TYPE RR FREQUENCY MULTIPLEX SYSTEM

HANDBOOK

contents:

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1.0 INTRODUCTION TO THE SYSTEM

Frequency-division multiplex

The AEI-General Signal type RR Reed system is a frequency-division multiplex system. That is to say, it is a means of connecting many circuits over a distance over a single pair of conductors; a specific frequency is allocated to each circuit, and a signal of this frequency is transmitted along the pair when the circuit is complete. Many signals of different frequencies are therefore transmitted along the pair, and the signal for a particular circuit or channel is separated out at the receiver end of the pair by means of suitable filters.

The type RR system can carry up to 60 circuits in one pair of conductors, over an unlimited distance. Since these circuits would normally require a pair each, it will be seen that a great saving in cable can be obtained, especially if the distance being covered is considerable.

The equipment is essentially simplex (i.e., one-way) in operation, although duplex (two-way) systems can be employed under certain circumstances. The transmitters and receivers for the various channels do not have to be grouped at the ends of the line; any channel can be connected into, and out of, the line at any point along its length, as required. Also, the equipment for a channel can be removed without affecting the operation of the rest of the system, so that, for instance, if a fault develops on a channel, it can be serviced without disturbing the rest of the system. The equipment is therefore very flexible in operation.

Type RR equipment is fail-safe to the standard required for vital circuits in railway signalling. In general, this means that the design is such that no practical component or unit fault can cause a transmitter to transmit, or a receiver to respond to, any frequency other than that to which it was originallytuned. By taking suitable precautions at the design stage, a level of integrity can be obtained for the line such that no single fault or combination of up to three faults in the complete system can give rise to an output from a receiver in the absence of a signal from the corresponding transmitter. How this is achieved will be seen from the description and application sections below.

1.2 The basic type RR system

1.2.1 For each channel, an independent transmitter is provided, which generates a signal at the particular frequency allocated to that channel when a contact is made in an external control circuit. The frequency is determined by a Reed filter, as described below. The output of each transmitter is connected across a load resistor, and the transmitters are connected together so that all the resistors are in series with each other and with the line(see fig. 1.2.1 - 1). Any transmitter may be placed at any point along the line, and is always connected with its resistor in series with one leg of the line.

Each channel also has an independent receiver, consisting of a Reed filter and an amplifier. The Reed filter is a band-pass filter, which passes only the frequency allocated to the particular channel and excludes all others, and is connected with its input across the line (see fig.1.2.1-1). Its output drives the amplifier, which gives a d.c. output voltage when a signal is present at its input. This voltage can be used to drive a relay, and it will therefore be seen that the relay is energised only when a signal of the correct frequency is present on the line.

Thus, closing of the contact in the control circuit of the transmitter for a channel causes the relay driven by the corresponding receiver to be energised (exactly as if the circuit was made through directly, with its own pair of conductors). The operation of any channel is completely independent of any other channel on the same pair.

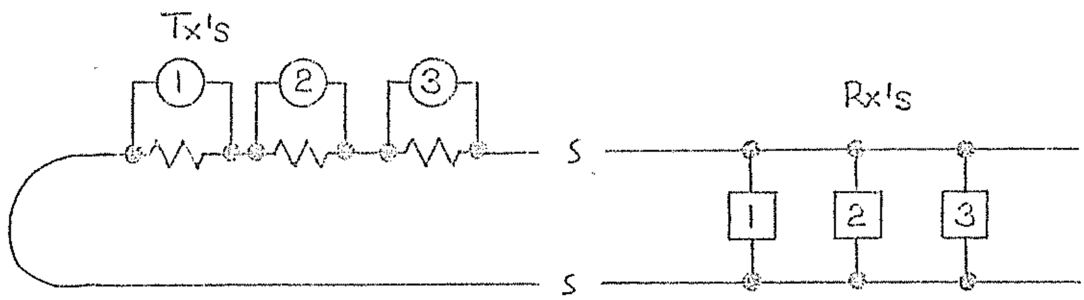


Fig. 1.2.1 - 1: Typical Reed System.

1.2.2 From the above, it will be seen that the frequencies of both transmitters and receivers depend upon the Reed filter. So that many frequencies at close spacing may be used, this must have a highly accurate and highly stable pass frequency. The necessary accuracy and stability are obtained by using mechanical resonance, on the tuning-fork principle, to tune it. (The filter is described in detail in section 2.2 below). Its selectivity is such that the system can be operated with frequencies at a spacing of 4Hz or less, so that a very large number of channels can be accomodated in a small range of frequencies.

The range of actual frequencies used is determined by the mechanical characteristics of the Reed filter, and is normally between 300Hz and 1 kHz. The frequencies are chosen within this range in such a way as tominimize effects due to intermodulation between channels, and to external interference from 50Hz mains. For fail-safe purposes, 51 frequencies between 393Hz and 887Hz are normally used, and 14 additional frequencies are also available in the same range for non-fail-safe purposes.

1.2.3 For operation over long distances, amplification of the signals is required at intermediate points. This is provided by means of the Reed line amplifier, described in section 2 below. The spacing between amplifiers is determined by the attenuation caused by the type of cable used; when the system is operated over standard signalling cable, it can be up to 4km. Large groups of transmitters or receivers at a location also load the line heavily, and the line amplifier is used in this case also, to prevent loss of signal level.

Interference from 50Hz power lines and other sources can give rise to large currents flowing in the Reed line, and to prevent these currents being transmitted along the full length of the line, it is often desirable to sectionalise it, either by means of the line amplifier, or by means of the Reed line isolating transformer if no amplification is required.

Provided, then, that amplifiers are provided at suitable intervals along the line, and that the line is sectionalised as may be necessary, Type RR Reed systems can be operated over virtually unlimited distances. Where many pairs in a multicore cable carry Reed signals, crosstalk between pairs may become significant over large distances, and can be minimised by regular transposition or twisting of the individual pairs, and by careful selection of the cores used.

1.2.4 The type RR system, therefore, offers great flexibility of application. It can be operated over long distances, and individual signals can be connected into or out of the line at any point along its length - not merely at the ends of the line. The system is designed so that units associated with individual channels can be removed, for repair, etc., without affecting the operation of other channels on the same pair, and this gives it a considerable advantage over time-division multiplex and other electronic systems, in which failure of a single unit often causes failure of the entire system.

1.3 Glossary of terms

The following expressions are used in this manual with particular meanings in connection with type RR equipment.

CHANNEL	-	A path for the transmission of a single item of information (e.g. a control, or an indication).
CORE	-	An individual Conductor in a cable
DUPLEX	-	Two-way
FREQUENCY-DIVISION MULTIPLEX	-	A multiplex arrangement in which channels are separated by being allocated signals of different frequencies
LINE, LINE-PAIR	-	A pair of electrical conductors used for the transmission of signals
MULTIPLEX	-	An arrangement for carrying many channels on a single line
REED	-	A mechanically-vibrating element, having resonant properties which are imparted to an associated electrical circuit
SECTIONALISATION	-	Splitting of the line into isolated lengths, connected together only by transformers
SIMPLEX	-	One-way
SYSTEM	-	All those channels carried in one line-pair, or all the equipment associated with them.

2.0 THE EQUIPMENT

2.0.1 Contents of Section 2

2.1 GENERAL

2.1.1 Physical construction of units

AEI-General Signal type RR Reed equipment is designed to conform physically with other standard railway signalling equipment. Transmitters, receivers and transmitter repeaters are designed to be mounted on standard miniature plug-boards, and occupy the same space as a relay, except only that each unit is deeper than a relay (the dimensions are 8.41 in x 5.50 in x 2.19 in, so that the unit projects 0.88 in below the plug-board). Other units are designed to be mounted directly on racks, in the space required for one or more plug-boards (as described in the appropriate sections following). The equipment is therefore suitable for mounting in relay rooms and location cupboards of standard design.

2.1.2 Ambient conditions

All Reed equipment is designed to operate in ambient temperatures over the range -20°C to 55°C, over the full range of humidity, and in corrosive atmospheres. Cupboards and relay rooms housing Reed equipment should be ventilated, as all units, and especially power supplies and line amplifiers, generate a small amount of heat.

Units which are specifically stated to be tropicalised can be operated over an extended temperature range, from -20°C to 75°C, and are treated to prevent fungus growth and corrosion under tropical conditions.

2.1.3 The line

The type RR Reed system can be operated over any pair of conductors, and does not require a matched or balanced transmission line. Pairs of cores in standard railway signalling cable, and pairs of conductors on an overhead pole route, are both suitable for carrying Reed signals. The resistance of the conductors determines the attenuation of the signal, and hence the spacings at which line amplifiers are necessary. Transposed or twisted pairs can be used to reduce crosstalk effects between pairs in the cable or on the same route (see part 3), and sectionalisation can be employed to reduce interference effects (see section 2.8).

2.1.4 Frequencies

Fifty-three frequencies, of which two are used as universal spares, are used for vital functions, and twelve others are available for non-vital functions; a list of the frequencies used is given in section 5.2. Each frequency is allocated a channel number, for ease of reference; for example, a frequency of 879.5Hz is channel f1.

2.2 THE REED FILTER

2.2.1 The Reed filter is the basis of the Type RR system, being used to determine the operating frequencies of both transmitters and receivers throughout the system. It is a band-pass filter, with an exceptionally stable and well-defined pass frequency determined by mechanical resonance, on the tuning-fork principle. It is designed so that it is impossible for it to respond to any frequency other than that to which it was tuned during manufacture under any reasonable fault conditions. This is the basic fail-safe feature of the system.

2.2.2. The filter contains a pair of tuned reeds. Each is a short bar of a special alloy, clamped at one end and shaped so as to vibrate at a specific frequency, which is set during manufacture by adjusting the thickness near the clamping point. It is placed so that it lies along the axis of a coil, with its free end between the poles of a permanent magnet, as shown schematically below:

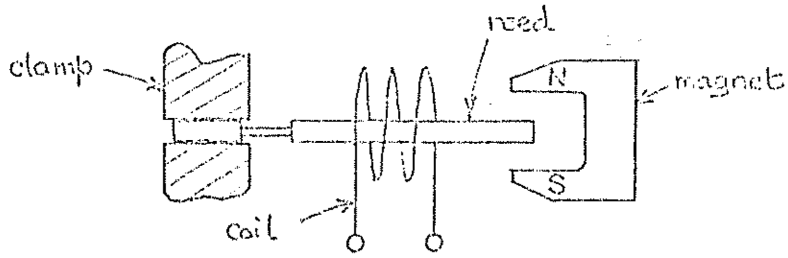


Fig. 2.2-1: Basic Reed.

