so that the pulse width will be approximately 0·33 microsecond. The echo time of the delay line will result in the echo of a

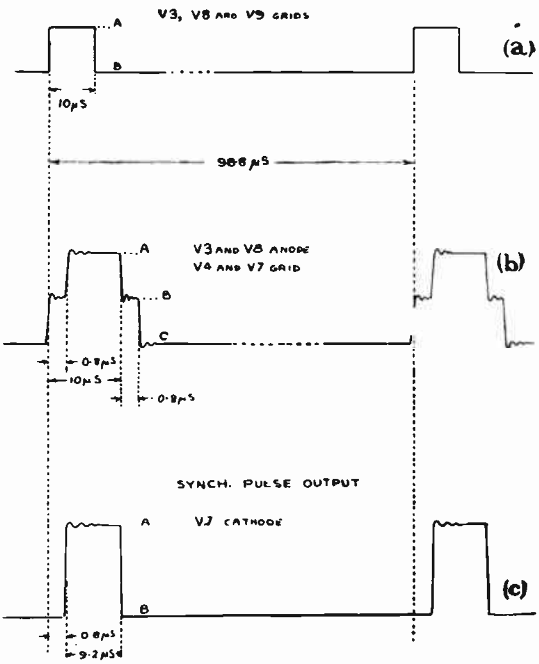

Fig. 5.—Waveforms appearing in the Line Synchronizing Signal Separator. It should be noted that the time scale of these diagrams is not true. The finer detail is expanded to show it more clearly.

pulse appearing alongside the original pulse in the same manner as the line synchronizing pulses in the frame synchronizing signal separator. A similar limiting operation then suppresses everything except the required line-frequency synchronizing pulses, Fig. 5*c*.

The use of the noise suppression circuit results in the line synchronizing pulses being delayed with respect to the picture signal. Although part of this delay is cancelled out by that added to the picture signal due to the phase correction between the cathodes of V_9 and V_{10} and the filter circuit in the anode of V_{10} of the video amplifier (Fig. 2), allowance must be made for it in the design of the line scan generator.

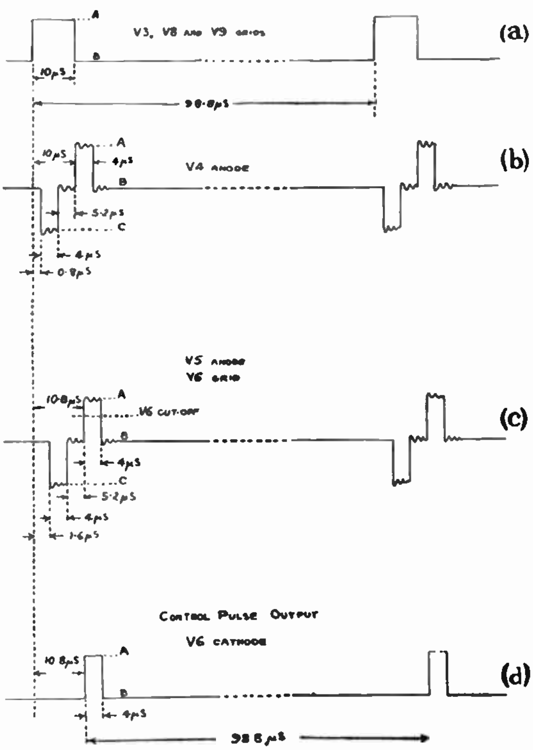

Fig. 6.—Generation of the switching pulse for the Black Level Control. The time scale of these diagrams is not true. The finer detail is expanded to show it more clearly.

