TECHNICAL INSTRUCTIONS

LINES

VOLUME 1

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LIST OF CIRCUIT DIAGRAMS

CARRIER COMMUNICATION SYSTEM

SECTION A

GENERAL PRINCIPLES OF CARRIER COMMUNICATION

Introduction

This instruction describes a carrier communication system recently introduced between BBC Regional Centres to provide adequate high-quality telephone communication for all normal inter-office and engineering requirements, together with telegraph services, chiefly for transmission of teleprinter signals for news, engineering service, and inter-office messages.

A comprehensive survey of BBC requirements was made by Lines Department in 1945* which indicated that these requirements could best be met by 3-channel carrier systems, each of which would provide three telephone channels with facilities for deriving a telegraph channel from each telephone channel where necessary. Six communciation channels would therefore be obtainable on one four-wire network.

Definition

For the purposes of this instruction, *carrier communication* implies the transmission and reception of telephone and telegraph messages over telephone lines by means of an amplitude-modulated carrier.

A carrier-communication system implies a number of telephone or telegraph channels, or a combination of both, derived from a system of lines, e.g., a four-wire network, by dividing the available frequency range into a number of bands of restricted width and using each band for a separate communication channel. In the 1 + 2 system used by the BBC, one telephone channel operates at voice frequency without a carrier, and two telephone channels operate with a carrier. The system is so designed that a telegraph channel may be derived from each telephone channel if required.

Advantages of a Carrier Communication System

The chief advantages of a carrier communication system are as follows :—

(i) Those carrier systems which operate during office hours only utilise lines which in any event would have to be rented for non-communication purposes, so that for these carrier systems no line rental is paid.

(ii) The provision of high-quality, low-loss circuits between BBC centres rather than between Post Office centres results in avoiding losses due to the local ends associated with the latter.

(iii) Greater reliability of the communications network is achieved because of the greater amount of control which the BBC can exercise over the apparatus concerned, and because of the higher grade of maintenance which obtains for the particular class of line rented from the Post Office.

(iv) Extreme flexibility of the system enables changes in traffic requirements to be accommodated without removal of equipment or incurring financial losses which would result from breaking rental agreements with the Post Office.

Basic Principles

Frequency Bands

It is generally accepted that an audio-frequency band of about 300-2,500 c/s is adequate for high-quality transmission and reception of speech, whereas the usable frequency range of a modern Post Office music line is of the order of 50-8,000 c/s. Tests have shown that telephone speech of good intelligibility is available from the 2,000-c/s band between 300-2,300 c/s. Furthermore, three bandwidths of this order can be derived from a line having an audio range of 8,000 c/s, with adequate margins for band separation. A telegraph channel used for teleprinter purposes requires a bandwidth of about 100 c/s. Therefore, if a telephone channel has a bandwidth of 2,300 c/s, a telegraph channel can be superimposed upon it with adequate separation between telephone and telegraph frequencies. The actual bandwidths used in the BBC carrier communication system are shown in Section B.

*Lines Report No. 50.1. Technical Basis for the Design of Proposed BBC Communication Network.

Modulation: Static Relay

Before discussing the method of modulating the carrier channels, we will consider the method used for converting teleprinter signals into tone pulses and vice versa. It so happens that the two methods make use of very similar principles.

Teleprinter machines depend for their operation on reversals of d.c., producing what are termed *mark* and *space* signals. For transmission over lines, these signals must be converted to a.c., or more correctly, they must be made to control the a.c. transmitted over the line. At the receiving end of the line, the a.c. signals are converted so as to control the operation of the receiving teleprinter.

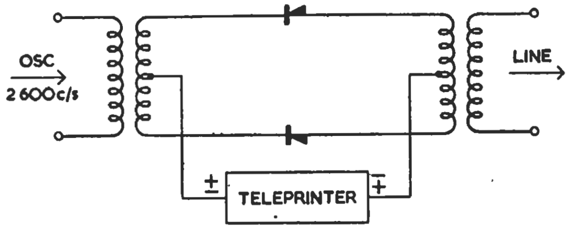


Fig. A1. Static Relay : Basic Circuit

The device used for the purpose is known as a *static relay*; it consists of a pair of centre-tapped repeating coils connected through two metal rectifiers (Fig. A1). The circuit shown has been reduced to its simplest form for purposes of explanation. If steady tone is applied at carrier frequency to the input of one repeating coil, it passes through the rectifiers and appears at the output of the other, provided the voltage applied to the centre-point of one repeating coil is in the right direction. If now, d.c., of opposite polarity is applied to the centre-tap, the rectifiers become non-conductive. The a.c. signal will not now pass through the circuit.

In teleprinter working, the d.c. pulses are produced by the movement of the tongue of the instrument, which changes the polarity of the d.c. with each movement. The rectifier circuit, Fig. A1, is so arranged that the positive d.c. voltages severely attenuate the a.c. tone whilst negative pulses attenuate the tone very little. Positive pulses therefore produce a "space" signal and negative pulses a "marking" signal. When the teleprinter is not working, steady tone from the carrier oscillator is sent to line. This arrangement facilitiates circuit testing and maintenance.

Ring Modulator

Fig. A2 shows the similarity between the ring modulator used on carrier telephone channels and the static relay described above. In the case of telephone transmission however, we have to consider audio-frequency (speech) signals instead of d.c. teleprinter signals.

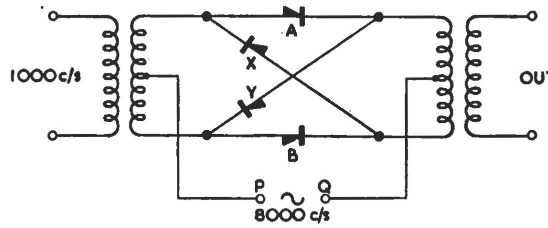


Fig. A2. Ring Modulator : Basic Circuit

Imagine the left-hand transformer to be fed with a 1-kc/s signal at low level, say –10 db ; at the same time suppose an 8-kc/s signal to be applied to the centre-tapped points, P, Q, at such a level (say +15 db) as to make the 1-kc/s level negligible by comparison.

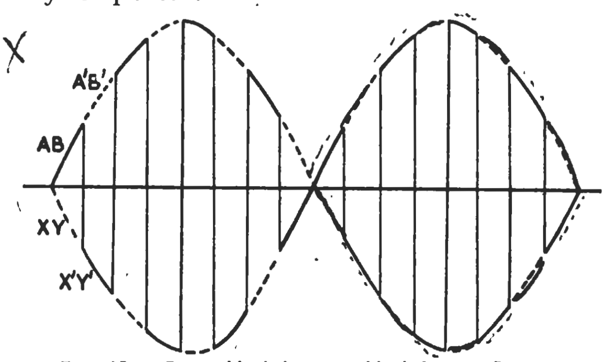


Fig. A3. Ring Modulator : Modulation Process

The process of modulation can now be explained by reference to Fig. A3. During the period that a positive voltage is supplied from the 8-kc/s oscillator to the points P Q, the arrangement of the rectifier causes A, B to become conductive and X, Y non-conductive ; for this half-cycle, therefore, the 1-kc/s signal begins to build up as shown at A B, on the carrier envelope. At the end of this half-cycle, the current from the 1-kc/s signal will continue to flow, but in the opposite direction through the primary of the second repeating coil, rectifiers A, B, being non-conductive and X, Y conductive. The output signal will therefore be negative as represented by X′ Y′ on the diagram. This process is repeated for each cycle of the 8-kc/s signal, breaking up the 1-kc/s signal in the manner shown. Since the 8-kc/s carrier is applied to the centre-taps, and passes through the windings in opposite directions, it does not appear at either input or output.

Such a waveform, with its sharp peaks, will be rich in harmonics, but these can be filtered out in practical circuits if necessary. Assuming this to be done, the waveform is very much like that for a normal low-frequency modulated carrier, but with carrier suppressed.

Demodulation

The circuit used for demodulating the carrier at the receiving end of a carrier communication system is almost identical with the modulator circuit, and need not be further discussed. The two signals involved consist of the incoming modulated carrier at low level and tone from an oscillator, tuned to the same carrier frequency, at high level, again applied across transformer centre-taps.

Four-wire to Two-wire Conversion

With the carrier communications system used by the BBC the links between main centres make use of four-wire circuits. Quite clearly it is necessary for the circuits to be extended to local lines at each centre. To use four-wire circuits for the local extensions would involve considerable cost for equipment and maintenance. Moreover, the use of local two-wire circuits provides easy means for switching and testing ; normally control lines and PBX circuits are two-wire circuits.

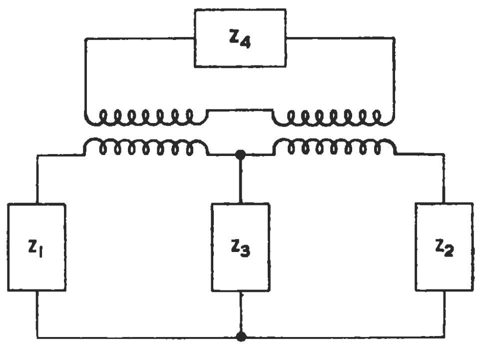


Fig. A4. Four-wire/Two-wire Conversion

The method employed for converting four-wire to two-wire circuits is based on the special properties of the hybrid coil, the theory of which is given in Appendix A1.

The application of the hybrid coil to four-wire/two-wire conversion is illustrated in Fig. A.4

Let us assume that one pair of the four-wire circuit (say the incoming line) be represented by Z1 and the outgoing by Z2. The two-wire circuit is represented by Z4, and Z3 represents the balancing impedance made as nearly equal to ½ Z4 as possible.

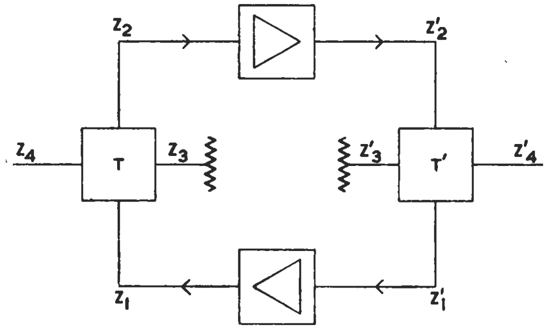


Fig. A5. Four-wire Circuit : Arrangement of Terminating Sets

Fig. A4 shows the theoretical arrangement of terminating sets for converting a four-wire circuit to the more usual two-wire circuit. It is explained in Appendix A that if Z1 equals Z2 and Z3 equals ½ Z4, there is no power transfer between Z1 and Z2 nor between Z3 and Z4. Fig. A5 shows the arrangement for both ends of a four-wire circuit, the hybrid coils being designated *terminating sets T and T′*. Since there is no transfer of power between Z1 and Z2 nor between Z1′ and Z2′, there is no howl round the circuit and it will be stable, the degree of stability depending on the balance achieved between Z3 and Z4. When power is applied to the two-wire circuit Z4, it divides equally between Z1 and Z2, but only one transmission path, through Z2, is open ; this is indicated by the direction pointers on the amplifiers. Therefore, half the power provided by the two-wire circuit is wasted and there is a resultant loss of 3 db due to the dissipation of power in Z1.

Tandem Communciation

From what has just been said, it would appear that if a number of communication circuits employing terminating sets are connected in tandem, a loss of 3 db would occur at each junction. The cumulative loss between the extremities of the BBC network would thus be very considerable. The method adopted to avoid this loss at the junctions is illustrated in Fig. A6. The terminating sets T1 and T2 are shown connected by cord A. On the tail end of each terminating set the balancing impedance is connected through a break jack ;

by inserting a double-ended cord into these jacks the balancing networks are removed and the tail ends of the terminating sets connected together. This is commonly referred to as *tail-eating* (Appendix A2). Details of circuit arrangements will be found in Section C under the heading Four-wire Terminating Set FWT/1.

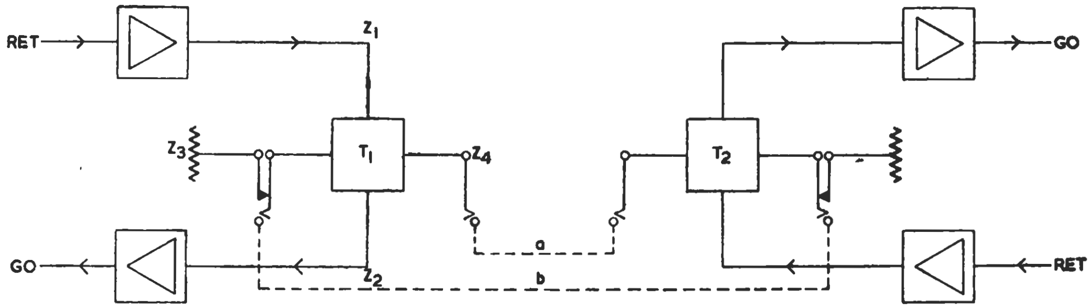


Fig. A6. Tandem Communication : Basic Circuit

The relative positions of main centres and transmitting stations are shown in Fig. 1. Apart from the many direct tie lines connecting studios and transmitters, or other local buildings, there are two main trunk routes from London, one to Cardiff through Bristol and one to Belfast and Edinburgh through Birmingham, Manchester and Glasgow ; a secondary route connects Manchester and Glasgow with Leeds, Newcastle, Edinburgh and Aberdeen.

A general idea of variation in requirements between different centres is indicated on the diagram by lines of different thickness ; these requirements are assessed on the number of callers and reasonable waiting times for establishment of individual calls.

Experience has shown that much delay on telephone circuits can be avoided by the use of a teleprinter service for transmitting queries about advance bookings, news items, scripts, etc. An additional consideration is the transmission of engineering service messages. The carrier communication scheme provides a separate service for this purpose, called the Engineering Telegraph Network (E.T.N.) ; this is described in Section B.

APPENDIX A1

THEORY OF THE HYBRID COIL

A simplified circuit incorporating a hybrid coil is shown in Fig. A1.1. It will first be assumed that the following equalities obtain: $ab=bc$; $Z_1=Z_2$; $Z_3=\frac{1}{2}Z_1$.

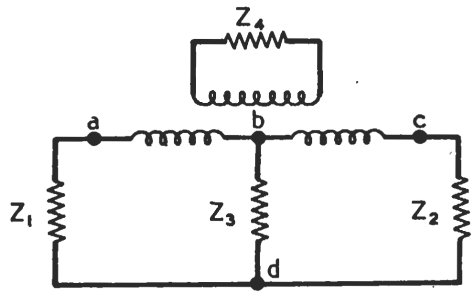


Fig. A1.1

Let the turns ratio be such that the impedance Z_4, viewed through either ab or bc is $Z_3=\frac{1}{2}Z_1$.

Under these conditions, no transference of power can take place between Z_1 and Z_2 nor between Z_3 and Z_4.

Imagine an alternating e.m.f. to be in series with Z_1, and Z_2 to be disconnected (Fig. A1.2). Then all the current due to this e.m.f. flows through Z_3, and, since $Z_{ab}=Z_3$, the voltage-drop across the points ab is equal to and in the same sense as that across the points bd, i.e.

$$V_{ab} = V_{bd} \qquad (1)$$

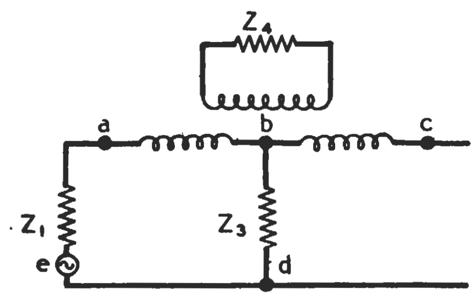


Fig. A1.2

From transformer theory, the current through ab induces an e.m.f. in the winding bc, and, since $bc=ab$, the voltage across bc is equal both in magnitude and sense to that across ab. Thus

$$V_{cd} = V_{bd}-V_{bc} = 0 \qquad (2)$$

Since the points c and d are at equal potential, no current can flow between them, whatever impedance may be connected across them. Thus, while there is a transfer of energy from Z_1 to Z_3 and Z_4, there is none from Z_1 to Z_2, and, because of the symmetry of the circuit, none can be transferred from Z_2 to Z_1.

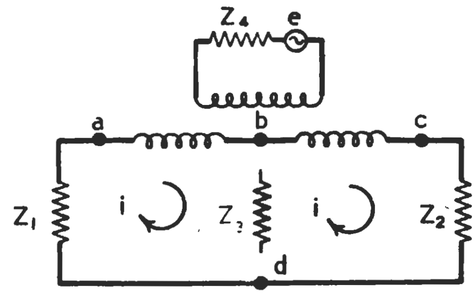


Fig. A1.3

Consider now an e.m.f. in series with Z_4 and let Z_3 be disconnected (Fig. A1.3). A current i will flow through the equal impedances Z_1 and Z_2. The electrical mid-point of the generator of this current is b, while that of the load is d. There is thus no p.d. between points b and d, whether Z_3 is connected or not, and no power can be transferred from Z_4 to Z_3.

Conversely, an e.m.f. in series with Z_3 produces no e.m.f. in the third winding (Z_4). This is because the two halves of the winding are equal and wound in series aiding. The currents in the two half windings will thus be equal and opposite and no flux is induced in the core.

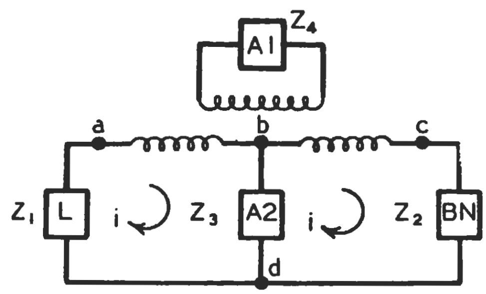
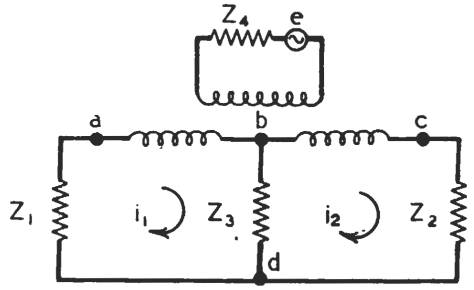


Fig. A1.4

Let it now be supposed that Z_4 comprises the output circuit of an amplifier A1 (Fig. A1.4). Z_1 and Z_2 represent a line L and its balancing network BN respectively; Z_3 represents the input impedance of a second amplifier A2.

Assuming $Z_1=Z_2$, the currents i in Z_1 and Z_2 will be equal, and there is no p.d. across Z_3.

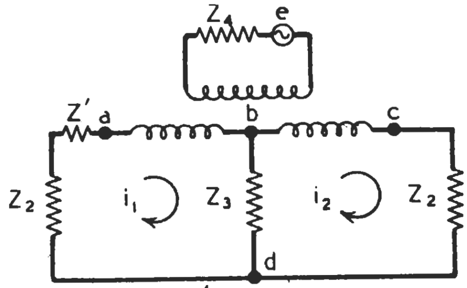
Under such conditions, power supplied from the amplifier A1 will be divided equally between the line L and balancing network BN. The amplifier A2 will have no potential across its input terminals and will remain inoperative.



$Z_2 = 2Z_3$
$Z_1 \neq Z_2$
$i_1 \neq i_2$

Fig. A1.5

It must now be shown what proportion of power will be transferred to A2 when line and network have *unequal* impedances (Fig. A1.5).



$Z' = Z_1 - Z_2$

Fig. A1.6

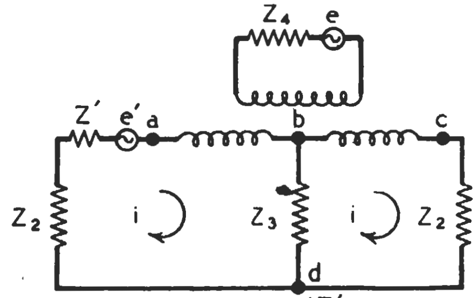
Let it be assumed that Z_1 differs from Z_2 by an amount Z' where $Z' = Z_1 - Z_2$ (Fig. A1.6). Let the currents in the two halves of the circuit be i_1, i_2. Then the current in Z_3 will equal $i_1 - i_2$. If the impedance Z' were reduced to zero, the currents i_1, i_2 would be equal, as in Fig. A1.4.

By the Compensation Theorem, i_1 and i_2 could also be made equal by introducing a compensating e.m.f. e' in series with Z' (Fig. A1.7). The magnitude and phase of e' must be such that it will produce a current equal in value but opposite in phase to the change in current produced by Z', i.e.

$$e' = -iZ' \qquad (3)$$

Given this condition, both i_1 and i_2 will be restored to their former value i.

If the e.m.f. in series with Z_4 now be suppressed (Fig. A1.8), the magnitude of the current change introduced by Z' can be ascertained by considering the current i_3 which remains, due to the retention in the circuit of e'.



$e = -iZ'$

Fig. A1.7

As previously shown in (2), there will be no current in Z_2 because the points c and d are now at equal potential. This indicates that the impedance change, Z', produces no change in the current through Z_2.

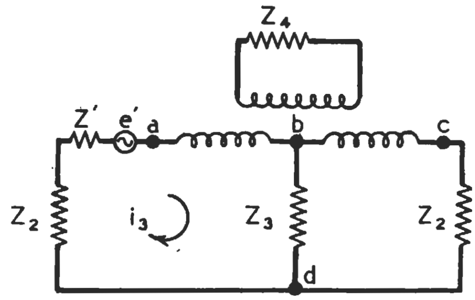


Fig. A1.8

The current i_3, due to e', flows in the left-hand branch of the circuit only and must therefore be equal in magnitude and opposite in phase to the current produced in Z_3 by the impedance change represented by Z'. Its value may be given as

$$i_3 = \frac{e'}{Z_2+Z'+Z_{ab}+Z_3} \qquad (4)$$

Since $Z_{ab}=Z_3=Z_2/2$ and $e' = -iZ'$, the unbalance current i' due to $Z' = -i_3$. Thus

$$i' = -i_3 = \frac{iZ'}{Z_2+Z'+Z_2/2+Z_2/2} \qquad (5)$$

But $Z' = Z_1 - Z_2$

$$\therefore i' = i\,\frac{Z_1-Z_2}{Z_2+(Z_1-Z_2)+2Z_2/2} \qquad (6)$$

$$= i\frac{Z_1-Z_2}{Z_1+Z_2} \qquad (7)$$

and $$\frac{i'}{i} = \frac{Z_1-Z_2}{Z_1+Z_2} \qquad (8)$$

Singing Point

In the practical case where the foregoing principles are applied to a two-way repeater, the ratio $\frac{i'}{i}$ forms part of the loss in the transmission path between the output of one amplifier and the input of the other, such loss being equal to 20 $\log_{10} \frac{i}{i'}$ db, see (8). This quantity is known as the singing point and is the factor which determines the maximum permissible gain of the repeater.

Total Loss in Two-Way Repeater Circuit

Consider, for the moment, a balanced circuit (Fig. A1.9). Power derived from speech currents arriving from Line 1 will divide equally between the output circuit of A2 and the input circuit of A1. There is thus a loss of 3 db between Line 1 and A1. Since the amplified signal is transmitted to Line 2 through a second hybrid coil, a further loss of 3 db occurs, due to the splitting of the power between Line B and network BN2. As the singing-point or return loss $= 20 \log_{10} \frac{Z_1+Z_2}{Z_1-Z_2}$, the total loss in the circuit is equal to

$$20 \log_{10} \left(\frac{Z_1+Z_2}{Z_1-Z_2}\right) + 6 \qquad (9)$$

$$= \log_{10} 2 \left(\frac{Z_1+Z_2}{Z_1-Z_2}\right) \qquad (10)$$

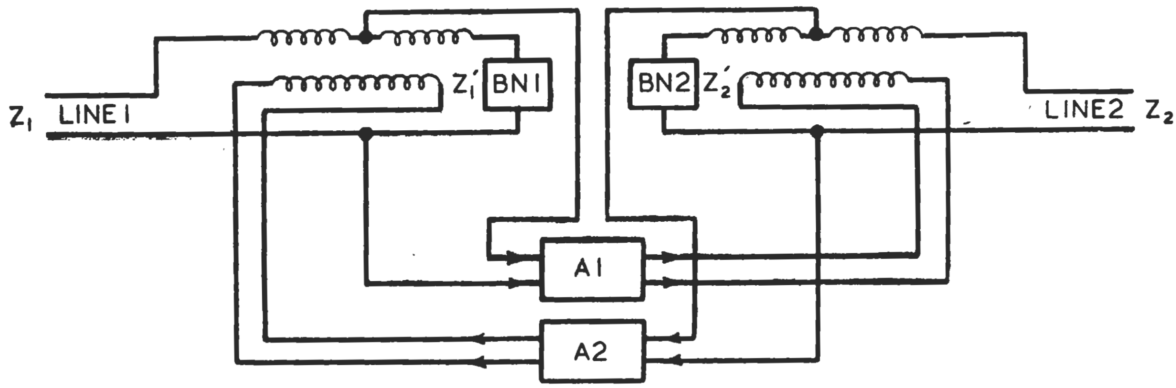


Fig. A1.9

Maximum Repeater Gain

The maximum permissible gain of the repeater is limited by the singing point, which is dependent upon the degree of balance between the impedances of the line and its associated network. Referring to Fig. A1.9, assume the gain of each *amplifier* to be Gdb. The repeater may oscillate or sing if there is zero over-all loss round the amplifier-hybrid coil loop.

From (10), this condition of instability will obtain when

$$2G = 20 \log_{10} 2\left(\frac{Z'_1+Z_1}{Z'_1-Z_1}\right) + 20 \log_{10} 2\left(\frac{Z'_2+Z_2}{Z'_2-Z_2}\right) \qquad (11)$$

$$= 20 \log_{10}\left(\frac{Z'_1+Z_1}{Z'_1-Z_1}\right) + 6 + 20 \log_{10}\left(\frac{Z'_2+Z_2}{Z'_2-Z_2}\right) + 6 \qquad (12)$$

If the logarithmic quantities are replaced by S_a, S_b respectively, from (12)

$$2(G-6) = S_a+S_b \qquad (13)$$

and

$$G-6 = \frac{S_a+S_b}{2} \qquad (14)$$

thus a condition of instability obtains when

$$G = \frac{S_a+S_b}{2} + 6 \qquad (15)$$

Since the insertion gain of the repeater will be equal to the amplifier gain, less 6 db lost by the division of power at each hybrid coil, it follows that the repeater gain g is given by

$$g = G-6 = \frac{S_a+S_b}{2} \qquad (16)$$

That is to say, maximum repeater gain must not exceed the average of the singing points of the lines against their respective networks. Thus the gain available from the repeater is a function of line impedance, together with the accuracy of the balancing network. In practice, a margin of safety is allowed, the repeater gain being set at 4 or 5 db below the point where instability occurs.

APPENDIX A2

THREE METHODS OF CONNECTING TELEPHONE CHANNELS IN TANDEM

On BBC carrier systems individual telephone channels are normally lined-up to have an insertion loss of 3 decibels. When it is necessary to operate two or more of such channels in tandem on a more or less permanent basis, it is desirable to arrange that the insertion loss is as low as possible, consistent with an adequate stability margin.

The three methods which can be used and still maintain adequate stability will now be examined :

(1) Simple connection of the 2 two-wire windings of the four-wire terminating sets at the intermediate stations. By this method the overall insertion loss will be the product of the number of individual channels × 3 db. This method, therefore, has the disadvantage that the total insertion loss of the circuit is proportional to the number of individual links and in many circumstances would not provide a low-loss service.

(2) Through connection of the GO and RETURN directions at the intermediate stations. This method requires suitable loss-pads to compensate for the removal of the Four-wire Terminating Set, FWT/1, and to maintain the correct level conditions at the intermediate stations. The overall insertion loss will be 3 db, but the system will be inflexible and testing arrangements unduly complicated because of the difficulties in bridging the GO and RETURN paths at the intermediate stations.

(3) " Tail-eating " connection of channels through the intermediate stations. In this connection, which has been used on new communication apparatus recently installed, the two-wire windings of the FWT/1 are connected together and a transference of the voltages which normally appear at the FWT/1 bridge points is arranged. By this method it is possible to obtain an overall insertion loss of 3 db over as many links as are required.

The theoretical explanation of this method of connection is not immediately obvious and will therefore be dealt with in greater detail. Knowledge of the theory of the hybrid coil (Appendix A1) is necessary for this analysis. Reference should be made to Fig. A2.1.

If a voltage E from a 600-ohm source is applied to the terminals A and B (Fig. A2.1) half of this voltage will be developed across the 300-ohm impedance presented by the hybrid coil winding tags 3—4 and the other half across the 300-ohm impedance presented by the bridge points of the second hybrid coil.

The voltage $E/2$ across winding 3—4 produces a voltage across the two-wire winding 1—2 of magnitude :

$$\frac{E}{2} \times \sqrt{2} = \frac{E}{\sqrt{2}}$$

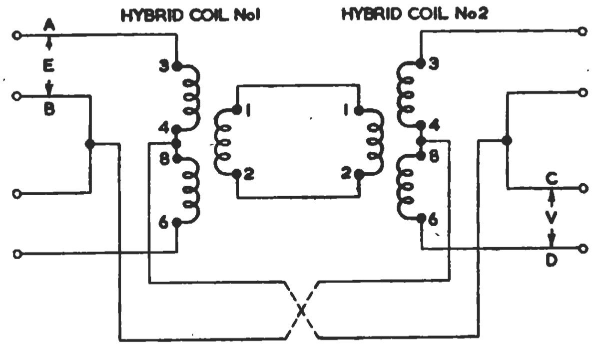


Fig. A2.1

This voltage is applied to the 1—2 winding of the second hybrid coil and produces a voltage :

$$\frac{E}{\sqrt{2}} \times \frac{1}{\sqrt{2}} = \frac{E}{2}$$

across the winding 6—8.

The voltage $E/2$ developed across the bridge points of hybrid coil No. 1 is applied to the bridge points of hybrid coil No. 2 and may either add to or subtract from the voltage across winding 6—8.

Let the voltage across terminals C and D be V.

Case 1. Assume voltages to be additive.

$$V = \frac{E}{2} + \frac{E}{2} = E$$

For a reasonable margin of stability to exist over the entire circuit under normal working conditions the voltage at these terminals must be 3·008 db lower than the applied voltage E.

Voltage ratio of 3·008 db $= 0{\cdot}7073$

$\therefore\ V = 0{\cdot}7073E$

To achieve this, a loss pad must be inserted in either the two-wire or the bridge points connection (Fig. A2.2).

For convenience in switching this loss pad has been fitted in the latter position.

Consider the expression :—

$$V = 0{\cdot}7073E$$

Since $0{\cdot}5E$ is produced from the two-wire side, only $0{\cdot}2073E$ is required across the bridge points. The voltage available here is $0{\cdot}5E$, therefore the loss required is :—

$$20 \log \frac{0{\cdot}5\,E}{0{\cdot}2073E} = 7{\cdot}648 \text{ decibels}$$

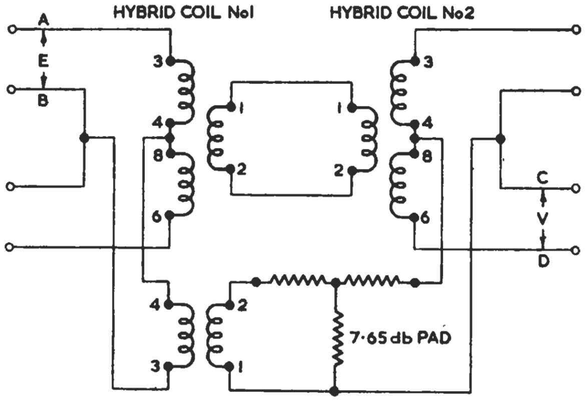


Fig. A2.2

The impedance required between the bridge points of each coil is 300 ohms; the loss pad must have image impedance equal to 300 ohms.

Consideration of the polarities of the induced voltages shows that it is necessary to have a reversal in either the two-wire or bridge-point connection for the voltages to be additive at hybrid coil No. 2. Since the circuit is unbalanced a transformer is used to provide the necessary phase reversal.

Case 2. Assume the voltages at hybrid coil No. 2 are not additive. Without a loss pad no voltage would be produced across terminals C and D, i.e. : $V = 0$.

Case 3. Assume the voltages are not additive but the loss pad has been fitted, it is possible that a reversal of the two-wire connections would cause this.

Under these circumstances, the voltages delivered to terminals C and D would be :—

$$V = 0{\cdot}5E - 0{\cdot}2073E = 0{\cdot}2927E$$

This represents $-10{\cdot}672$ decibels.

The through loss would thus be 7·66 decibels greater than in Case 1.

SECTION B

GENERAL DESCRIPTION OF THE BBC CARRIER COMMUNICATION SYSTEM

Introduction

The practical design of the BBC Carrier Communication System was first outlined in Lines Department Report No. 51.5 issued in 1946. A summary of the final design appears in Design Department's Description No. 24 issued in 1950. This section is based on the information supplied in those reports, modified where necessary to bring the section up to date.

The terminals of the system are installed at main BBC centres, and the system works on music-type lines which have a useful bandwidth of 50-8,000 c/s approximately. It has been shown in Section A that telephone channels of some 2,000 c/s bandwidth, and using frequencies from 300 c/s to 2,300 c/s are satisfactory for commercial-quality telephone channels. This is subject to a condition that the over-all loss on any one channel does not exceed 15-20 db.