If a current flows in the coil, it magnetises the reed, which is therefore displaced by the field of the permanent magnet, by an amount depending on its mechanical stiffness. If the current is made to vary sinusoidally, the reed will oscillate in the field. At most frequencies, the amplitude of this oscillation is small, but if the frequency of the current flowing in the coil is the same as the frequency of free mechanical vibration of the reed, the amplitude becomes large. Alternatively, if the assembly is vibrated mechanically, the reed will oscillate between the poles of the magnet, causing a voltage to appear between the terminals of the coil. This voltage will be small unless the frequency of the impressed vibration is the same as the resonant frequency of the reed, in which case it will become much larger (by a factor of several hundred in practice).

2.2.3 The complete Reed filter consists of two of these reed assemblies tuned to the same frequency, fastened together. The clamp for the reed takes the form of a brass block, on which the coil and the permanent magnet are mounted. In the complete filter, the mounting blocks of the two assemblies are joined by a rigid connecting plate, and the whole is suspended in its case on resilient mountings.

2.2.3 cont.

The complete arrangement is as shown:

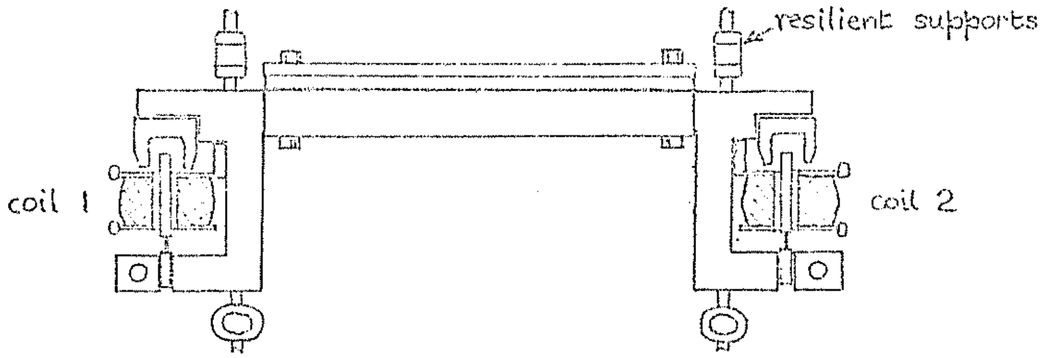


Fig. 2.2-2 Complete Assembly of Reed Filter.

It will be seen that the unit has two pairs of terminals, one pair for each reed coil.

Suppose now that an a.c. current flows in coil 1. If its frequency is the same as that of the reeds, then reed 1 will be excited to vibrate with large amplitude. Since the whole assembly is rigid and suspended on resilient mounting, the vibration will be acoustically coupled through to reed 2, which will vibrate in sympathy, since it is tuned to the same frequency. This in turn will cause a large voltage to appear between the terminals of coil 2. If the frequency of the current in coil 1 is not in tune with the reeds, the vibration coupled from one reed to the other will be small, and the voltage produced across coil 2 will be correspondingly small. The device can therefore be seen to act as a band-pass filter ; only signals having the frequency to which the reeds have been tuned are coupled through from coil 1 to coil 2. Typical figures for an actual Reed filter are as follows : for an input of 1.0V across the terminals of coil 1, the output voltage across coil 2 would be 400mV (on-tune) or about 1mV (off-tune). The band-width is very narrow (typically 0.6 to 0.9Hz between half-power points).

2.2.4 The frequency of free vibration of a reed is determined by its physical characteristics; in particular, by the thickness of the neck near the clamping point, and by the properties of the material used. Faults which cause the frequency of a reed to alter, while allowing it to continue vibrating, can thus only arise as a result of mechanical damage to the reed and are therefore rare. However, if one reed in a filter was so affected, the two reeds in the filter would now have different resonant frequencies, and the input would no longer be coupled through to the output. Only if the frequencies of both reeds shifted by exactly the same amount could the filter respond to a frequency other than that to which it was originally tuned, and the probability of this occuring is clearly very small.

The Reed filter is thus a fail-safe device in that, under any reasonable fault conditions, it will not respond to a frequency other than that to which it was originally tuned. Any fault which does occur will indicate its presence by causing a decrease in, or loss of, output voltage.

2.2.5 In physical configuration, the Reed filter occupies a rectangular moulded box; together with the appropriate amplifier unit, which clamps on top of it, it forms a complete unit which plugs into a BRB standard miniature relay plug-board (see the following sections on the Transmitter and the Receiver). The filter has two pairs of stud terminals on its top, which are designed to engage with contacts on the amplifier. The front pair of terminals is connected to the input coil, and the rear pair to the output coil.

The filters used for transmitters are different from those used for receivers, because of differences in the fine tuning of the reeds. Transmitter filters must not be used with receiver amplifiers, or vice versa.

Transmitter and receiver filters (and also amplifiers) are distinguished by the colours of their labels, thus :

blue label - transmitter;

yellow label - receiver.

RR

2.3 THE TRANSMITTER

2.3.1 Description

The type RR Reed transmitter consists of two parts : a transmitter filter; and a transmitter amplifier. The two parts clip together, and are held by a retaining scrw, to form a sicgle unit which plugs into a BRB standard miniature relay plug-board, occupying the same space as a relay.

The circuit of the complete transmitter is shown in fig. 2.3 - 1; it consists of a feedback oscillator, in which the Reed filter (see section 2.2) acts as the frequency-discriminating element in the feedback path, and an output stage. All the components except the actual Reed filter are contained in the transmitter amplifier. In order for the signal from the oscillator to be coupled to the output stage so that the transmitter gives an output, an external connection must be made between two terminals on the unit; the output can thus be controlled by a relay or switch contact.

In normal practice, a resistor is connected between the output terminals. The unit is then connected into the line in such a manner that this resistor is in series with one leg (see section 1.). The resistor is usually a 24 ohm, 1 watt metal oxide film or glaze unit, fitted with an overall insulating sleeve and crimp terminals, and fits on a small terminal block at the back of the plug-board for the corresponding transmitter. Thus, if a transmitter in a system is removed from its plugboard, the line circuit remains complete through the resistor, and the rest of the system can continue to operate normally. This feature is an important part of the flexibility of the type RR system, and enables maintenance to be carried out on one or more channels in a system without disturbance to the remaining channels

Transmitter filters and amplifiers are distinguished by means of blue labels from the corresponding receiver units, which have yellow labels.

2.3.2 <u>Electrical characteristics</u>

The terminals on the unit are numbered on the plug-board in exactly the same way as miniature relay terminals.

A smoothed and stabilised d.c. power supply at 12V is required, connected between terminals A3 (negative) and D3 (positive); the current consumption of one transmitter is 50mA.

The output from the unit appears between terminals A1 and D1, between which terminals the output resistor (see section 2.3.1 above) is connected. When the d.c. supply voltage is 12V, the output voltage should lie between 590mV and 650mV (rms.), with an output resistor of 24 ohm or 33 ohm.

For normal operation, a link is connected between terminals A2 and D2, and the output is switched between terminals A4 and D4 (by a relay or switch contact); the unit gives an output when A4 and D4 are connected together, and none when they are disconnected. With this arrangement, the reeds oscillate continuously, and the switching is accomplished in the output stage, and is very fast. If a delayed-action feature is required, then A4 and D4 can be permanently connected together, and the switching contact connected between A2 and D2 instead. This has the effect of switching the power supply to the whole unit, including the oscillator. Now the reed oscillator has long starting and stopping times, because the reeds themselves take a long time to start and stop vibrating; hence, this arrangement gives a delay, typically 3 sec., between switching and change of output.

When the unit is switched off (not transmitting), the impedance looking into the output is sufficiently high to be negligible in parallel with the 24 ohm or 33 ohm output resistor; when it becomes switched on, this impedance drops to become a resistance of about 2.7 ohm.

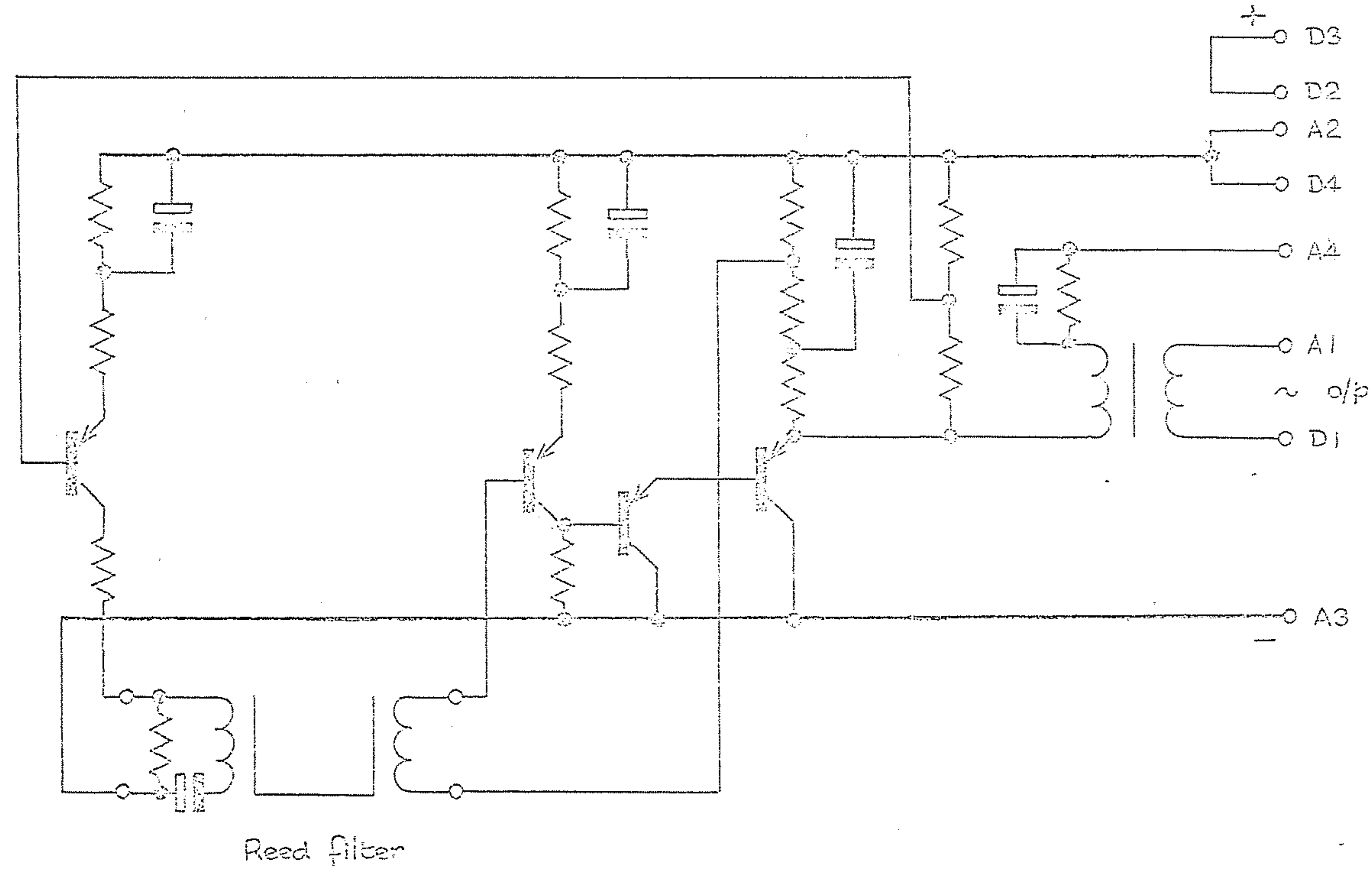


Fig. 2.3 – 1 : transmitter circuit

2.4 THE RECEIVER

2.4.1 Description

The type RR Reed receiver, like the transmitter, consists of two parts : a receiver Reed filter; and a receiver amplifier. The two parts clip together, and are held by a retaining screw, to form a single unit which plugs into a BRB standard miniature relay plugboard, and occupies the same space as a relay.