3.5.4. *The Black Level Control Unit Switching Pulse*

The switching pulse is derived from the mixed synchronizing signal. The synchronizing signal is first passed through an interference suppression stage, in the same manner as the line synchronizing signal, which then feeds a valve having a short circuited, artificial delay line in its anode circuit. The echo time of the line is designed to be 4 microseconds, and the circuit arranged so that a negative-going and a positive-going pulse is produced by the leading and trailing edges of the line synchronizing pulses respectively (Fig. 6*b*). Both derived pulses are delayed by a further 0·8 microsecond (Fig. 6*c*). The negative pulse from the leading edge is suppressed, leaving the positive pulse (Fig. 6*d*), which is the required one and which occurs in the " back porch " part of the vision signal, well clear of the trailing edge of the line-synchronizing pulse.

During the frame-synchronizing interval, the derived pulses are produced in the reverse order, i.e., positive and then negative, by the twice line-frequency serrating pulses, with the result that the wanted pulse still occurs when the vision signal corresponds to black level.

The output pulse is fed to the black level control unit and serves to switch on a valve at the correct time.

The artificial delay lines used in this unit are not four but two terminal networks, with the exception of that providing the extra delay for the switching pulse, which are designed on the basis of Foster's Reactance Theorem.[7] These networks are considerably easier to make and adjust than the corresponding four terminal networks.

3.6. *Line Scan Generator*

The line scan generator consists of two parts ; a pulse generator, which in turn drives the second part, the scan generator proper.

3.6.1. *The Pulse Generator*

The pulse generator is a cathode-coupled multivibrator designed to produce negative switching pulses of accurately constant duration. It is synchronized to the incoming line-synchronizing pulses.

3.6.2. *The Scan Generator*

The scan generator[8, 9] operates on the following basic principle.

It has long been known that in a circuit comprising mainly inductance and in which the resistance is negligibly small, the current is approximately proportional to the time integral of the e.m.f. applied to the circuit. If, for example, a constant e.m.f. is applied, then the current will build up linearly with time. If, in addition, a switch is included in the circuit, which is opened at suitable intervals for a period of time equal to half the periodic time of the resonant circuit made up of the inductance and its self capacity, the circuit will perform a half-cycle of oscillation when the switch is opened, at the end of which the current in the inductance will be reversed in direction. Since the switch is immediately closed at this point, the result is a periodic current of saw-tooth waveform flowing in the inductance.

A scan generator of this form has the great advantage that all the energy stored in the inductance during a scan period is recovered during the flyback period except for that part dissipated in the resistance representing the losses of the system.

In this case, the inductance is that of the deflecting coils referred to the primary of a transformer; and the switch is a two-valve electronic type, controlled by the pulse generator, employing a feedback circuit which causes it to present a very low impedance when in the closed state.

This type of scan generator has two useful advantages over other types.

It is relatively simple to derive and apply the corrections necessary to allow for the losses in the deflecting coils, coupling transformer and electronic switch, and the effect of tube geometry. This latter correction requires that the spot velocity in the centre of the scan be some 6 per cent. greater than that at the sides. When corrected, the current in the deflecting coils is that required to produce a stereographic projection of the ideal flat picture on the screen of the tube, provided that a pin-cushion corrector is used.

As already mentioned, the efficiency of the circuit can be quite high provided that the losses in the system are kept reasonably small, which is not difficult to do if care is taken in the design of the deflector and transformer. The line scan generator fitted to the monitor dissipates a total of 33 W, of which 10 W are required for the pulse generator, when deflecting a 13-kV beam through a total angle of approximately 50°.

3.7. *Frame Scan Generator*

The frame scan generator comprises two sections, a pulse generator and an integrating amplifier.

3.7.1. *The Pulse Generator*

The pulse generator, which is synchronized to the incoming frame synchronizing pulses, comprises two valves forming a trigger pair. The circuit is designed so as to produce a pulse of constant "weight." For example, in this case, the total charge fed into the integrating capacitor during one operation of the trigger pair is constant and independent of its rate of repetition. The effect of this feature is that small irregularities in the timing of the synchronizing signals do not cause any change in the quantity of electricity delivered by the pulse to the integrating amplifier, and, if the latter is perfect, the result must be a constant flyback amplitude.