The system is designed on this basis and consists of three telephone channels, 1 + 2 (i.e., one channel operated at voice-frequency without a carrier and two channels operated on a carrier frequency). Each channel has a bandwidth of 2,400 c/s, with a loss, measured at the terminal apparatus, of 3 db; a telegraph channel can be derived from each of these channels, which reduces the bandwidth of each telephone channel to 2,000 c/s. The telegraph channels have a bandwidth of 120 c/s, which is wider than the minimum band necessary for teleprinter working, but provides a good margin of safety when a number of channels are connected in tandem. The over-all loss on the telegraph channels is 0 db.

The system incorporates nothing fundamentally new to ordinary carrier communication practice, but it has been developed to suit particular conditions and requirements.

Layout of Equipment

The terminal apparatus is mounted on a number of apparatus bays as follows, but the bays may not all be fully equipped.

1. Communication Carrier Bay CCB/1

Front of Bay (top to bottom)

- 2 Channel Sets CHS/2, each comprising :
  - 1 Filter F/27.
  - 1 Four-wire Termination Set FWT/1.
  - 1 Amplifier GPA/3.
  - 1 Ring Modulator MR/2.
  - 1 Ring Modulator MR/3.
  - 1 Trap-valve Amplifier TV/23.
- 1 Channel Set CHS/1, comprising :
  - 1 Four-wire Termination Set FWT/1.
  - 3 Amplifiers GPA/3.
  - 1 Trap-valve Amplifier TV/23.
- 1 Attenuator Panel AT/24.
- 1 Key Panel KP/1.
- 5 Jackfields JF/1A.
- 2 Filter Splitting Panels FSP/1.
- 1 Mains Unit MU/31.

Rear of Bay (top to bottom).

- 3 Filter Splitting Panels FSP/2.
- 2 Mains Distribution Panels MDP/1.
- 3 Connection Strips No. 23A.

2. Communications Telegraph Bay CTB/1.

Front of Bay (top to bottom)

- 3 Telegraph Convertors TGC/5.
- 1 D.C. Jackfield containing miscellaneous jacks and equipment.
- 1 A.C. Jackfield containing seven JF/1A's.
- 2 Telegraph Convertors TGC/5.
- 2 Mains Unit MU/31.

Rear of Bay (top to bottom)

- 3 Telegraph Convertors TGC/5.
- 1 Mains Distribution Panel MDP/2 (No. 2).
- 2 Telegraph Convertors TGC/5.
- 1 Mains Distribution Panel MDP/2 (No. 1).
- 3 Connection Strips—1 No. 41A and 2 No. 23A.

3. Communication Miscellaneous Bay CMB/1

Front of Bay (top to bottom)

1 Carrier Oscillator Unit COU/1C.
1 Carrier Oscillator Unit COU/1B.
1 Carrier Oscillator Unit COU/1A.
1 Voice-frequency Oscillator OS/7A.
1 Telegraph Combiner TCB/1. (London only.)
1 Key Panel KP/8.
3 Jackfields JF/1A.
1 Filter Splitting Panel FSP/3. (London only.)
1 Voice-frequency Dialling Receiver TDR/A. (London only.)
1 Mains Unit MU/29.
2 Mains Unit MU/31.

Rear of Bay (top to bottom).

1 Telegraph Convertor TGC/6. (London only.)
2 Telephone Units TLU/1.
2 Mains Distribution Panels MDP/1A.
3 Connection Strips No. 23A.

4. Communications Telegraph Test Bay CTTB/1

Front of Bay (top to bottom).

1 Telegraph Distortion Measuring Set TDM/2 comprising:
  Time Base Unit.
  Mains and Oscilloscope Unit.
  Calibration Unit.
1 D.C. Jackfield.
1 Jackfield JF/1A.
1 Key Panel KP/2.
1 Telegraph Relay Tester TRT/2.
1 Teleprinter Margin Tester TPMT/1.
1 Waveform Regenerator.
2 Connection Strips No. 23A.

Frequency Distribution of the Carrier System

Telephone Channels

The three telephone channels each have a bandwidth of 2,400 c/s. When telegraph channels have been derived from them, this bandwidth is reduced to just over 2,000 c/s. The loss of the channels between each two-wire terminal is 3 db with a sending level of −10 db. The limiting effect is negligible at a sending level of −10 db but is appreciable at zero level. (See Section C.)

The frequency allocation for the three channels is approximately as follows:

Channel 1 (non-carrier) 50-2,730 c/s.
Channel 2 (carrier) 2,900-5,300 c/s (carrier frequency 5,600 c/s)
Channel 3 (carrier) 5,700-8,000 c/s (carrier frequency 5,400 c/s)

It will be noted that the second channel uses the lower side-band of the higher carrier frequency, 5,600 c/s, whilst the third channel uses the upper side-band of the lower carrier frequency, 5,400 c/s. This has been done to economise in the frequency space taken up by the carrier system. Neither of the carrier channels transmits frequencies below 250 c/s; by suppressing these low frequencies the intelligibility of speech is slightly improved because of the reduction in boominess. The frequency characteristics of the channels are shown in Figs. B1, B2, B3 (attached to page 13).

Telegraph Channels

The bandwidth of each telegraph channel is approximately 120 c/s; this compares favourably with Post Office practice, where a bandwidth of 80 c/s is normally used for similar carrier equipment. The loss on the telegraph channels is approximately zero db.

The d.c. signals from the teleprinter are passed on to a static relay MR/4, which converts the d.c. pulses to voice-frequency pulses at 2,600 c/s. For telegraph Channel 1 the tone pulses are passed over a channel derived from telephone channel 1 at 2,600 c/s. (Fig. B.1) For telegraph channel 2, modulated tone pulses are passed over a channel derived from telephone channel 2 at 3,000 c/s. (Fig. B.2.) For telegraph channel 3, modulated tone pulses are passed over a channel derived from telephone channel 3 at 8,000 c/s. (Fig. B3).

In the " Rest " condition, when no signals are being sent, steady tone is maintained on the channel. Signalling is effected by interrupting the tone according to the particular telegraphic code used, in this case the " 5-unit " code. This method is adopted so that automatic gain-control can be employed. In addition, the presence of tone with no signals passing enables a continuous watch to be kept on the channel, while its prolonged absence gives warning of an abnormal condition.

Four-wire Terminating Set

The function of this panel is to convert a four-wire *Go* and *Return* circuit to a two-wire " both-way " circuit. Provision is made for connecting two panels to different carrier groups in tandem, with an overall loss of only 3 db between terminals. This is done by connecting the hybrid coils together in a special manner as explained in Section A. A voltage limiter is used to prevent speech volume sent to line from being excessive, so avoiding overloading of repeaters. Details of the panel FWT/1 will be given in Section C.

Filters

The efficiency of the filters has been made as high as possible by employing high-Q inductors and mica capacitors. To economise in space a number of filters are mounted on one side of a 13½-in. panel termed a *Filter Splitting Panel.* Low-pass and high-pass filters have been used in preference to band-pass filters. Full details of the filters are given in Section D.

Modulators and Demodulators

Copper-oxide rectifiers arranged in ring form are used for both modulation and demodulation (see Section A). Selection of the rectifiers forming the ring is necessary in order to obtain good carrier suppression; the rectifiers are, therefore, detachable from the main unit; they are mounted on an accessible paxolin platform so that they can be easily replaced. Full details are given in Section E.

Trap Valves

These are used to buffer the carrier supply oscillators from the modulators. Two types are used, designated TV/23 and TV/24.

The TV/23 is used to feed tone to the modulator and demodulator copper-oxide rings. It has a high input impedance and an output impedance of 50 ohms.

The TV/24 is used to supply power to the telegraph sending static relay MR/4; when used for this purpose it has zero gain. When used in the Engineering Telegraph Network circuits at intermediate stations the gain is switched to 15 db. It has high input impedance and an output impedance of 600 ohms. Details of these amplifiers are given in Section F.

Amplifier GPA/3

This general purpose amplifier is used both as a channel amplifier (at the receiving end) and a sending amplifier. For both purposes the gain is pre-set. Input and output impedances are 600 ohms. Details are given in Section F.

Attenuator Panel AT/23

This panel is provided so that the receiving level from the control room equipment (normally equaliser and D amplifier) and also the channel loss may be adjusted to the correct levels. The panel contains four similar attenuators which can be varied in steps of 0·5 db from zero to 15·5 db by manipulating U-links. The channel attenuator acts as a buffer between the filter and demodulator in channels 2 and 3; therefore the minimum value of the channel 2 and 3 attenuators should not be less than 5 db. Details are given in Section G.

Carrier Supply Oscillators COU/1

The carrier frequencies are generated by high-stability oscillators Type COU/1. These have separate code letters to denote working frequencies as follows:

COU/1A	2,600 c/s	(Telegraph Channels)
COU/1B	5,400 c/s	(Telephone Channel 3)
COU/1C	5,600 c/s	(Telephone Channel 2)

At each station each central oscillator is provided with a spare which is automatically brought into service should a fault develop on the normal oscillator. Trap-valve amplifiers are provided as buffers between the supply oscillators and the carrier equipment. Details of these oscillators are given in Section H.

Recall Unit RCL/1

This unit is used on PBX lines which use voice-frequency ringing panels so that a supervisory signal can be given at an intermediate or terminal switchboard when one of the operators at the end of the line is ringing. Each unit contains two recall circuits, and five such units, which are mounted on one side of a 9-in. panel, are termed a Recall Unit Set RCLS/1. Details are given in Section J.

Voice-frequency Telegraph Convertor TGC/5

The sending side of this apparatus consists of a TV/24 which feeds the 2,600-c/s tone to the sending relay. This relay is a static-type modulator MR/4 operated by +80 volts and −80 volts from the teleprinter. On the receiving side, incoming voice-frequency signals pass through an auto-gain amplifier AGA/1 which holds the signal level at its output terminals constant for a very wide range of input level. The signals are then passed to the detector TGD/1 which drives a Carpenter telegraph relay for sending d.c. pulses to the teleprinter. All these units as well as a 80-0-80 voltage power supply unit MU/37 are mounted on one side of a 9-in. panel. Details are given in Section K.

Telegraph Combiner Unit TCB/1

This unit is used in London only. It enables a d.c. signal received from one of four stations to be sent to the remaining three. In addition, the received signal is prevented from returning to the source so that the local copy of the sending teleprinter is not mutilated. Details are given in Section L.

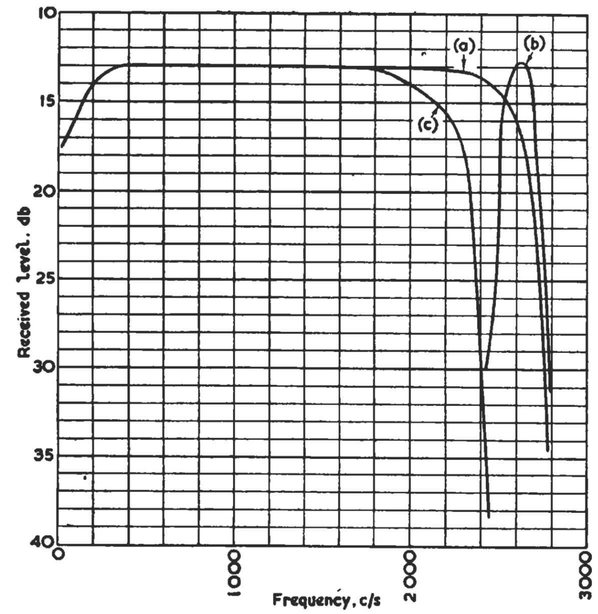


Fig. B1. Frequency Characteristic, Channel 1

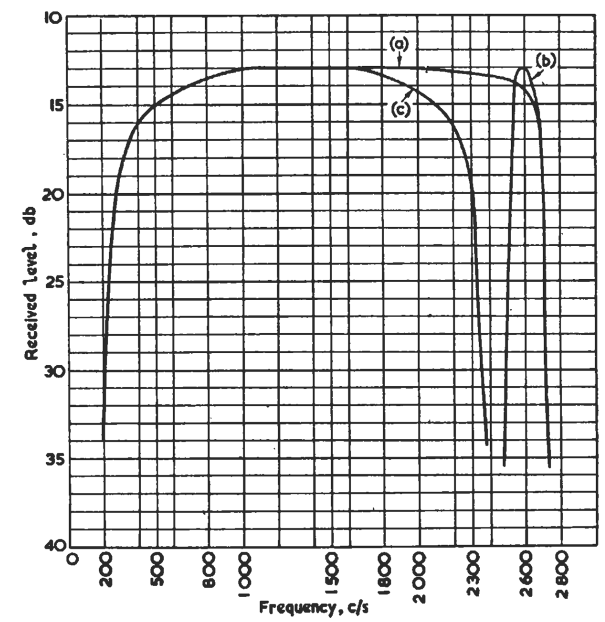


Fig. B2. Frequency Characteristic, Channel 2

(a) Telephone Channel
(b) Telegraph Channel
(c) Telephone Channel with Telegraph Channel derived

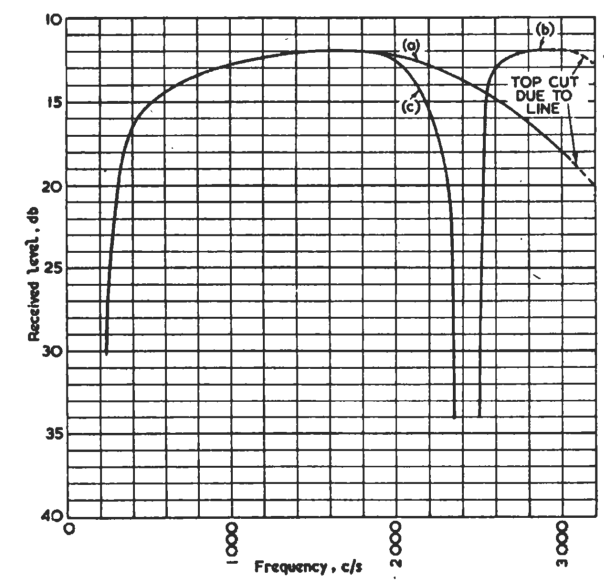


Fig. B3. Frequency Characteristic, Channel 3

Telegraph Bridging Unit TBG/1

This unit is employed at intermediate stations, and combines the d.c. signals received from the *Up* and *Down* directions in the windings of a single telegraph relay, which operates a local teleprinter. Details are given in Section M.

Mains Unit MU/37

This supplies 80 volts positive and negative at 20 mA and is used to supply power to the telegraph relay. Details are given in Section N.

Mains Unit MU/38

This supplies 30 volts positive and negative at 10 mA, for sending d.c. telegraph signals over lines. Details are given in Section N.

Ringing Arrangement

The standard 700-c/s voice-frequency ringing arrangements are used, and the ringing convertor is a voice-frequency panel VFR/1 which supercedes the convertors Type RR/3A, B and C. To enable an operator at an intermediate station to be recalled by the end station, special provision is made to give the operator a recall supervisory signal; a PBX recall panel RCL/1 is associated with each VFR/1. When an operator plugs into the answering jack a relay is operated within the RCL/1, and if a ring is received while the operator's plug is still inserted in the answering jack, an open-circuit lasting about one second followed by a short-circuit of about one second will cause the disk or lamp indicator on the PBX switchboard to flash.

Interception of Circuits on Jacks

The only points in the carrier system which can be intercepted on jacks are those where routine measurements have to be taken. All circuits are, however, readily available on tag blocks on the individual units.

Metering of Circuits

Stations are supplied with two portable milliammeters which can be hung in slots provided on the bays. One meter is intended for measurement of feed currents; this is a left-hand zero instrument and has three ranges, 0-4, 0-20, 0-40 milliamps. The other meter is intended for measurement of double-current telegraph feeds; this is a central-zero meter and has two ranges, 6-0-6, 30-0-30 milliamps. Both meters have plug-ended cords attached.

Engineering Telephone Facilities

Two telephone sets are provided for engineers operating the system. Two telephone units TLU/1 are mounted on the Miscellaneous Bay, and two portable hand-sets with plug-ended cords can be plugged into appropriate jacks placed at suitable points so that conversations can be carried out in front of all bays. (The line sides of the TLU/1 are also paralleled to jacks at some of these points.) Speak-ring keys are provided on a number of the bays.

The Engineering Telegraph Network (E.T.N.)

This network carries engineering service messages. It is an omnibus service, that is, a message sent by any one station is received by all the others. As (ultimately) the distance over which messages are sent is great involving many links in tandem, the signals are passed through intermediate stations at voice frequency. This arrangement prevents telegraph distortion which would be considerable if at each station the voice-frequency pulses were converted to d.c. pulses and then back to voice-frequency pulses once again. Fig. B4 shows the circuit arrangement at an intermediate station. It will be noted that the tone received from the UP and DOWN directions is amplified by a trap-valve TV/24 and passed on to the next station via a static relay MR/4. The signals are also tapped at the intermediate station and converted to d.c. signals by convertors Type TGC/5. The outputs of both convertors are combined in a relay in the Telegraph Bridging Unit TBG/1, before being passed to the local teleprinter.

Signals sent from the local teleprinter operate the static relays MR/4 in the UP and DOWN channels.

At London special arrangements are made because signals are received from and sent to more than two stations. The voice-frequency signals are converted to d.c. pulses and combined in a Telegraph Combiner Unit TCB/1.

Lining-up Channels

Fig. 2 ~~B5~~ shows the levels that should be maintained at various points in the carrier circuits. The gain of all the amplifiers is fixed at 23 db. The incoming line and channel levels are, however, adjustable by manipulating U-links on an attenuator panel AT/23 in steps of 0·5 db. When checking levels at points where the carrier and two sidebands are present, a tuned detector (such as a wave analyser) must be used ; no routine measurements are required at these points. Attention is drawn to the fact that Fig. 1. shows test levels ; a level of −10 db is used for sending to the channel jacks because the effect of the limiters at this test level is negligible.

Connecting Channels in Tandem

Each telephone channel is normally set up so as to have an insertion loss of 3 db when a sending level of −10 db is used. Provision is made so that two or more channels may be connected in tandem maintaining the insertion loss of the chain of channels at 3 db. (See Section A.) This is done by connecting the two-wire sides and the bridge points of the hybrid transformers together, the latter via an attenuator pad. A reversal of phase is made between the bridge points. By throwing a switch, mounted on one of the two four-wire terminating sets involved, to the " Reverse " position, the phase reversal and attenuator pad referred to are brought into circuit. (*To avoid confusion the switch to be thrown to the reverse position should be that on the four-wire terminating set that is nearest to London.*)

Provision has been made so that an engineer at an intermediate station may test each channel in the Up or Down directions by merely plugging into the appropriate channel jack.

Apparatus For Testing Telegraph Equipment

At some centres a bay termed the Telegraph Test Bay CTTB/1 is installed. It is not thought necessary that every station should have this bay, as circuits and apparatus can be " loop-tested " from two or three main stations.

The bay contains a Start-Stop Telegraph Distortion Measuring Set with a special holder for mounting a Mullard E.800 or E.805 portable oscilloscope. There is provided also a Teleprinter Margin Tester and a Carpenter Telegraph Relay Testing Panel. All centres are provided with this relay testing panel which is mounted at some suitable location at stations where a Telegraph Test Bay is not provided. Both a.c. and d.c. jackfields are provided for carrying out tests and intercepting circuits.

Test Teleprinter and Test Teleprinter Panel TTP/1

A test teleprinter and a panel consisting of keys and meters are provided at each centre beside the telegraph bays. They are mounted on a Post Office teleprinter table. This equipment enables an engineer to test and send messages over the voice-frequency channels and the local teleprinter circuits. Provision is made for him to intercept or monitor these circuits. Suitable meters are provided as indicators of the circuit conditions.

Schematic Circuit

The way the communication system works can be readily understood by a study of Fig. 2. In this figure, the terminal apparatus is shown in schematic form for both ends of a four-wire network, and operating levels are shown at each point of change.

Go and Return directions are indicated by triangles at amplifying points, the apex pointing in the direction of transmission.

Telephone Channel 1

The Go circuit starts at the terminals of the Four-wire Termination set FWT/1 (on the left of Fig. 2), the sending level being −10 db. The limiter L1 is designed to prevent the transmitted level from exceeding a pre-determined value thus guarding against cross-talk between channels and against overloading of repeaters. The hybrid coil permits the connection of two or more systems in tandem and is arranged so that under these conditions the overall loss between terminals is the same as for a single system, viz., 3 db.

From the FWT/1, the circuit passes through the Filter-Splitting Panel FSP/1. Since channel 1 operates without a carrier, no modulator is wanted ; an attenuator precedes the low-pass filter LP1, the latter having a cut-off frequency of 2,730 c/s. After LP1 the circuit passes through the sending amplifier GPA/3 which raises the system output to the specified level.

An attenuator, variable over a range of 6 db, permits small adjustments of level as required. The channel path is determined by LP1/HP1 in Filter Set FSP/1 ; it passes through LP1, a fixed and a variable attenuator (the variable attenuator equalises channel losses) and a channel amplifier GPA/3, thence through the hybrid coil to the channel terminals. The Return circuit is identical but, of course, via the return line.

Telephone Channel 2

This channel operates on a carrier frequency of 5,600 c/s, speech being transmitted on the lower sideband only (2,900-5,300 c/s), Go and Return circuits being identical. The speech path is from Channel 2 terminals via the limiter of the hybrid coil as for Channel 1 ; it then passes through an attenuator to MR/2 where it modulates a carrier of 5,600 c/s. The lower side-band is selected by LP2 and further limited by HP1 at the line side of which it joins the path of channel 1.

At the receiving end the only path possible for the frequencies of channel 2 is via HP1 and LP2 to demodulator MR/3 ; as a result of the demodulation process with tone at 5,600 c/s, side-bands of 200-2,700 c/s and 5,900-8,600 c/s are produced as well as the carrier frequency. Since only the first side-band is wanted the others are suppressed by the low-pass filter LP4.

Telephone Channel 3

This channel operates on a carrier frequency of 5,400 c/s, speech being transmitted on the upper sideband only (5,700-8,000 c/s). Frequencies below 5,600 c/s are cut off by HP2, so that although the circuit is taken through HP1, channels 2 and 3 are effectively separated.

At the receiving end, the path is selected by FSP/1 as indicated by the cut-off frequencies of the filters. From the output of the FSP/1, the circuit is via the associated demodulator as for channel 2.

Telegraph Channels

In Fig. 2 a telegraph circuit is superimposed on channel 3. Carrier tone at 2,600 c/s from the oscillator COU/1C is fed to the modulator via the trap-valve amplifier, teleprinter d.c. pulses being used to modulate tone. The modulator MR/4 is sometimes called a static relay ; it consists of four rectifiers so arranged that the carrier tone is sent to line when a *mark* signal (−80 V) is applied to the centre tap of input transformer T1 ; when a *space* signal (+80 V) is applied no tone is sent to line. The interrupted carrier signals (voice-frequency pulses) are passed through the high-pass filter HP3, which has a cut-off frequency of 2,500 c/s. At the receiving end, the telegraph and telephone signals are separated by the filter FSP/2. The output of HP3 is connected to the auto-gain amplifier AGA/1, the function of which is to maintain the signals at a constant level at the output for wide variations of input level. This is necessary to reduce telegraph distortion which occurs if the level of the signals varies at the telegraph detector terminals.

The following unit is the Telegraph Detector Unit TGD/1, which converts the 2,600-c/s pulses to d.c. pulses for the operation of the teleprinter.

Full details of individual units are given in subsequent sections. Fig. 2 shows the points at which a telegraph channel may be superimposed on either channel 1 or channel 2.

SECTION C

FOUR-WIRE TERMINATING SET FWT/1

General

The function of this panel is to convert a four-wire *Go and Return* circuit to a two-wire circuit. Provision is also made so that two channels of different carrier systems can be connected in tandem with only 3 db loss between the terminals; this is done by connecting the hybrid transformers together in the special manner described in Section B.

A voltage limiter is employed to prevent the volume of speech sent to line from being excessive.

coil T3, with a voltage ratio of 1 : 1 is used. A 300-ohm 8-db pad is inserted between the network terminals of the two terminating sets. This is done so that the insertion loss of the two FWT/1 sets is 5 db as measured from the *Return* side of one set to the *Go* side of the other, using a sending level of −10 db.

To simplify maintenance of these circuits, the channel jacks have been provided with extra contacts so that when a plug is inserted into one of the jacks the following conditions obtain.

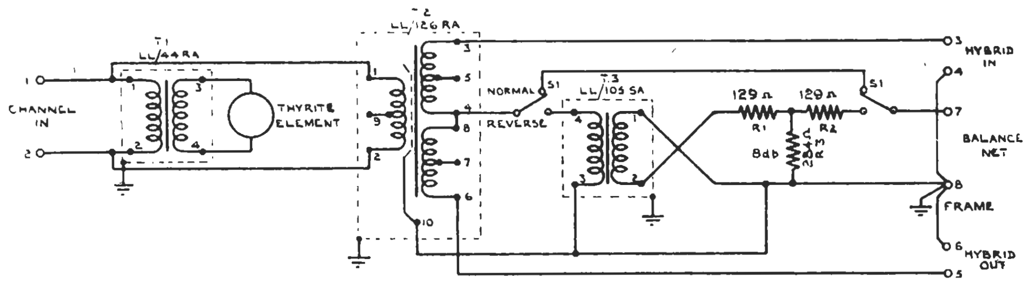


Fig. C1. Four-wire Terminating Set FWT/1 : Circuit

Circuit Description Fig. C1.

A BBC hybrid transformer type LL/126 is employed, and the windings are connected to be balanced on the two-wire side and to be unbalanced on the four-wire side. This has been done because the *Go and Return* circuits are connected to unbalanced filters and attenuators.

With the 2-pole toggle switch S1 in 'Normal' position, the balance point of the hybrid coil, terminals 4 and 8, is connected direct to tag 7 of the unit, thence via the distribution frame to the 300-ohm balance resistor remotely mounted, and Earth.

If the FWT/1 is to be connected to another FWT/1 in the tail-eating arrangement, the switch S1 *on one FWT/1 only* should be thrown to the *Reverse* position. In this condition, a phase-shift of 180 deg. is introduced by reversing the connections between the network points of the two hybrids. As the circuit is unbalanced, a repeating

1. The tail-eating connection is broken and a 300-ohm resistor is connected between the network points of the hybrid coil and earth. The channel can then be tested by itself and will have a loss of 3 db between two-wire terminals, using a sending level of −10 db.
2. If the tail-eating connection is not in use, the normal 300-ohm network resistor is disconnected from the hybrid network points and another 300-ohm resistor inserted in its place. This latter resistor is located in the wiring at the rear of the appropriate jack.

Transformer T1 has a high step-up voltage ratio of 1 : 25. Across its secondary winding there is a non-linear Thyrite element which acts as a limiter; this element has a fairly constant resistance of about two megohms, provided that the potential between its two ends does not exceed 20 volts. With 50 volts, the resistance of the element falls to about 50 kilohms; this resistance, reflected back to the primary, causes a considerable shunt path across the two-wire circuit. Thus a level of +20 db sent into the limiter will be reduced to +9 db. At zero level, the limiting effect is about 1·5 db; at a level of −10, the limiting effect is negligible.

Mechanical Construction

The components of the FWT/1 are mounted on a small sub-chassis measuring $7\frac{7}{16}$ by $3\frac{17}{32}$ inches; the sub-chassis is mounted on one side of a 9-inch panel called a Channel Set CHS/1.

Operation

To connect two channels in tandem, throw switch S1 to *Reverse* on one of the two FWT/1 sets only (Fig. C.1); this is in addition to the connection of the 2-wire sides and the balance points. (See Section B under "Connecting Channels in Tandem.")

Performance of Thyrite Element

Applied Volts	*Current μA*	*Resistance*
20	13	1·5 megohm
25	40	625 kilohms
30	85	350 ,,
35	168	210 ,,
40	310	130 ,,
45	555	80 ,,
50	950	52 ,,

SECTION D

FILTERS USED IN CARRIER (1+2) SYSTEM

General

The filters employed to derive the channels of the carrier system are mounted on one side of 13½-inch panels termed Filter Splitting Panels. There are two of these panels, coded FSP/1 and FSP/2 (Figs. 3 and 4).

FSP/1 mounts filters LP.1, LP.2, HP.1, HP.2.

FSP/2 mounts filters LP.3 and HP.3.

The low-pass filters LP.4 which follow the demodulators MR/3 are each mounted on a small sub-chassis, which forms part of the channel set CHS/2. The filter with its sub-chassis is coded F/27.

All the inductors used in the filters have a high "Q" factor and all capacitors have mica dielectric.

Function of Individual Filters

LP.1 delineates the speech band of Channel 1.

HP.1 and LP.2 derive Channel 2.

HP.2, in conjunction with the frequency characteristic of the line (or LP.3), derives Channel 3.

LP.3 restricts the bandwidth of speech to 2,370 c/s when a telegraph channel is derived.

HP.3, in conjunction with other filters (or in the case of Channel 3, the frequency limit of the line) derives the telegraph channel on speech channels 1, 2 or 3.

LP.4 follows the demodulators MR/3 and has a cut-off frequency of 3,050 c/s. Its function is to eliminate unwanted high-frequency terms which appear in speech at the output of the demodulator.

Filter Performance

The figures quoted below include the insertion loss of the repeating coils used in the associated circuits, Figs 3. and 4. The figures are also averages of results obtained from a number of filters.

Low-pass Filter LP.1

Frequency c/s	50	1,000	2,730	3,000	4,000	8,000	10,000
Insertion Loss db	1·0	0·8	10	66	75	72	72

Low-pass Filter LP.2

Frequency c/s	50	1,000	2,200	4,500	5,400	5,600	6,000	8,000	10,000
Insertion Loss db	1·2	1·7	0·8	0·8	14·2	54·5	67	77·5	62

Low-pass Filter LP.3

Frequency c/s	50	1,000	2,370	2,600	3,000	4,000	8,000	10,000
Insertion Loss db	1·2	0·5	13	70	58·5	39	45	47

Low-pass Filter LP.4

Frequency c/s	50	1,000	2,000	3,000	3,800	5,400	6,000	8,000	10,000
Insertion Loss db	0·3	0·2	0·5	4·5	50	51	51	43	44

High-pass Filter HP.1

Frequency c/s	50	1,000	1,500	2,000	2,860	3,600	5,000	7,000	10,000
Insertion Loss db	66·5	57	57	75	8	0·8	0·7	0·5	0·5

High-pass Filter HP.2

Frequency c/s	500	1,000	3,000	4,500	5,100	5,400	5,600	6,500	8,000	10,000
Insertion Loss db	68	67·5	80	70	72	58	11·5	0·6	0·5	0·5

High-pass Filter HP.3 (with LP section)

Frequency c/s	500	1,200	1,500	2,000	2,300	2,500	2,600	3,000	4,000	6,000	7,000
Insertion Loss db	77	58	57	56·5	46	7	2·5	3·3	7·5	18·5	23

High-pass Filter HP.3 (without LP section)

Frequency c/s	500	1,200	1,400	2,000	2,300	2,500	2,600	3,000	4,000	6,000	7,000
Insertion Loss db	66	50	47	48	42	9·5	1·3	0·7	0·5	0·5	0·5

SECTION E

RING MODULATOR MR/2 AND MR/3

General

The function of ring modulators in the communication system has been explained in Section A. The unit MR/2 is used as a modulator and MR/3 as a demodulator. The difference between them is that MR/2 has a 600-ohm pad across its input and a variable control for minimising the carrier leak. (Figs. E1 and E2.)

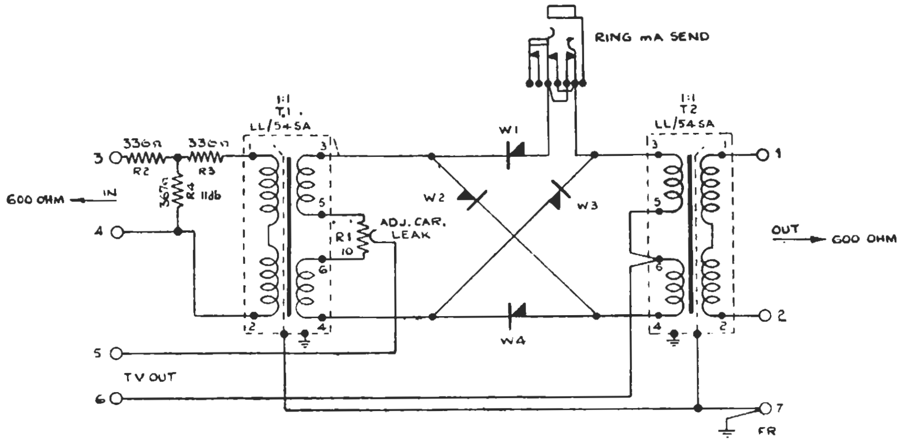


Fig. E.1. Modulator MR/2 : Circuit

The components of each unit are mounted on a small sub-chassis which in turn is mounted on a 9-inch panel coded Channel Set CHS/2. This panel also mounts the low-pass filter LP.4 (Section D.)