The circuit of the complete receiver is shown in fig.2.4 - 1. The input of the Reed filter (see section 2.2) is connected across the line. If a signal of the frequency to which the filter is tuned is present on the line, then a voltage appears at the output; this is amplified and rectified by the receiver amplifier to give an output at 12V d.c., which is used to drive a follower relay of standard railway signalling type (see section 2.5) which occupies its own plug-board. Clearly, the relay is only energised when the appropriate signal is present on the line, and, because of the fail-safe characteristics of the Reed filter, spurious energisation by other signals, even under fault conditions, is impossible.

Since receivers are connected in parallel with the line, they can, like transmitters, be removed from the system without affecting the operation of other channels in the same system.

Receiver filters and amplifiers are distinguished by means of yellow labels from the corresponding transmitter units, which have blue labels.

2.4.2 Electrical characteristics

There are two types of receiver amplifier in current use, differing in sensitivity, and in the connections to their terminals. They are designated types RR2002 and RR2003 ; the former is distinguished by a silver case, and the latter by a black case. A suffix T after the type number, e.g., RR/2002/T, indicates that the unit is tropicalised.

The connections to the units are as follows:

		RR 2002	RR 2003
Input from line		A4 D4	A4 D4
Output to relay	(+) (-)	D1 A1	D1 A1
D.C. power supply	(+) (-)	D2 A3	D3 A2
Connections to immunisation unit (see below)		- -	A3 D2

It will be seen that provision is made in the case of type RR2003 for the use of an immunisation unit. This device gives protection against the effects of interference from 50Hz a.c. traction currents, and is generally required for vital systems in a.c. electrified areas ; it is described in section 2.10. Where immunisation Units are not used, a link is required between terminals A3 and D2 on a plug-board for type RR2003.

The d.c. supply voltage required in both cases is 12V d.c. nominal, the permissible limits being 12.0 to 13.5V. The units draw 100mA (when energised and driving a relay). The signal levels at the input terminals required for pick-up and dropaway of the relay are as follows (figures measured at a d.c. supply voltage of 12.0V):

	RR 2002	RR 2003
dropaway (minimum)	63mV	112mV
pick-up (maximum)	95mV	165mV

The input impedance of a receiver (with either type of amplifier) is the impedance of the input coil of the Reed filter. Off-tune, it is equivalent to a resistance of 360 ohm and an inductance of 400mH in series. Near the filter frequency, it has a magnitude of 750 ohm, and indeterminate phase (the figures quoted are typical values).

Contacts of other relays which are for proving, and are normally closed when the receiver is energised, may be connected in the output circuit. However, to avoid damage to the amplifier electonics, it should not normally be possible for the output circuit to be open when the receiver is energised.

(RR 2002)

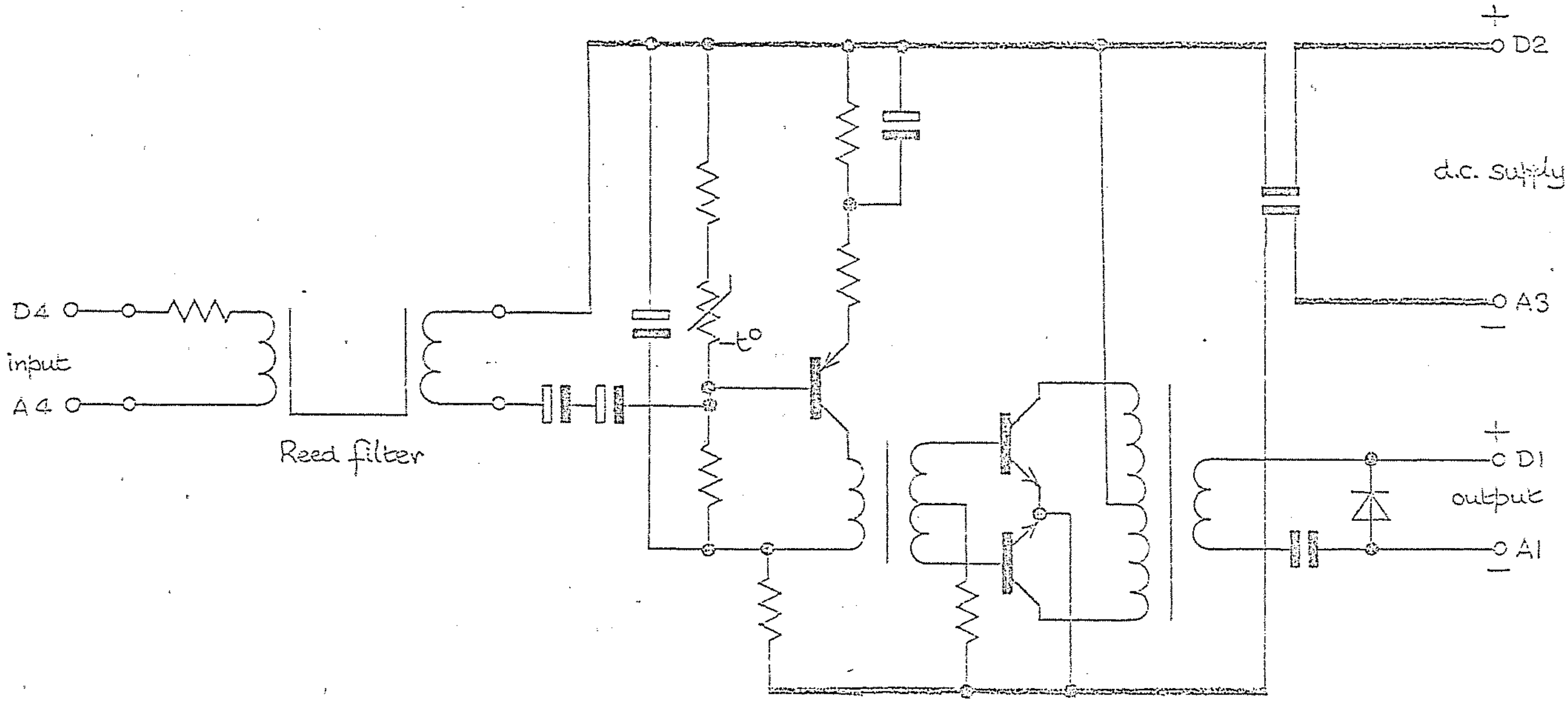


Fig. 2.4 - 1 : (i) circuit of type RR 2002 receiver

(1st of 2 sheets)

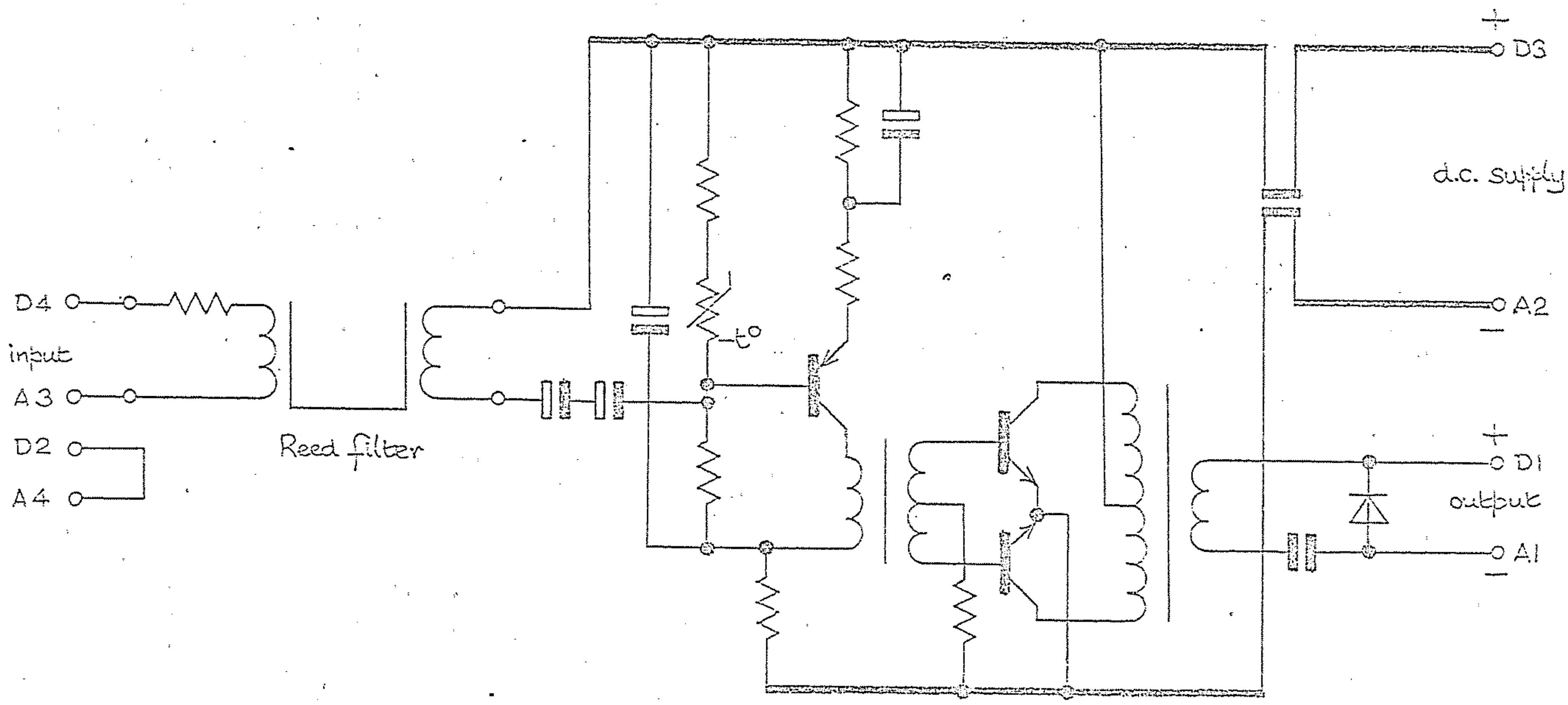


Fig. 2.4 - 1 (cont.): (ii) circuit of type RR 2003 receiver

(2nd of 2 sheets)

2.5 THE REED FOLLOWER RELAY

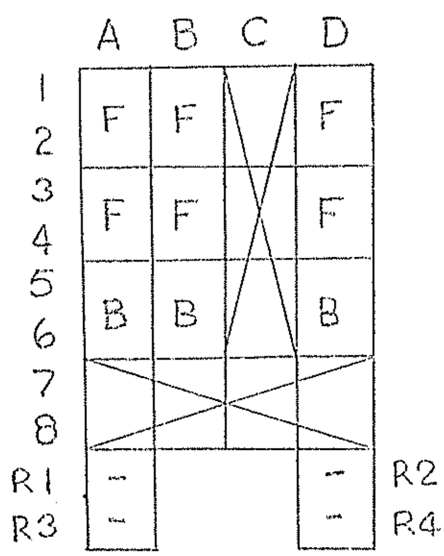
The reed receiver operates a reed following relay whose contacts can be used in the circuits of the signalling function operated by the reed channel. The relay used is AGS type ZS2411 (or equivalent type 32H10), and is a fully fail safe signalling relay to the requirements of the BR930 specifications except that it has 6F 3B contacts and a coil whose input impedance is designed to match the reed receiver output.