3.7.2. *The Integrating Amplifier*

The integrating amplifier comprises a cathode-coupled pair of valves driving a third valve which is the output stage and has the deflecting coils effectively connected in its anode circuit by means of a transformer.

The pulses fed into the amplifier are integrated in a capacitor and, if the integration were perfect, this would produce a "staircase" waveform at the output. However, the D.C. component is lost, and a sawtooth waveform is the result. Moreover, this sawtooth is not rectilinear, but is modified to contain a third-power component, to compensate for the effect of tube geometry, which results in the spot velocity at the centre of the scan being some 4·5 per cent higher than at the top and bottom.

Feedback is applied in two parts from the anode of the output valve to the cathode-coupled stage in order to obtain the desired output waveform, despite the fact that the inductive component of the load, the leakage inductance and magnetizing current of the output transformer, and the time constants of the various coupling circuits all produce distortion.

In the design of the feedback network, which is outside the scope of this paper, account is taken of the necessity for balancing the amount of variation in the D.C. supply voltage which can reach the grids and screens of the amplifier valves and thus cause the scan to " bounce " or " jitter."

This scan generator produces the correct current waveform in the deflecting coils to provide a picture which is a stereographic projection of the ideal flat picture on a plane surface when pin-cushion correction is employed.

The interlace produced by the scan generator is accurate and is free from " jitter " or " bounce " or interaction effects from the line scan generator.

3.8. *Deflector and Focus Coil*

An iron-cored deflector is used for scanning the tube, partly for reasons of efficiency and partly for the inherently high mechanical accuracy which is easily obtainable in this way. The deflection coils themselves are toroidally wound on an internally toothed, laminated yoke, which is mounted co-axially with the tube neck. The windings are graded round the ring to produce the desired uniform field across the tube neck with the result that the deflector is capable of handling large diameter beams while introducing very little deflection astigmatism.

The magnetic lens is an iron-clad coil carrying at its centre a lockable spherical mounting by which it is supported coaxially with the tube neck. This mounting allows the coil to be adjusted to any required angle with the tube axis, for centring the picture in the mask, but at the same time the centre of the coil remains coincident with the axis of the neck.

Aberrations introduced by this method of centring the picture have been found to be negligible provided that the total amount of shift required is small. When finally adjusted the coil is locked in position.

The lens current is supplied from a separate stabilizer which keeps it constant at the particular setting required, despite changes in the coil resistance due to temperature or fluctuations in the voltage supply to the circuit.

3.9. *Cathode Ray Tube Protection Unit*

The purpose of the cathode ray tube protection unit is to ensure that the electron beam of the cathode ray tube cannot be produced or brought to a focus on the screen unless both line and frame frequency scan generators are operating. This precaution is necessary, because of the high beam intensity, which would result in permanent damage to the screen if the focused beam were allowed to trace a single line upon it or, even worse, remain stationary.

The unit detects the voltages appearing across the line and frame deflecting coils and when these are present operates two relays, the contacts of which are in series with the power supply to the E.H.T. supply and the focusing coil. Failure of either scan generator will switch off the E.H.T. and defocus the tube.

3.10. *Sound Channel*

The sound channel, which is capable of good quality reproduction, comprises a moving coil loudspeaker driven by a 10-watt amplifier (B.B.C. type MPA/1), which is arranged for connection to a 600 Ω balanced line. A signal level of not less than 5 db below 1 mW in 600 Ω is required to give the full output, while very much larger signals may be accepted.

The amplifier comprises an input attenuator, followed by a voltage amplifier, phase splitter and push-pull power output stage. Use is made of negative feedback in order to reduce distortion and to obtain a constant output over a wide frequency range.

The loudspeaker employed is a 12-in, high performance, permanent-magnet instrument with a low leakage field, and is mounted at the front of the cabinet immediately below the cathode ray tube.