Circuit Description

A copper-oxide rectifier ring W1—W4 is placed between transformers T1 and T2. These transformers have a turns ratio of 1 : 1 and differ only in that T1 MR/2 has its primary brought out to terminals so that a variable resistor R1 may be inserted to replace the junction of the two primary windings. This is done to minimise the carrier leak passed back to the subscriber's telephone through the FWT/1.

Tone at carrier frequency is obtained from Carrier Oscillator Unit COU/1 and passed from Trap Valve Amplifier TV/23 to the modulator MR/2 and the demodulator MR/3 in parallel, and applied to the rings via the centre points of the two transformers T1 and T2. The ring current should be set at 10 mA (a jack is provided for this measurement) and to equalise the currents in the two rings, a resistor is inserted in series with tag 5 of one of the two units. This resistor is connected between tag 5 on the appropriate unit and tag 5 on the panel block.

The 600-ohm pad R2, R3, R4 (MR/2) is used to attenuate speech to the correct volume for application to the modulator. With the MR/2, the two sidebands plus a partially suppressed carrier will be found at the output. With the MR/3, demodulated speech will be found at the output, together with high-frequency terms which are eliminated by the low-pass filter LP.4 (F/27).

Layout of Components

The components of each of the two units are mounted on a sub-chassis measuring $1\frac{3}{4}$ by $7\frac{7}{16}$ inches. The copper-oxide ring of rectifiers is mounted on a small detachable plastic holder, and the assembly can be plugged into a 5-pin valve-holder on the sub-chassis.

The ring modulator MR/4 which is used as a static relay in the telegraph circuits, is mounted on a similar sub-chassis but uses a 7-pin valve-holder. This unit is described in a later section under Telegraph Converter Unit TGC/5.

Selection of Rectifiers for a Ring Modulator

It is essential that the rectifiers used in the ring should be carefully selected to prevent the carrier leak from being excessive. Selection is made by measurement of impedance; all the rectifiers should have approximately the same forward impedance. This can be conveniently measured by passing 0·5 mA and 10 mA through each rectifier in turn and measuring the voltage-drop across them.

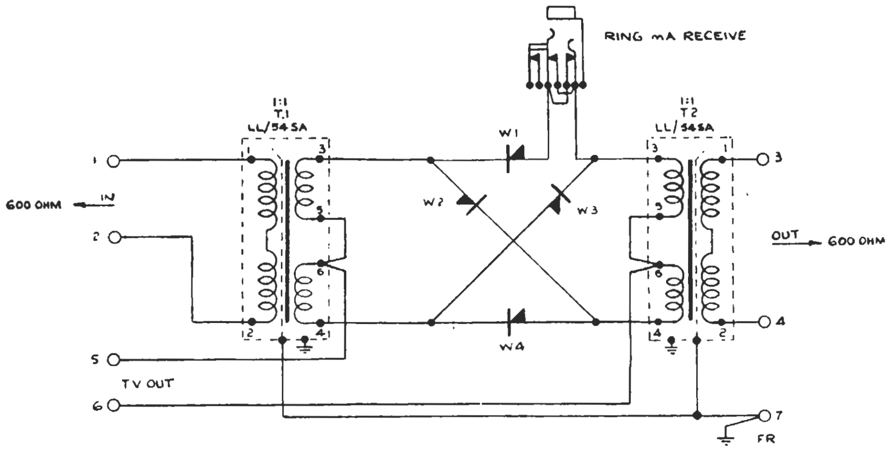


Fig. E.2. De-modulator MR/3: Circuit

General Data (MR/2 and MR/3)

Ring Current 10 mA

Input Level −26 db

Output level. Each sideband −31 db; Carrier below −25 db.

Note: It is important that when measuring the level of a sideband, a tuned detector circuit be used if the other sideband is present.

Input and Output Impedance

The input and output impedance will depend on the state of the switching action due to the carrier at any particular instant. As the two units are nearly always preceded, and also followed by filters whose impedance depends upon their being correctly terminated, it is essential to buffer the filters from the modulators or demodulators by a 600-ohm attenuator. This attenuator is the variable channel attenuator on panel AT/23; its value should never be less than 5 db.

SECTION F

COMMUNICATIONS AMPLIFIERS

The amplifiers TV/23, TV/24 and GPA/3 are all single-stage units, using an EF50 valve. Each of the amplifiers is mounted on a sub-chassis of similar dimensions ($7\frac{7}{16}$ in. × $3\frac{17}{32}$ in.) and having the same drilling holes; the sub-chassis is designed for fixing to a General Purpose Mounting, GPM/1. To simplify manufacture the same component values are used wherever possible.

1. TRAP VALVE AMPLIFIER TV/23 (Fig. F.1)

This amplifier is used on the telephone channels of the carrier communications system and functions as a buffer stage between the common Carrier Supply Unit COU/1 and the separate channel modulators MR/2 and demodulators MR/3. (See Fig. 2).

The input impedance is high (22,000 ohms) and the output impedance low (50 ohms), the output circuit being designed to deliver a current of 45 mA into a 50-ohm load.

The input impedance of 22,000 ohms is obtained by incorporating R1, R2 in series with the primary winding of the input transformer T1. (Fig. F.1). R3, R4 provide the correct loading conditions for the secondary winding. R7 is the usual anti-squeggering resistor in the grid circuit; C1, C2, C3 and R10, R9, R12 are the decoupling components. A negative feedback path between anode and grid is provided by C4 and R6, R5, the feedback and hence the gain, being adjusted by R5. This control is designated *Adj. Ring Current*; it ensures that the carrier power supplied to the modulators or demodulators is at optimum for operating conditions. R8 provides a resistive load for the valve. R11 enables a measurement of anode feed to be taken with a milliammeter plugged into a jack; normally R11 is shorted by the jack contacts.

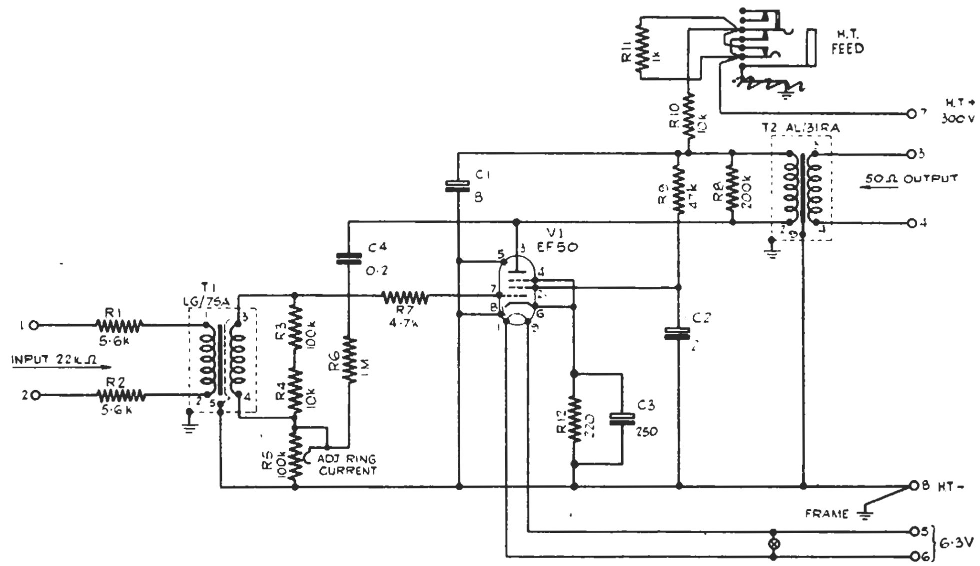


Fig. F.1. Amplifier TV/23 : Circuit

General Data

Valve	*Anode Current*	*Fil. Volts*
EF50	6·5 mA	6·3
H.T. Supply	300 volts	

Impedances

Input	22,000 Ω at 1,000 c/s
Output	50 Ω at 1,000 c/s

Test Data

Gain at 1,000 *c/s.* 15 db with input shunted by 600 Ω and output terminated in 50 Ω. Input level at zero db. *Adjust Ring Current* control at maximum.

Frequency Response. From 250 to 10,000 c/s, flat within ±1·5 db. *Adjust Ring Current* control at maximum.

Harmonic Content. Less than 3 per cent. at 1,000 c/s with maximum gain at zero input level.

Noise Level. Signal-to-noise ratio greater than 55 db for zero level output.

2. TRAP VALVE AMPLIFIER TV/24 (Fig. F.2)

This amplifier is used as a buffer stage between the common Carrier Oscillator Unit COU/1 and individual telegraph sending modulators MR/4. (Fig. 2). It is also used as an amplifier in the Engineering Telegraph Network. Since the required working gain is different for the two purposes, a switch is incorporated in the grid circuit (Fig. F.2), having 0-db and 15-db positions. When used as a buffer stage, the switch is set to 0 db, the 600-600 ohm gain being zero. For use with the E.T.N., the switch is set to the 15-db position, the 600-600 ohm gain being 15 db.

For either position of the switch, the input impedance is 22,000 ohms and the output impedance 600 ohms.

Resistors R1, R2 in series with the primary winding of transformer T1, build out the impedance, as seen from the input terminals, to 22,000 Ω. (Fig. F.2). R3 and R4 provide the correct secondary load, and their values are so proportioned that the toggle switch connected to the tappings changes the gain by 15·0 db.

R7 is the anti-squeggering resistor in the grid circuit; C1, C2, C3 with R10, R9 and R12 are the decoupling components.

A negative feedback path between anode and grid is provided by C4, R6 and the variable resistor R5, labelled *Trim Gain*. It is important that, under working conditions, this control should be used only to trim the gain to 0 or to 15 db, according to the position of the toggle switch. The reason for this is that large variations in feedback would cause the output impedance to depart from 600 ohms.

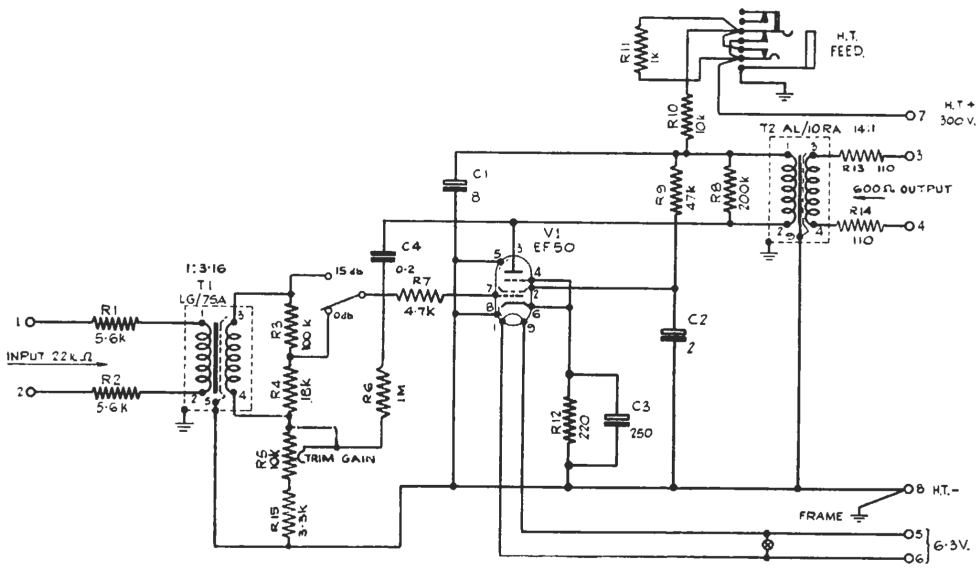


Fig. F.2. Amplifier TV/24 : Circuit

The resistor R8 across the primary winding of transformer T2 provides the correct termination for an output impedance of 600 ohms. The resistor R11 enables anode feed to be measured with a milliammeter plugged into the *H.T. Feed* jack. Normally R11 is shorted out by the jack contacts.

GENERAL DATA

Valve	*Anode Current*
EF50	7 mA
H.T. Supply	300 volts

Impedances

Input	22,000 Ω at 1,000 c/s
Output	600 Ω at 1,000 c/s (at normal working gain).

Test Data

Gain at 1,000 *c/s* (600-*ohm Test*)

With toggle switch at zero, Trim Gain at max., gain = 7 db.

With toggle switch at +15 db., Trim Gain at max., gain = 22 db.

Frequency Response. From 250-10,000 c/s, flat within ±1·5 db. Toggle switch in either position; Trim Gain set for 0 or for 15 db, according to position of toggle switch.

Harmonic Content. Less than 3 per cent. up to an output level of +10 db at 1,000 c/s.

Noise Level. Signal-to-noise ratio greater than 53 db for zero output level.

3. AMPLIFIER GPA/3 (Fig. F.3)

This single-stage amplifier is used for two purposes in the carrier communications system. It functions as an amplifier at the sending end of the system, and is connected between the common point of FSP/1 and the outgoing line; in this capacity it is designated the *Send* amplifier. (Fig. 2). The same type of amplifier is also used at the receiving end of the line, one such amplifier being allotted to each received channel; in this capacity it is called the *Channel* amplifier. For both purposes, the working gain is 23 db, fixed by the selection of the values for R5 and R7, R6 acting as a gain trimmer with limits of ±2 db.

Higher gain, to a maximum of 37·5 db, is available by suitable adjustment of the values of R5 and R7. To obtain a gain lower than 23 db, provision is made for the insertion of a 600-ohm attenuator, R1, R2, R3, between input terminals and input transformer. If fitted, the values of the resistors are chosen to provide the loss required for specific conditions.

Cathode-injection feedback is provided, by returning the cathode circuit to earth via a feedback winding on the output transformer. The secondary of this transformer is loaded by the 6·8-kilohm resistor R13, which holds the output impedance, presented to the output terminals, at 600 ohms. Decoupling arrangements are normal for this type of amplifier.

H.t. feed can be measured directly on a milliammeter, the feed resistor R11 being shorted out by the jack contacts when there is no plug in the jack.

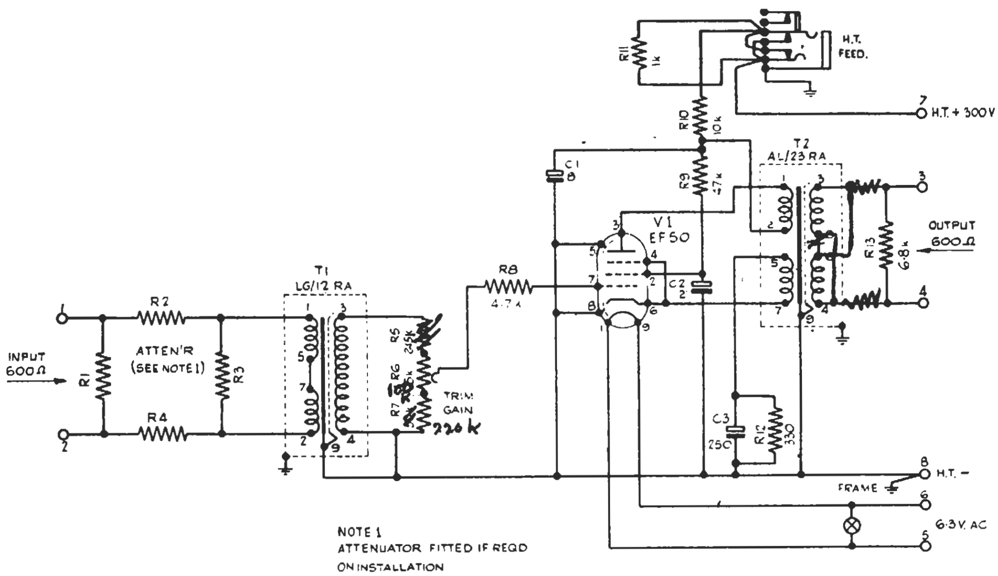


Fig. F.3. Amplifier GPA/3 : Circuit

General Data

Valve	*Anode Current*	*Screen Current*	*Fil. Volts*
EF50	5·5 mA	1·5 mA	6·3
H.T. Supply	300 volts		
Total Feed	7·0 mA		

Impedances
Input and Output 600Ω

Test Data
Gain (600-ohm Test)
With ' Trim Gain ' set at maximum, 26 ± 1 db.
With R8 connected to terminal 3 of T1 and with 300 kilohms across terminals 3 and 4, of T1, 37·5 ± 1 db.

Frequency Response
From 50 to 10,000 c/s, flat to within ± 1 db.

Harmonic Content at 1,000 c/s
With output = +10 db, less than 0·5%
With output = +20 db, less than 3%

4. AUTOGAIN AMPLIFIER AGA/1 (Fig. F4)

This amplifier is used on the telegraph circuits of the carrier communications system. Its position in the telegraph circuit will be seen in Fig. 2. The components are mounted on a small sub-chassis forming part of the Telegraph Convertor TGC/5.

The voice-frequency telegraph signals are applied to the input of the AGA/1, which maintains these signals at a constant level at its output for wide variations of input level. This is necessary to reduce telegraph distortion which occurs if the level of the signals varies at the input terminals of the telegraph detector, TGD/1, which converts the 2,600-c/s pulses to d.c. pulses

The AGA/1 is a single-valve amplifier, with amplified gain control (Fig. F.4). The voice-frequency telegraph signals applied to the input terminals are amplified by the variable-mu valve V1.

The output transformer of the amplifier is fed from the anode circuit of this valve.

The first diode V2 has its striking voltage set by the bleeder network, R11, R12 connected across the h.t. supply ; any peaks of tone received from V1 which exceed the striking voltage are made to drive the grid of V3 negative. The pulses thus applied to V3 are amplified, inverted in phase, and passed to the second diode of V2 which rectifies them and thus produces a negative d.c. bias for V1.

The controlling voltage is developed across R10 and C6 and is applied to the grid of V1 via R3 ; this resistor, in conjunction with C2 provides smoothing for the A.G.C. The time constants of R10 and C6 are carefully chosen so that no discrimination is made between characters of different *mark-to-space* ratio in the telegraph signals. (Section B). The impedance across the primary winding of T1 is 300 ohms ; to maintain 600 ohms

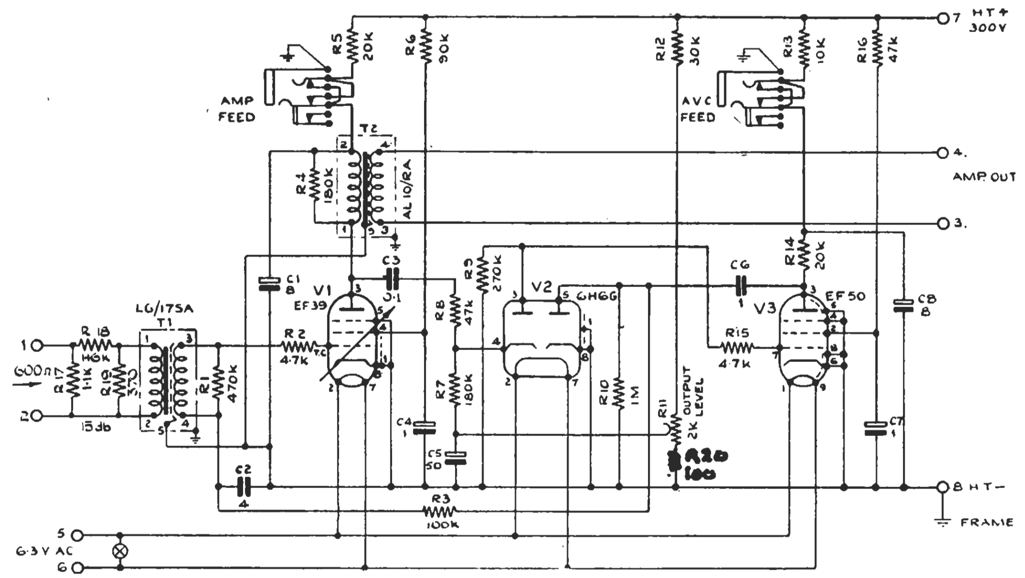


Fig. F.4. Amplifier AGA/1 : Circuit

at the input terminals of the amplifier, the attenuator following the input terminals is a 600-to-300 ohm pad, the value of which is chosen so that the average tone input level is the optimum for correct working conditions. The resistor R1 provides the right loading for T1, and R4 connected across the secondary of T2 maintains circuit stability.

The anodes of both V1 and V3 are decoupled, and the usual feed jacks are provided in the anode circuits.

General Data

	Valves Type	*Anode Feed*	*Fil. Volts*
V1	EF39	8·5 mA*	6·3
V2	6H6G	—	6·3
V3	EF50	10·8 mA*	6·3

*With no input signal. With input at —25 db. V1 = 3·0 mA.

H.T. Supply 300 volts.

Test Data

600-ohm Gain Test

Apply tone at 2,600 c/s and at a level of -10 —25 db; adjust the *Output Level* control for zero level at the output.

To check A.G.C. vary the tone level in steps over the range —20 to —0 db; the output level should remain at zero with a tolerance of ±0·2 1 db.

SECTION G

ATTENUATOR PANEL AT/23

This variable-attenuator panel consists of four separate but similar attenuators (Fig. G.1). Each of the attenuators can be varied in steps of 0·5 db from zero to 15·5 db by the manipulation of U-links.

One attenuator, designated the Receive Attenuator, is placed in circuit following the receive-line Amplifier, which in the control room is normally a D amplifier. The receive attenuator is used for compensating small changes in the gain or loss of the line and line-terminating equipment.

The other three attenuators, designated Channel Attenuators, are placed in the three receive channels and are used to adjust the channel loss.

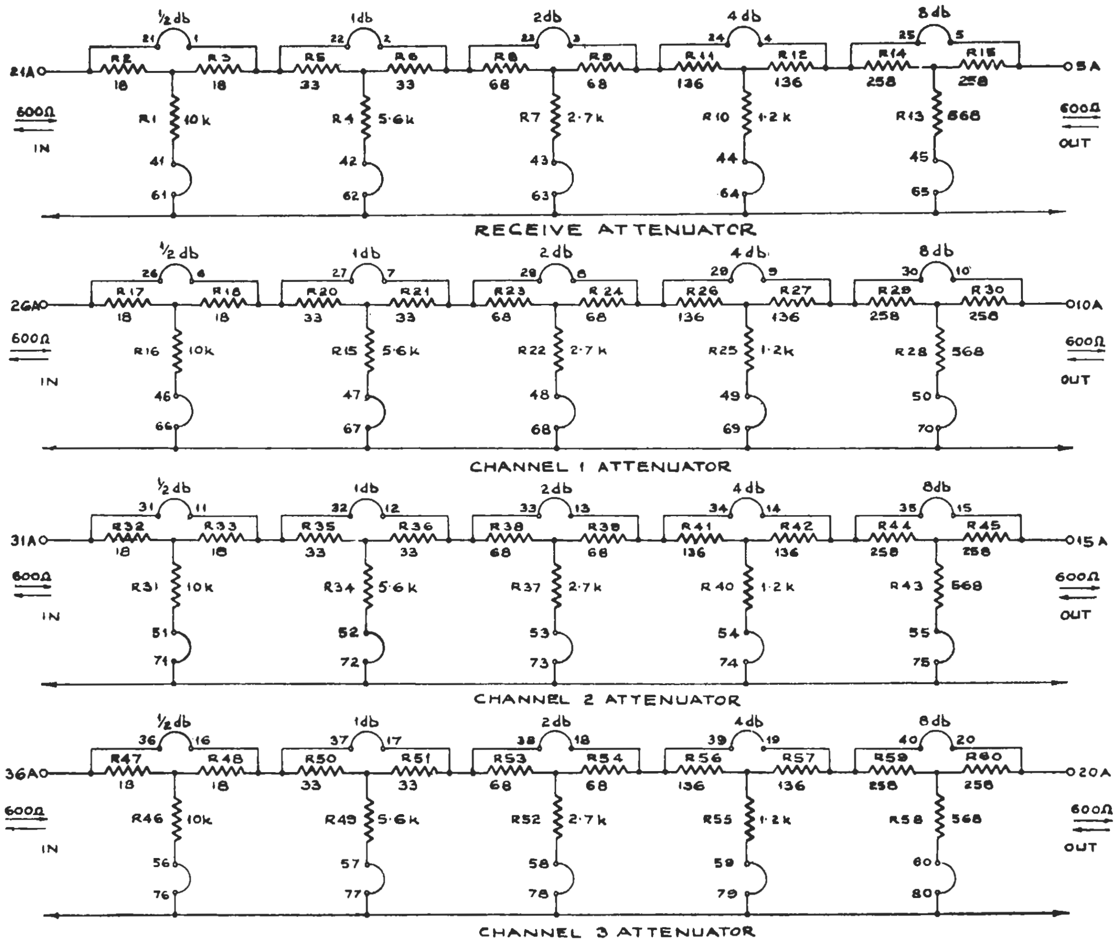


Fig. G.1. Attenuator AT/23 : Circuit

The attenuators are of the unbalanced type with an impedance of 600 ohms. The component resistors are mounted on the back of a 4½-inch U-link panel which is provided with a dust cover.

The panel contains four rows of U-link sockets. To select the required value of attenuation, the U-links are placed in the lower two rows; when all the U-links are in the upper two rows the attenuation is zero. Normally all the attenuators are set for a loss of 6 db. As the attenuators in channels 2 and 3 act as buffers between the filters and the demodulators (see Fig. 2) the loss should not be reduced below 5 db.

SECTION H

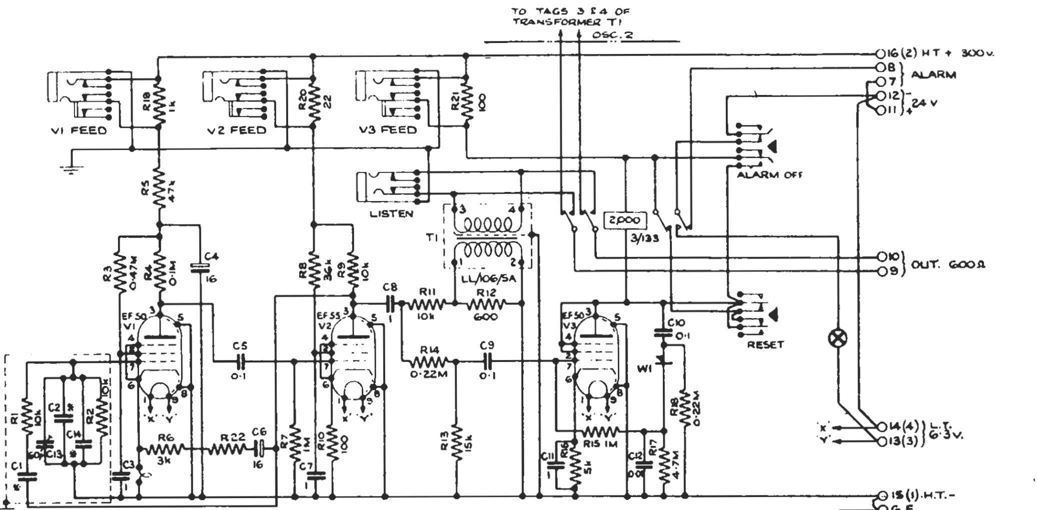
CARRIER SUPPLY UNIT COU/1

General Description

The Carrier Supply Unit COU/1 is an oscillator unit for supplying tone at carrier frequency in the Carrier Communications System. The same unit is used to supply tone for telephone channels 2 and 3 and for the telegraph channel. Since each of these channels uses a different carrier frequency, the carrier supply units have been coded A, B and C with the following frequencies obtaining :

COU/1A	2,600 c/s	Telegraph Channel
COU/1B	5,400 c/s	Telephone Channel 3
COU/1C	5,600 c/s	Telephone Channel 2

Each unit comprises two identical oscillators, a normal and a spare. If the normal oscillator fails, the spare is switched into circuit automatically. The two oscillators are mounted on a standard 6¾-inch panel. The three sets of units, A, B and C, are installed on the Communications Miscellaneous Bay CMB/1.



CODE N°	C1 *	C2 *	C14 *	FREQUENCY
COU/1A	6120 p	5340 p	750 p	2600 c/s
COU/1B	2950 p	2560 p	360 p	5400 c/s
COU/1C	2840 p	2450 p	360 p	5600 c/s

NOTES.
1. VALUE OF R22 TO BE DECIDED ON TEST.
2. CIRCUIT DIAGRAM FOR OSC. 2 IDENTICAL EXCEPT FOR RELAY WIRING AS SHOWN ABOVE. TAG NUMBERS FOR OSC. 2 SHOWN IN BRACKETS. TAGS 7, 8, 11 & 12 COMMON TO BOTH OSC.S.

Fig. H.1. Carrier Supply Unit COU/1 : Circuit.

Circuit Description. Fig. H.1

The circuits of the two sections are similar but not identical since the change-over contacts of the relay in the reserve oscillator are not wired. The circuit is basically that of a two-stage amplifier, which is made to oscillate by the application of positive feedback from the anode of V2 to the grid of V1, via a resistance-capacitance network formed by R1, C1, R2 and C1, C13 and C14. The phase-shift and loss introduced by this network vary as frequency varies ; oscillation occurs at the frequency at which the phase-shift is zero, provided that the amplifier gain at this frequency is at least equal to the loss in the frequency-determining network.

The network is in the form of a detachable assembly, the components being selected to give the functional frequency ; fine adjustment is by means of the variable capacitor C13. Compensation for frequency drift with varying temperature is provided by the shunt capacitors, which contain a proportion of negative temperature coefficient capacitance.

The output level is maintained sensibly constant by using a varistor lamp in the negative feedback path between the anode of V2 and the cathode of V1 ; this path consists of C6, R22, R6 and the lamp, which is in series with the cathode of V1. The characteristics of the lamp are such that its resistance increases as the current passing through it increases, so that the percentage of negative feedback varies if the output level varies. The value of R22 is adjusted on test to suit the particular lamp supplied ; if the lamp is changed, the value of R22 may also have to be changed.

The output is taken from a potentiometer, R11, R12, through the 1 : 1 transformer T1 to the output terminals via relay contacts ; a listen jack is connected across the secondary of T1.

The valve V3 controls the relay which switches the spare oscillator into circuit should the normal oscillator fail. It is used as a triode and functions as an anode-bend detector, biased nearly to the cut-off point ; its grid is fed from the anode of V2 and its output is rectified and applied to its own grid as a positive d.c. signal, thus opposing the standing negative bias on the valve. When the oscillator is functioning normally therefore, the anode current of V3 is high enough to energise the relay, the contacts of which complete the oscillator output circuit.

If the output from V2 falls, the positive bias to the grid of V3 also falls ; hence the anode current of V3 falls and the relay becomes de-energised. The de-energising of the relay in the normal oscillator effects the following operations :—

(i) The output terminals of the unit as a whole are switched from the faulty oscillator to the reserve.

(ii) The pilot lamp on the faulty oscillator goes out.

(iii) An alarm buzzer sounds.

Operations (ii) and (iii) therefore provide an alarm system indicating that the output circuit has been changed from one oscillator to the other. An *Alarm Off* key is provided to prevent the buzzer from sounding continuously after the alarm has been given.

When the faulty oscillator again functions normally, it may be put back into circuit by depressing the *Re-set* button associated with that oscillator ; (depressing the button removes a short-circuit across the relay winding). Before the re-set button is operated, the *Alarm Off* button should be released.

If the reserve oscillator should fail, its relay will become de-energised causing the alarm buzzer to sound ; the pilot lamp goes out, but as stated previously, the output circuit is not transferred to the normal oscillator until the *Re-set* button of the latter has been operated.

General Data

Output Impedance	600 Ω ± 10%
Output Level	Zero ± 1 db into 600 Ω load
Frequency Stability	Within 1·5 c/s of nominal value
Harmonic Content	1%

Valve Data

		Total Feed mA	*Avo Major readings (1·2V Range) at Feed Jacks*
V1	EF50	0·8-1·5	0·13V-0·23V
V2	EF55	22-30	0·38V-0·52V
V3	EF50	1.0-2·0 (de-operated)	0·07V-0·15V
		8·0-12·0 (operated)	0·6V-1·0V

L.T. Supply 6·3V 3·2A
H.T. Supply 300V.

Designs Specifications

Capacitors in the Positive Feedback Network

The values required are as follows :—

(a)	Frequency	2,600 c/s	6,120 pF
(b)	,,	5,400 c/s	2,950 pF
(c)	,,	5,600 c/s	2,840 pF

The values shown above are for both the series and shunt arms in the positive feedback network. The series arm is a single-unit capacitor as shown above. The shunt arm however, is made up of a number of capacitors to give a proper proportioning of positive and negative temperature coefficient components and to facilitate adjustment.

COU/1A

1 capacitor 5,340 pF
SM 1007 ± 1% U.I.C.

2 capacitors 250 pF
SCT3 ± 5% U.I.C.

1 capacitor 250 pF
SCT15 ± 5% U.I.C.

COU/1B

1 capacitor 2,560 pF
SM 1007 ± 1% U.I.C.

2 capacitors 120 pF
SCT3 ± 5% U.I.C.

1 capacitor 120 pF
SCT13 ± 5% U.I.C.

COU/1C

1 capacitor 2,450 pF
SM 1007 ± 1% U.I.C.

2 capacitors 120 pF
SCT3 ± 1% U.I.C.

1 capacitor 120 pF
SCT13 ± 5% U.I.C.

As the temperature coefficient of these components varies over fairly wide limits from batch to batch, it may be necessary to rearrange the proportions shown above. For this reason the parts list shows a superfluity of values. Any rearrangement that is necessary will be shown up by the temperature test and Designs Department will give guidance on this matter if necessary.