NO OTHER type of relay should be used for vital reed systems.

This relay has a d.c. operating value of 8.8 volts maximum and a d.c. release value of 5.7 volts minimum. Note that the output from a reed receiver is not pure d.c. as it is not full-wave rectified and meter readings may be misleading.

The relay is fitted with BRB non-interchangeability pins to code 133, and is used with AGS plugboard type RY133.

The arrangement of coil connections and contacts is as follows:



2.6 THE TRANSMITTER REPEATER UNIT

2.6.1 Description

In centralised interlockings and other large installations, controls are transmitted from the relay room over many different systems (i.e., in many different pairs) from the one point, and the same Reed frequencies are used over and over again in the various systems. In order to economise in transmitters at such an installation, the transmitter repeater unit is used; it is driven by the transmitter directly, and provides three separate isolated switched outputs, at the transmitter frequency, which can be used for three separate systems. Since one transmitter can drive up to seven repeater units, it will be seen that up to twenty-one systems can be fed from a single set of transmitters, one for each frequency.

The outputs from the t.r.u. are switched by external contacts, such as relays or switches, and each output is connected across a resistor of 24 ohm or 33 ohm connected in series with the particular system which it feeds, in exactly the same way as a transmitter output. (When a transmitter is used with a repeater unit, it is made to transmit continuously by connecting terminals A2 and D2, and A4 and D4, with permanent links). The outputs are completely isolated from each other, so that there is no possibility of unwanted connections between systems, or of interference from one system to another.

The unit plugs into a BRB standard miniature plug-board, and is the same size as a miniature relay. It is distinguished by green labels.

2.6.2 Electrical characteristics

A diagram of the circuit of the unit is given in fig.2.6. - 1. it requires a smoothed and stabilised d.c. supply at 12V, connected between terminals B3 (positive) and A3, and draws 150mA.

The input from the transmitter is connected between A1 and A2. The tree outputs appear between terminals A7 - A8, B7 - B8 and C7 - C8, and they are switched by connecting contacts between A4 - A6, B4 - B6 and C4 - C6 respectively. As stated above, a 24 ohm or 33 ohm 1 W metal oxide resistor is connected externally across each output.

The gain of the unit from its input to each output is 1, so that the signal levels at its outputs are the same as the output level for a transmitter (see section 2.3.2).

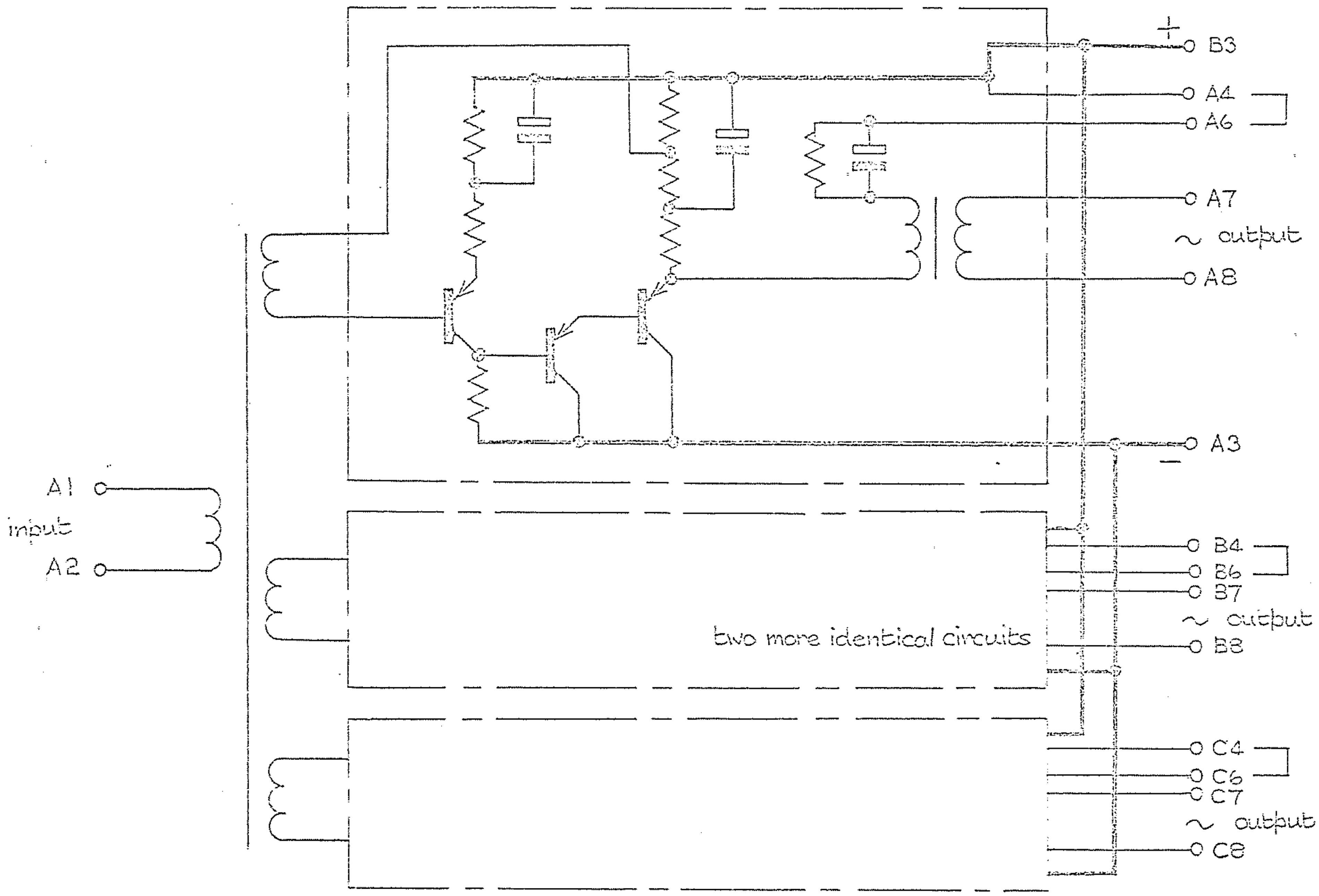


Fig. 2.6-1 : transmitter repeater circuit

(RR 1990)

2.7 THE LINE AMPLIFIER.

2.7.1 Description

For transmission over long distances, amplification is required at intermediate points to counter-act the attenuation caused by the resistance of the line. This is provided by means of the Reed line amplifier, of which the circuit is shown in fig. 2.7.1. This is a one-directional amplifier with negative feedback which can be adjusted to set the voltage gain. An outline of the unit is shown in section 5.2.

The unit is designed to be mounted on racks or in cupboards and occupies the space required for four standard miniature plug-boards. It has its own built-in rectifying and smoothing circuit, and requires an a.c. power supply at 24-26V rms., which can be obtained from 110V a.c. mains by means of the Reed line Amplifier supply transformer (type RR9210).

All the external connections to the amplifier, together with the link that sets the gain, are made to a comb with eleven 2BA terminals on it, which attaches to the terminals on the amplifier itself and makes contact with them. If the amplifier should fail for any reason, it can thus be replaced without altering the connections to the comb, which can be disconnected intact from the amplifier.

2.7.2 Electrical Characteristics.

The input terminals to the amplifier are terminals 2 and 6. The incoming line is connected to terminals 1 and 6 on the contact comb, and either a link or a resistor is connected between terminals 1 and 2 on the comb. The value of the resistor can be selected, so as to give fine control over the signal level at the output from the amplifier.

The output appears between terminals 7 and 9, and the power supply (24V a.c.) is connected between terminals 10 and 11. The feedback connection is made through a link between terminal 6 and one of the terminals 5, 4 and 3, and can be adjusted, so as to give coarse control over the voltage gain, as follows:

Link between terminals	% feedback	Voltage gain	input resistance
6 - 5	100%	1.0	1300 ohm *
6 - 4	75%	1.35	1150 ohm *
6 - 3	50%	1.9	900 ohm *

* typical values.

The gain and input resistance are independent of frequency within the Reed spectrum. At 50 Hz, however, the input resistance is considerably reduced, so that the amplifier shunts stray 50 Hz currents, and does not propagate them along the system.

The output impedance of the amplifier is typically 20 ohm, both at Reed frequencies and at 50 Hz.

2.7.3 Line Sectionalisation

Since the amplifier contains transformers in both input and output circuits (see fig.2.7-1), it sectionalises the line where it is inserted, isolating the section connected to its input from that connected to its output for d.c. and surge currents. (If sectionalisation is required without amplification, the isolating transformer, described in section 2.8 below, may be used for this purpose instead).

However, it passes 50 Hz currents, through with a gain reduced to about half its value at Reed frequencies. To block these currents, and prevent heavy 50 Hz currents from saturating the input and output transformers, additional filters may be required (see section 2.10).