3.11. *Power Supplies*

The power supplies to the monitor are of conventional design. All the relevant D.C. supplies are stabilized against mains input voltage and load current fluctuations. The transformers and smoothing chokes are orientated so that there is negligible stray magnetic field from them in the space occupied by the tube. If the monitor is operated on mains not locked to the frame synchronizing pulses, no brightness or focus modulation is visible on the picture and the deflection in any direction is of the order of 0·5 mm.

The E.H.T. supply for the cathode ray tube is provided by a radio frequency operated pack,[10, 11, 12] which uses a half-wave circuit and provides an output voltage of 13 kV. This voltage is stabilized against variations of the D.C. input voltage to the oscillator and the load current drawn by the tube.

The monitor operates from a 190-250-V, 50-c/s single-phase supply and its power consumption is approximately 780 W.

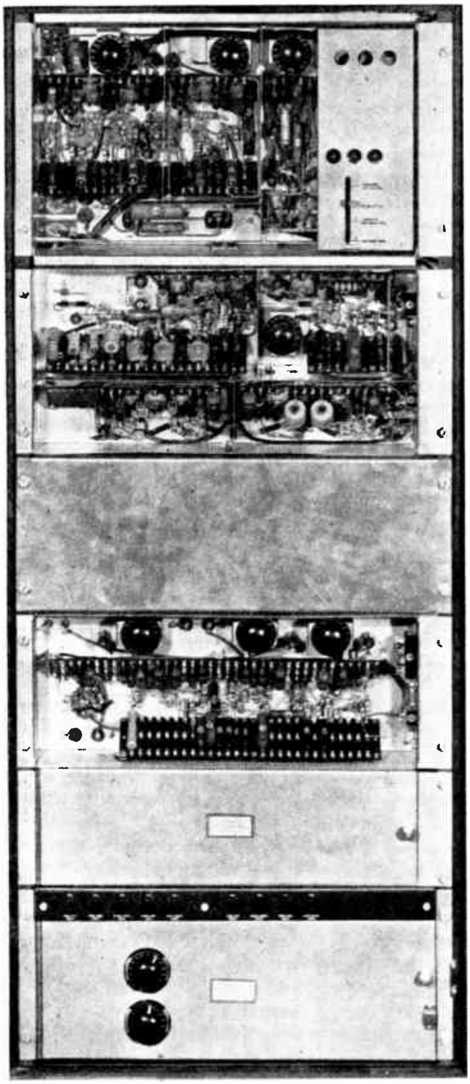

Fig. 7.—Side view of Monitor showing method of mounting the electrical equipment on the side members

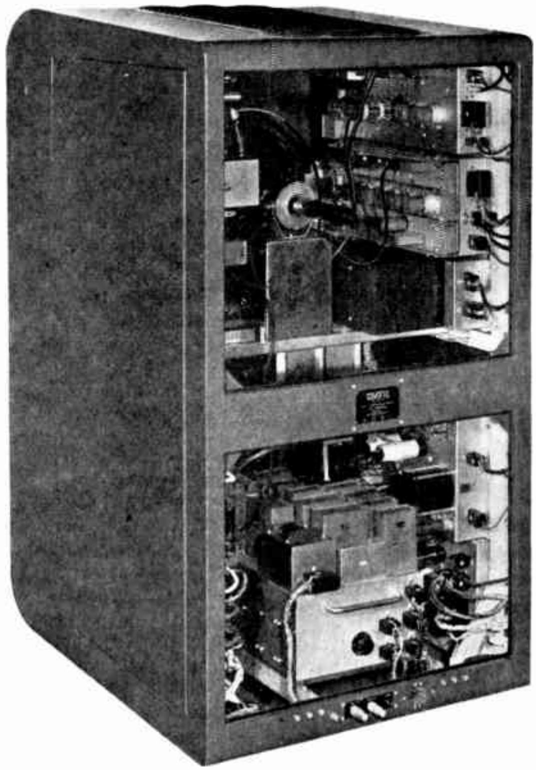

Fig. 8.—Rear view of monitor showing arrangement of electrical equipment and main power pack

3.12. *Mechanical Construction*

The monitor comprises a sheet steel cabinet mounted on castors for ease of handling. The various units containing the electrical circuits are mounted upon vertical bearers at either side of the cabinet, Figs. 7 and 8, so that the wiring, the majority of the components, preset controls and test jacks are readily accessible on removal of the side panels. The power unit, which is of considerable weight, is fitted in roller slides at the bottom of the cabinet and is removable from the rear. The cathode ray tube is fitted in a cradle running in similar slides in the upper part of the cabinet and is removable together with its mask, deflector and focus coil from the front.