Adjustment of Oscillator for Level and Waveform

Having assembled the positive feedback unit in accordance with the above specification and joined it into the proper part of the circuit, an adjustment of R6 should be made (if necessary) so that the alternating current in R6 is 6 ± ·5 mA. The waveform should then be examined for purity and the total harmonic content should not exceed − 40 db; it should not be better than − 50 db because then instability of oscillation might ensue. If the waveform is found unsatisfactory during these tests a new varistor lamp should be inserted and the rest of the circuit checked. The lamp used for setting the oscillator up in this manner should be left associated with that particular oscillator. The output level should now be checked and this should be zero ± 1 db into a 600-ohm load.

Adjustment of Frequency

The frequency of the individual unit must be adjusted to within 1 c/s of the frequency given for that unit. This is achieved by means of the small adjustable capacitor associated with the positive feedback-path network. After the unit has been switched on for 5 hours the frequency should again be checked; a small readjustment will probably be found necessary.

Frequency Stability

Frequency stability should now be checked by observing the change of frequency which occurs when the temperature of the unit rises by approximately 50°F. Change due to such temperature variation should not exceed a total of ± 1·5 c/s from the nominal frequency. In practice this test may be made simply by comparing the frequency at the time of switching on from cold with that of five hours later when the unit has thoroughly warmed up. This should be emphasised by roughly covering the dust covers with cardboard to provide thermal lagging.

A change of ± 10% in supply voltage (from its nominal value) should not change the frequency by more than ± ½ c/s.

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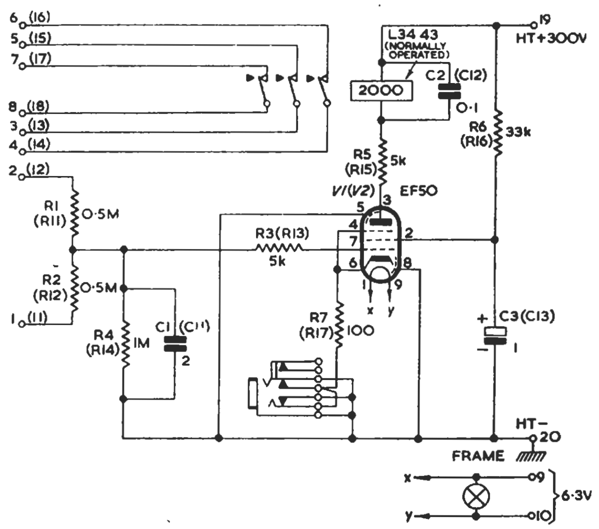
SECTION J

RECALL UNIT RCL/1

General Description

This unit has been designed for use on PBX lines which use BBC voice-frequency ringing panels, so that a supervisory signal can be given at an intermediate switchboard, when one of the operators at the ends of the line is ringing. Each unit contains two recall circuits, and five units are mounted on one side of a 9-inch panel termed a Recall Unit Set RCLS/1.



NOTE.—TWO UNITS TO THIS CIRCUIT ARE MOUNTED ON ONE CHASSIS. TERMINAL AND COMPONENT NUMBERS IN BRACKETS REFER TO SECOND UNIT. TERMINALS 9, 10, 19 AND 20 ARE COMMON TO BOTH UNITS.

Fig. J.1. Recall Unit RCL/1 : Circuit.

Mechanical Details

Each Recall Unit RCL/1 consists of two recall circuits, and each unit is mounted by means of four screws to a 9-inch panel designated a Recall Unit Set RCLS/1. Thus five units can be fitted to one side of a 9-inch panel.

Circuit Description. (Fig. J.1)

When a call is in progress a loop is presented to PBX and the supervisory signal is unoperated (lamp unlit or disk not showing). As soon as either subscriber replaces the receiver, the loop on that side is broken and the relative supervisory signal is operated ; the operator then clears the connection.

It is not possible to provide these conditions when using a standard ringer panel VFR/1 and therefore a special unit, the RCL/1, has had to be fitted.

The input terminals 1 and 2 are connected across the output terminals of the voice-frequency ringing panel VFR/1 in parallel with the answering line jack on the PBX switchboard. When a plug associated with an answering cord circuit is inserted into this jack, a negative voltage from the exchange battery will be applied via R1 or R2 to the grid of an EF50 valve, and will cause a normal standing feed of about 10·5 mA to drop to zero. Reduction of the feed in this way de-operates the relay in the anode circuit, and the 17-cycle ringing supply to the associated VFR/1 is broken. C1 and R4 in the grid circuit have a long time-constant to prevent any faulty operation occurring. The effect is therefore to present alternate closed and open circuits to the PBX equipment, so causing the supervisory indicator to operate.

Relay Spring Tension Adjustments

These are standard for Relays Type L34.43. Adjustments can be made by withdrawing the valve from its holder.

Operating Conditions

1. Normal standing anode feed = 9·5 mA.
2. Feed when cord circuit plug on PBX is inserted into answering jack (greater than 12 volts negative on valve grid) = 0 mA.
3. Relay A operates at 6·0 mA approximately.
4. Relay A de-operates at 2 mA approximately.
5. Feed measured at cathode: 14 mA at 300 V H.T. and zero grid volts.

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SECTION K

TELEGRAPH CONVERTOR TGC/5

General

The function of this apparatus is to convert the d.c. signals from a teleprinter, consisting of negative and positive mark and space pulses, into voice-frequency signals suitable for transmission over a carrier telegraph channel; conversely the apparatus also translates the voice-frequency pulses received from a distant station into d.c. pulses capable of operating a local teleprinter.

Each teleprinter channel employs a separate convertor, the convertors being mounted on a Communications Telegraph Bay CTB/1 (Section B); this bay is capable of accommodating any number of convertors up to ten, as may be required by a particular installation.

Each convertor consists of the following five sub-units, mounted together on one side of a 9-inch panel:

Trap-valve amplifier TV/24
Modulator MR/4
Auto-gain Amplifier AGA/1
Telegraph Detector TGD/1
Mains Unit MU/37

The modulator, MR/4 and detector, TGD/1 are described in this Section. Details of trap-valve amplifier TV/24 and auto-gain amplifier AGA/1 are given in Section F, and of mains unit MU/37 in Section N.

The "send" and "receive" channels of a two-way telegraph circuit are shown in schematic form in Fig. 2. The sending side of the telegraph convertor comprises trap-valve amplifier TV/24 and modulator MR/4. Zero-level tone at the standard telegraph frequency of 2,600 c/s is supplied by a COU/1A oscillator to the TV/24. The amplifier normally operates at zero gain, but when the convertor is used at intermediate stations in the Engineering Telegraph Network, the gain is switched to 15 db. The trap-valve output passes to the modulator; this latter unit is arranged so that when a −80-volt signal is applied to its d.c. input terminals the tone is sent to line, but when a +80-volt space signal is applied the tone is suppressed. The tone levels through the convertor are shown in Fig. 2. The loss-pad at the output, shown separately in the figure, is in fact incorporated in the MR/4.

The receiving side of the convertor comprises auto-gain amplifier AGA/1 and detector TGD/1. The voice-frequency pulses are applied to the AGA/1, whose function is to maintain a constant-level signal at the detector input, thereby minimising the distorting effect of variations in the level of the signal received from line. The detector, which converts the voice-frequency pulses to d.c. pulses, incorporates a Carpenter telegraph relay whose fixed contacts are supplied with 80 volts positive and negative from the MU/37.

Modulator MR/4

Circuit Description: *Fig. K.*1.

The modulator is fundamentally a balanced attenuator with variable-impedance elements consisting of metal rectifiers. The impedance of each attenuator arm, and hence the loss introduced, is controlled by the rectifier-biasing potential.

Rectifiers W1 and W2 (Fig. K.1) which constitute the series arms, are connected to T2 secondary winding with opposing polarity, while rectifiers W3 and W4, also oppositely connected, are in shunt across T1 primary. Carrier tone at zero level is applied across the modulator input terminals on the primary side of T2, and alternate positive and negative 80-volt space and mark signals from the teleprinter are applied between terminal 5 and earth.

When a +80-volt space signal is applied to terminal 5, a negative bias is placed on W1 and W2, and the operative "back" resistance of the rectifiers introduces a high series impedance in the signal path through the modulator. Simultaneously, W3 and W4 become positively biased; these rectifiers conduct, their "forward" resistance thus constituting a low-impedance path in shunt with the output transformer primary. The resulting attenuation of the 2,600-c/s signal tone, measured across T1 secondary winding, is greater than 55 db.

When a −80-volt mark signal is applied to terminal 5, the series rectifiers, W1 and W2, are positively biased and therefore conduct, while the shunt rectifiers, W3 and W4, are negatively biased and present a high impedance. The resulting attenuation of the 2,600-c/s tone level is now only about 1·5 db.

The value of direct current flowing in the modulator depends upon the value of R3, and has been fixed for convenience at 20 mA. The choice of values for R1 and R2 is governed by the need for restricting the rectifier back voltage to a safe value of 2 to 3 volts. A 600-ohm 13·5-db loss-pad is inserted between the secondary winding of T1 and the output terminals, the value of attenuation being fixed by the required sending level for a telegraph channel.

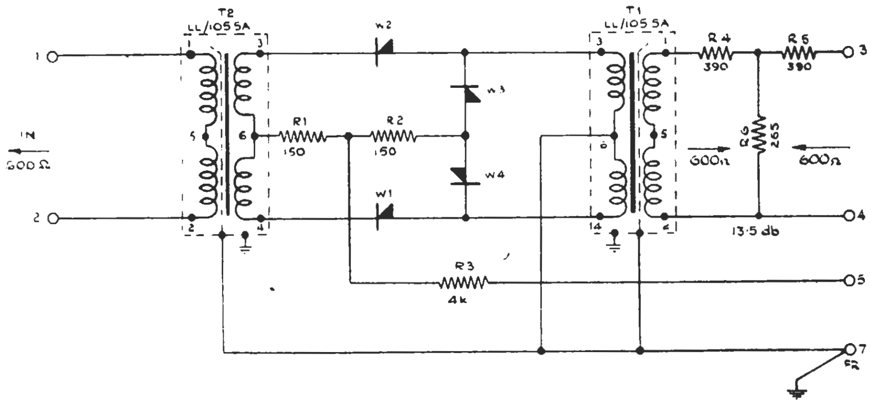


Fig. K.1. Modulator MR/4 : Circuit

Performance Tests

With −80 volts d.c. applied to terminal 5, and 2,600-c/s tone applied to terminals 1 and 2, the level measured across terminals 3 and 4, using a 600-ohm Amplifier Detector should be 15 db ± 0·5 db.

With +80 volts d.c. applied to terminal 5, and the other testing conditions unaltered, the additional attenuation introduced should be greater than 55 db.

Telegraph Detector TGD/1

Circuit Description : Fig. K.2.

The unit functions by first converting the voice-frequency telegraph signals to unidirectional current pulses capable of operating a Carpenter relay. This relay then varies the polarity of the local 80-volt direct-current supply to the teleprinter receiving magnet. A description of the Carpenter relay appears in Appendix K1.

The voice-frequency input signals at zero level are applied to terminals 1 and 2. The signals pass to the diode, V1 through transformer T1 and coupling resistor R4 ; the value of 0·6 megohms for R4 serves to maintain reasonable equality between the backward and forward time constants of the diode circuit. The unidirectional voltage pulses produced across C1 after rectification are taken to the grid of the pentode, V2 via a *Sensitivity* control and a smoothing network which attenuates the ripple by 16 db. In the anode circuit of V2 is the operating winding of the Carpenter telegraph relay, and also R17, the anode load.

In the absence of a signal at the detector input, the anode current of V2 is 9 mA, this value being adjustable by means of the *Standing Feed* control, R9, but when a signal is applied a negative voltage appears at the grid of the valve and the anode current drops to 3 mA.

An additional winding on the relay, provided for biasing purposes, is connected across the h.t. line in series with R13 and the *Bias* control, R15. The current in this winding is set at 6 mA, the mean value of the current in the operating winding ; the relay is therefore controlled by the variation in flux produced by the rise and fall of the current in the operating winding. Normally, the tongue of the relay is connected to a teleprinter via terminal 5 ; alternatively d.c. pulses may be passed on to the sending side of another convertor, for retransmission of the signals as voice-frequency pulses.

Spark-quenching components, C4, R11 and C5, R10 are connected between the relay tongue and its fixed contacts. Anode and screen decoupling for V2 are provided by C6, R12, and C7, R14.

Component Layout

All the components are carried on a small sub-chassis on the upper portion of which, besides the valves and input transformer, is mounted the Carpenter relay. This projects horizontally through the front cover, and is plugged into a special relay holder. A metal guide is provided to assist in locating the socket holes when plugging the relay into the holder. The guide also helps to keep the relay firmly seated.

3 mA by means of the *Sensitivity* control.

(3) Apply " reversals " to the input, and check that the mean value of V2 anode current is 6 mA. (See Section O.)

(4) Adjust the current in the relay bias winding to 6 mA by means of the *Bias* control.

Measurement of Distortion

Suitable test signals, consisting of voice-frequency pulses derived from a modulator **MR/4,**

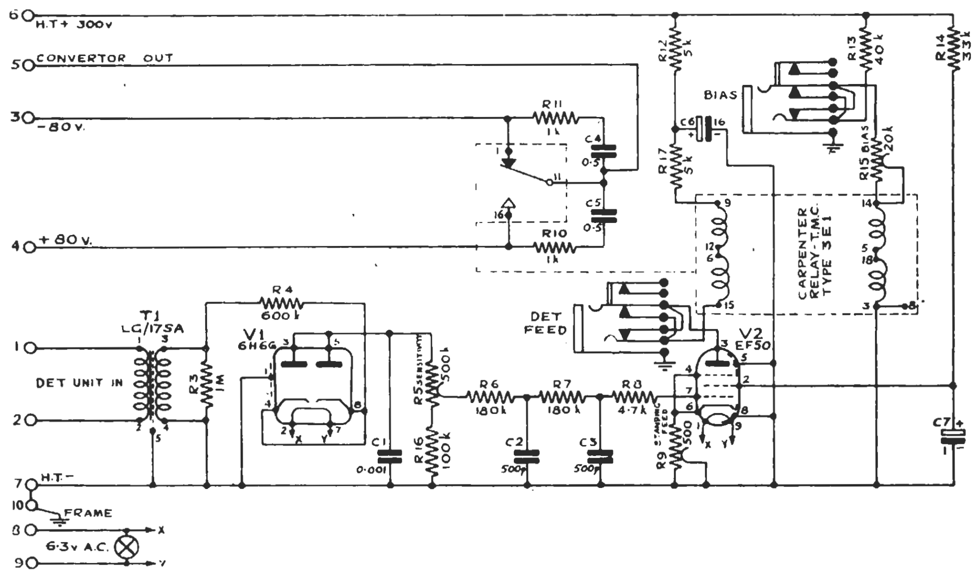


Fig. K.2. Telegraph Detector TGD/1 : Circuit

Lining-up Procedure

The adjustment of the Carpenter telegraph relay should first be checked using a portable plug-in milliameter (see Section O) the procedure being then as follows :

(1) With no signal input, adjust V2 anode current to 9 mA by means of the *Standing Feed* control.

(2) Apply 2,600-c/s tone at zero level to the input terminals through an auto-gain amplifier AGA/1, and adjust V2 anode current to

should be passed via an AGA/1 amplifier to the input of the TGD/1. The distortion should then be measured with the aid of a Telegraph Distortion Measuring Set TDM/2 (Section O).

When the TGD/1 is correctly lined up, the distortion should be less than 2·5% if test signals of ideal wave shape are used, such signals being obtainable from the output of an MR/4. If, however, the signals are applied via a standard 120-c/s bandwidth telegraph channel, the distortion will be increased, but should still be less than 7%.

APPENDIX K1

THE TELEGRAPH RELAY

Relays in telegraph circuits must be capable of responding to feeble current pulses of variable duration, and of reproducing these pulses with a minimum of time distortion. Telegraph relays are characterised, in comparison with telephone relays, by high sensitivity combined with rapidity of operation. These properties call for specialised design and also for precision in manufacture.

The magnetic circuit and contact unit of a Carpenter telegraph relay are shown in Fig. K1.1.

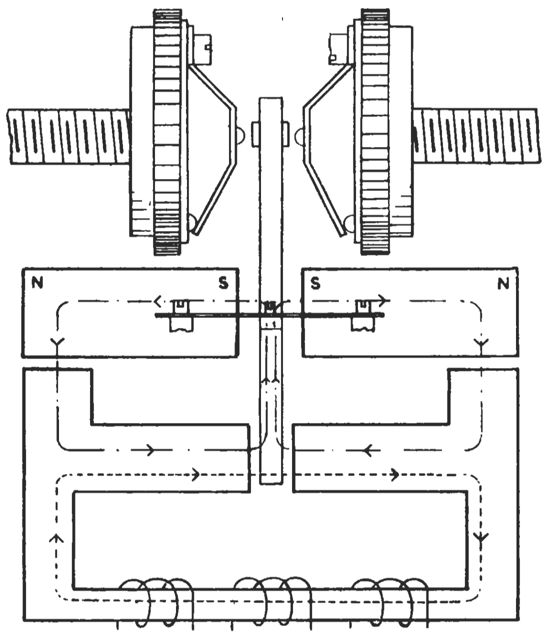


Fig. K1.1. Carpenter Relay ; Magnetic Circuit

The magnetic circuit is symmetrical and includes two permanent magnets, the other parts being made of soft iron. The heel of the armature, in the central gap, has induced south polarity.

The lower limb carries a number of separate windings. With no current passing through any of the windings, the fluxes in the left and right-hand upper branches of the magnetic circuit are equal and flow in opposite directions, so that the armature tends to remain in the neutral position. As this is not a position of stable equilibrium, some form of biasing is normally employed, in order to locate the armature definitely against one of the fixed contacts.

The passage of current through one or more of the windings results in the circulation of a flux round the lower and central limbs. If this flux circulates clockwise, as shown in the diagram, the tips of the left-hand upper and middle limbs of the soft-iron yoke acquire north polarity. Since the lower end of the armature has induced south polarity by virtue of the permanent magnets, the armature now rotates in a clockwise direction, and its upper extremity or " tongue," carrying the moving contacts, is attracted towards the right-hand fixed contact.

The contact gap is adjustable by the two knurled-headed screws shown, and is set to 0·001 inch approximately. This extremely narrow gap is an essential feature of the relay design, since, by limiting armature travel, sensitivity is increased and the transit time reduced so that the relay is capable of operating in less than 1 milli-second.

Biasing the relay, so that the armature normally rests against a particular fixed contact, may be effected as follows :—

(i) By displacement of the fixed contacts.

(ii) By upsetting the magnetic equilibrium with the aid of a magnetic shunt across one of the air gaps.

(iii) By passing a biasing current through one of the windings.

The various windings may be used either separately or together, in any combination as required by the circuit design. The telegraph relay on the TGD/1, for example, employs two series-connected windings for bias and a further two similar windings for operation. The bias current of this relay is normally set at 6mA, while the current passed via V2 through the operating windings is varied on receipt of a signal from 9 mA to 3 mA. The winding sense is such that the flux in the magnetic circuit is proportional to the sum or difference of the bias and operating-winding currents, and the flux therefore changes direction with " signal " or " no signal " condition. When this happens, it alters the polarity of the tips of the yoke branches adjacent to the armature, thus operating the relay to one side or the other.

On the TCB/1 (Section L) two series windings of the combiner relay are used for bias, and four separate windings are connected to different incoming circuits. On all apparatus where a bias current is used, proper adjustment of the bias-current control is essential in order to minimise pulse distortion.

SECTION L

TELEGRAPH COMBINER UNIT TCB/1

General

This unit is installed at the London termination of the Engineering Telegraph Network, where it is used to receive signals incoming over any one of four two-way teleprinter circuits and to re-transmit them over the other three. In order to avoid mutilation of the local copy on the sending teleprinter, the received signal is prevented from returning to the source.

The Combiner works with d.c. at 80 volts positive or negative ; if the main channel works for example, at voice frequency, it must be transformed to d.c. by means of the Telegraph Convertor TGC/5 described in Section K. Examples of this are the existing main circuits to Birmingham and the proposed circuit to Bristol. The circuit to Tatsfield is worked by d.c. on a phantom circuit derived from two lines.

The Telegraph Combiner depends for its operation on five Carpenter telegraph relays, T.M.C. Type 3E/1, a description of which appears in Appendix K1.

Circuit Description. Fig. L.1.

The essential components of the unit are the combiner relay, the four suppressor relays, and two bridge-connected metal-rectifier sets connected to earth and providing a positive and negative-polarity outgoing-power supply. The combiner relay employs five windings, one for biasing and one for each of the four channels, while the suppressor relay provided for each channel employs a single winding. In series with each winding of the five relays there is a fixed resistor which limits the current to a safe figure, a variable resistor permitting the value of this current to be adjusted, and a jack for connecting in circuit an external milliammeter. Each relay employs a single set of change-over contacts, across which are spark-quenching circuits consisting of a resistor in series with a capacitor.

The teleprinter circuit between London and each outstation comprises an incoming channel and an outgoing channel. The signals from the four incoming channels are applied across terminals 1, 3, 5, 7 and earth, while the outgoing signals are obtained across terminals 2, 4, 6, 8 and earth. Each receiving circuit of the combiner unit (e.g., between terminal 1 and earth) comprises a working winding of the combiner relay in parallel with the winding of a suppressor relay. Each sending circuit of the combiner unit (e.g., between terminal 2 and earth) passes via the tongue of the appropriate suppressor relay to either the break or the make contact on this relay. The break contact (the upper fixed contact as drawn in Fig. L1) is connected to the tongue of the combiner relay, the break contact of which is taken to earth via the 80-volt negative supply, and the make contact via the 80-volt positive supply. The connection from the make (i.e., lower) contact on the suppressor relay by-passes the combiner-relay contacts and is taken to earth through the −80-volt supply.

Circuit Operation

All four combining circuits are identical in operation, and it is necessary to consider only one of them, for example, circuit 4. The input to the combiner unit from the incoming channel for this circuit is at terminal 1, and the output from the unit for transmission over the outgoing channel is at terminal 2.

When no intelligence is being transmitted from the outstation over the incoming channel, a continuous marking signal, consisting of uninterrupted tone, is sent from the outstation over the channel. The tone is translated by a telegraph convertor at the London end into a standing 80-volt negative signal which is applied, via terminal 1 of the combiner unit, to No. 4 suppressor relay and in parallel to one of the combiner-relay working windings. The signal, being in the negative sense, does not operate the suppressor relay ; the signal on the channel under consideration for the same reason fails to operate the combiner relay, but this latter relay is also affected by signals incoming on the other three channels. When no intelligence is incoming over any of the channels, the combiner relay remains inoperative, and a marking signal from the negative pole of the rectifier unit is then applied to terminal

2 through the series break contacts of the two relays.

Suppose now, that intelligence, consisting of space and mark signals is received at terminal 1 over the incoming channel of circuit 4. The combiner relay operates on the space pulses and returns to the non-operated condition on the mark pulses, thereby causing the signals to be repeated over the outgoing channels of the remaining three circuits, via terminals 4, 6, and 8. The outgoing *mark* signals are also passed to the outgoing channel for the sending station, via terminal 2 of circuit 4, but the outgoing *space* signals on this channel are cut off by the operation of No. 4 suppressor relay and replaced by additional mark signals. A continuous mark signal is thus transmitted to the sending station, and mutilation of the sending teleprinter local copy is avoided.

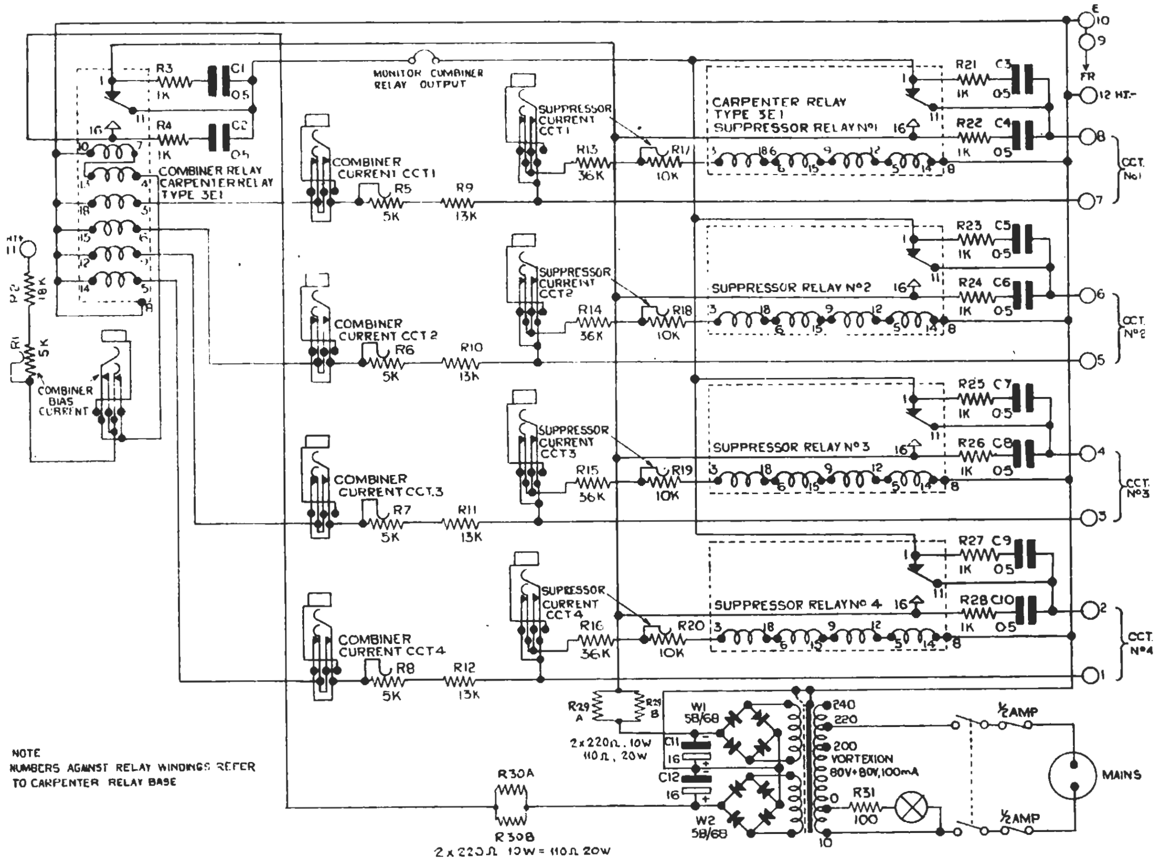


Fig. L.1. Telegraph Combiner Unit TCB/1 : Circuit

Similar considerations apply when intelligence is received over the incoming channel on circuit 1, 2 or 3.

Power Supplies

The double-bridge rectifier unit is capable of delivering a current of 60 mA at ±80 volts d.c. This current passes to the telegraph convertors on the outgoing channels through the contacts of the combining relay. A U-link provided in the combiner-relay output circuit allows measurement of the total sending current to all channels. The U-link also permits the channels to be disconnected, so that distortion measurements can be made; during these measurements a permanent marking signal, equivalent to standing tone on the carrier channels, should be sent to the outstations.

The current for the bias winding of the combiner relay is derived from a 300-volt d.c. external supply.

Mechanical Construction

All the components are mounted on a 9-inch panel, on the front of which are the variable controls together with feed-jacks and the telegraph relays. The fuses, pilot lamp and on-off switch are also mounted on the front of the panel.

Lining-up Procedure

The following adjustments should be carried out using the controls on the front of the panel in conjunction with a portable plug-in type milliammeter :

(i) Set the current in the bias winding of the combiner relay to 15 mA.

(ii) Applying a marking signal of −80 volts to each incoming channel in turn, adjust the current in each working winding of the combiner relay to 5 mA, and the current in the winding of each suppressor relay to 2 mA.

Performance Tests

Check that the current supply to each outgoing channel is 20 mA.

To ensure that the suppressor relays are functioning correctly, connect a centre-zero voltmeter across the outgoing channel of each circuit in turn while signals are being received on the incoming channel of that circuit. The instrument should show a marking condition.

The distortion introduced in the outgoing channels by the combiner should be checked with a Telegraph Distortion Measuring Set TDM/2 (Section O).

SECTION M

TELEGRAPH BRIDGING UNIT TBG/1

General

The Telegraph Bridging Unit is employed at intermediate stations on the Engineering Telegraph Network, its function being to combine the signals received from the *Up* and the *Down* directions, so that both may operate the local teleprinter. Facilities are also included for putting a marking signal on to both the outgoing channels (by the operation of a *Send Mark* key), so that if the local teleprinter sending circuit develops a fault, the distant teleprinters may be prevented from "racing." The usual 80-0-80 volt telegraph power supply is provided within the unit.

A general description of the Engineering Telegraph Network (E.T.N.) has already been given in Section B ; a diagram of the network appears as Fig. 5. The incoming voice-frequency telegraph signals are amplified at the intermediate station by a TV/24 and passed on to the next station via a modulator MR/4. The signals are also tapped at the intermediate station and applied via an AGA/1 to a detector TGD/1. To accommodate signals travelling in both directions, the units mentioned above are duplicated, the necessary apparatus being provided by two Telegraph Convertors, TGC/5 ; one of these convertors handles engineering telegraph traffic in the *Up* direction, and the other in the *Down* direction.

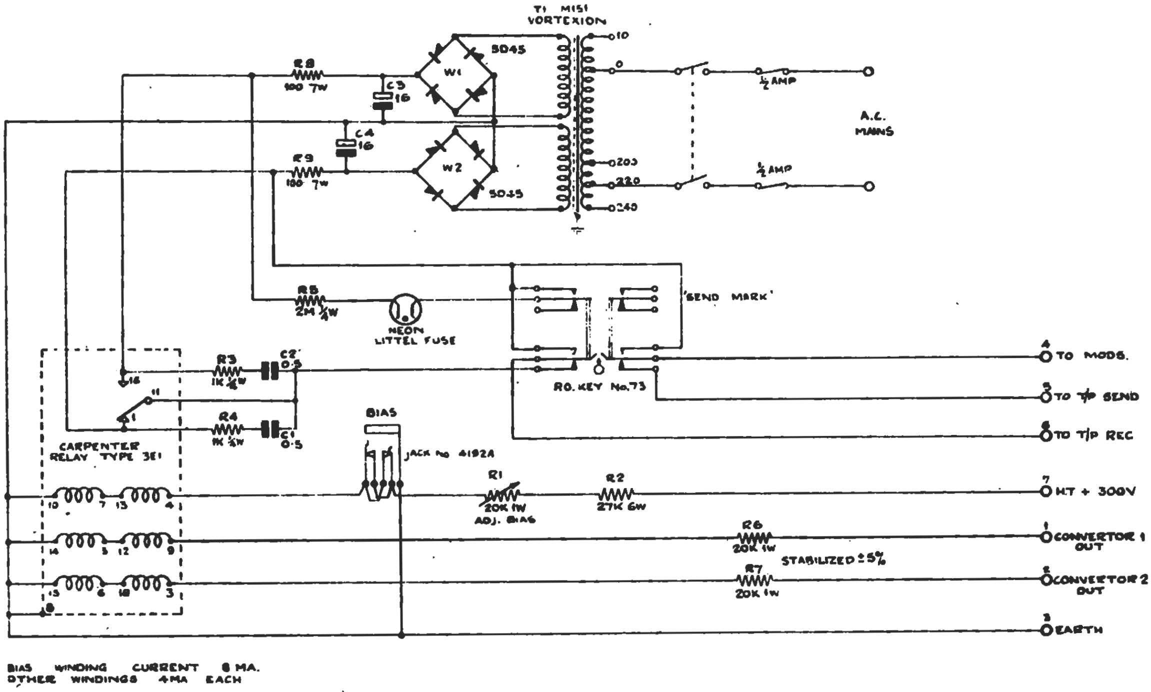


Fig. M.1. Telegraph Bridging Unit TBG/1 : Circuit

Circuit Description. Fig. M.1

The detector outputs of the two Telegraph Convertors are applied between terminals 1 and 2 respectively, on the bridging unit, and earth. The signals then pass to the two operating windings of the telegraph relay, the bias winding of which is supplied from an external d.c. source.

When no message is incoming from either

direction, a continuous marking signal is received in the form of standing tone at the input to each detector, this signal appearing as a negative voltage at the bridging-unit inputs. With the *Send Mark* key in the normal position, a similar negative voltage is applied through the relay contacts and terminal 6 to the local teleprinter receiving magnet. When the key is in this position, the local teleprinter sending circuit is connected via terminals 3, 4 and 5 to the modulators on the outgoing channels.

When a message is received from either direction, the positive and negative space and mark signals are regenerated by the relay before passing to the teleprinter receiving circuit.

With the *Send Mark* key in the operated position, the negative lead from the power supply is connected via terminal 6 to the teleprinter receiving magnet, and also to the modulators in the *Up* and *Down* channels on the E.T.N. When the key is thrown, a neon indicator-lamp lights up to serve as a warning that no local signals can now be sent out over the E.T.N.