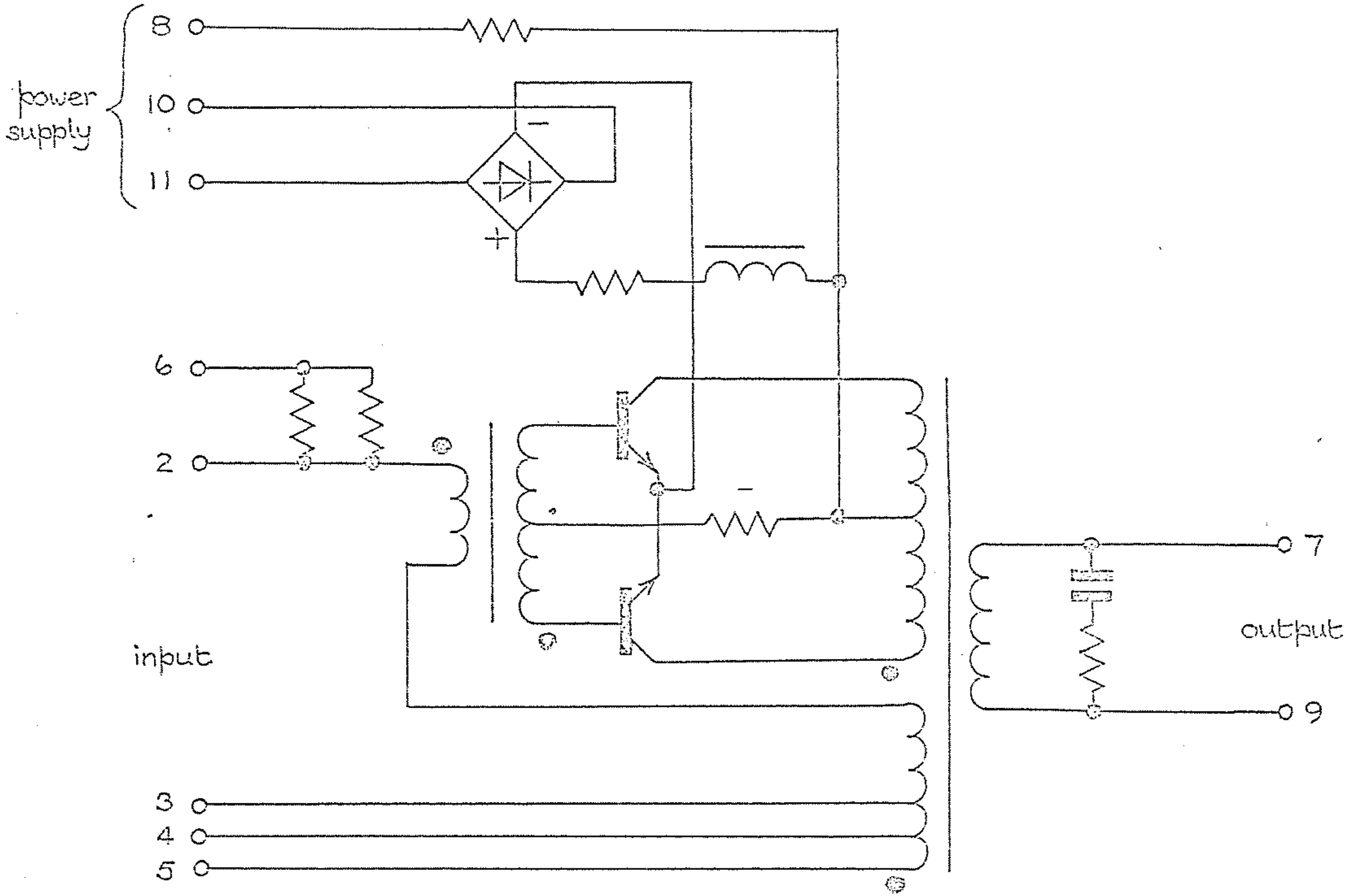


Fig. 2.7−1 : line amplifier circuit (RR8101)

2.8 THE LINE ISOLATING TRANSFORMER

2.8.1 Sectionalising the Line

In systems operating over long distances it is usually necessary to divide the line into isolated sections. This sectionalisation is achieved in the type RR system by means of the line isolating transformer type RR8200, which permits the passage of the Reed signals along the system but blocks d.c. currents and surges, and attenuates 50Hz currents due to interference from mains or a.c. traction supplies. It should be noted that the line amplifier (see section 2.7) also acts as a sectionalising device. Thus, in typical system where line amplifiers are required every 4km and the line is to be divided into 2km sections (for example), amplifiers and isolating transformers would be alternated, as shown in fig. 2.8-1:

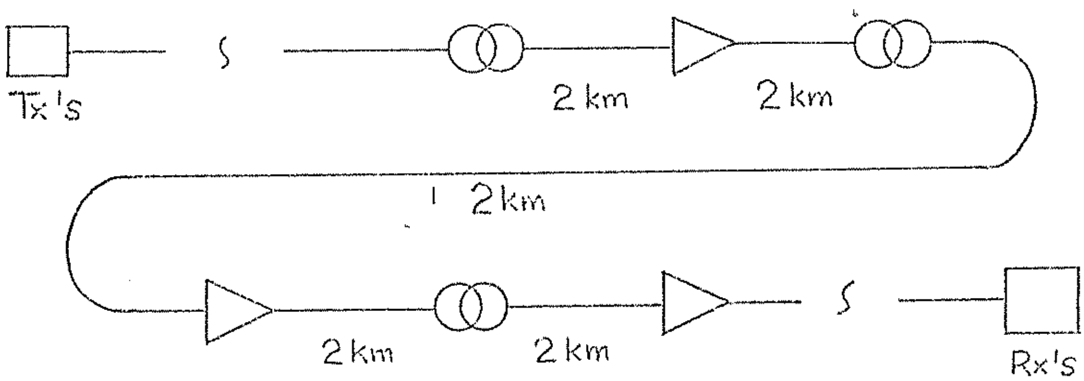


Fig. 2.8-1: Sectionalisation of a typical system.

2.8.2 Electrical Characteristics

The line isolating transformer is attached to a plate which enables it to be mounted in the space occupied by a standard miniature plug-board in a relay-room or cupboard.

Six terminals, in the form of 2BA studs, numbered T1 - T2 and t1 - t4, are arranged on the front of the transformer. T1 and T2 are connected to the primary winding, and are used for the section of line coming from the transmitter end of the system; t1 - t4 are connected to the secondary winding and used for the receiver end section of the line. The turns ratios between the various secondary taps and the primary winding are as follows:

Secondary terminals	Turns ratio
t1 - t2	1 : 1
t1 - t3	1 : 1.2
t1 - t4	1 : 1.4

The taps are used to give an increase in signal level, to counteract the attenuation due to the resistance of the line. The amount of voltage gain that can be obtained in this way is limited by the fact that, as the turns ratio is increased, so the line impedance looking into into the transformer primary winding decreases, and it is usually necessary to use line amplifiers at intervals to maintain the signal level along the system, as described in section 2.8.1.

The primary inductance is 70 mH. At 50 Hz, this constitutes a low impedance connected across the line, and the transformer therefore attenuates 50 Hz signals on the line by shunting them.

2.9 REED POWER SUPPLIES

2.9.1 Description

Reed transmitters and receivers, and also transmitter repeaters, require d.c. power supplies at 12V. These are generated from 110V a.c. mains by Reed power supply units. These are available in two current ratings. Line amplifiers normally derive their power supplies from the line amplifier supply transformer (see section 2.7.1), which also works from 110V a.c. mains. The only external supplies to cupboards and relay rooms required for Reed equipment, therefore, are 110V mains supplies.

The signal levels at the outputs of transmitters and receivers increase if the power supply voltage is increased. It is therefore essential to the integrity of the system that the output voltage from the d.c. power supplies should not be able to increase even under fault conditions, and also that the level of ripple voltage on the d.c. output should not be able to increase. These requirements are met by an arrangement consisting of a 110/12V constant-voltage transformer, whose output is rectified by a bridge rectifier of silicon diodes, and smoothed by large electrolytic capacitors connected across the d.c. output. The smoothing capacitors are four-terminal devices, connected in such a way that, if a capacitor became disconnected from the supply, then the output circuit would be broken. This ensures that, even under fault conditions, it is impossible for an output to appear with 100% a.c. ripple superimposed on it. The complete arrangement, for both types of d.c. supply, is as shown in fig. 2.9.-1 :

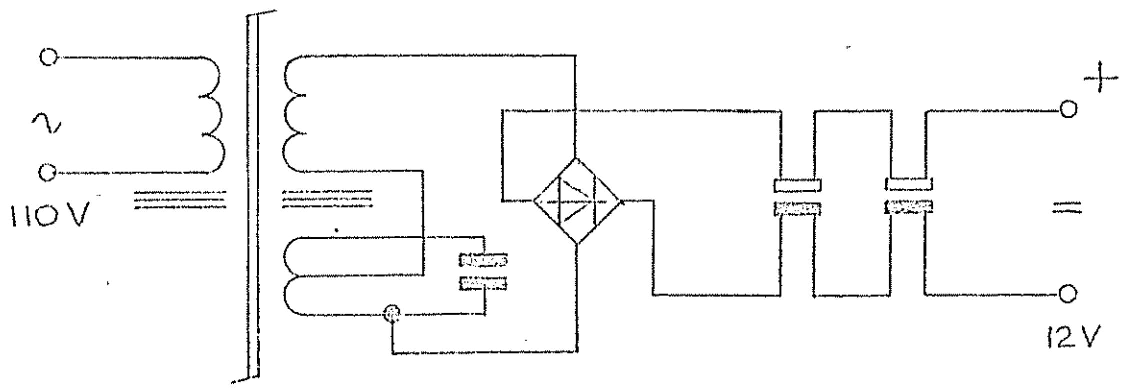


Fig. 2.9.-1: Circuit of Reed power supply.

The two types of d.c. supply give maximum currents of 600mA and 5A, at 12V d.c., respectively, and are used according to the power requirements at each location. Where there is equipment belonging to several systems at a location, a separate supply unit must be provided for each system, so that transmitters and receivers belonging to different systems are never fed from the same supply unit.

2.9.2 Electrical Characteristics

The two types of d.c. supply are designated RR9120 (600mA) and RR9130 (5A) respectively. They have the following characteristics when fed from 110V mains :

Type	RR9120	RR9130
Full load current	600mA	5A
Max. ripple at full load (peak to peak)	300mV	700mV
Permissible range of output voltage	12.0-13.5	12.0-13.5

The supply voltage should lie between 95V and 125V rms.

The units are designed to be mounted directly on relay room or location cupboard racks, in the same way as standard miniature plug-boards. The RR9120 requires the same space as one plug-board, and the RR9130 the same space as three.

2.10 A.C. IMMUNISATION

In railway territory where there are 50Hz a.c. traction power supplies, and in areas where lines carrying Reed systems pass near power transmission lines, it is possible for large 50Hz currents to be induced in the Reed lines, especially under fault conditions. When such currents pass through the input windings of Reed receivers and line amplifiers, they can cause the windings to saturate magnetically, and, under such conditions, the composite Reed signal, containing as it does many frequencies at close spacing, can generate intermodulation products and give rise to signals at spurious frequencies. In a frequency-division multiplex system this is clearly incompatible with safe operation of vital circuits.

Fuses are therefore provided in the input and output circuits of the line amplifier, of such a rating that they will rupture at a current level below that at which the circuits saturate. For the receiver an immunisation unit is used, consisting of a filter, which is a series inductor and capacitor, together with a fuse which will rupture before the inductor saturates. Two types of unit are required to cover the entire range of Reed frequencies; they are as follows:

type RR 8510 - colour code GREEN - use with channels

f1 - f31, f71, f86 - f92.

type RR 8520 - colour code BROWN - use with channels

f32 - f51, f72, f81 - f85.