Two small panels, placed behind doors at the top of the cabinet near the front, carry the operating controls of the instrument.

The monitor is 53 in. (1·34 m) high, 28½ in. (0·72 m) wide, 39 in. (0·99 m) deep and weighs 340 lb (154 kg).

4.0. Methods of Test and Adjustment

It is clear that, if a picture-quality checking monitor is to perform its function properly, means should be available for checking its performance independently of the picture it has to monitor.

A picture signal is necessary, however, for testing and adjusting the synchronizing signal separator and the black level control. Also, for test purposes, a picture signal subject to various forms of interference must be available if the monitor is required to operate under these conditions.

In the case of the video amplifier and the scanning generators, very misleading results are likely to be obtained if attempts are made to utilize a picture, or in many cases test patterns.

4.1. *Video Amplifier*

The frequency response of the video amplifier can, of course, be checked in the conventional way by means of a signal generator and a valve voltmeter. This process will be found very laborious, however, when adjusting filter networks, and a much simpler and quicker way is to use a sweeping, video beat-frequency oscillator having a range, for a 400-line system, of approximately 50 kc/s to 5 Mc/s. The response of each filter network is then adjusted by means of the trimmer capacitors, while examining the display on an oscilloscope synchronized to the sweep frequency.

The constants for the phase-correcting networks can be determined by the use of adjustable phase correctors as described by Nuttall,[4] with the addition of a suitable pulse generator as a signal source. The frequency response of the amplifier must be adjusted to its final form before the phase correction is attempted.

The low frequency performance can be checked in the usual way with a variable-frequency square-wave generator and oscilloscope.

4.2. *Scan Generators*

The deflecting currents generated by the scan generators have to be accurately adjusted to a particular waveform as previously described. A satisfactory way of doing this is to insert into the deflecting system a specially designed search coil, one each for the line and frame frequencies, and to observe the waveform of the voltage so generated on a suitable oscilloscope. The oscilloscope should be fitted with a D.C. coupled amplifier which, while having sufficient gain to observe the waveform accurately during the scanning interval, must not be adversely affected by the severe overload which takes place during the flyback period. The waveform observed represents the rate of change of spot velocity. The preset controls on the scanning generators are adjusted, therefore, to produce the variations of spot velocity required to scan the tube, so that the picture will be the desired geometric projection of the ideal flat picture.

When all the adjustments have been made, suitable test patterns and pictures can be used for checking their accuracy and the overall performance of the monitor. If, however, the performance is not as good as expected in some particular aspect, adjustments should not be made using the picture. The fault should be investigated by means of instruments and any maladjustment rectified.

The above methods were used in the monitors described in section 3 and the overall performance was entirely as predicted.

5.0. Conclusion

It will be observed that the monitor described in section 3 does not incorporate three of the refinements described in section 2, namely a pin-cushion corrector, a spot wobbler and focus modulation.

A pin-cushion corrector has not yet been designed to suit a 20-in. tube but the scanning waveforms were modified as if one were fitted, a worthwhile reduction in distortion being obtainable thereby.

The spot wobbler had not been developed when the monitor was designed and it will probably be incorporated at a later date.

A design for a focus-current modulator was available, but it was thought that the extra complication was not justified in this case, since the monitor was intended for picture viewing rather than quality checking and the extreme corners of the picture are hidden behind the rounded corners of the mask.