The bias winding of the telegraph relay is supplied with a current of 8 mA from an external 300-volt source. In series with this winding there is a feed-jack together with a fixed and a variable resistor. A standard spark-quenching circuit, C1, C2, R3, R4 is connected across the relay contacts.

The power-supply circuit includes two safety resistors, R8, R9. These are to save the rectifiers from damage under abnormal load conditions, such as the application of an accidental short circuit.

The current taken by the neon indicator-lamp is limited to a few microamps by the series resistor, R5.

Mechanical Construction

The components are mounted on both sides of a 4½-inch panel, on the front of which are the Carpenter telegraph relay and *Adjust Bias* control, the *Send Mark* key, and the neon indicator-lamp. Also mounted on the front of the panel are the mains on-off switch and fuses and the mains pilot-lamp.

Conditions for Correct Operation

For correct operation the current in either working winding of the relay on a mark signal should be 4 mA, the current in the bias winding being 8 mA as previously stated. The current supplied to the local teleprinter and to each sending modulator should be 20 mA. The output voltage on either the positive or the negative supply should be 90 volts $\pm 5\%$ with a 20-mA load, or 70 volts $\pm 5\%$ with a 60-mA load.

The distortion of telegraph signals by the bridging unit can be checked with the aid of a Telegraph Distortion Measuring Set, TDM/2. The amount of distortion introduced is affected by the setting of the relay bias-current control, and the position of this control should be varied slightly until minimum distortion is obtained.

SECTION N

MAINS UNITS MU/37, MU/38

General

The MU/37 is used to supply power for operating or biasing a telegraph relay, and delivers 20 mA at 80 volts positive and negative. The MU/38 is used for sending d.c. telegraph signals over lines, and delivers 10 mA at 30 volts positive and negative.

Circuit Description. Fig. N.1.

The two units employ the same circuit arrangement (Fig. N.1), but have certain component differences indicated later. The numbering of resistors shown in brackets on Fig. N.1 applies to the MU/38.

The mains transformer, T1 on each unit has two secondary windings supplying the selenium bridge rectifiers, W1 and W2 the a.c. inputs and d.c. outputs of which are across opposite bridge diagonals. The input to each rectifier is entirely separate, but the two rectifier outputs are connected in series. The positive pole of W1 is connected through a current-limiting resistor to output terminal 1, and the negative pole of W2 is connected through a second current-limiting resistor to output terminal 3 ; the negative pole of W1 and positive pole of W2 are connected together and to the common output terminal, 2. Thus, a positive-going output is obtained at terminals 1 and 2, and a negative-going output (with relation to terminal 2) at terminals 3 and 2.

The two current-limiting resistors protect the rectifiers in the event of a short circuit across either output due to an external fault. In conjunction with reservoir capacitors C1 and C2, the resistors also assist in smoothing out the ripple. The 100-ohm resistor in series with the 6·3-volt pilot-lamp across the 10-volt tapping on T1 is inserted to reduce the voltage across the lamp to a suitable value.

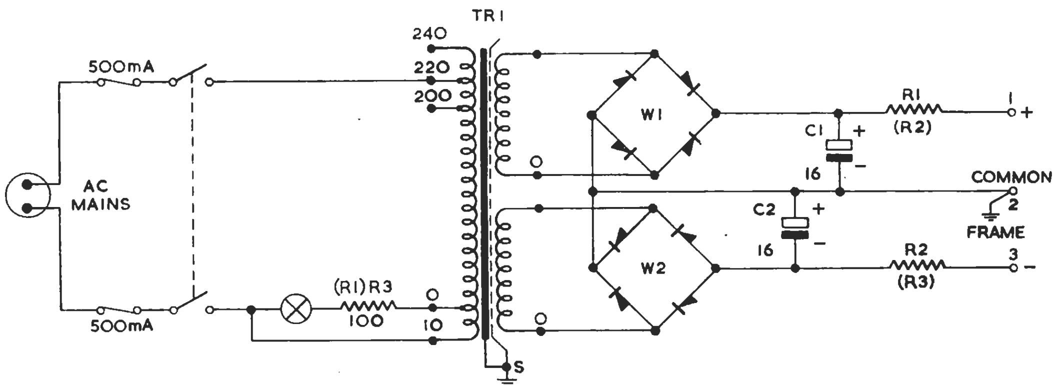


Fig. N.1. Mains Units MU/37, MU/38 : Circuit

The MU/37 and MU/38 have different earthing arrangements, those for the MU/37 being as shown in Fig. N.1. On the MU/38, the connection between terminal 2 and frame is omitted, but the mains earth and transformer screening are brought out together to an additional terminal (4) not shown on the diagram.

Mechanical Construction

All components are carried on a small sub-chassis of the type used in communication apparatus and suitable for mounting on a general pupose mounting GPM/1. The mains-input socket with the fuseholder, pilot-lamp, on-off switch and mains transformer are on the top of the chassis, and the remaining components are underneath.

General Data

Mains Transformer
MU/37 : BBC Type M 151.
MU/38 : BBC Type M 152.

Bridge Rectifiers
MU/37 : Westinghouse selenium Type 5D45.
MU/38 : Westinghouse selenium Type 5D23.

Reservoir Capacitors
16 microfarad, B.E.C. Type CE.15129.

Output Resistors
MU/37 (R1, R2) : 380 ohm, Painton Type P302.
MU/38 (R2, R3) : 330 ohm, Painton Type P301.

Lamp Resistor
MU/37 (R3), MU/38 (R1) : 100 ohm, $\frac{1}{4}$ watt, Painton Type 9.

Test Data

Rectifier Input Voltage
Measured across either secondary winding of T1 with corresponding rectifier on load.
MU/37 : 75 volts r.m.s.
MU/38 : 26 volts r.m.s.

Normal Output
MU/37 : 20 mA at 80 volts positive and negative, tolerance ± 3 volts.
MU/38 : 10 mA at 30 volts positive and negative, tolerance ± 2 volts.

Hum Voltage with Normal Load Current
Less than 5% of normal output voltage.

Output Current into a Short Circuit
MU/37 : approximately 110 mA.
MU/38 : approximately 65 mA.

SECTION O

TELEGRAPH TEST BAY CTTB/1

General

The CTTB/1 carries the following test equipment for the new communications system :

Telegraph Distortion Measuring Set TDM/2, comprising :
- Time Base Unit.
- Mains and Oscilloscope Unit.
- Calibrator Unit.

D.C. Jackfield.

A.C. Jackfield.

Key Panel KP/2.

Telegraph Relay Tester TRT/2.

Teleprinter Margin Tester TPMT/1, comprising :
- Waveform Generator Panel.
- Waveform Regenerator Panel.

All the units on the bay have self-contained power supplies, and four mains points are provided for feeding (*a*) the oscilloscope, (*b*) the TDM/2 mains and oscilloscope unit, (*c*) the TRT/2 and (*d*) the TPMT/1 waveform-generator motor. The key panel, KP/2 (Fig. O.1) carries two speak-ring keys for use with the portable engineering telephone handsets referred to in Section B.

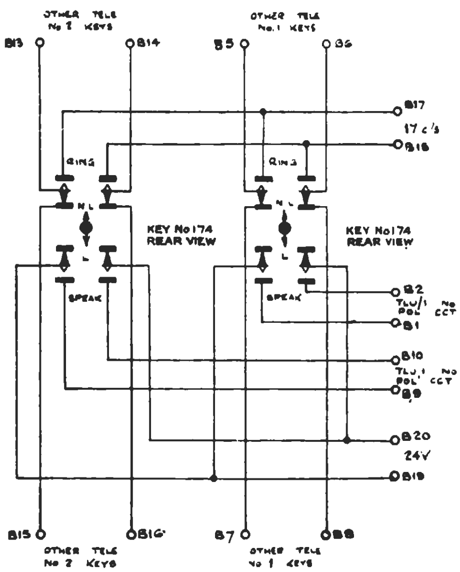


Fig. O.1. Key Panel KP/2 on Bay CTTB/1

TELEGRAPH DISTORTION MEASURING SET TDM/2

Introduction

This apparatus is used to measure distortion in the waveforms of teleprinter characters.

Every teleprinter character contains five signal elements, each lasting for 20 milliseconds and having either positive or negative voltage. These elements are preceded by a positive ' start ' signal, also lasting for 20 milliseconds, and followed by a negative ' stop ' signal having a minimum duration of 30 milliseconds.

Distortion of the characters consists in prolonging the positive elements at the expense of the negative elements, or vice versa. Thus, in the five-unit code, distortion occurs when the moment of change-over in signal-polarity is advanced or retarded with respect to the standard time-interval of 20 milliseconds, or a multiple thereof, measured from the beginning of the ' start ' signal. The distortion is termed negative when the change-over is early, and positive when it is late. The ratio between the time-displacement of the change-over and the normal 20 millisecond signal length, expressed as a percentage, is used as a measure of the distortion and, when testing, the greatest percentage noted in the period of observation is taken as the circuit distortion.

Figs. O.2a and O.2b depict the waveform of an undistorted and a distorted signal respectively. In the distorted signal the duration of the space element has been decreased and that of the adjacent mark elements increased ; the percentage of positive distortion thereby introduced is $100a/x$, while the percentage of negative distortion is $100b/x$.

General Description Fig. O.3

The TDM/2 is designed to measure distortion in telegraph signals received at random time-intervals and can therefore be used while circuits are handling traffic. The equipment is entirely electronic and has no moving parts, the signals whose distortion is to be measured being displayed on an oscilloscope.

A greatly simplified block schematic of the Measuring Set is shown in Fig. O.3 In order to lock the oscilloscope time base with the incoming

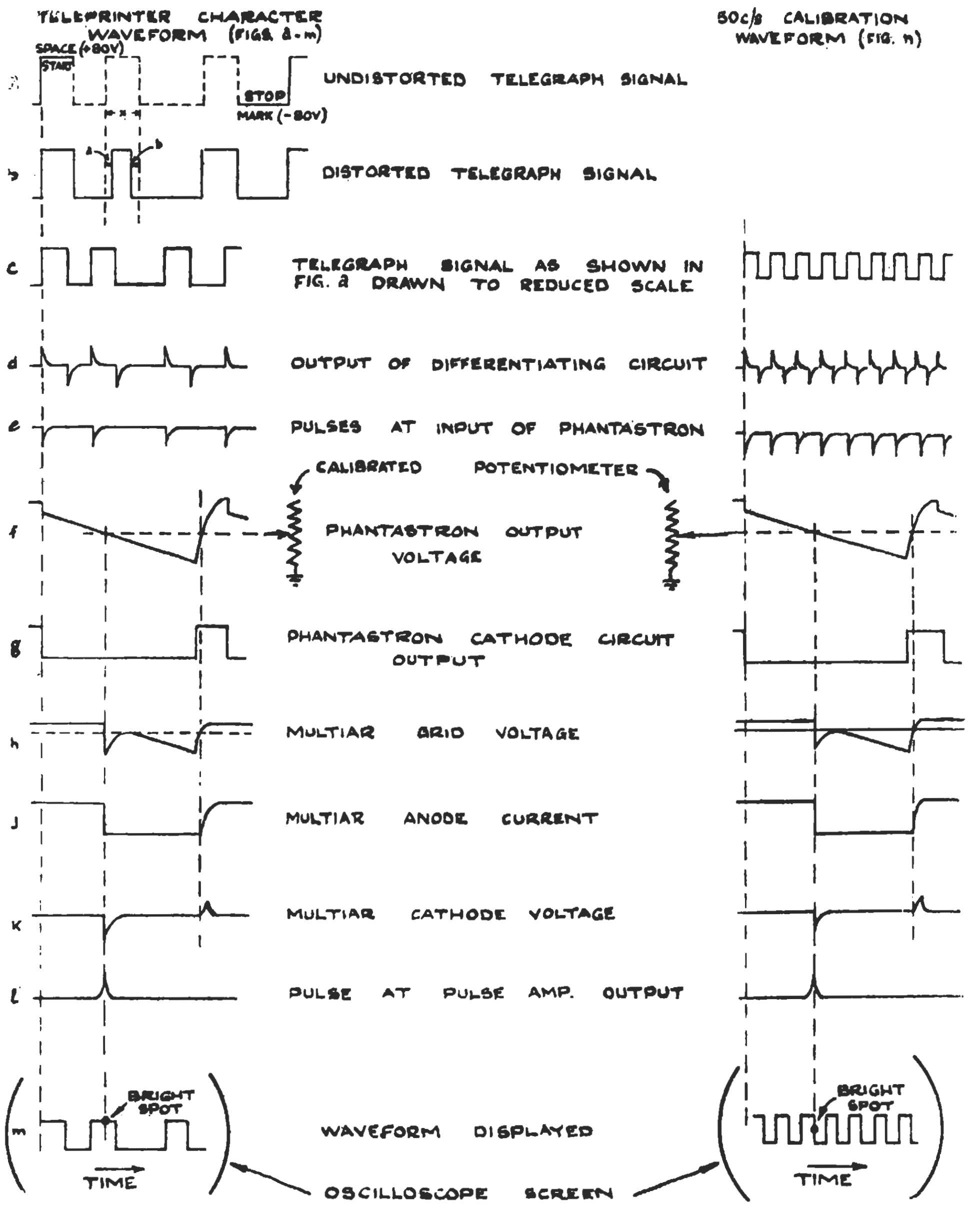


Fig. O.2. TDM/2 : Waveforms

signals these latter are tapped off and first applied to a differentiating circuit which generates a pulse at each change from mark to space and vice versa. The pulses representing negative incoming signals are suppressed, and the positive pulses are inverted and passed to the time base generator which takes the form of a phantastron circuit. This circuit

The pulse for brightening the waveform trace is derived from a multiar circuit, which produces a pulse at its output whenever two voltages applied to it become equal. One of these voltages is obtained from the time base generator; the other is a constant auxiliary voltage which is set at any chosen value by means of coarse and fine

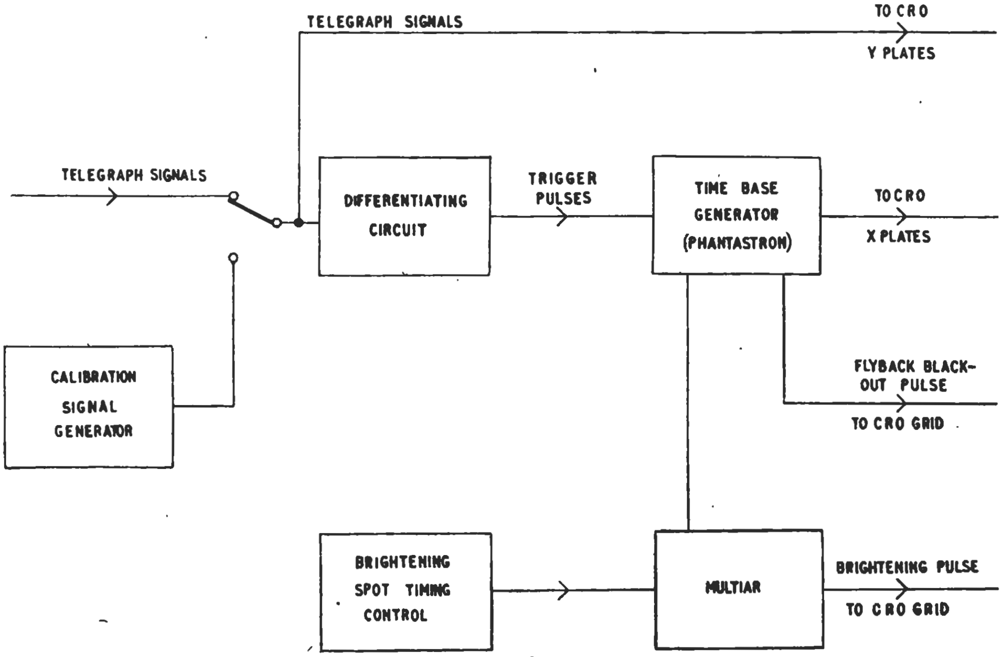


Fig. O.3. TDM/2 Simplified Block Schematic

is used because once it is triggered by a marker pulse from the differentiating circuit, it continues on its sweep cycle unaffected by subsequent marker pulses until it has returned to the quiescent condition. Thus the phantastron time base is the electronic equivalent of the rotating camshaft of a teleprinter which is set in motion by a 'start' signal.

The output of the time base generator is applied to the X plates of the oscilloscope, and the received signals to the Y plates; the distortion of the displayed character waveform is measured by causing a bright spot to move along the trace to certain reference points and reading the results on a calibrated potentiometer scale. The distortion is indicated directly in milliseconds with reference to the 'start' element of the character, and may thus easily be converted to a percentage.

timing controls whose scales are graduated in milliseconds. The scales are calibrated initially by means of pulses shaped from the 50-c/s voltage waveform of the mains, and therefore reversing in sign at 10-millisecond intervals. The fine control is marked in 0·5 millisecond steps, corresponding to 2·5 per cent of a complete signal element; a probable reading accuracy of 1 per cent may be obtained by interpolation.

Circuit Description

The equipment consists of three units—the Time Base Unit, the Calibrator Unit and the Mains and Oscilloscope Unit.

Time Base Unit Fig. 6

Included in this unit, as well as the phantastron time-base circuit proper, are a trigger-pulse amplifier, a return-sweep blackout amplifier and the multiar circuit together with its brightening-pulse amplifier. Cathode-follower valves are inserted as buffer stages in appropriate positions.

The waveforms occurring in the various parts of the circuit when teleprinter signals are incoming are shown in Figs. O.2c to O.2 m. Corresponding waveforms occurring when the equipment is being calibrated from the 50-c/s mains are shown in Fig. O.2n.

The telegraph signals whose distortion is to be measured are applied to terminals on the equipment marked TPR SIGS, or via tag 1 of the Time Base Unit. The incoming peak-to-peak voltage of 160 is attenuated by R35 and R36 to about 30 volts, and the signals are then taken to the Y plates of the cathode ray tube via R41, this resistance acting as a safeguard should the plates be connected to a circuit with low impedance to earth. To minimise radiation, which might adversely effect other circuits, a screened lead is used.

The incoming signals are also applied to the potentiometer R38, R39, which attenuates their voltage to 8 volts peak-to-peak approximately. The attenuated signals then pass to the differentiating circuit C6, R44, the time constant of which is short compared with a signal element. The marker pulses at the differentiating-circuit output are passed to the trigger-pulse amplifier, V4, which suppresses the pulses due to negative telegraph-signal elements, while amplifying and inverting those due to positive signal elements. A large amount of decoupling is required in the screen and anode circuits of V4, due to the low frequencies involved. The valve is heavily biased by the voltage developed across the 10-kilohm cathode resistor R45, and it is for this reason that only positive-going pulses are amplified. The voltage developed across R47, the anode load, is used to trigger the phantastron time base, comprising V5, V6 and V7. The amplitude of the trigger pulse is adjusted to 40 volts by the preset resistor R48, and the pulse is applied to the phantastron via the d.c.-blocking capacitor C11A.

Fig. O.4 shows the voltage waveforms in the phantastron circuit. Voltages shown are all positive with respect to earth.

The suppressor grid of V6 is at 26 volts and the cathode of V7 at 42 volts above earth. These voltages are set by the bleeder chain R50, R54, R53, R52 and are stabilised by the electro~~static~~ lytic capacitor C12, without which the voltages would be affected by variations in the current passing through R50 via V5 and V7.

As the grid of V6 is connected via R58 to V7 anode, and this diode normally conducts, V6 grid is also at 42 volts above earth. The quiescent cathode potential of V6 is set at 47 volts above earth by selection of a suitable value for the cathode-load resistor, R57.

Since the potential of the cathode of V6 is 47 volts and that of the suppressor grid only 26 volts, the suppressor grid, whose potential is 21 volts negative with respect to the cathode, cuts off the anode current and the whole of the current flows to the screen grid in the static condition. Upon the application of the 40-volt negative trigger pulse, the cathode of V7 is driven negative, its anode and the grid of V6 follow it, and so does the cathode of V6 by virtue of the presence of the unshunted cathode-load resistor R57. The potential of V6 cathode falls below that of the suppressor grid and this immediately causes a flow of anode current and, at the same time, drives the screen potential positive owing to the resultant fall in screen current which has been flowing through the resistor R61.

When anode current commences to flow in V6, the anode potential necessarily falls, and this fall is applied via the capacitor C13 to the grid of V6, which acquires an equilibrium potential from which point it slowly becomes slightly more positive as the run-down continues.

The diode V5 is connected to the anode of V6 and through the cathode-load resistor R51 to a tapping point on the bleeder chain R50-R52. Since in the quiescent condition V6 anode takes no current, its potential is controlled in part by the current through V5 and the resultant voltage drop across R55, R56 and R51. This is important because the potential from which the anode of V6 commences its run-down controls the duration of the sweep.

The anode of the diode V7 is connected to R55 via R59 and the resistance chain R88-R99, the tapping point on which is selected by the *Sweep Duration* control, SW4. By varying the current supplied to V7, this control affects the quiescent voltage drop across R55, and hence the voltage applied to V6 anode and the duration of the sweep. The resistance of the chain R88-R99 can be varied by SW4 in 0·5-megohm steps from 8·2 megohms to 13·6 megohms, the resultant change in sweep duration being from 100 to 150 milliseconds. The duration of the approximately square waveforms produced at the screen grid and cathode of V6 is similarly controlled by SW4.

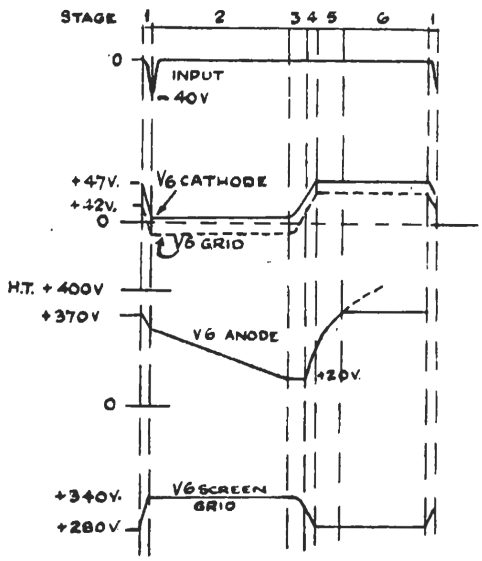


Fig. O.4. Phantastron Waveforms

Examination of the waveforms of Fig. O.4 will show that the potential of the grid of V6 reaches a value which is in the neighbourhood of zero volts before the linear part of the anode run-down commences, so that the anode current in the diode V7 is cut off even though the control pulse may not be completed. Since the diode V7 now has no effect upon the operation of the circuit, the valve V6 continues to function as a Miller[1] time base until the end of the run-down is reached.

When the anode potential approaches the completion of the run-down, i.e., when the anode potential approaches a potential near the knee of the anode-volts/anode-current characteristic, it remains fairly constant while the total space current increases since the grid becomes more positive. Although the space current increases, the anode current falls and the screen-grid current increases. Since the anode potential is relatively constant, the feedback ceases, thus permitting the mentioned increase of grid potential, together with an increase in the cathode potential by cathode-follower action, until finally the potential of the cathode exceeds that of the suppressor grid, whereupon the anode current is once more cut off. The anode and grid voltages rise rapidly toward the potential of the h.t. supply until the grid is caught at 42 volts by the diode V7.

The foregoing explanation of the phantastron circuit operation is based on that given by Puckle[1], and is much abbreviated. The particular variant of the circuit employed in the TDM/2 is similar to that referred to by Puckle as the 'cathode-coupled' phantastron, and for a complete description of its operation, reference should be made to the second edition of his *Time Bases*, which is the standard work on the subject. Various forms of the circuit have also been described by Williams and Moody.[2]

The phantastron output is taken from the anode of V6 to the X plates of the oscilloscope via the cathode follower stage, V9. R69 is the *Sweep Amplitude* control, and C18 is a d.c.-blocking capacitor.

In order to prevent the time-base flyback trace from appearing on the screen, a blackout pulse obtained from V6 cathode is applied to the grid of the blackout amplifier, V13, via the d.c.-blocking capacitor C24 and the preset *Blackout Amplitude* control, R81. V13 passes no current until a pulse is received on its grid at the start of the flyback; this pulse is applied after amplification to the grid of the cathode ray tube via the d.c.-blocking capacitor C29 and the *Blackout On-Off* switch SW5. The purpose of SW5 is to allow the grid of the cathode ray tube to be isolated from the TDM/2 when the oscilloscope is employed for measuring quantities other than distortion.

The output of the phantastron is also fed to the multiar circuit comprising V10, V11 and T4.

[1]. Puckle, O. S. *Time Bases*. Chapman and Hall (Second Edition, London, 1951). Chapter IX.
Material relating to the phantastron given on pages 173-176 of the above work is used here by permission of Messrs. Chapman and Hall, Ltd.

[2]. Williams, F. C. and Moody, N. F. 'Ranging Circuits, Linear Time-Bases and Associated Circuits.' *Journal I.E.E. Part IIIA*, 93 (1946) 320-321 and 1188-1199.
Material relating to the multiar, given on page 321 of the above paper, is included in this Instruction by permission of the Institution of Electrical Engineers.

The waveforms in this circuit are shown in Fig. O.5 A buffer stage between the phantastron and the multiar circuit is provided by V8 ; the value of the cathode-bias resistor, R65, in the circuit of this valve has been made high in order to prevent the flow of grid current.

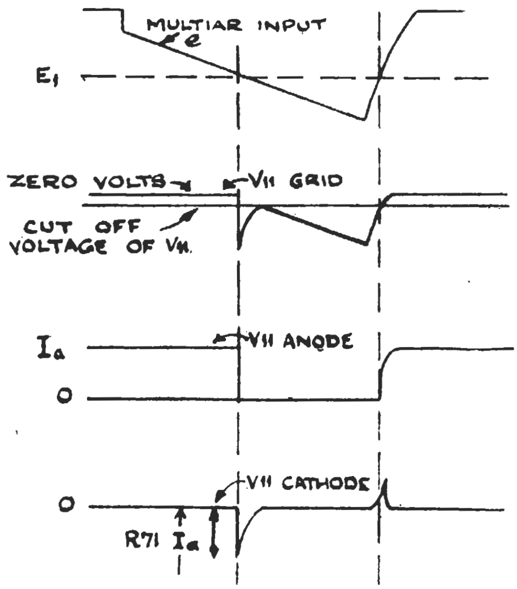


Fig. O.5. Multiar Waveforms

The constant auxiliary voltage for firing the multiar is obtained from timing controls via a cathode follower, V3 ; these controls and also the cathode follower are situated in the Calibrator Unit, Fig. 7. The h.t. supply at 270 volts to V11 is obtained via R7 from the 400-volt h.t. supply. In order that the grid and anode voltages of V11 shall not be affected by current surges in other stages, extra smoothing is provided by the inclusion of C4 and C5.

The multiar circuit itself is an adaptation of a radar strobe circuit which has been described by Williams and Moody.[2] By a suitable choice of cathode potentials for the buffer valves, V8, V3 a bias voltage, represented in Fig. O.5 by — E_1, is applied across the multiar diode, V10, making the anode of this valve negative with respect to its cathode. The time-base sweep waveform from the cathode of V8 is applied in a negative sense through one winding of T4 to V10 cathode. The anode of V10 is taken via C19 to the control grid of the multiar pentode, V11, and also via R72 to the cathode of V3.

The diode V10 will not conduct until the time-base sweep voltage on its cathode approaches the value — E_1, and until V10 conducts, V11 is isolated from the applied waveform and hence draws both grid and cathode current. At the instant when the time-base waveform reaches — E_1, V10 conducts and completes the regenerative circuit formed by T4. The result is a substantially instantaneous cessation of the cathode current through V11, accompanied by a sharp fall in the cathode voltage as shown in Fig. O.5.

During the remainder of the time-base sweep V11 remains cut off, since the time constant C19, R73 of the grid circuit is chosen to cause negligible differentiation of the applied sawtooth. When the time-base flyback occurs, a positive pulse is produced at V11 cathode, but this is suppressed by V12.

Since the time-base is itself linear, the time elapsing between the commencement of the time-base sweep and the multiar firing point is a linear function of the preset voltage E_1, and hence the delay may be controlled by this voltage. The value of E_1 is governed by V3 cathode voltage, this in turn depending on the setting of the timing controls on the Calibrator Unit.

The output pulses from the multiar circuit are passed via a short-time-constant R-C circuit C21, R76 to the brightening-pulse amplifier, V12. This valve has no cathode-bias resistor, and normally runs in a saturated condition. Hence only the negative ' pips ' from the multiar are amplified, these appearing in V12 anode circuit as large positives ' pips.' The anode load resistor R79 is tapped and serves as a *Brightening Pulse Amplitude* control. From R79 the pulses are taken via a d.c.-blocking capacitor C25 to the grid electrode of the cathode ray oscilloscope.

Calibrator Unit Fig. 7

This unit carries the coarse and fine timing controls for the multiar circuit and also the associated cathode follower valve, V3. The unit contains in addition a double-diode valve V1 which shapes the waveform used for calibration. This waveform is derived from the 50-c/s mains via transformer T1, which steps up the mains voltage to 530 volts r.m.s. The secondary-voltage waveform of the transformer is squared by severe clipping action of the two diodes comprising V1, the r.m.s. amplitude of the squared output being

[1] See note 2, page 49.

26 volts, fixed by the tappings on the bleeder chain R3, R4, R5. The squared pulses are passed to the Time Base Unit via transformer T3. C1 is a d.c.-blocking capacitor, while R1 limits the current through V1.

The multiar-circuit timing controls consist of two calibrated potentiometers embodying rotary switches, one for coarse control and the other for fine control. The *Coarse Timing* control, comprising the resistance network R8-R32, has a scale calibrated at 20-millisecond intervals from + 20 ms to + 120 ms, any inaccuracies in these timings revealed during calibration tests being corrected by means of trimming controls R15-R21. The *Fine Timing* control, comprising the tapped resistor, R33, is calibrated at 0.5-millisecond intervals from − 10 ms to + 10 ms.

The voltages set by the timing controls would be liable to variation if any appreciable current were to flow in the potentiometer sliders, and for this reason the resistance of the fine-control potentiometer R33, has been made extremely high, thus minimising the slider currents of the potentiometers selected by the *Coarse Timing* control rotary switch. The resistance of the slider circuit of R33 itself has been made even higher, by the use of the cathode follower, V3. The brightening-spot timing voltage is applied via R33 slider to the grid of this valve, which acts as a buffer stage preventing the multiar firing surges from affecting the functioning of the potentiometer.

Mains and Oscilloscope Unit Fig. 7

This circuit follows conventional lines. Mains transformer T2 and rectifying valve V2, with smoothing components L1 and C2, provide a power supply at 400 volts, the value chosen for R2 being such that this voltage appears at the terminals when the output current is 60 mA.

Mains transformer T5, together with V14 and the associated smoothing circuit, C30, L2, C31 delivers 15 mA at 300 volts and also supplies the valve-heater current for the Teleprinter Margin Tester TPMT/1 mounted on the same bay as the TDM/2.

Mechanical Construction

Time Base Unit

This unit employs a 9-inch panel with all wiring on the front and valves and electrolytic capacitors at the rear. The more frequently used controls, including all switches, are carried on a sub-panel and can be operated without withdrawing the front dust-cover. The monitoring sockets are mounted inside the front cover on a hinged sub-panel which, when lowered, allows ready access to all components and wiring.

Calibrator Unit

This unit employs a 4½-inch panel on the front of which are the coarse and fine timing controls and the trimming controls for the coarse-control potentiometers.

Mains and Oscilloscope Unit

The components of this unit are carried on a 13½-inch panel. The unit includes, in addition to the power supplies, a container for mounting a Mullard portable oscilloscope Type E800 or E805. The oscilloscope is connected to the Distortion Measuring Set by means of 'banana plugs' and suitable sockets. By the side of the oscilloscope is a desk which may conveniently be used to hold a data pad for recording distortion measurements.

Initial Alignment of TDM/2

(i) Switch on the mains unit.

(ii) Set the *Use-Calibrate* switch to *Calibrate.*

(iii) Adjust the fine-timing control to − 10 ms and the coase-timing control to + 20 ms.

(iv) Set the time-base switch on the oscilloscope to *External.* The calibration waveform should now appear. If necessary, adjust the *Sweep Amplitude* control and the *Trigger Pulse Amplitude* control until the waveform is displayed within the limits of the screen.

(v) Adjust the *Sweep Duration* control to display 6½ cycles of the 50-c/s waveform, thus obtaining a sweep duration of 130 milliseconds. (Note that if the sweep duration is less than 120 ms or more than 150 ms the TDM/2 will not synchronise on the 'start' element of a telegraph signal).

(vi) Operate the toggle switch on the front panel of the time base unit to obtain a blackout pulse, and adjust the *Blackout Amplitude* control until the flyback trace of the time base is eliminated.

(vii) Operate the *Brightening Pulse* toggle switch so that a bright spot appears on the displayed waveform, and adjust the *Brightening Pulse Amplitude* control until this spot becomes well defined. If the spot is not observed, or more than one spot appears, adjust the preset *Multiar Pulse Amplitude* control until a single well-defined spot is obtained. If necessary, readjust the *Brightening Pulse Amplitude* control.