The whole body of the unit is painted in the code colour. An immunisation unit must not be used with a receiver of a frequency for which it is not intended. For small systems, where the full range of frequencies is not used and the use of two types of unit is not justified, a third type can be used instead, covering the middle band of frequencies:

type RR 8530 - colour code WHITE - use with channels

f17 - f44 and f84 - f86.

One immunisation unit can be used in the input to a group of up to five receivers, providing they are all in the right frequency range. The unit has a cylindrical case, 1½in diameter and 3¼in long, and is designed to be mounted on a 4 x 2 BA. terminal block at the back of the receiver plug-board.

3.0 APPLICATION OF THE EQUIPMENT

3.0.1 Contents of Section 3

3.1 DESIGN OF TYPE RR SYSTEMS.

3.1.1. Type RR Systems

In the previous two sections, the basic principles of type RR equipment have been described, together with the individual units. In this section it will be shown how the units are combined to form complete systems.

The distinction must be made here between NON -VITAL and VITAL systems. Vital systems are those which are used for carrying vital signalling functions, so that fail-safe characteristics are required throughout. The safety features of the individual type RR units have been described in section 2, and the distinction therefore principally concerns the integrity of the line-pair. It will be seen that the requirements for the line are much more stringent for vital systems than for non-vital ones. The following is therefore divided into two sections; the first covers requirements for all Type RR systems, and the second covers additional requirements for vital systems.

3.1.2. Requirements for all systems

The following considerations apply to all Type RR systems. They are concerned with the basic parameters of the equipment, and not with safety features.

3.1.2.1. The line pair

Broadly speaking, type RR equipment will function using any pair of conductors as the line and in particular does not require a matched transmission line. Because the input/output circuits of all the units include transformers (see section 2), it is not advisable to use a pair in which a steady d.c. is present without taking special precautions to isolate the equipment.

In general, pairs of conductors in standard railway signalling and telecommunications cables and on overhead pole routes are suitable for Reed systems. In cables, twisted pairs can be used with advantage to minimise crosstalk on long systems (longer than 25 km). On pole routes, it should be noted that galvanised-iron conductors have a high resistance which severely limits the maximum possible distance between amplifiers, so that such conductors are unsuitable, and copper should be used instead.

Whatever type of line is employed, its series resistance per unit length, considered in conjunction with the input resistance and voltage gain of the line amplifier, determines the maximum spacing at which amplifiers will be required in a system. For example, the resistance of 1/.036 Copper conductors as used in standard railway signalling cable is approximately 50 ohm/km loop; the total resistance of a 2 km section of line in this cable would therefore be 100 ohm. The input resistance of the amplifier depends upon the load connected across its output, as shown in fig. 3.1-1; its voltage gain is nominally 1 (note that this figure is for the 100% setting -see section 2.7).

Each transmitter is connected in parallel with a resistor (either 24 or 33 ohm) and all the resistors are connected in series with the line (see section 1.2.1.). The loading effect of the transmitter itself is negligible in comparison with the resistor and each transmitter therefore appears simply as a resistance of either 24 or 33 ohm in the line at the appropriate point.

Each receiver appears as an impedance of 1500j ohm in parallel with the line (approximately) to Reed frequencies other than its own. To its own frequency, it appears as an impedance of 750j ohm in parallel with the line.

The line isolating transformer has a nominal ratio of 1:1, and also has inductance, which appears as a load of 250j ohm connected across the line in parallel with the primary winding.

3.1.2.1. cont.

The level of the output signal from a transmitter is nominally 700 mV. So as to allow an adequate margin, systems should be designed so that the levels at the input terminals of all receivers are all approximately 300 mV (in the case of type RR 200 1 and type RR 2003 using external inductors or immunisation units in series with their inputs (see section 2.10.2), this does not include the voltage drop across the inductor or immunisation unit, for which an additional 30 mV should be allowed).

Using the various figures quoted above, it will be seen that a complete Type RR system can, if necessary, be designed by calculation step by step. This procedure is necessary whenever a special case arises; for instance, if the use of a non-standard type of cable is being considered, or if a possible duplex system is being investigated. As an illustration, an equivalent circuit fora typical type RR system, based on the above figures, is shown in fig. 3.1-2.

However, for many standard systems, it is possible to derive a set of rules for design, and these can then be used satisfactorily in the majority of cases, without the need for detailed calculations; calculation can be used as a check wherever any doubt arises. The rules are set out in sections 3.1.2.2. to 3.1.2.10 below.

3.1.2.2. Line levels and isolation.

If it is proposed to use pairs for type RR systems in cables shared with telecommunications circuits, attention is drawn to the peak transmission level of up to 30V for a full system, which is likely to produce unacceptably high crosstalk levels in the telecommunications circuits.

In a.c. electrified areas where the Reed systems are in cable, or where serious parallelism with supply authority overhead lines occurs, the system should be sectionalised, by means of line amplifiers or isolating transformers as appropriate, every 2 km or at such distances as the safety requirements of the C.C.I.T.T. require. Amplifiers and transformers may be used at alternate isolating points, bearing in mind the rules for additional line amplifiers given below (section 3.1.2.3.), but transformers at successive isolating points should NOT be used, because of their loading effect on the line.

In sections where there is no traction or supply interference, the spacing of line amplifiers depends upon the type of conductor; for 1/.036 conductors in signalling cable, the maximum advisable spacing is 4 km; for 40 lb. conductors on pole routes, it is 10 km . Basically, a loop resistance of 200 ohm per section should be aimed for.

3.1.2.3. Rules for Additional Line Amplifiers.

An additional line amplifier should be inserted into the system or substituted for a line transformer in accordance with the following rules.

1) If the number of transmitters which would have occurred in the input to one line amplifier or between two line amplifiers would have been 25 or more then an additional line amplifier should be introduced so as to reduce the number to below 25.

   An exception is made in the case of the initial line amplifier of a control system situated in the relay room or location housing all the transmitters of the system.

2) If more than 4 transmitters would have occurred on the input of one isolating transformer or between the previous amplifier and the isolating transformer, the transformer is replaced by an amplifier.

3) If more than 17 receivers would have been connected on the output of an amplifier, or between one amplifier and the next amplifier, additional line amplifiers should be introduced to reduce the number of receivers to 17 or less.

   An exception is made in the case of the final line amplifier of an indication system situated at the relay room or location housing all the receivers on the system.

4) If more than 4 receivers would have been connected on the output of a line transformer or between it and the next amplifier ahead, replace the transformer with a line amplifier, and observe 3) above.

3.1.2.4. Terminal Amplifiers for Control and Indication Systems.

An amplifier is always interposed at the relay room or location at which the system terminates between the incoming line and the receivers of an indication system. Similarly a line amplifier is used between the transmitters or TRUs of a control system and the outgoing line.

The nearest isolation point to the terminal line amplifier of an indication system should also be fitted with a line amplifier and not an isolating transformer.

3.1.2.5 Branched systems

There are many possible configurations of systems having one or more branches, and they cannot be treated in detail in a standard set of rules. Short branches can sometimes be treated as part of the main system, i.e., just as a group of transmitters or receivers in one place. For long branches, use should be made of amplifiers to isolate the branches. Note that the output impedance of the amplifier is very low (about 20 ohm), and it can therefore readily be connected, in series with the branch, to the input of a second amplifier feeding the main system, thus:

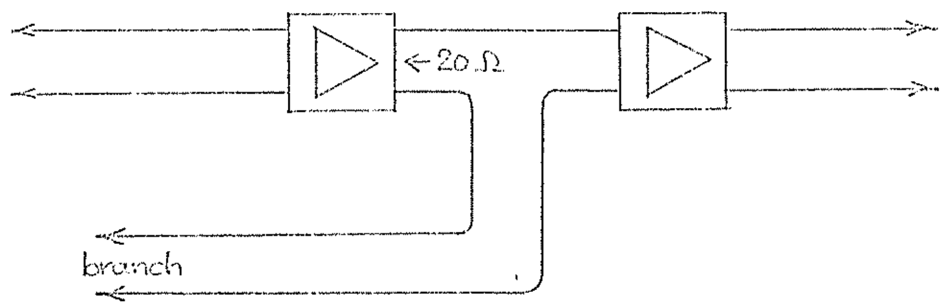


Fig. 3.1.2 - 1

3.1.2.6 Use of transmitter repeater units

In large interlockings where transmitter repeater units are used, up to nine can be fed from a single standard Reed transmitter; this economises in Reed filters. The connections from the transmitter should be in twin screened cable (e.g., twin 14/.0076, braided - screen), with all screens earthed at one end only to a single independent low-resistance earth; this is necessary to avoid coupling between the t.r.u. input and its three outputs. For the same reason, the three output pairs should not be closely bundled together.

3.1.2.7 Transmitter switching circuit

There is no restriction on the length of the transmitter switching circuit (see section 2.3), within the same relay room or location cupboard. If the run exceeds about 2m, it should be made in twin 9/.012 twisted-pair cable, or a suitable equivalent size.

Connections outside the relay room or cupboard isolated from other sources of interference may be made in the same cable, up to a distance of 250m only.

3.1.2.8 Receiver Outputs

Connections from receiver to reed follower relay should be made in twin 9/".012 twisted pair cable and should not exceed 20 m in length.

Contacts in this circuit which are for proving, and which are normally closed when the receiver is energised, are acceptable. This circuit should not, however, be normally capable of being open when the receiver is energised, because damage to the receiver can result if it is energised when its output is open circuit.

3.1.2.9 Power Supplies

One 5 amp supply unit type RR9130 should be allowed for each system at the relay room. The connections should be made in the manner described section 3.2.1.

Power supplies for master transmitters should be taken from groups of supply units type RR9120 arranged and wired in the manner described in section 3.2.1.

Type RR9120 supply units will normally be used in locations in the field, and each unit will supply up to the following numbers of transmitters or receivers:

Number of Transmitters	Together with Number of Receivers
10	-
8	1
7	2
5	3
3	4
1	5
-	6

Power supply units should not be used to feed transmitters of the same frequency in different systems.

All d.c. supply leads should be as short as possible, be run straight rather than in loops when single and in twisted pair cable when paired. Follow the instructions on wiring in section 3.2.

3.1.2.10 Selection of frquencies

Although the response of individual line amplifiers and isolating transformers is almost independent of frequency over the range (350 - 900 Hz) used in the Type RR systems, there is sufficient discrimination present to produce a measurable effect in long systems, such that higher frequencies are transmitted with slightly less attenuation than lower ones (note that this effect is the opposite of that which would be expected from a plain length of cable, with no intermediate amplifiers, transformers, etc.). To counter the effect, the following rules should be observed:

(i) Systems should be designed so that channels with higher frequencies work to points further from the control point;

(ii) Where the full number of available channels is not required for a system, those in the middle of the frequency band should be used in preference for those near its ends;

(iii) Within individual sections, frequencies should be grouped as closely as possible;

(1V) A few spare frequencies should be left unused throughout the range, so that, if additions are required after installation, they can be made without infringing the above rules.