It is, perhaps, of interest to note that many of the circuit techniques used in the monitor were developed in connection with the design of a large screen television projector which incorporates all the refinements described in this paper with the exception, at present, of a pincushion corrector.

Monitors such as are described in this paper are complex and expensive, partly because of the high performance required and partly because the very few which have been made have had to be custom built. It seems probable, however, that, with the spread of television in the future, there will be an increasing demand for such instruments. Such a demand, together with improved and simplified circuit and manufacturing techniques may well result in a standard monitor being produced which would be considerably cheaper and at the same time retain its high performance.

6.0. Acknowledgments

The author wishes to thank Messrs. Cinema-Television Ltd., for permission to publish this paper. His thanks are also due to all his colleagues for help and advice and in particular to Mr. T. C. Nuttall, who is responsible for many of the circuit techniques used and for the work on reduction of scanning distortions. He has given help and encouragement throughout the work described in this paper.

7.0. References

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12. A. J. Brown, British Patent No. 440,912.

ADDITIONAL TRANSFERS AND ELECTIONS TO MEMBERSHIP

A further meeting of the Membership Committee was held on March 31st, 1950.

Nineteen proposals for direct election to Graduate or higher grade of membership were considered, and eighteen proposals for transfer to Graduate or higher grade of membership.

The following list of elections has been approved by the General Council : Fifteen for direct election to Graduate or higher grade of membership, and thirteen for transfer to Graduate or higher grade of membership.

Direct Election to Full Member

Matthews, William Thomas, B.Sc.(Hons.)	Hereford

Direct Election to Associate Member

Ames, Frank Rollason	Waterlooville, Hants.
Seymour, Patrick William	London, N.W.9
Simpkin, Kenneth Henry	London, S.E.19
Wolff, Henry Arnold	Launcester, Tasmania
Yates, William John, Lt./Cdr.	Devonport

Direct Election to Associate

Carnegie, George Carnegie	Canberra, Australia
Davies, Christopher Sylvester, F/Lt.	Birmingham
Dearson, Kenneth John	Newbury, Berks.
Morton, Stuart Robertson	Edinburgh
Nielsen, Franck Martin	Aalborg, Denmark
Smith, Harold, Capt.	Manly, Australia
Steele, William	Oldham, Lancs.

Direct Election to Graduate

Bidgood, Derrick Frank	Bristol
Tingle, Anthony Hubert	Liverpool

Transfer from Associate to Associate Member

Cox, Raymond John, B.Sc.	Wantage

Transfer from Student to Associate

Benson, Francis William	Hull, Yorks.
Catlow, Robert Harvey	Cardiff
Hill, Richard Edgar	London, S.W.2
Kynaston, John Alfred Charles	Cardiff

Transfer from Student to Graduate

Barnes, George Raymond	Blackburn, Lancs.
Brovig, Aanen	Kristiansands, Norway
Holywell, Keith Harold, B.Sc.	Victoria, Australia
Kemp, Alan	Darwen, Lancs.
Lee, Fong Lim	Singapore
Riesel, Herbert	Tel-Aviv, Israel
Sears, John	London, N.6
Williams, William Elwyn	London, N.13

STUDENTSHIP REGISTRATIONS

In addition thirty-seven studentship proposals were dealt with at the meeting of the Membership Committee held on March 31st, 1950. The following registrations have been approved by the General Council and the remainder will be published in the May Journal.

Abott, Percy William	Watford, Herts.
Agarwal, Harsh Kumar	Delhi, India
Ambrose, Dermit Min	Natal, S. Africa
Avinor, Michael	Tel-Aviv, Israel
Bebbington, Roy Edward	Yeovil, Somerset
Bennett, John Antony	London, W.1
Costello, Daniel James	Dublin, Eire
Cottrell, John Gilmour	Bognor Regis, Sussex
Cox, Kenneth Charles Herbert Berkley	Natal, South Africa
Dickson, Paul Richard	London, W.2
Fairall, Sidney Richard	Johannesburg, S. Africa
Fleet, William Norman	Burwood, Australia