(viii) The bright spot should be situated on the first voltage change-over point on the displayed waveform. If it is not, adjust the 10-ms trimming potentiometer on the calibrator panel until the spot is correctly located.

(ix) Varying the settings of the coarse and fine timing controls as necessary, adjust the 30, 50, 70, 90, 110 and 130-millisecond trimming potentiometers.

(x) Repeat operations (viii) and (ix) as a check.

(xi) Finally, return the fine-timing control to the centre position.

(xii) To carry out distortion measurements, throw the *Use-Calibrate* switch to *Use.* With the switch in this position, the bright spot is stationary on the screen when no teleprinter signals are being received, and to avoid burning the screen the *Use-Calibrate* switch should therefore be left on *Calibrate* except when signals are incoming.

Checking of TDM/2 Operation

Carry out adjustments (iii), and (ix) to (xi) as described under the previous heading. If a fault is apparent, switch off the blackout and brightening pulses and examine the shape and amplitude of the waveform at each monitoring point, comparing the waveform so obtained with the corresponding waveform shown in Fig. 8.

Additional guidance as to the nature of the fault may be obtained by checking the operation of the circuit against the data below.

Circuit Data

Voltages shown are measured with an Avometer Model 7 on the 400-volt range. D.c. voltages are with respect to earth. Unless otherwise stated, all readings are taken with the fine-timing control at centre scale and the coarse-timing control at + 20 ms.

Mains and Oscilloscope Unit

Power consumption (with signals applied): 0·45 amp at 230 volts a.c.

H.T. supply to TDM/2: 60 mA at 400 volts with signals applied, 75 mA at 375 volts with no signals applied. Hum, 1 volt r.m.s.

T2 secondary voltage (with signals applied): 750.

H.T. supply to TPMT/1: 15 mA at 300 volts.

Calibrator Unit

	Signals Applied	*No Signals Applied*
T1 primary voltage ...	230 V. a.c.	
T1 primary current ...	110 mA a.c.	
T1 secondary voltage ...	530 V. a.c.	
T1 secondary current ...	10 mA a.c.	
Voltage at junction R3, R4	26 V. d.c.	
Voltage at junction R4, R5	13 V d.c.	
Current through R3, R4, R5 with calibrator unit operating	11·5 mA d.c.	
H.T. to multiar via tag 10	320 V	250 V
V3 cathode current with coarse-timing control at + 20 ms ...	5·8 mA	4·3 mA
+ 120 ms ...	0·68 mA	0·68 mA

Slider voltages to earth, with coarse-timing control set in appropriate position, fine control at centre scale, trimming control fully clockwise and signals applied:

R15	340
R16	278
R17	278
R18	278
R19	185
R20	185
R21	185

Slider voltages to earth, as above but with trimming controls set to positions required for correct calibration:

R15	270
R16	218
R17	173
R18	131
R19	90
R20	50
R21	11

Time Base Unit

Valve		*Signals Applied*	*No Signals Applied*
V4	Anode volts ...	310	300
	Screen volts ...	320	310
	Cathode current (mA)	7·5	7·2

V5	Anode volts ...	175	
	Cathode volts ...	345	345
V6	Anode volts ...	170	165
	Screen volts ...	365	265
	Cathode current (mA)	2·5	10
V7	Cathode volts ...	42	
V8	Anode volts ...	400	375
	Screen volts ...	370	360
	Cathode current (mA)	2·4	7·1
V9	Anode volts ...	400	375
	Screen volts ...	375	360
	Cathode current (mA)	1·25	2·35
V10	Anode volts ...	175	220
V11	Anode volts ...	320	250
	Screen volts ...	255	170
	Cathode current (mA)	8·5	17·5
V12	Anode volts ...	4.5	
	Screen volts ...	110	105
	Cathode current (mA)	9·0	8·5
V13	Anode volts ...	100	70
	Screen volts ...	240	310
	Cathode current (mA)	2·35	0·36

TELEGRAPH RELAY TESTER TRT/2

General

This relay testing panel is intended for measuring the performance of the T.M.C. Type-3E/1 telegraph relay (designed by R. E. H. Carpenter) used on apparatus employed in the carrier communication scheme. The panel has its own mains-supply unit, and at stations where a Telegraph Test Bay is not installed it is mounted in some other suitable location.

Testing Facilities

Facilities are provided for carrying out the following tests :

(a) *Bias Test.* The armature of the relay is made to vibrate, and the time during which it rests against one side contact is compared by electrical means with that during which it rests against the other. (If the armature rests for an equal time against each contact, the bias is said to be zero ; by contrast, if it rests against the same contact all the time, i.e., it is not vibrating, the bias is said to be 100 per cent.)

(b) *Sensitivity Test.* This test is carried out by passing an alternating current through the operating winding of the relay, and increasing the current until the armature just vibrates with zero bias. The value of current required is a measure of the relay sensitivity.

(c) *Gap-width (or " Transit Time ") Test.* In this test the ratio between the time during which the relay armature is in transit and the time during which it rests on the side contacts is indicated on a meter. The ratio is a function of the operating current of the relay and the width of the contact gap, so that if the operating current is standardised, the ratio can be used to measure the gap.

Circuit Description Fig. O.6

The mains input to the test panel is through two 0·5-amp fuses and a double-pole on-off switch connecting to variable tappings on the mains transformer. Across the 10-volt tapping is a 6-volt pilot-lamp in series with a voltage-dropping resistor.

The transformer has two secondary windings, one of which supplies alternating current to the operating winding of the relay under test, via the *Adj. Wdg. Current* control R1, and a metal rectifier W2, which, with a moving-coil milliameter, M1, is used for measuring the coil current. The other transformer winding is connected to metal rectifier W1 ; the output of this rectifier, after smoothing, is applied at 16 volts d.c. via the *Adj. Bias Full Scale* control R7 to a bridge circuit in which are the relay contacts and a galvanometer M2. The bridge (Fig. O.6) includes two variable elements, the *Bal. Bdge.* (*Bias Test*) control R10 and the *Adj. Zero* (*Gap Test*) control R14, and by means of a 3-position key S1, the bridge connections can be arranged either as shown in Fig. O.8 or as in Fig. O.9. The galvanometer is normally protected by two series resistors, R16 and R17, but R16 can be short-circuited when required by means of a key labelled *Galvo* × *5*, multiplying the sensitivity by five.

Meters

The moving-coil milliammeter M1 is basically a 0-9 mA d.c. instrument, which for use with the rectifier W2 has been re-calibrated to indicate 0-10 mA a.c. The instrument has an edgewise scale, and is provided with a magnetic screen.

The galvanometer M2 is a flush-mounting 500-0-500 moving-coil microammeter with a modified scale. It is calibrated in terms of percentage relay bias, the scale on either side of the centre zero having 20 small divisions, each normally representing a bias of 5 per cent or, when the magnifying key is depressed, a bias of 1 per cent. A gauge mark on either side of the scale at 48 per cent (i.e., 9·6 divisions, or 240 μA) is provided for use in gap-width tests.

Connection to an External Circuit

A toggle-switch is mounted on the panel below the galvanometer magnifying key, and when this switch is moved from *Normal* to *External*, the relay-jack on the panel is disconnected, so that the circuits of the TRT/2 can be used to test a relay on the Teleprinter Margin Tester TPMT/1, on the same bay. With this arrangement the operating winding of the TPMT/1 relay continues to be energised from the Margin Tester, thus allowing the overall performance of this instrument to be estimated.

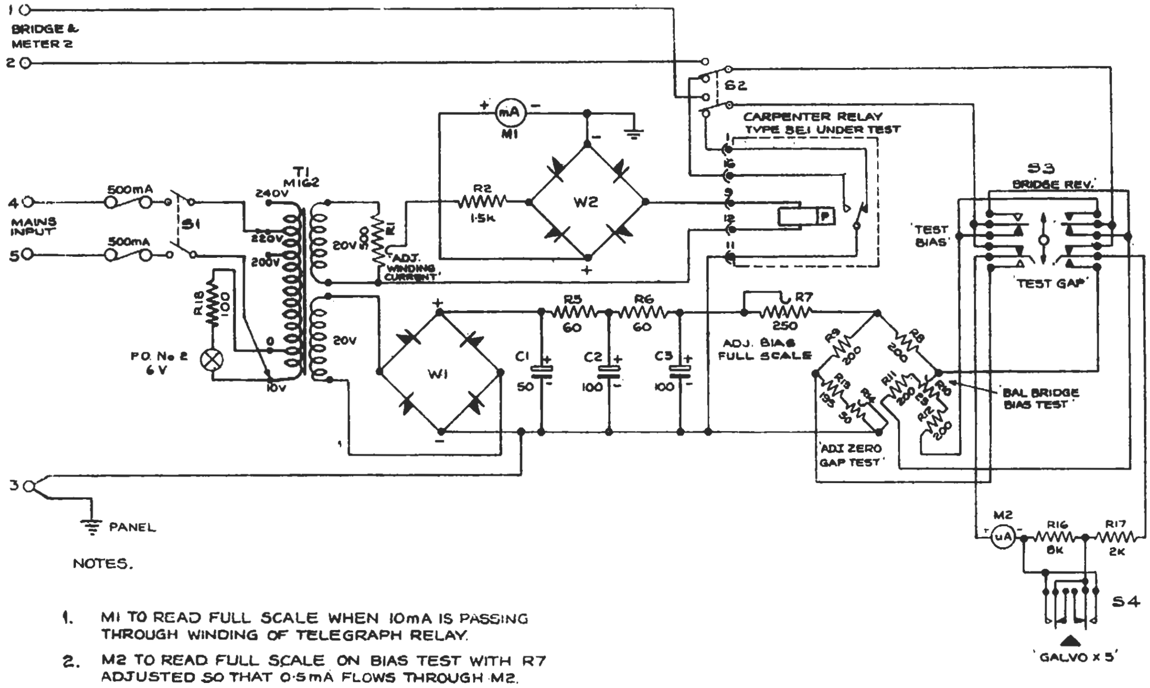


Fig. O.6. Telegraph Relay Tester TRT/2 : Circuit

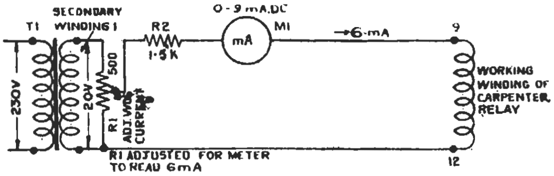


Fig. O.7. TRT/2 : Relay Sensitivity Test

Bias Test Fig. O.8

General Principles

The armature of the relay is set into vibration by the application of a sine wave derived from the 50-c/s mains. A positive d.c. potential is applied to the fixed or " side " contacts of the relay through two resistances, the values of which have been adjusted to exact equality during a preliminary calibration test, and the moving contact of the relay and negative pole of the supply are earthed. The voltage drops developed across the resistances are compared by a null method, in which the voltages are applied to the galvanometer alternately, with opposite polarity, as the relay armature vibrates. Due to the inertia of the moving system of this instrument, the deflection produced is dependent only upon the difference between the average values of the voltages applied.

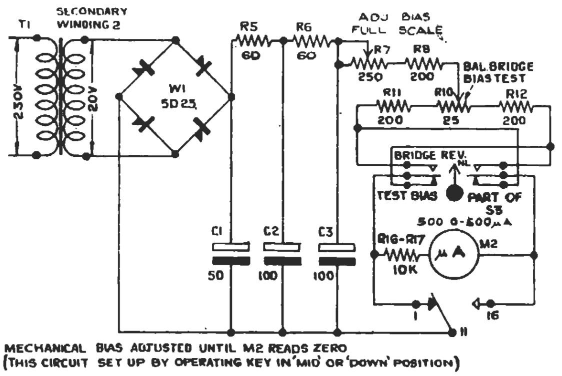


Fig. O.8. TRT/2 : Relay Contact Bias Test

When the relay is biased, although the current pulses through both side contacts are of equal magnitude, the pulse lengths and hence the mean values of current differ. Consequently, unequal mean voltages are developed across the series resistors, and unequal impulses are therefore applied to the galvanometer. As, by suitable adjustment of the side contacts, the bias is progressively reduced, there is a corresponding fall in the difference between the voltages across the resistors. When zero bias is approached, the opposing impulses applied to the galvanometer cancel out, and the pointer of the instrument remains in the central zero position.

Calibration of Test Circuit

With a relay in position on the panel, and the relay armature at rest against either of the side contacts, the key S3 is operated from the *Test Bias* to the *Bdge. Rev.* position. The galvanometer M2 is observed and the *Bal. Bdge.* (*Bias Test*) control R10 is adjusted until equal meter deflections are obtained in both positions of the key. The bridge being now in " static " balance, the *Adj. Bias Full Scale* control R17 is adjusted until full scale deflection is obtained on M2.

The relay armature is then set into vibration by passing 6 mA a.c. through the winding, and the bridge is balanced by adjusting the side contacts for zero bias as described.

Gap-width Test Fig. O.9

General Principles

To adjust the width of the contact gap, the relay is inserted in one of the arms of an equal-ratio bridge, with two equal resistances connected as before to the side contacts, as shown in Fig. O.9. While the armature of the relay is resting against either one of the side contacts, a current flows through the bridge arm containing the relay, passing via R11 or R12, but while the armature is actually moving, no current flows through the arm.

The bridge is first adjusted to balance with the armature at rest. The armature is then set into vibration, and the consequent reduction in the mean value of the current flowing through the relay contacts disturbs the balance of the bridge. The out-of-balance current across the bridge diagonal is a measure of the transit time of the armature, and hence of the width of the gap. This current is observed from the deflection of the

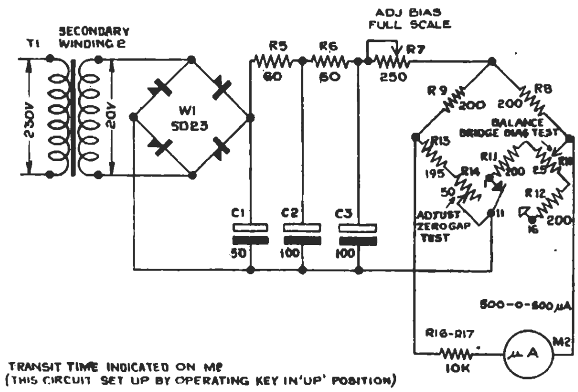


Fig. O.9. TRT/2 : Relay Contact Gap-Width Test

galvanometer, and the gap width is varied by adjusting the positions of the side contacts until the instrument pointer is opposite a calibration mark on the scale. If the frequency, magnitude and waveform of the alternating current in the operating winding of the relay conform to a standard, and provided that the previously obtained condition of zero contact bias has not been disturbed by the gap-width adjustment, the meter indication signifies that the gap width is now correct. It is, however, not easy to adjust the width of the gap without upsetting the bias, and it will generally be necessary to repeat both adjustments alternately a number of times before they can be made simultaneously correct.

Calibration of Test Circuit

This calibration consists in balancing the bridge (Fig. O.9) with the armature of the relay at rest. Since resistors R10 and R7 have already been adjusted for the bias test, it only remains to adjust R14, the *Adj. Zero (Gap Test)* control. The circuit is first set up by throwing key S3 to *Test Gap*, and R14 is then adjusted until galvanometer M2 reads zero. This indicates that the bridge, consisting of arms R8, R9, R13 and R14, and part of R10 plus R11 or R12, is balanced. The armature of the relay is then made to vibrate by passing 6 mA a.c. through the winding, and the relay contacts are adjusted to balance the bridge again as described.

Complete Procedure for Setting up a Relay

Preliminary Operations

(1) Remove the dust cover from the relay and, with the aid of a magnifying glass, make a careful examination of the magnet system for particles of magnetic dust. The presence of any such particles in the gaps will seriously impair performance ; even if they are adhering closely to the pole faces or armature they are liable to get into the gaps when the relay is operated, so it is absolutely essential that they should all be removed. For clearing away the particles, the relay manufacturers recommend an air blast at a pressure of 200 lb/sq in., but it is also possible to remove them with the aid of adhesive tape, such as "Selotape," "Durex" tape or black Empire tape.

(2) Slacken off the clamps on the screws carrying the side contacts of the relay, and turn the screws until both side contacts are as far away from the traveller as possible.

(3) With a smooth burnishing tool (such as a P.O. contact cleaner No. 2, or a feeler gauge of 0·006 in. thickness or less) gently burnish the steel pips and the surfaces between the bowed springs on which the side contacts are mounted. This operation, which improves the performance of the relay when it has become erratic, should be carried out with great care and only very occasionally, perhaps once a year.

Bias Adjustment

(4) Insert the relay in its socket on the panel.

(5) Turn the bias magnet so that it is central.

(6) Apply power to the tester by operating the mains toggle-switch S1 situated near the pilot-lamp and fuses on the left-hand side of the panel.

(7) Adjust the current in the relay winding, indicated on the edgewise-scale milliammeter M1, to its maximum value by means of the *Adj. Wdg. Current* control. (At this stage in the test, the relay armature is well outside its equilibrium position, and does not therefore vibrate.)

(8) Throw the toggle-switch S2 on the right of the galvanometer to *Normal.*

(9) Set the lever-key controlling the bridge circuits to its middle position, marked *Test Bias.*

(10) Advance the side contact nearest the armature until it just touches the traveller. This will be indicated by a deflection of the galvanometer M2.

(11) Calibrate the bias-test circuit as follows :

(a) Rotate the *Adj. Wdg. Current* control as far as possible anti-clockwise, so that zero winding current is indicated on the milliammeter.

(*b*) Throw the lever-key to *Bdge. Rev.* (Bridge Reversed), and observe the galvanometer ; if its reading alters, vary the setting of the *Bal. Bdge. (Bias Test)* control by means of a screwdriver until movement of the key from *Test Bias* to *Bdge. Rev.* and back again does not affect the galvanometer reading.

(c) Vary the *Adj. Bias Full Scale* control until full-scale deflection is obtained on the galvanometer.

(12) Again increase the current in the relay winding to maximum. Then slowly advance the side contact against which the traveller is resting as a result of (10) until the armature flops over to the other side. (The armature will not touch the other contact until this also is screwed forward.) Advance the second side contact until it is touching the armature, this being indicated by a deflection of the galvanometer when

the lever-key is thrown to *Test Bias*. Continue to advance the contact slowly until the armature either flops back to the first side contact or else vibrates. If the armature returns to the first side contact, advance this contact slowly until the armature either vibrates or moves over to the other side. Continue this procedure by slowly advancing one contact at a time until the armature is vibrating.

(13) Adjust the side contacts until the bias has been reduced to 5 per cent, indicated by a galvanometer deflection of one small division. Depressing the magnifying key to the right of the galvanometer, the reading should now increase to five small divisions. With the key depressed, adjust the contacts until the reading is again reduced to one division, which now corresponds to a bias of 1 per cent. Continue with the adjustment until the bias is reduced to a minimum.

(14) Reduce the operating current in the winding step by step to 5 mA, carrying out the adjustment indicated in (13) at each step as the current is reduced.

WARNING :—During operation (12), it is possible to screw the side contacts solidly against the armature, and as this is liable to cause damage, it must be avoided by watching the galvanometer closely, and withdrawing both contacts immediately if a zero reading is seen. Although this reading may possibly indicate that the relay is in correct adjustment and vibrating with zero bias, at this stage in the procedure it should always be taken as a warning that the contact gap may have been completely closed.

Gap-width Adjustment

(15) If the complete procedure as described has not already been carried out, first calibrate the bias-test circuit by performing operation (11). Now throw the bridge key to *Test Gap*, and turn the *Adj. Wdg. Current* control as far as possible anti-clockwise, so that the armature of the relay does not vibrate. If the galvanometer now reads zero, this is an indication that the bridge in the test circuit is balanced ; if the galvanometer pointer is deflected in either direction, even with the magnifying key depressed, the bridge must be balanced by varying the setting of the *Adj. Zero* (*Gap Test*) control until a zero reading is obtained.

(16) Rotate the *Adj. Wdg. Current* control until a winding current of 6 mA is indicated on the milliammeter. The relay armature should now vibrate and, if the gap width is correct, on depressing the magnifying key the galvanometer pointer should come to rest opposite the red line at 9·6 small divisions on the scale. This indication corresponds to a transit time of 10·5 per cent, or an operating time* of 89·5 per cent. If the galvanometer does not come to rest opposite the red line, adjust the side contacts until the required indication is obtained ; while carrying out this adjustment, make frequent checks to ensure that zero bias is maintained.

Final Adjustment and Testing

(17) When the relay armature is vibrating with 6 mA in the operating winding and the correct gap width is registered with no bias, lock the clamps on the screw adjustments for the side contacts and repeat the measurements of gap width and bias. If these are still correct, replace the dust cover on the relay, and secure the cover in position by tightening the retaining screw.

(18) The replacement of the dust cover is almost certain to affect the bias, so that the following adjustment is required. Ensuring that a current of 6 mA continues to flow in the operating winding, rotate the bias magnet by means of a screw-driver engaging in the slot accessible through the hole in the dust cover until there is " zero " (i.e., less than 1 per cent) bias. The replacement of the dust cover may also affect the apparent gap width, and this also should be checked. If an incorrect gap width is indicated, remove the dust cover and adjust the side contacts before again replacing the cover.

*The expression " percentage operating time," as used by R. E. H. Carpenter, denotes that portion of the time occupied by a complete cycle of vibration during which the armature of the relay is at rest.

(19) As a further check, the relay sensitivity should now be measured by increasing the operating current slowly from zero until the armature vibrates with zero bias. The value of current required should be 2·8 mA ± 0·5 mA, and if the bias is not zero with this current, it can be made so by adjustment of the bias magnet, as in (18), without affecting the bias at any greater value of current.

Routine Testing of a Relay

(a) Insert the relay in the test socket. Switch on the power supplies. Set the Normal-External switch to *Normal*.

(b) Calibrate the bias-test circuit as in operation (11).

(c) Calibrate the gap-width test circuit as in operation (15).

(d) With an operating current of 6 mA the bias test should show less than 1 per cent of bias, and for the gap-width test the galvanometer needle should be opposite the red mark on the scale when the magnifying key is operated. If the bias is not zero, it can be adjusted by turning the bias magnet with a screw-driver. The sensitivity should be checked as in operation (19).

(e) If operation (d) shows that the relay is erratic, the complete setting-up procedure should be carried out.

Maintenance Data for TRT/2

Sensitivity-test Circuit Fig. O.7

With 10 mA a.c. (indicated on milliammeter M1) flowing through the relay winding, the voltage across the *Adj. Wdg. Current* control R1 should be 18 ± 2 volts.

Bias-test Circuit Fig. O.8

When this circuit is correctly calibrated, the d.c. potential across C1 should be 22 ± 2 volts, and that across C3 should be 16 ± 2 volts.

Smoothing Network Fig. O.8

If the voltages across C1 and C3 are checked on an oscilloscope, it should be found that the smoothing network reduces the hum content by at least 15 to 1.

TELEPRINTER MARGIN TESTER TPMT/1

General Description

The apparatus is used for determining the distortion margin of a teleprinter, i.e. the maximum percentage time-distortion of the applied signal-waveform which can be tolerated by the teleprinter before it ceases to interpret the received signals correctly.

The Margin Tester consists of two panels, one referred to as the Waveform Generator and the other as the Waveform Regenerator. The Waveform Generator panel carries a glass disk with a photographic record of the test signals, a light source and photocell, and a small detachable sub-chassis mounting the components of the Head and Differential Amplifier. The Waveform Regenerator panel carries a valve regenerator and a Carpenter telegraph relay for operating the teleprinter under test.

Thirteen test signals, of varying degrees of distortion, are arranged on the glass disk in concentric tracks. There are also two tracks of distortionless repetitive signals for testing telegraph apparatus other than teleprinters and for estimating the performance of the tester itself. Any track required can be selected by operating a rotary switch on the front panel.

The glass disk is driven at a speed of 33 1/3 r.p.m. by a standard gramophone motor, Garrard Type 37, via a worm drive. The speed can be adjusted by operating a control on the front panel, and it can be checked with the aid of a neon stroboscope. The neon is viewed through a glass window, and a special track on the disk is used to obtain the stroboscopic effect.

The electrical pulses, derived from the record, which appear at the output of the photocell are not suitable for use as test signals as they contain random amplitude variations and are trapezoidal in shape. If these pulses were applied to a telegraph relay random time-distortion would result, and for this reason the pulses are first differentiated, the marker pips so produced being used to trigger a side-stable ' flip-flop ' circuit, termed a regenerator, the output from which is applied to the relay. The output waveform of the regenerator contains negligible random time-distortion and leaves untouched the distortion as generated by the glass disk record. Fig. O.10 shows the shape of the above-mentioned pulse waveforms.

Test Signals on the Glass Disk Record

Starting at the outside and working inwards, the tracks on the glass disk contain the following test signals:

Track I	Repetitive signal of equal mark-to-space ratio, frequency 20 c/s.	
Track II	Repetitive signal of mark-to-space ratio 1 : 5 (25 to 125 millisec.).	
Track III	PURGATORY	(Zero distortion)
,, IV	+ 20%	
,, V	SALVATION	(+ 20% distortion)
,, VI	− 20%	
,, VII	DAMNATION	(− 20% distortion)
,, VIII	+ 30%	
,, IX	SALVATION	(+ 30% distortion)
,, X	− 30%	
,, XI	DAMNATION	(− 30% distortion)
,, XII	+ 40%	
,, XIII	SALVATION	(+ 40% distortion)
,, XIV	− 40%	
,, XV	DAMNATION	(− 40% distortion)

In addition to the above information the tracks also contain 'letters,' 'figures,' 'line-feed' and 'carriage-return' and 'space' signals.

Circuit Description

Motor, Stroboscope and Light Source

These are supplied from the 50-c/s mains through a plug and socket and a d.p.s.t. switch, S3. The Garrard Type-37 motor is connected directly across the incoming supply and the Osglim neon indicator, BBC Type S1, for the stroboscope is connected to the supply in series with R25, a 10-kilohm 1-watt resistor. The light-source for the photocell is provided by an Osram b.c. 10-volt lamp, drawing a current of 5 amps supplied through S3 via a 240-V/9·75-V transformer, T2.

Head and Differential Amplifier *Fig.* 9

The signals from the output of the photocell are applied to the grid of the head-amplifier valve, V1A. The cathode-follower circuit used for this stage has a high input impedance and therefore allows a large voltage output to be obtained from the cell. A screened co-axial cable connection is employed between the photocell and the grid of the triode, to prevent the introduction of noise and mains hum from neighbouring circuits.

The voltage applied to the photocell is derived across the preset resistor R3, the *Adj. Gain* control, which allows the voltage across the cell, and therefore the signal amplitude, to be varied, the maximum photocell voltage being 90 volts d.c. The value of R1 is selected to give V1A the required input impedance. R2 is a cathode-bias resistor.

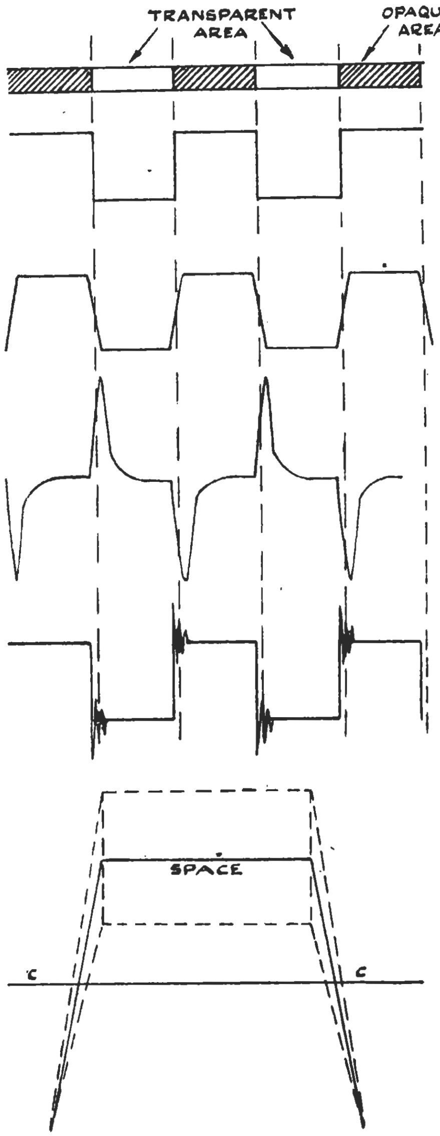
The signals from the cathode-follower output are applied to the differentiating circuit C1, R4 and the marker pulses so produced are amplified by the differential amplifier V1B before being used to trigger the 'flip-flop' circuit of the Waveform Regenerator.

The voltage waveforms at various points in the circuit can be observed by connecting an oscilloscope to monitoring sockets provided on the front panel of the Waveform Generator. A representation of an ideal current waveform as applied to the winding of a telegraph relay is shown in Fig. O.10b. The waveform obtained from the cathode follower at the monitoring point *Head Amp. Out* is shown in Fig. O.10c. The trapezoidal shape is due to aperture distortion in the light-path. In addition, owing to variations in the degree of transparency of the track on the glass disk, the amplitude of the signals of Fig. O.10c tends to vary in the manner depicted in Fig. O.10f. From this figure it will be seen that a relay set to operate and de-operate at *CC* would do so at a time dependent upon the amplitude of the signals. It is in order to obviate this form of distortion that the signals are differentiated, to be subsequently regenerated by a telegraph relay operated by the 'flip-flop' circuit comprising V2A and V2B. The marker pulses at the output of the differentiating circuit can be monitored at a socket designated *Diff. Out*, and the amplified pulses obtained from the anode of V1B at a further socket, designated *Diff. Amp. Out*. The waveform at this point is shown in Fig. O.10d.

Waveform Regenerator and 80-*volt Supply* *Fig.* 9

The marker pulses from the Differential Amplifier V1B are supplied to a side-stable 'flip-flop' circuit employing the two sections of the double-triode valve V2.

The operation of this circuit is briefly as follows. A positive marker pulse opens V2A and closes V2B while a negative marker pulse causes V2A to close and V2B to open. The change-over from one condition to the other is extremely rapid and as a result the voltage waveform, which can be monitored at the *Regen. Out* socket, has very steep sides as shown in Fig. O.10e. The damped oscillations occurring at the change-over points are due to the inductive reactance in the circuit. Since the positions of the change-over points on the



(a) SIGNAL TRACK ON GLASS DISK

(b) IDEAL VOLTAGE WAVEFORM OUTPUT FROM PHOTOCELL

(c) ACTUAL WAVEFORM SHAPE OF (b) DUE TO APERTURE DISTORTION

(d) DIFFERENTIAL AMPLIFIED WAVEFORM

(e) WAVEFORM AT OUTPUT OF REGENERATOR

(f) ENLARGED PULSE SHOWING DISTORTION DUE TO VARIATION IN AMPLITUDE WHICH WOULD OCCUR IF A RELAY WERE SET TO OPERATE AND DE-OPERATE AT C-C

Fig. O.10. TPMT/1 : Waveforms

output waveform are controlled by the marker pips, the final signal is free from the distortion in the form of random pulse-length variations which would otherwise occur due to variations in the transparency of the glass disk.

The grid of the first section of V2 is held at a positive potential by the potentiometer R7, R8, R9 across the h.t. supply. The network R11, R12, R13 is so proportioned that the anode of V2A and grid of V2B are held at the correct relative potentials above earth. The circuit includes two variable resistors, R8 and R15; R8, the *Adj. Regen.* control, is used for varying the positive potential on the grid of V2A, and R15, the *Adj. Feed* control, is used for altering the cathode-bias voltage of V2A and V2B.

In the anode circuit of V2B is the working winding of the Carpenter telegraph relay, the bias winding of which is connected in series with R17 and the *Adj. Bias* control R18 across the h.t. supply. The usual spark-quench circuits across the relay contacts are provided by R19, C6 and R20, C7. The switch S2 allows the performance of the Tester to be checked with a centre-zero meter on the Telegraph Relay Test Panel TRT/2 mounted on the same bay as the TPMT/1. By the operation of this switch the contacts of the relay can be disconnected from the internal 80 volt source and connected to the circuit of panel TRT/2 instead.

Mechanical Construction

Waveform Generator Panel

The components of the Head and Differential Amplifier are mounted on a small sub-chassis which is screwed to the Waveform Generator Panel and located close to the photocell. The gain control, monitoring sockets and feed-jack are mounted on the front panel of the Waveform Generator, and connections between the sub-chassis and the main panel are made via a tag strip. The Waveform Generator also contains the glass disk record, the photocell and light source, the light-path condenser lens and the neon stroboscope. The Garrard a.c. motor is mounted beneath the glass disk. On the front of the panel is the track-selecting switch by means of which the position of the light-source, lens and photocell can be adjusted to make the light pass through the desired concentric signal track. An adjustable element in the lens system allows the light to be focused sharply on to the track.

Waveform Regenerator Panel

The components are mounted on both sides of a 4½-inch panel. Variable and preset controls together with feed-jacks and monitoring sockets are mounted on an ebonite sub-panel visible through a cut-out in the front dust-cover. A switch and indicator-lamp also mounted on this sub-panel are provided for the power supply.

The telegraph relay can be withdrawn for testing without removing the front dust-cover of the panel.