Note that a list of frequencies and their associated channel numbers is to be found in section 5. Note, in particular that the lower channel numbers correspond to the higher frequencies, and vice versa (e.g. f.1 is 879.5 Hz; f.51 is 395.25 Hz).

3.1.2.11 Lightning protection

When considering the provision of lightning protection, it is necessary to weigh the cost of full protection against the anticipated risk to the equipment; only in regions with very high incidence of electrical storms is provision of full protection justified.

For full protection, surge diverters such as AEI type 16A and Reed surge protection units type RR8401 are connected into every line pair entering a location or relay room, and, in addition, surge diverters alone are connected to every other cable entering; any unprotected core whatsoever can provide a possible route into the location for surges. This degree of protection would normally only be required where overhead lines are used.

Where conditions are less extreme, it is sufficient for non-vital type RR systems to provide surge diverters only, and where systems run entirely in cable, it may be considered possible to dispense with these as well. It should be noted, however, that different considerations apply to vital systems (see section 3.1.3 below).

3.1.3. Additional requirements for vital systems.

In systems which are used for the transmission of vital signalling functions, it is necessary to take steps to secure the integrity of the line for each system at the same high level as that of the individual units. The design of the line must therefore be such that the levels of spurious signals developed in it are kept within safe limits in all reasonable conditions. Such spurious signals can occur as a result of crosstalk between systems where lines run adjacent to one another, and also as a result of intermodulation between the various frquencies in a system (and between system frequencies and harmonics of the mains frequency, at places where the latter are induced into the line, either from power distribution cables or from a.c. traction systems). To protect against their effects, the additional rules set out below must be observed for vital systems.

3.1.3.1. Multicore cables.

It is recommended that a twisted-pair cable, generally to British Railways specification BR 972A, be used wherever possible. However, standard multicore signalling cable to British Railways specification BR 972 A can be used for vital systems, and all the cores can be employed, providing the following conditions are observed.

a) The cable must be of a type in which successive layers of cores are laid with opposite directions of rotation (i.e. NOT 'unilay').

b) No system must use two cores in different layers in the cable.

c) Where line-pairs for successive systems lie adjacent to one another within a layer, alternate pairs of the series should be transposed at a break point approximately midway between line sectionalising points throughout. The principle is illustrated in fig. 3.1.3-1 below:

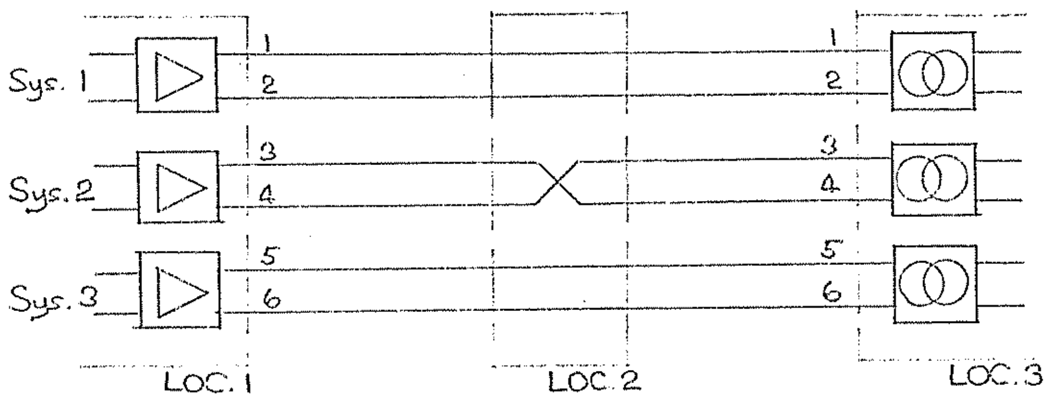


Fig. 3.1.3 - 1 : typical transposition in multicore cable.

In the illustration, systems 1,2 and 3 occupy cores 1 to 6, which are successive cores in one layer of a cable, as shown. All three systems are sectionalised at location 1, and again at location 3, and a cable break also occurs at location 2, which lies approximately half-way between locations 1 and 3. At this point, system 2 only is transposed, so that core 3 coming from location 1 is connected to core 4 going to location 3, and vice versa. This has the effect of making cross-talk voltages induced by each system into the others cancel out in each half-section. The transposition point should be as near the middle of the section as possible, and in any case not more than 400 m from the mid-point.

d) For vital systems in multicore cable, sectionalisation at intervals not greater than 2 km is essential to minimise crosstalk, whether or not there is interference from power lines.

3.1.3.2 Overhead lines

Overhead line is acceptable for vital systems, except in a.c. electrified territory. A standard scheme of transpositions must be used to minimise crosstalk in cases where there is more than one system on a route, and sectionalisation is also essential, at intervals not greater than 10 km.

Composite systems, partly in cable and partly on overhead lines are acceptable providing the appropriate rules are observed for the individual sections.

3.1.3.3 Line levels

Because of the importance of keeping interference levels to a minimum, it will be understood that it is essential to control signal levels on the line closely, and, in particular, to prevent levels rising above a certain limit. It is recommended that all signal levels should be kept within the range 270 to 350 mv for vital systems.

To prevent the output levels from transmitters from rising, the d.c. supply voltage to the transmitters must be prevented from rising. This feature is inherent in the design of the power supplies (see section 2.9), but is dependent on the frequency of the mains supply to the power units remaining within ± 3% of the nominal 50Hz (i.e., between 48.5 and 51.5 Hz). (It should be noted that this is a much greater range of variation than would normally be expected from the national grid; it is with stand-by supplies at relay rooms that care is required).

3.1.3.4 Earth faults

Where there are many vital systems in a cable or on a pole route, earth faults on the lines are fundamentally dangerous in that crosstalk levels can be increased considerably by such faults, especially when several occur in combination. Every possible precaution must therefore be taken to protect against them. In particular, it should be noted that a single earth fault can occur on a system without affecting its normal operation, and can therefore remain undetected until further faults occur and give rise to a potentially dangerous situation. It is therefore essential to check such systems regularly with an earth leakage detector. Regular measurement of the 'background' levels on channels when they are not energised will assist in early detection of earth faults; such a procedure is described in section 4 of this handbook. To protect against earth faults, it is recommended that crimped connections be used whereever possible in preference to screw terminals for connections between multicore cables, and for connections to local extension leads within locations.

3.1.3.5 50 Hz immunisation

For vital systems in areas where there is interference from 50 Hz traction or power supply lines, 50 Hz immunisation is essential as a safety feature, to prevent saturation of the input and output transformers of receivers, line amplifiers, etc., and consequent generation of spurious signals by intermodulation. The apparatus required is fully described in section 2.10.

3.1.3.6 Lightning protection

For non-vital systems, the use of surge diverters for lightning protection has already been recommended (see section 3.1.2.10). These operate by providing a low-resistance path to earth from the line for surges, and normally consist either of gas discharge tubes or of non-linear resistors. From the above remarks on earth faults (section 3.1.3.4), however, it will be seen that the introduction of such earth connections into close proximity with the line is incompatible with safe operation in cases where there are several systems per route, and lightning protection is therefore ruled out in such cases.

For vital systems in multicore cables, therefore, surge diverters must <u>not</u> be used; similarly, they must <u>not</u> be used for vital systems on overhead pole routes if number of systems per route exceeds four (crosstalk conditions are less severe on overhead lines than in cables). However, in many areas,