Optical Alignment

Centring the Glass Disk

The glass signal-disk is clamped between two steel supporting plates, the diameter of the lower plate being such that the tracks on the disk can be made exactly concentric with the centre spindle. When the glass disk is correctly positioned, the outer edge of the lower clamping plate can be seen through the centre of a transparent locating-circle on the disk.

Note that the disk must be fitted correct side up, i.e. plain-glass side uppermost. (The lower side is matt, due to the photographic emulsion). Both sides of the disk should be kept clean, and care must be taken to prevent scratching.

Adjusting the Light-path in Relation to a Track

The number of the track through which the light is passing is shown by an indicator-plate, clamped to the control-spindle of the track-selecting mechanism. If the light does not pass through the centre of the appropriate track the position of the lamp should be altered after loosening the two grub-screws which secure the plate to the spindle.

Focusing the Light Source

(i) To adjust the position of the lamp forming the light source, unclamp the lamp-holder so that it is free to rotate and to move backwards and forwards in a horizontal plane. Then adjust the lamp so that its filament is horizontal and directly underneath the lens system.

(ii) To focus the light on to a track, first unclamp the holder of the photocell and move the cell away from the light-path until the light can be seen through the glass disk when viewed from above. Then focus the light sharply on to the track by means of the coarse and fine adjustments provided. The coarse-focusing adjustment is made by loosening the thumb-screw securing the lens assembly and sliding the complete assembly up or down in the vertical plane. The fine adjustment is made by rotating a concentric ring on the top of the lens-holder; this ring is locked in position by a clamping ring.

(iii) To orientate the light-slit correctly, so that the narrow beam of light produced by the lens system lies directly across the track, loosen the thumb-screw on the coarse-focusing control and rotate the lens assembly as a whole.

Circuit Alignment

(i) After checking that the telegraph relay has been correctly adjusted, apply power to the Margin Tester and start up the motor, checking the motor speed with the stroboscope provided.

(ii) Select the distortionless repetitive signals recorded on Track 1 of the test disk.

(iii) Vary the Waveform-generator *Adj. Gain* control until the current as measured at V1A feed-jack is 4·3 mA, corresponding with an anode potential of about 90 volts on the photocell. Check the feed of V1B; this should be 1·2 mA. The peak-to-peak amplitudes of the voltage waveforms at monitoring sockets *Head Amp. Out*, *Diff. Out* and *Diff. Amp. Out* should now be 2 volts, 56 mV and 8·6 volts respectively, as measured with Mullard oscilloscope E800 or E805.

(iv) On the Waveform-Regenerator panel set the *Adj. Regen.* control to about mid position and vary the *Adj. Bias* control until the relay bias current as measured at the appropriate jack is 2·5 mA.

(v) Turn the *Adj. Feed* control fully anti-clockwise so that the telegraph relay ceases to vibrate, and measure the feed of V2B; this should be 8 mA.

(vi) Vary the setting of the *Adj. Feed* control, while observing on an oscilloscope the waveform at the *Regen. Out* socket, until the waveform becomes symmetrical.

(vii) Set the *Adj. Regen.* control so that it is midway between the two positions at which the relay ceases to vibrate. The feed of V2A should now be 2·8 mA, and that of V2B 2·5 mA, approximately, and the peak-to-peak amplitude of the voltage waveform measured with an oscilloscope at the *Regen. Out* socket should be 40 volts.

(viii) Throw switch S2 to *Adj. Tester*, thus enabling the performance of the Margin Tester to be estimated on the centre-zero meter on Telegraph Relay Test Panel TRT/2. The distortion as read on the TRT/2 panel should be less than 3 per cent. If the distortion exceeds this figure, vary slightly the setting of the *Adj. Bias* control.

(ix) Throw S2 to *Use Tester* and switch on the 80-volt supply. The tester is now ready for use.

Checking of TPMT/1 Operation

Once the TPMT/1 has been fully and correctly aligned it remains very stable in operation, but the following points should be checked from time to time:—

(i) The speed of the motor; this is very important.

(ii) The performance of the telegraph relay.

(iii) The distortion of the tester. This can be checked by selecting the distortionless repetitive signals on Track 1, operating switch S2 to *Adj. Tester*, and measuring the distortion on the centre-zero meter of Telegraph Relay Test Panel TRT/2. Any slight adjustment which may be found necessary can be made by means of the *Adj. Bias* control.

Valve Data

Valve	*Anode Volts*	*Anode Current mA*	*Cathode Volts*	*Fil. Volts*	*Fil. Amps*
Photocell					
PE50	90	0·6	0	—	—
Waveform Gen.					
6SN7				6·3	0·3
V1A		4·3	113		
V1B		1·2	6·1		
Waveform Regen.					
6SN7				6·3	0·3
V2A	192	2·8	81		
V2B	213	2·5	81		

Note.—Voltages measured with respect to earth, using Avometer Model 7. Photocell anode volts measured when V1A anode current is 5·8 mA. Data for 6SN7's, except V1A and V1B anode currents, are mean values with reversals signal applied.

Supplies

Obtained from Mains and Oscilloscope Unit of TDM/2.

H.T. supply, 300 V.

Total feed, 14 mA including relay bias current.

Test Data

Telegraph Relay

Carpenter relay, T.M.C. Type 3E/1.

Current in working winding (mean value with reversals signal applied), 2·5 mA.

Current in bias winding, 2·5 mA supplied from TDM/2.

Voltage at Slider of Adj. Regen. Control R8

Measured to earth using Avometer Model 7.

40 V approx.

Waveform Amplitudes at Monitoring Points

Measured peak-to-peak, using Mullard oscilloscope Type E800 or E805.

At *Head Amp. Out* socket, 2·1 V.

At *Diff. Out* socket, 560 mV.

At *Diff. Amp. Out* socket, 8·6 V.

At *Regen. Out* socket, 40 V.

TELEPRINTER TEST PANEL TTP/1

General Description

The TTP/1 is used in conjunction with a test teleprinter to intercept and monitor telegraph signals. It is mounted on the test-teleprinter table and not on Telegraph Test Bay CTTB/1. As the TTP/1 forms an essential part of the test apparatus designed for use with the new communications system, its description is included for convenience in the present section, together with that of the test apparatus mounted on the bay.

The panel carries a Carpenter telegraph relay Type 3E/1 and four keys for setting up the test circuits. Four centre-zero milliammeters scaled 30-0-30 mA are provided to indicate the behaviour of circuits under test, and an 80-0-80 volt power supply for the test teleprinter is included on the panel.

Circuit Description. Figs. 10 and 11

The general arrangement of the TTP/1 is shown in Fig. 10 and operational schematics under various test conditions are given in Fig. 11.

The test teleprinter and panel are connected to the d.c. circuit to be tested by means of plugs and jacks on a d.c. telegraph jackfield. A 4-conductor cord terminated in Type-408 or 610 double plugs is used, one end of the cord being plugged to the *Test Teleprinter* jack and the other end to the circuit test-jack.

Provision is made for carrying out the following tests :

(i) Checking the d.c. 'Send' and 'Receive' currents in any teleprinter circuit while the circuit is in the *Through* condition and handling traffic.

(ii) Intercepting any circuit on the d.c. side of the local v.f. equipment, and replacing the local teleprinter by the test teleprinter in order to check the circuit through to an adjacent station.

(iii) Connecting any local teleprinter to the test teleprinter, so that two-way signals can pass between them.

(iv) Bridging the test-teleprinter receive circuit across either the outgoing channel from the local teleprinter to a distant station, or the corresponding incoming channel, or both at once. (These arrangements are generally referred to as 'Monitoring one way' and 'Monitoring both ways.')

In tests (ii) to (iv) the signals incoming to the test teleprinter are regenerated by the Type-3E/1 Carpenter telegraph relay. Resistors R1, R2, R5 and R6 are provided to limit the current through the 3E/1 working windings to 4 mA when the telegraph circuit is being monitored 'one way.' R3 with W1 in shunt, and R4 with W2 in shunt provide paths of high and low resistance when the circuit is being monitored 'both ways.' C1, R9, C2 and R8 are the spark-quench components across the relay contacts.

The current in the receiving electromagnet of the test teleprinter is limited to 20 mA by R7. The steepness of the current pulses applied to the electromagnet is increased by C5 in shunt with R7.

The 80-0-80 volt supply to the fixed contacts of the 3E/1 relay is provided from the mains transformer via W3 and W4.

Intercepting a Telegraph Circuit

Fig. 11a shows in simplified form the normal circuit arrangement between the local station, *A*, and a distant station, *B*. The arrangement shown may also be used to represent the connection between the local teleprinter and the local v.f. equipment, and both alternatives are therefore indicated on the diagram. Fig. 11b indicates the position of the *Local* and *V.F.* meters on the test panel when the circuit is connected via the panel with the control keys set to give the *Through* condition, i.e., *Test* (*i*). The required position for each of the four keys, as seen from the front of the panel, is given on the diagram.

Fig. 11c shows the arrangement of the test circuit when the keys on the panel are set to intercept the v.f. side of the teleprinter circuit for *Test* (*ii*), and Fig. 11d shows the corresponding arrangement when intercepting the local side for *Test* (*iii*). It should perhaps be mentioned that the 'v.f.' side is that nearer to the carrier equipment as seen from the *Test* jack, and the 'local' side is that looking towards the *Instrument* jack from the *Test* jack, the *Instrument* jack being wired in many instances to the local teleprinter.

When testing to 'v.f.,' the local teleprinter sending leg is looped back via the *Local* meter on the test panel to the receiving leg in order to provide a holding current and thereby to prevent the local teleprinter from racing. The test teleprinter is connected to the carrier system sending leg via the *Send* meter, and to the receiving leg via the *V.F.* meter.

When testing toward the 'local' side, the v.f. circuit is looped back via the *V.F.* meter to prevent a spacing signal being sent to line. The test teleprinter is connected to the local teleprinter sending leg via the *Local* meter, and to the receiving leg via the *Send* meter.

It is to be noted that if the two tests just mentioned are carried out with the *Local Record* key (No. 4 in Fig. 11) in the mid position, the send-receive switch of the test teleprinter is out of circuit and the receiving electromagnet is connected directly to the line. In this condition, provided that the send-receive switch of the distant teleprinter is also out of circuit, the sending and receiving channels operate independently, and Duplex working (i.e., simultaneous two-way sending) can be carried out.

Monitoring with the Test Teleprinter

This is the arrangement previously referred to as *Test* (*iv*). When the keys on the panel are set as shown in Fig. 11f, the circuit can be monitored both ways simultaneously. One section of the Carpenter relay winding is then connected to the send leg of the line via W2, R4, R6 and the other section to the receive leg via W1, R3, R5.

In the marking condition, a negative voltage appears on both lines, with the result that W2 and W1 pass no current, but a current of 2 mA flows through each winding of the relay (in the same sense) via resistors R4 and R3, and the relay tongue is attracted to the mark contact. When, however, a space signal is received from either direction, the voltage on that line becomes positive, and the appropriate rectifier short-circuits the resistor R4 or R3 across it. A reversed current of 6 mA then flows through one of the windings of the relay, causing the relay tongue to move to the space contact. Under these conditions, the telegraph signals on both the incoming and the outgoing channel of the circuit are received and transcribed by the test teleprinter.

To monitor one way only, the keys are set in position as shown in Fig. 11e. With this arrangement, the two rectifiers, together with their shunting resistors are removed from circuit and replaced by R2 and R1, and a current of 4 mA now flows in the selected winding of the 3E/1 telegraph relay. The direction of this current, and hence the position of the relay tongue relative to the fixed contacts, is controlled by the monitored signals.

Note that when monitoring tests are being carried out it is essential that the *Local Record* key (No. 4 in Fig. 11) should be left in the mid position, otherwise the 'Who-are-you?' signal received from line will operate the answer-back mechanism on the test teleprinter and confusion will result.

ERRATA

To Editor,

Technical Instructions,

305, *St. Hilda's, Maida Vale.*

The following errors have been noted in **Instruction**

Station................................ *Date*............................. *Signature*........... ....

ERRATA

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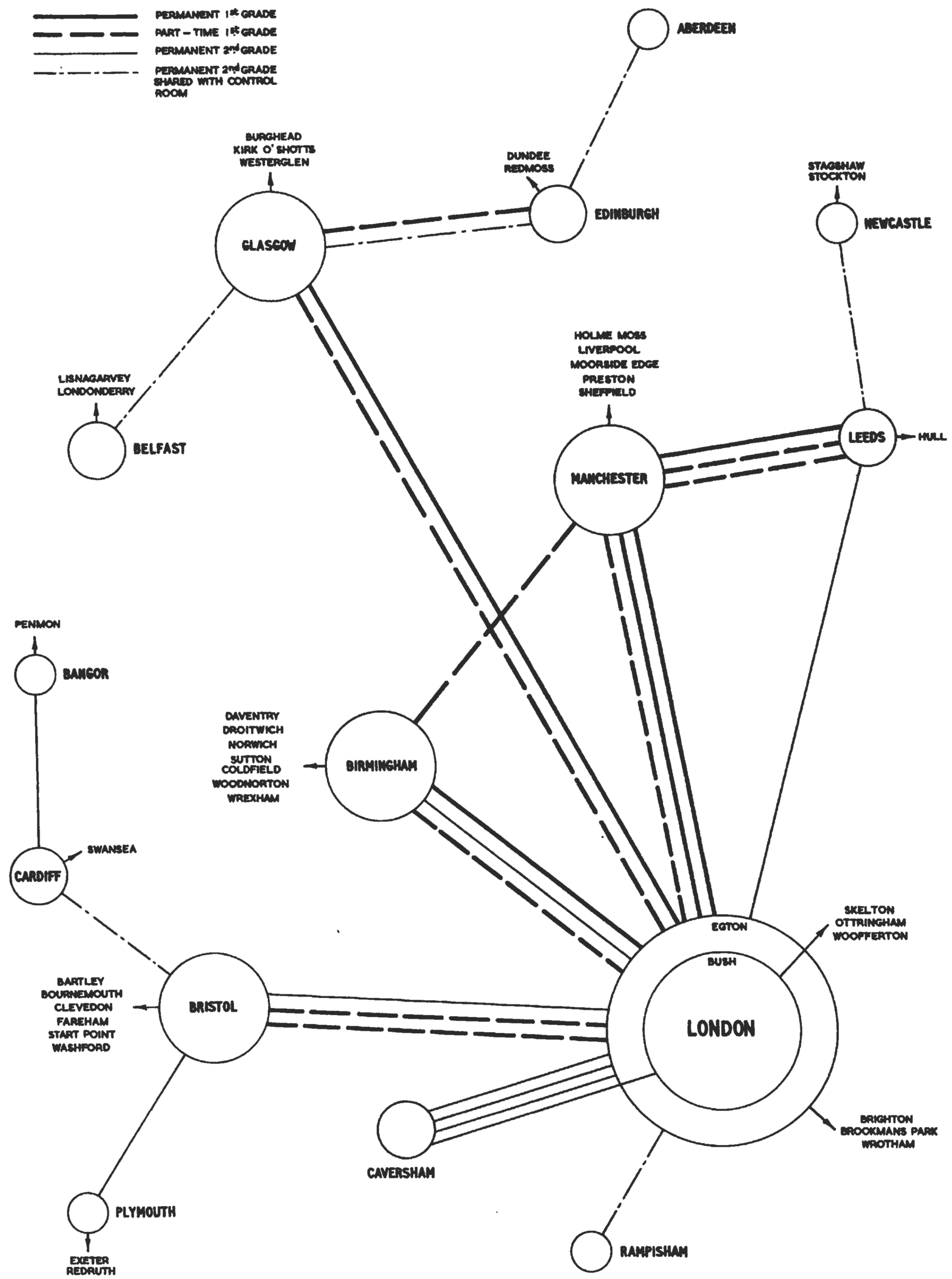
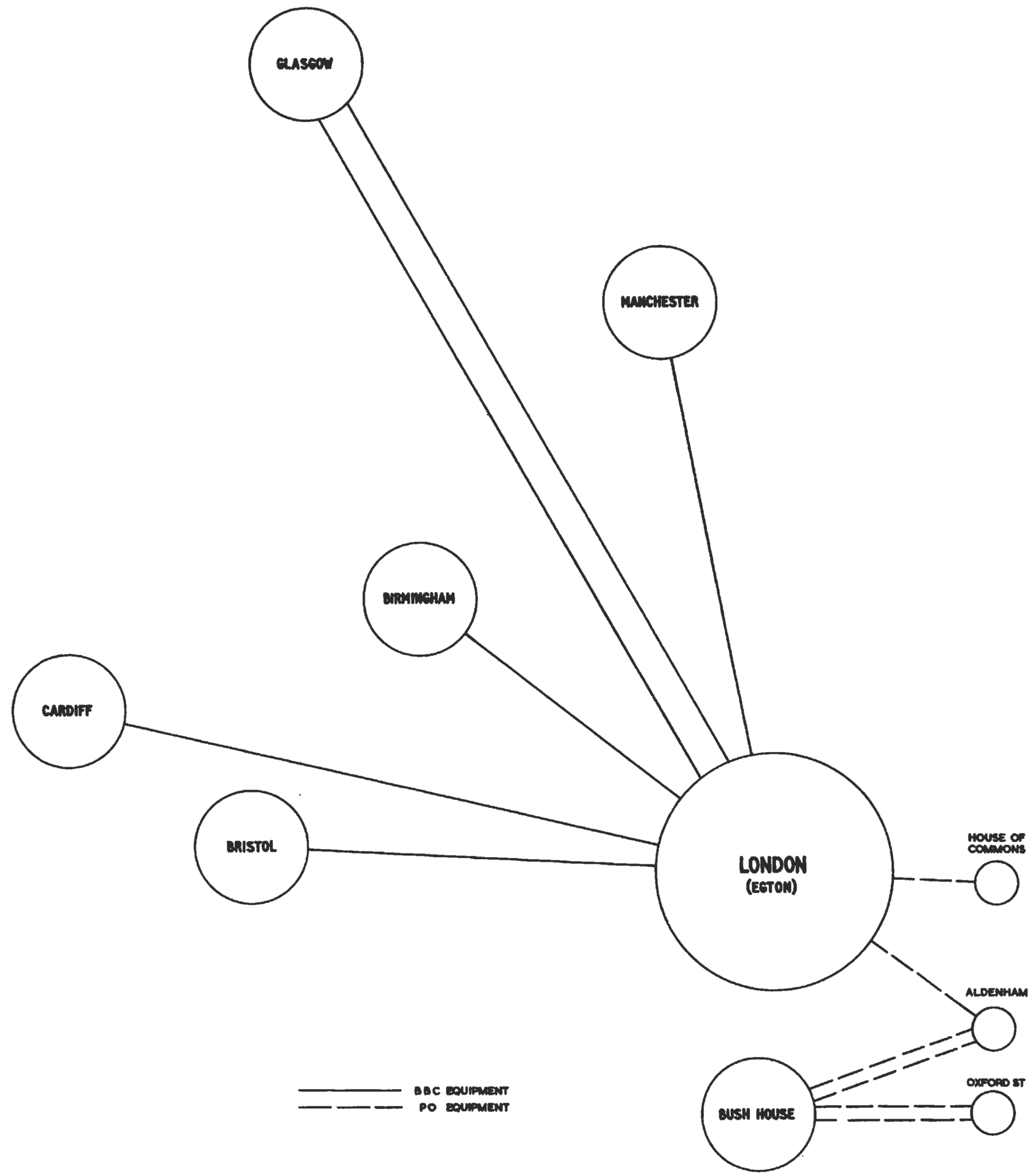
Station................................ *Date*............................. *Signature*..........................

51/JWG/001/DJE

FIG I



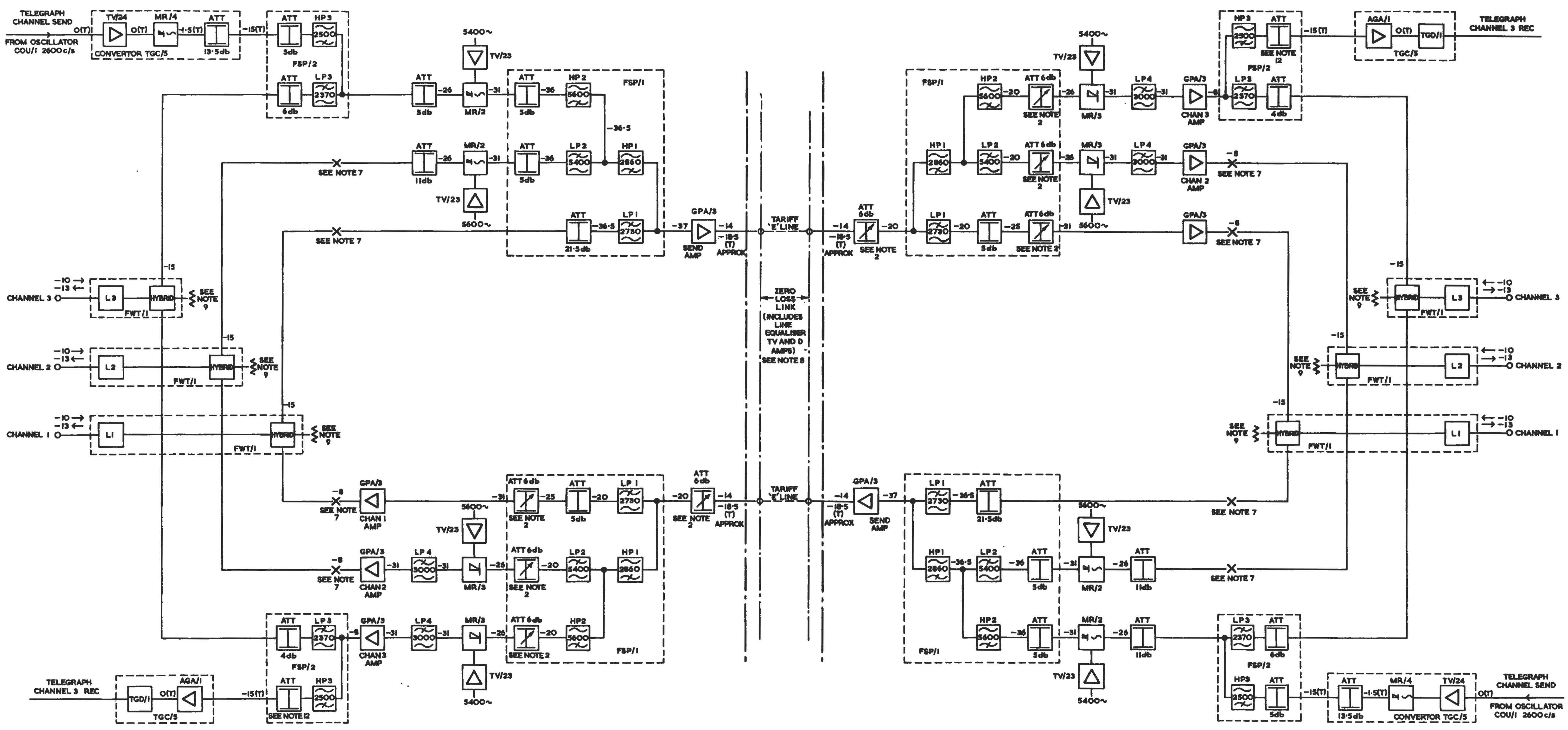
BBC LONG-DISTANCE P B X CIRCUITS



TELEPRINTER CIRCUITS OPERATED BY LONDON AREA

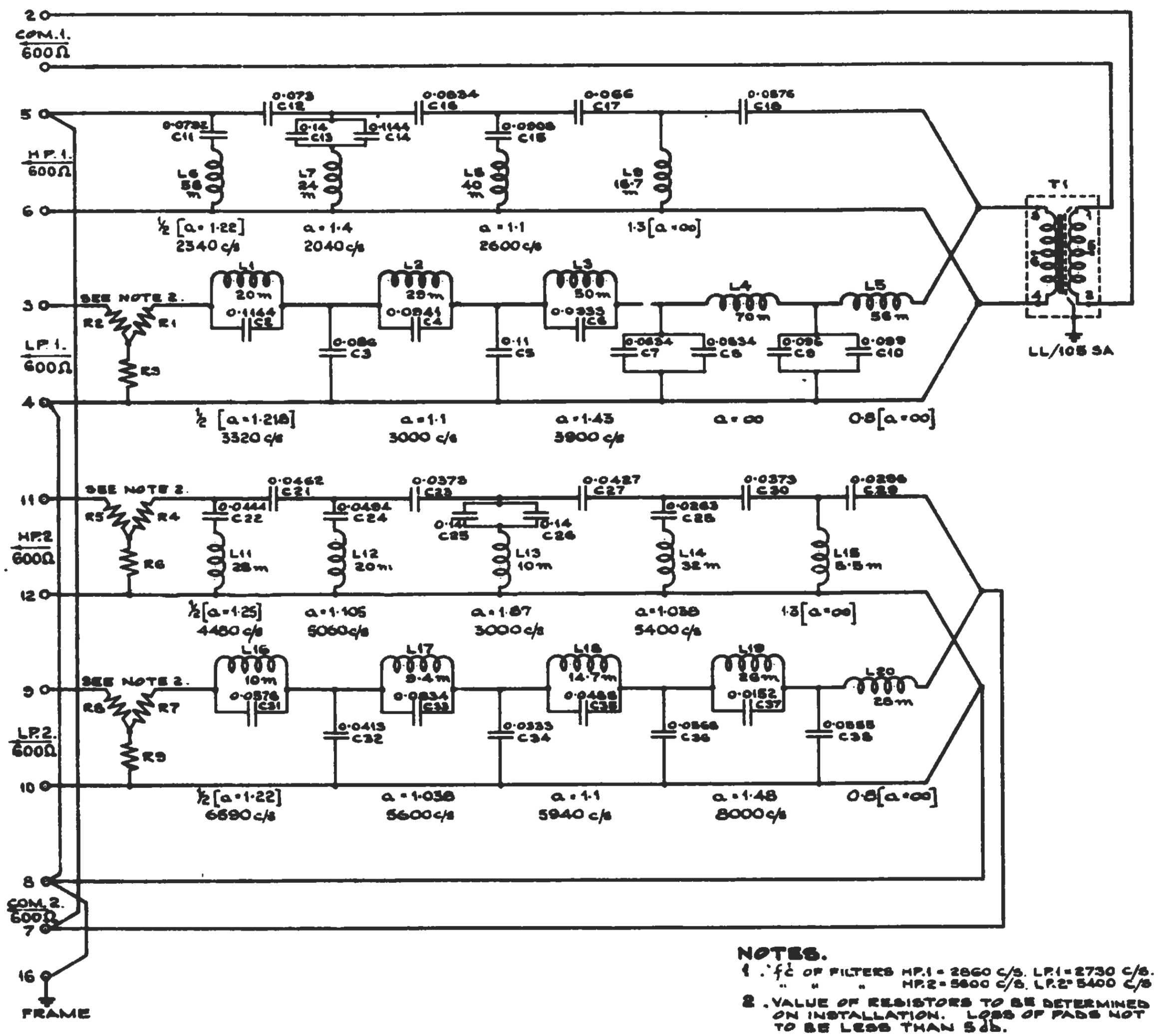
51/JWG/002/DJE

FIG 2



B B C (1+2)-CHANNEL CARRIER: BLOCK SCHEMATIC

NOTE
1 L = LIMITER
2 ATTENUATION AS REQUIRED = 6db APPROX
3 LP=LOW-PASS FILTER
4 HP HIGH-PASS FILTER
5 ATT=ATTENUATOR
6 FIGURE WITHIN EACH FILTER DENOTES CUT-OFF FREQUENCY
7 X: INSERT LP3 AND HP3 FILTER SET IF TELEGRAPH CHANNEL 1 OR 2 IS REQUIRED
8 D AND TV AMPLIFIERS ASSOCIATED WITH LINES ARE IN CONTROL ROOM
9 BRIDGE POINTS OF 4 WTS ARE EITHER CONNECTED DIRECT TO 300Ω OR VIA TAIL-EATING ARRANGEMENT
10 FIGURES INDICATE TEST LEVELS AT 1000 c/s SENT AT -10db FROM CHANNEL JACKS
11 FIGURES FOLLOWED BY (T) ARE TELEGRAPH TONE LEVELS. THE LOSS OF A TELEGRAPH CHANNEL MEASURED FROM THE INPUT OF THE HP3 FILTER TO THE LINE IS APPROX 2db DEPENDING ON THE TELEPHONE CHANNEL NUMBER FROM WHICH IT IS DERIVED. SIMILARY THE CHANNEL GAIN FROM THE LINE TO THE OUTPUT OF THE HP3 FILTER IS ABOUT 2db
12 ATTENUATOR VALUE ADJUSTED TO PRODUCE A LEVEL OF -15db AT THE AGA INPUT



NOTES.

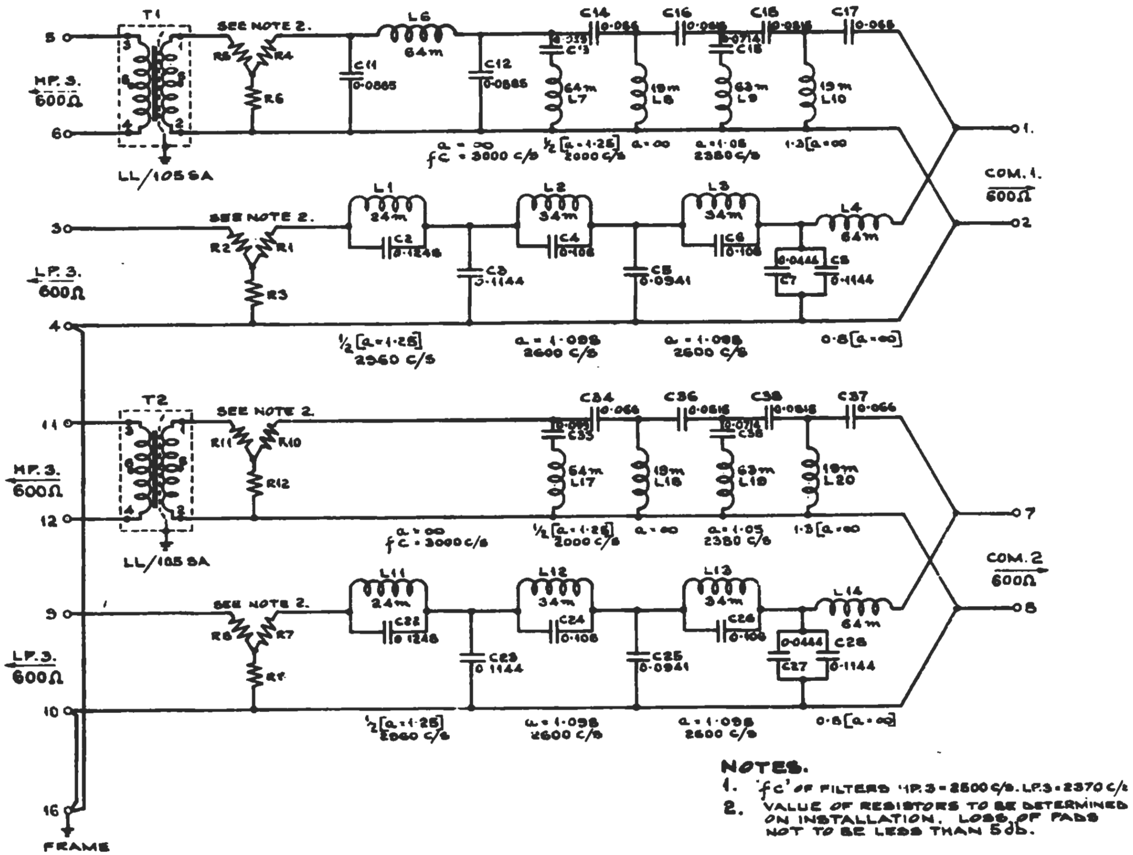
1. fc OF FILTERS HF.1 = 2860 C/S. LP.1 = 2730 C/S.
   " " " HF.2 = 5600 C/S. LP.2 = 5400 C/S.
2. VALUE OF RESISTORS TO BE DETERMINED ON INSTALLATION. LOSS OF PADS NOT TO BE LESS THAN 5 db.

FIG 3

FILTER SPLITTING PANEL FSP/1: CIRCUIT

L1

EB6802



NOTES.

1. 'fc' OF FILTERS H.P.3 = 2500 c/s. L.P.3 = 2370 c/s
2. VALUE OF RESISTORS TO BE DETERMINED ON INSTALLATION. LOSS OF PADS NOT TO BE LESS THAN 5db.

FIG 4

FILTER SPLITTING PANEL FSP/2 : CIRCUIT

L1

52/JWG/103/NB
DD/45/2

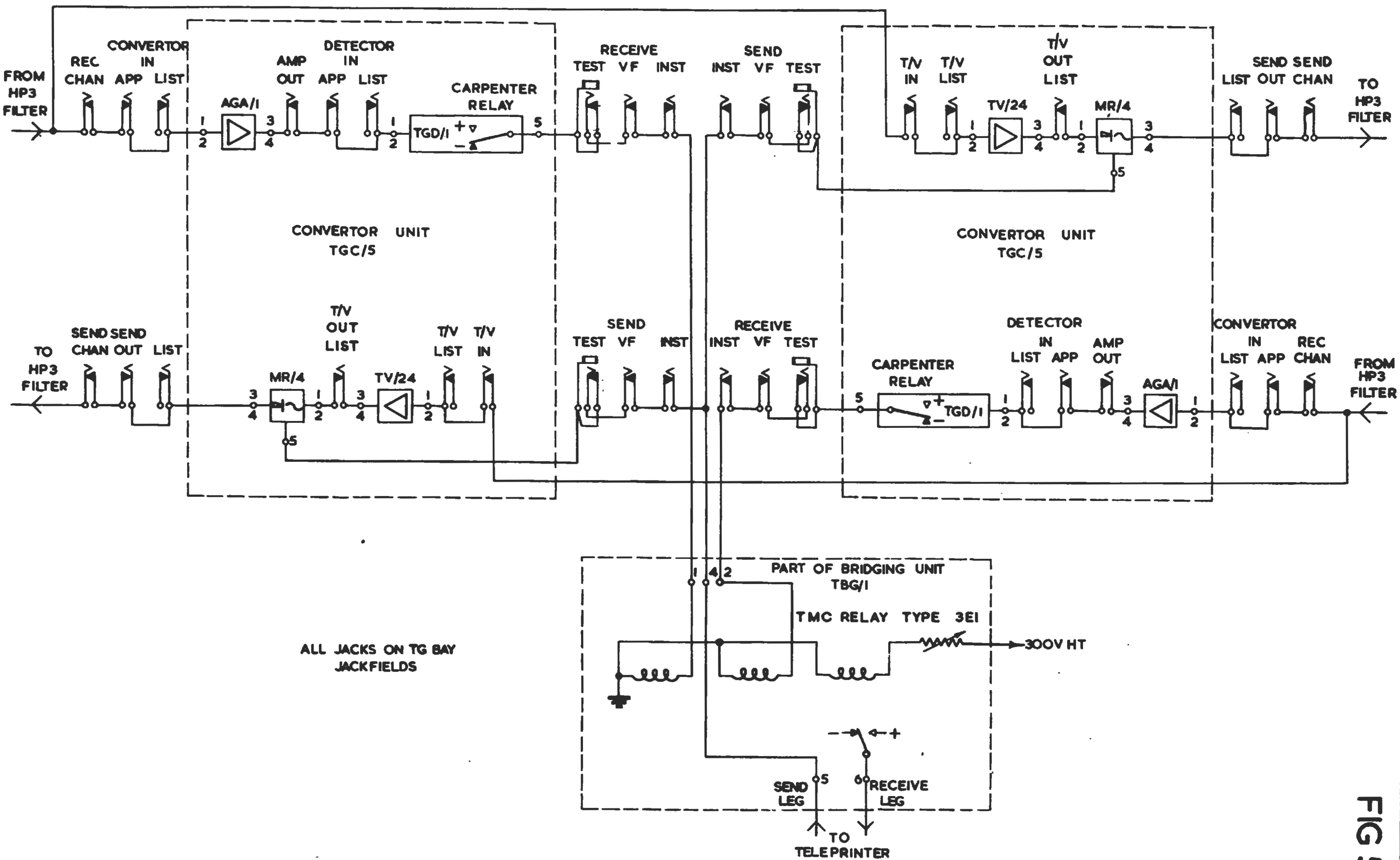


FIG 5

ENGINEERING TELEGRAPH NETWORK
BLOCK SCHEMATIC FOR INTERMEDIATE STATION

L1

COMPONENT TABLE: FIG. 6

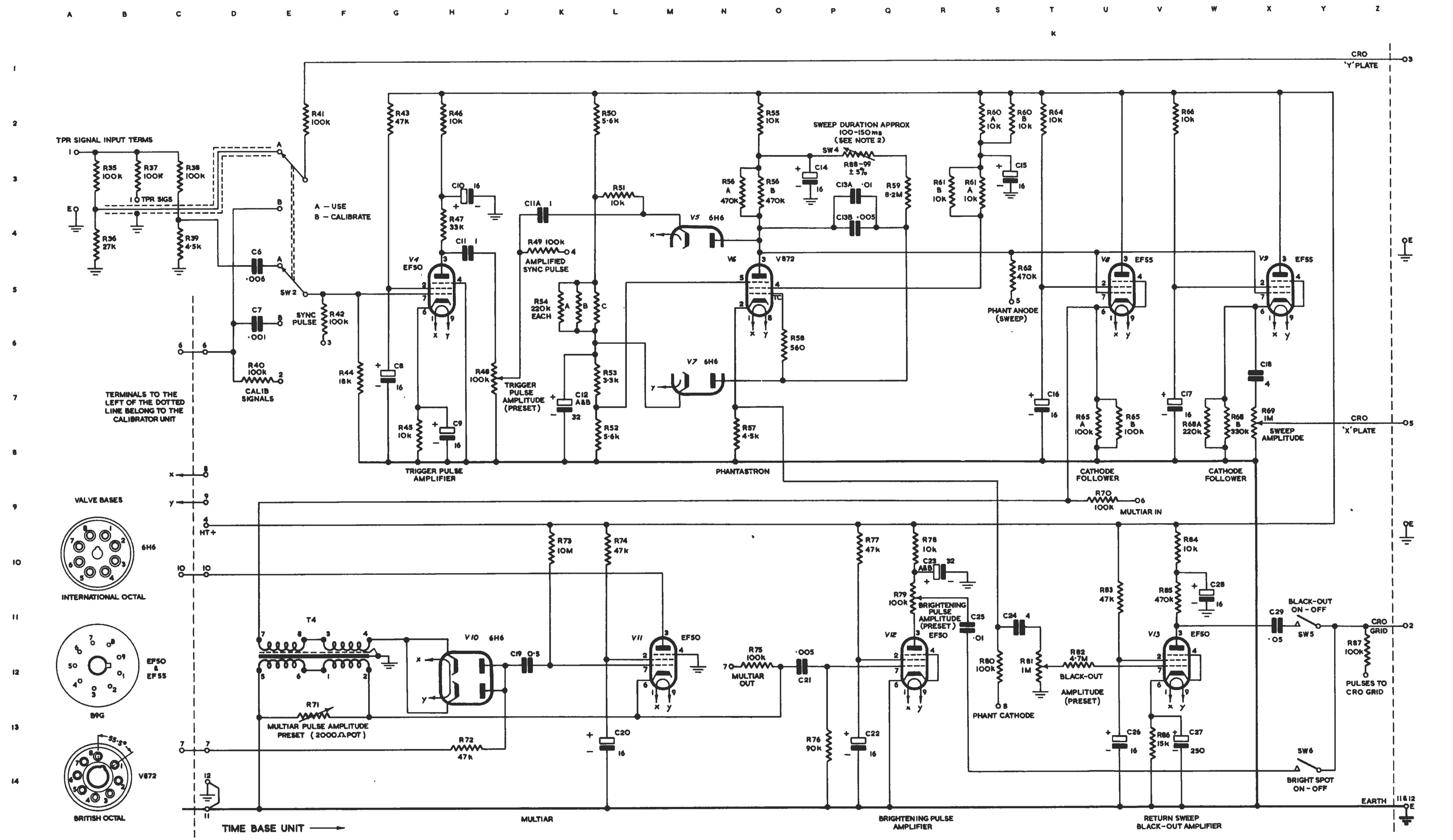
Comp	*Loc*	*Type*
C6	E4	500 V. T.C.C. M3N
C7	D6	500 V. T.C.C. MAN
C8	G7	450 V. B.E.C. CE15129
C9	H8	450 V. B.E.C. CE15129
C10	H3	450 V. B.E.C. CE15129
C11	H4	450 V. Muirhead 39AT
C11A	K4	450 V. Muirhead 39AT
C12A, C12B	K7	B.E.C. CE15129
C13A	P3	500 V. T.C.C. M3N
C13B	P4	500 V. T.C.C. M3N
C14	P3	450 V. B.E.C. CE15129
C15	S3	450 V. B.E.C. CE15129
C16	T7	450 V. B.E.C. CE15129
C17	V7	450 V. B.E.C. CE15129
C18	X7	450 V. Muirhead 39AT
C19	J12	450 V. Muirhead 39AT
C20	L13	450 V. B.E.C. CE15129
C21	O12	500 V. T.C.C. 545
C22	Q13	450 V. B.E.C. CE15129
C23A, C23B	R10	450 V. B.E.C. CE15129
C24	S11	450 V. Muirhead 39AT
C25	S11	500 V. T.C.C. 545
C26	U13	450 V. B.E.C. CE15129
C27	V13	20 V. T.C.C. CE26C
C28	W11	450 V. B.E.C. CE15129
C29	X11	450 V. Muirhead 39AT
R35	B3	1 W. Erie Type 2
R36	B4	½ W. Erie Type 8
R37	B3	1 W. Erie Type 2
R38	C3	1 W. Erie Type 2
R39	C4	½ W. Erie Type 8
R40	D7	½ W. Erie Type 8
R41	E2	½ W. Erie Type 8
R42	F6	½ W. Erie Type 8
R43	G2	2 W. Erie Type 1
R44	F7	½ W. Erie Type 8
R45	G8	½ W. Erie Type 8
R46	H2	1 W. Erie Type 2
R47	H4	1 W. Erie Type 2
R48	J7	MNAP 10450 16000
R49	K4	½ W. Erie Type 8
R50	L2	½ W. Erie Type 8

Comp.	*Loc*	*Type*
R51	L3	½ W. Erie Type 8
R52	L8	½ W. Erie Type 8
R53	L7	½ W. Erie Type 8
R54A, R54B, R54C	K6	1 W. Erie Type 2
R55	O2	1 W. Erie Type 2.
R56A, R56B	N3	1 W. Erie Type 2
R57	N8	½ W. Erie Type 8
R58	O6	½ W. Erie Type 8
R59	Q3	½ W. Erie Type 8
R60A, R60B	S2	1 W. Erie Type 2
R61A, R61B	R3	1 W. Erie Type 2
R62	T5	½ W. Erie Type 8
R64	T2	2 W. Erie Type 1
R65A, R65B	U8	2 W. Erie Type 1
R66	W2	2 W. Erie Type 1
R68A, R68B	W8	1 W. Erie Type 2
R69	X7	MNAP 10550 28000
R70	U9	½ W. Erie Type 8
R71	E13	LHNAR 20250 16000
R72	H13	½ W. Erie Type 8
R73	K10	½ W. Erie Type 8
R74	L10	2 W. Erie Type 1
R75	O12	½ W. Erie Type 8
R76	O13	½ W. Erie Type 8
R77	Q10	2 W. Erie Type 1
R78	R10	1 W. Erie Type 2
R79	Q11	2 W. Colvern CLR 4001/11S
R80	S12	½ W. Erie Type 8
R81	T12	MNAP 10550 16000
R82	U12	½ W. Erie Type 8
R83	U11	2 W. Erie Type 1
R84	W10	1 W. Erie Type 2
R85	V11	1 W. Erie Type 2
R86	V13	1 W. Erie Type 2
R87	Z12	½ W. Erie Type 8
R88-99	P3	½ W. Erie Type 8
T4	E12	S.T. & C. C4102-3

52/GWH/102/DJE
DE 292

FIG 6

L1



TDM/2 TIME BASE UNIT: CIRCUIT

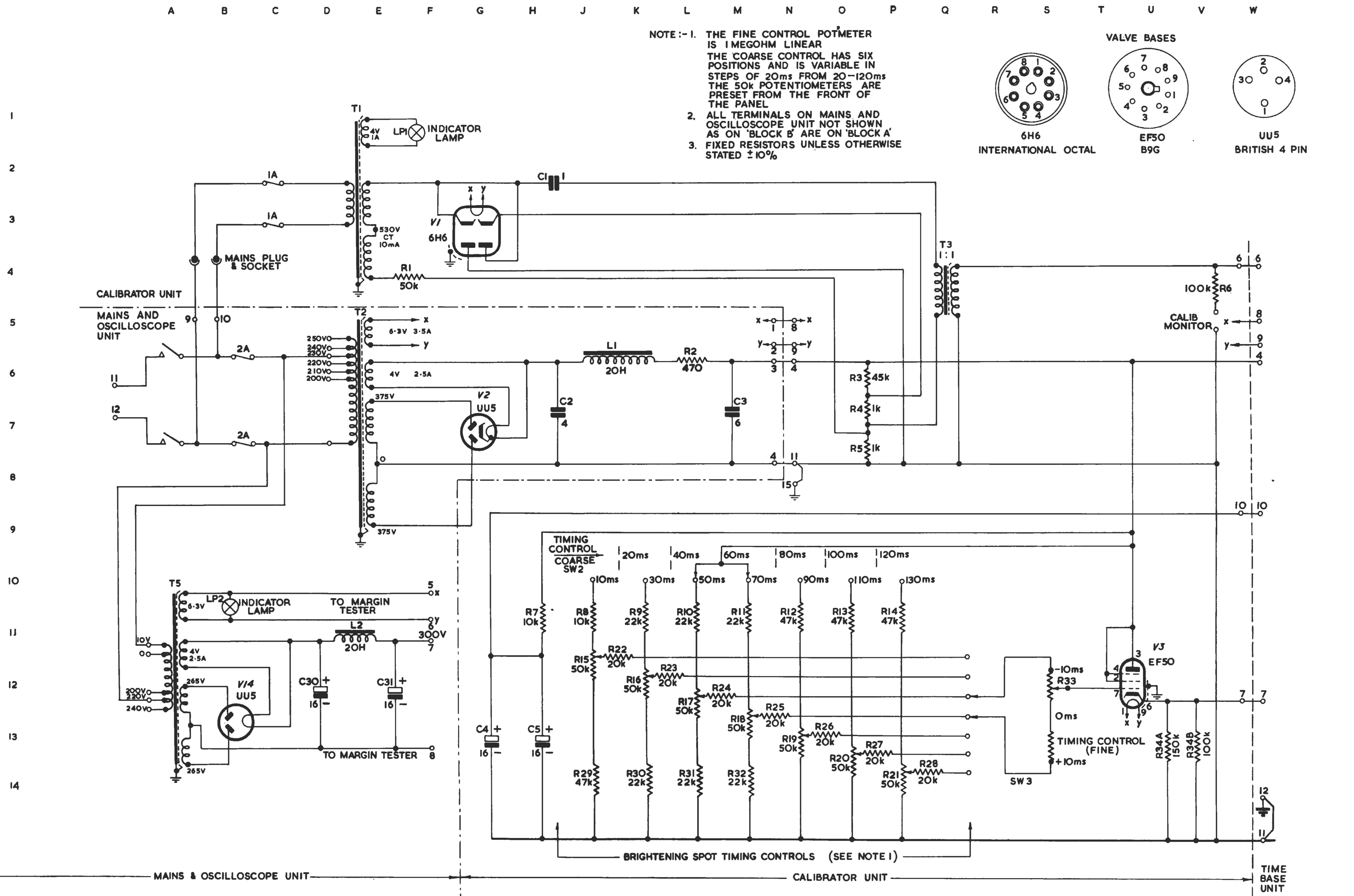
NOTES
1 V5 AND V7 ARE IN THE SAME ENVELOPE
2 THE SWEEP DURATION CONTROL IS VARIABLE IN STEPS OF ½ MEGOHM FROM 8·2 MEGS TO 13·6 MEGS
3 ALL TOLERANCES ± 10% EXCEPT WHERE OTHERWISE STATED (FIXED RESISTORS ONLY)

COMPONENT TABLE: FIG. 7

Comp	*Loc*	*Type*	*Comp*	*Loc*	*Type*
C1	H2	450 V. Muirhead 39AT	R16	K12	1 W. Colvern CLR 3001/11
C2	H7	450 V. Muirhead 39AT	R17	L12	1 W. ,, ,,
C3	M7	450 V. Muirhead 39AT	R18	M13	1 W. ,, ,,
C4	G13	450 V. B.E.C. CE15129	R19	N13	1 W. ,, ,,
C5	H13	450 V. B.E.C. CE15129	R20	O13	1 W. ,, ,,
C30	D12	450 V. B.E.C. CE15129	R21	P14	1 W. ,, ,,
C31	F12	450 V. B.E.C. CE15129	R22	K11	½ W. Erie Type 8
L1	K6	CH19	R23	L12	½ W. ,, ,, 8
L2	E11	CH19	R24	M12	½ W. ,, ,, 8
R1	F4	10 W. Painton P302	R25	N12	½ W. ,, ,, 8
R2	L6	2 W. Erie Type 1	R26	O13	½ W. ,, ,, 8
R3	P6	10 W. Painton P302	R27	P13	½ W. ,, ,, 8
R4	P7	1 W. Erie Type 2	R28	Q13	½ W. ,, ,, 8
R5	P7	1 W. ,, ,, 2	R29	J14	2 W. ,, ,, 1
R6	V5	1 W. ,, ,, 2	R30	K14	1 W. ,, ,, 2
R7	H11	2 W. ,, ,, 1	R31	L14	1 W. ,, ,, 2
R8	J11	1 W. ,, ,, 2	R32	M14	1 W ,, ,, 2
R9	K11	1 W. ,, ,, 2	R33	S12	Painton Type B
R10	L11	1 W. ,, ,, 2	R34A	U13	1 W. Erie Type 2
R11	M11	1 W. ,, ,, 2	R34B	V13	1 W. ,, ,, 2
R12	N11	2 W. ,, ,, 1	T1	E3	M158
R13	O11	2 W. ,, ,, 1	T2	E7	M174
R14	P11	2 W. ,, ,, 1	T3	Q4	LL/53C
R15	J12	1 W. Colvern CLR 3001/11	T5	A12	M158

52/GWH/101/AJP
DE 292

FIG 7 L1

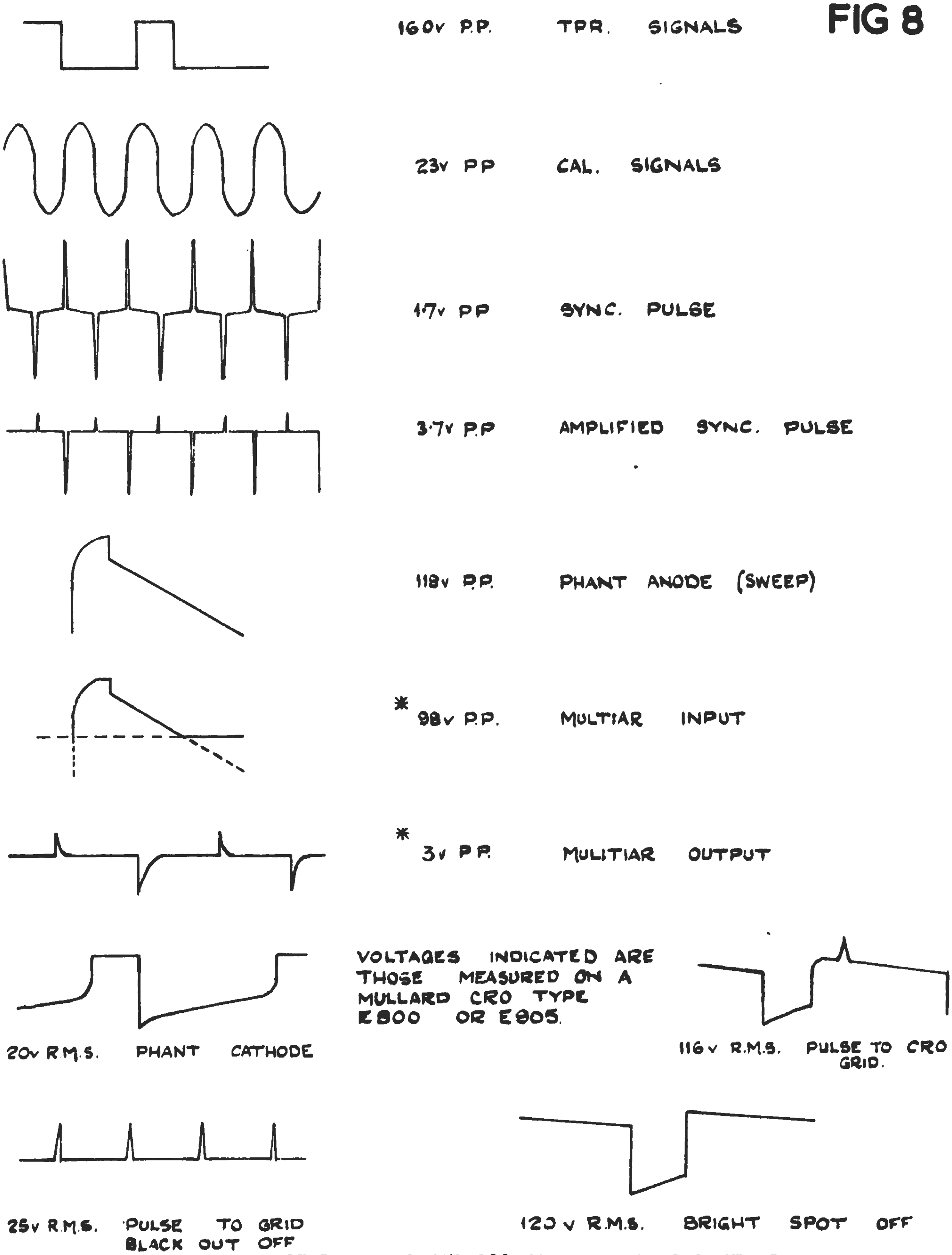


TDM/2 CALIBRATOR UNIT & MAINS-AND-OSCILLOSCOPE UNIT

52/GWH/103
DA694

L1

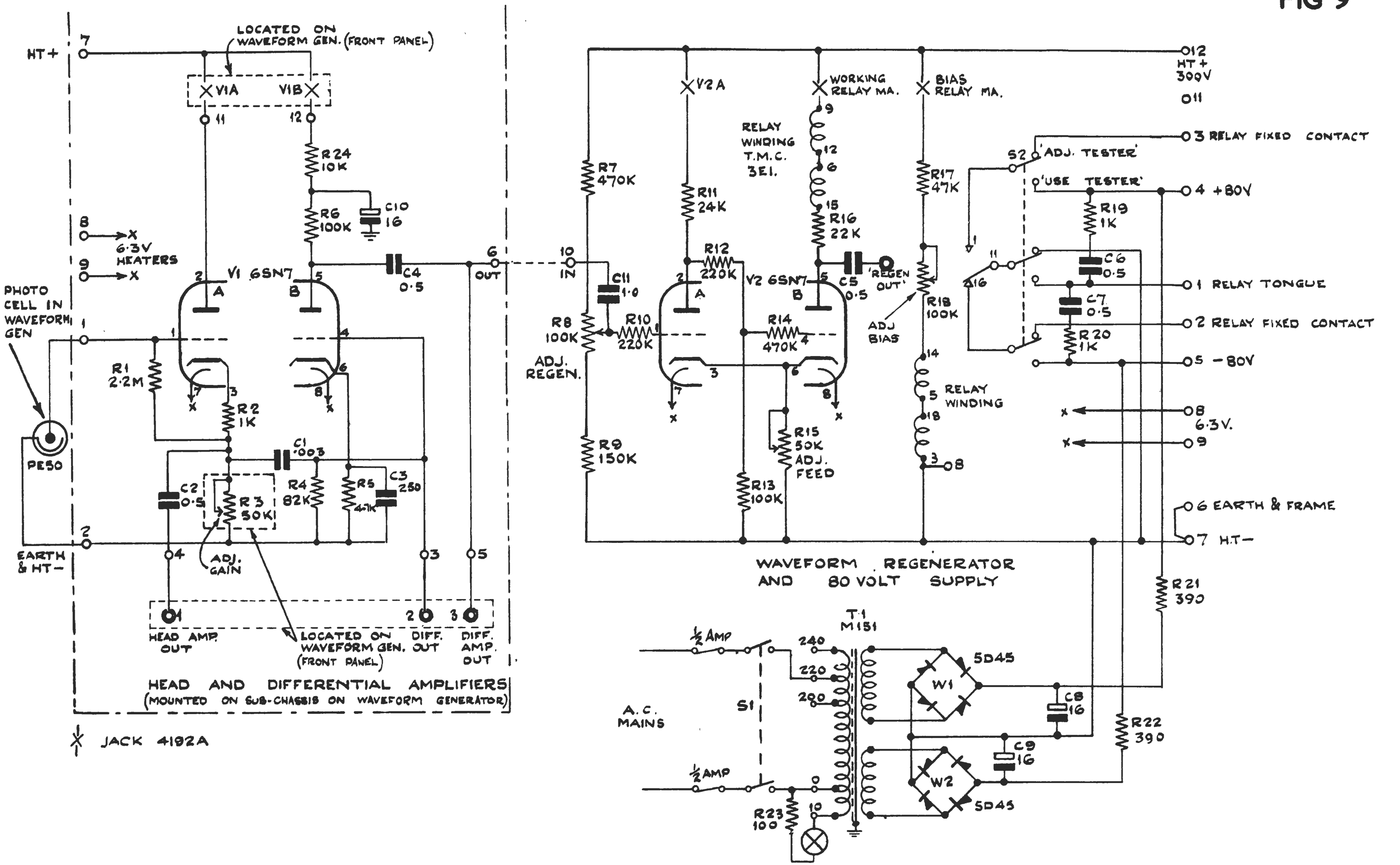
FIG 8



* FINE TIMING CONTROL AT CENTRE SCALE AND COARSE TIMING CONTROL AT + 20 ms

TDM/2 TIME BASE UNIT : WAVEFORMS AT MONITORING POINTS

FIG 9



TELEPRINTER MARGIN TESTER TPMT/1 : CIRCUIT

52/GWH/105
DG 770

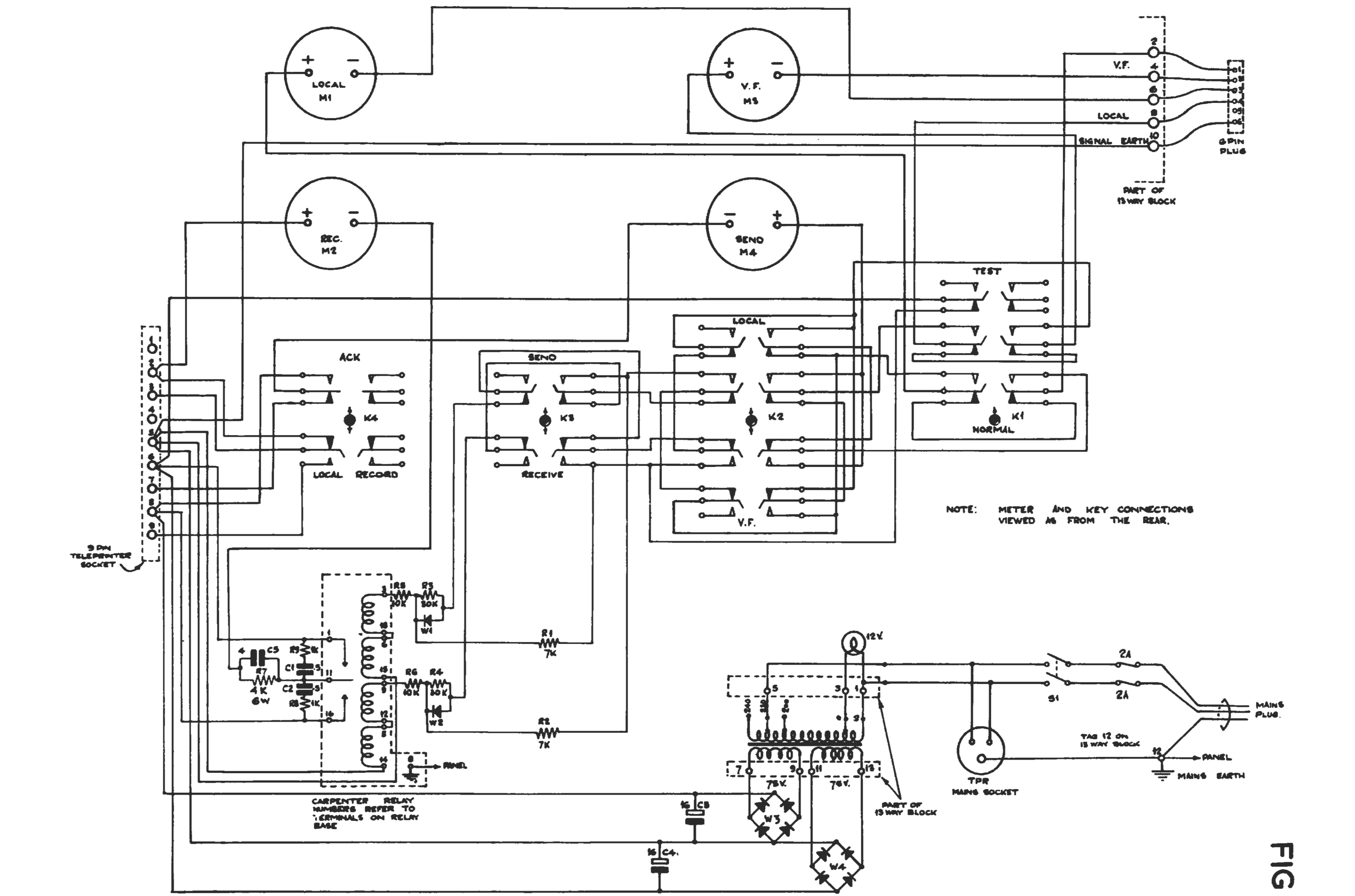
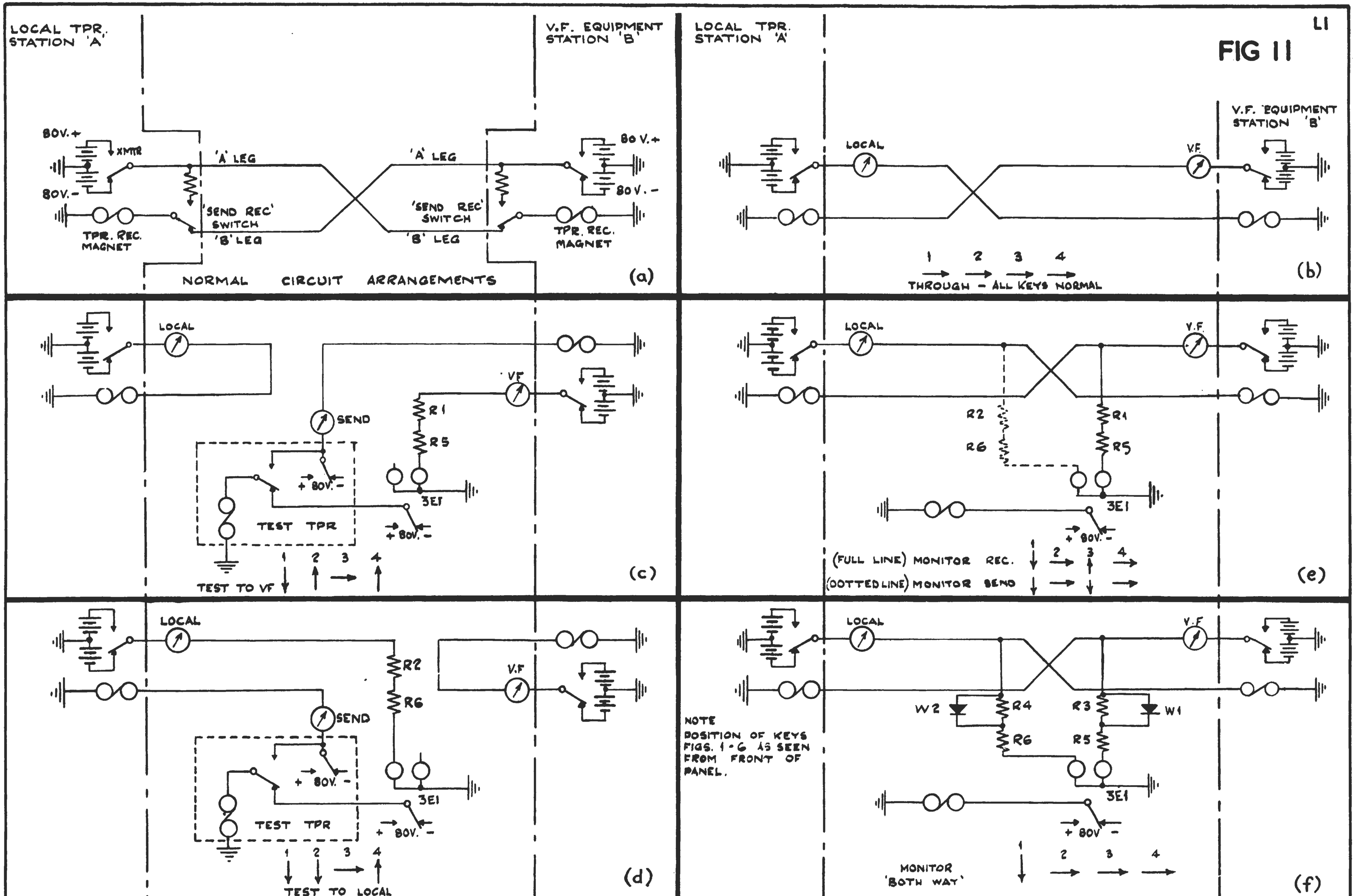


FIG 10

TELEPRINTER TEST PANEL TTP/1 : CIRCUIT

52/GWH/106
DB771



TELEPRINTER TEST PANEL TTP/1 : OPERATIONAL SCHEMATICS

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