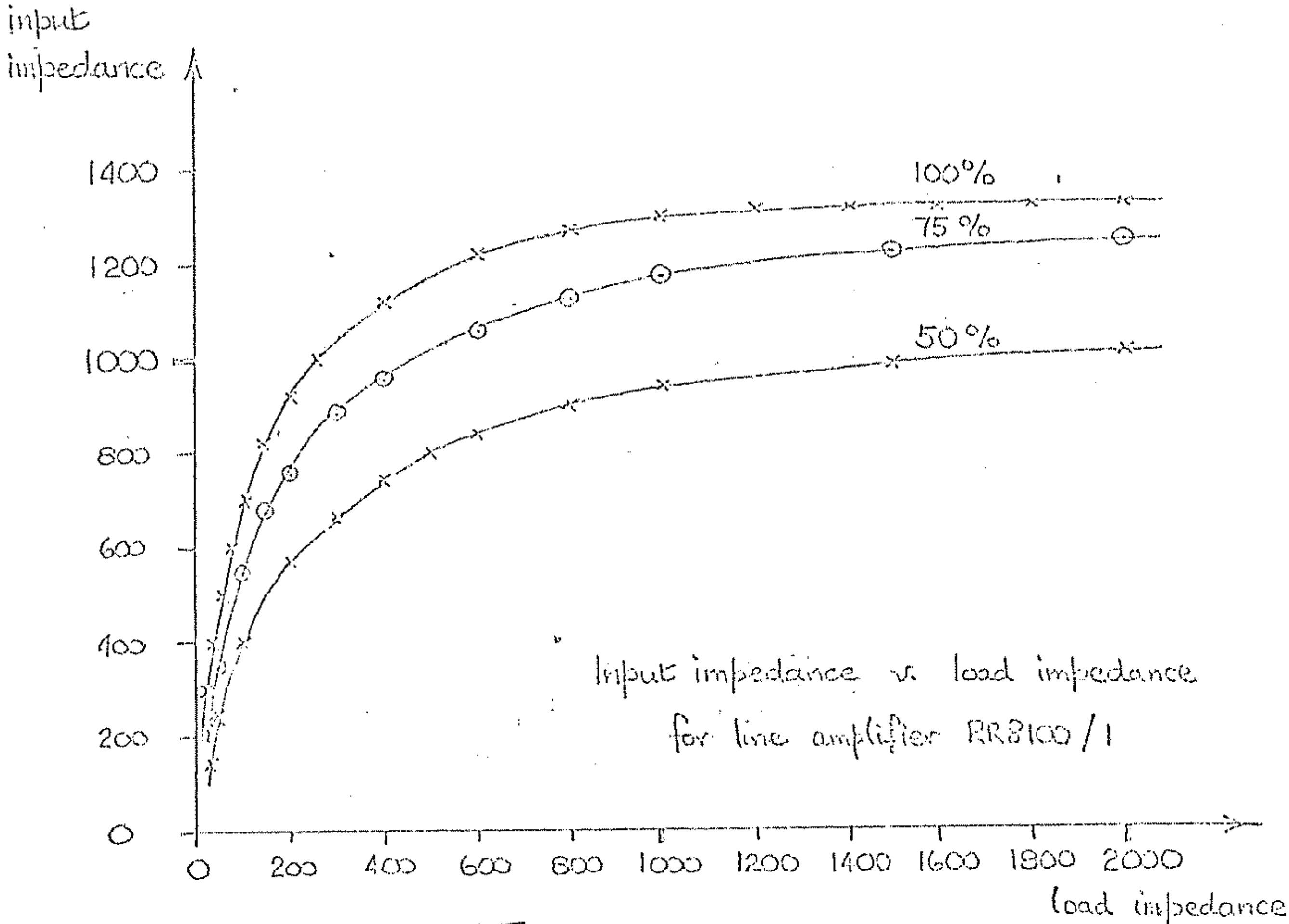


FIG. 3.1 – 1

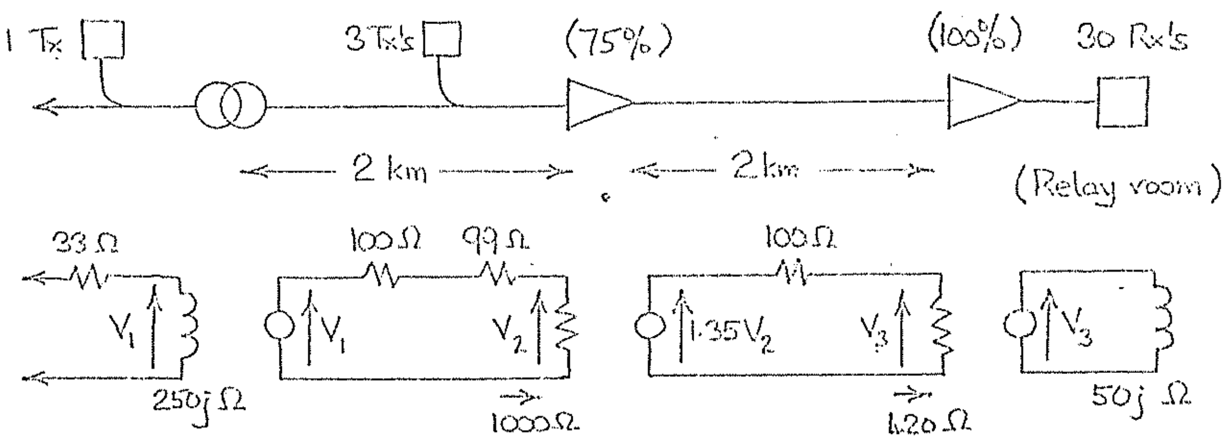


FIG. 3.1 – 2

Equivalent circuit of part of a typical system (controls), in cable having a resistance of 50 Ω/km loop.

3.2 INSTALLATION AND COMMISSIONING

3.2.1 Installation of the equipment

This section gives the procedures that are required on site when a large scheme using Type RR equipment is being installed.

Particular attention is drawn to the requirements for the wiring of connections between units, as they affect the integrity of vital systems.

Note that a table of equivalent cable sizes (Imperial/metric) is given in section 3.2.3; in order to conform with existing practice, cable sizes are specified in Imperial units in the test.

3.2.1.1 Wiring of equipment in the centralised interlocking

The recommended cable is 250V grade, PCP/VIR insulated to class C1, B.R. 972 A. In general, twin twisted pair 9/".012 should be used with the following connections needing special attention.

(a) POWER SUPPLY UNITS TO EITHER RECEIVERS OR TRANSMITTERS (NOT MASTER TRANSMITTERS).

When a type RR 9130 power unit is used to feed all the units on a particular system, the units should be fed from up to six connections, each spur feeding not more than twelve units, with all the units on a particular spur being on the same row of the rack. The RR 9130 power unit has three parallel outputs, enabling two spurs to be fed off each output as necessary. Each cable from the power unit to thefirst transmitter or receiver unit must be no longer than 3m. and is to be twin twisted pair 9/".012. The looping wires between transmitters or receivers should be as short as is reasonably possible, and preferably in 1/".044 cable.

(b) POWER SUPPLY UNITS TO MASTER TRANSMITTERS

For vital Systems, type RR9120 Power Units must be used, with each unit feeding no more than eight transmitters, all the transmitters fed from a particular unit being on the same row of the rack. Each cable from a power unit to the first transmitter must be no longer than 3m. and is to be twin twisted pair 9/".012. The looping wires between transmitters should be as short as is reasonably possibe and preferably in 1/".044 cable.

For non-vital Systems, all master transmitters may be fed from a single type RR 9130 power unit; the same wiring rules should be followed.

(c) POWER SUPPLY UNIT TO TRANSMITTER REPEATER UNITS (TRUS)

One type RR 9130 power unit may feed a maximum of 33 TRUs, and these should be fed from up to nine spur connections, three connections being made to each output terminal of the power supply unit as necessary. Not more than 4 TRUs should be fed from one spur, with all the units on a particular spar being on the same row of the rack. Each cable from the power unit to the first unit must be no longer than 3m. and is to be twin twisted pair 9/".012. The looping wires between units should be as short as is reasonably possible and preferably in 1/".044 cable.

3.2.1.1 (cont.)

(d) MASTER TRANSMITTER OUTPUTS TO TRUS.

Connections between associated transmitter repeater units and their master transmitters are to be twin twisted screened cable 14/".0076.
All screens on cables from a particular transmitter are to be connected together with the final connections taken to a free independent earth.

(e) RECEIVERS TO REED FOLLOWER RELAYS.

The twin twisted pair 9/".012 cabling between these relays should be kept as short as possible and should not exceed 20m.

(f) TRANSMITTER AND TRU OUTPUT CONNECTIONS.

Resistors should be crimped directly on to the plugboard spades.
For transmitters these will be A1 and D1, and for TRUs A7 and A8, B7 and B8, and C7 and C8.

For vital Systems, alternate TRU outputs in each systems should be connected in antiphase, i.e., each system should be connected A7 and A7 and A8 to A8 (or B, or C, as appropriate) on adjacent units. This minimises interference coupled through the TRU outputs.

3.2.1.2 Wiring of equipment in location cases.

All wiring should be in 9/".012 single core, 250V grade, PVP/VIR insulated to class C1, B.R. 972 A. Wire runs should be as short as possible and arranged in a logical order.

3.2.1.3 Checking the line before plugging in units.

Normal cable testing techniques should be used to ensure that the line, be it either overhead or multicore, is free from earths and high resistance joints.

Where approved crimp terminals rather than slotted links with their assocoated nuts and washers are used for line connections at interlockings and location casos, it is necessary to carry out normal cable continuity and insulation testing before units are plugged in and connections made to line amplifiers and isolation transformers.

At this stage it is useful to ensure that good telephone communication exists between each Reed location and the relay room, as this is absolutely essential for the setting up of the Reed systems.

3.2.1.4 Preliminary testing in the relay room and locations before plugging in units

Check the wiring of the reed systems, noting in particular that the correct polarities have been observed on the plugboards for the power supply connections. This is most important as incorrect polarity will damage or destroy the amplifiers. Ensure that the number of plugboards connected to one power supply does not exceed the maximum number scheduled. If standby supplies are provided check for correct polarities on plugboards and also, where applicable, on line amplifiers, as again these will be destroyed with incorrect polarities.

Receiver outputs (A1, D1) are connected to a reed follower plugboard, terminals R1 and R4, with a permanent link between R2 and R3. Carefully check that this circuit is complete, strapping out any contacts which may be present and finally mounting the reed follower relay, type 32M10. It is most important that receiver output circuits are complete, and if it is found necessary to switch reed following relays directly from a local test panel to facilitate internal signalling testing, then a 1500 ohm 1 watt resistor must be connected across the output terminals A1 and D1 of each affected receiver, and care taken to ensure that the d.c. test supply is not connected to any receiver.

3.2.1.5 Plugging in units and associated testing.

After satisfactorily carrying out the preliminary testing, and having mounted the follower relays as detailed in para 3.2.1.4, transmitters, TRUs, and receivers may be plugged in and the power switched on. Check that all line amplifiers are working and that they are set to 100% and that isolating transformers are on the 1:1 tap. Switch on each transmitter by temporarily shorting terminals A4 and D4 (or A2-D2 if h.t. switching is employed) and check that each output is between 0.62 and 0.75 volts a.c. If the voltage is lower, change the amplifier portion first before suspecting the filter. Ensure after testing that each transmitter is switched off.

Check the master transmitter outputs in a similar manner. The switching contacts on each TRU should also be temporarily shorted out and the outputs observed.

3.2.2 Setting up the systems

3.2.2.1 The object of setting up the systems is to ensure that each reed receiver is operated within the optimum input voltage levels of 270 to 350mV. When small systems are to be set up, it is in order to switch on one channel at a time and observe the input volts to a particular receiver, but on larger systems it is essential to switch on all channels which are normally energised. Consequently, to obtain an individual channel level it is necessary to use, the appropriate receiver filter and, for convenience, a filter adaptor (see section 4.2.1, noting that intermediate line amplifier is unnecessary during setting up). The reading obtained corresponding to the optimum input level should be between 110 and 150mV.

3.2.2.2 System levels may be adjusted by the following :

(i) Line Amplifier

By changing the feedback tap and, if finer adjustment is necessary, by adding suitable resistance in series with the input circuit. Suitable resistors would be a metal oxide glass encapsulated type rating 1 watt with a range of values between 68 and 820 ohms.

(ii) Isolating Transformer

By changing the tap on the secondary winding.

System channel levels are adjusted by working progressively away from the relay room. A system may be divided into sections, each section being terminated with either a line amplifier or an isolating transformer.

In the typical indication system shown in fig. 3.2.2-1, adjustment of the isolating transformer at location A will alter the received levels from all the transmitters in section 2 (and to a lesser extent from the following sections). Adjust this isolating transformer at location A until the received levels in the relay room from transmitters in section 2 are correct and follow a similar procedure progressively for all other sections, i.e. line amplifier at location C to be adjusted for correct received levels from transmitters in section 3 etc., until the system is completed and all receiver levels are correctly set.

In the typical control system shown in fig. 3.2.2-2, adjustment of the isolating transformer at location A should be made to ensure correct input levels to the receivers in section 2; in this instance a check must be made to ensure that the receivers at location B are also correctly fed. A similar procedure is to be followed for all other sections i.e. line amplifier at location B to be adjusted for correct received levels in section 3 etc.

It is important to keep the gain of both line amplifiers and isolating transformers as low as possible i.e. to compensate for losses in previous line section, and this is particularly important in long systems where there may be many sections between the first field unit and the relay room. For indication systems of this type, it is convenient to switch on in the field a high and low frequency (possibly f6 and f47) transmitter, checking and adjusting these levels progressively section by section back to the relay room. Conversely, with a control system of this type, having switched on the appropriate high and low frequency transmitters, check and adjust these levels section by section progressively away from the relay room to the first field units. These individual channel levels in each section should be adjusted to lie between 270 and 350mV.

3.2.2.3 When a fairly large system has to be set up, all channels which are normally energised should be switched on with at least one in every six functions at a particular location being either fed or energised. Check receiver levels both in the relay room and in the field; although at this stage these will probably be low, they may indicate the state of system and enable faults to be located and rectified. Set the received channel levels for the switched-on functions section by section (for the particular type of system as previously described) and ensure that the d.c.voltage across each operated reed follower relay lies between 10.5 and 16 volts. A high reading (50 volts) will be observed if the follower relay circuit is incomplete; as previously stated, this condition must not be allowed to persist. A significently lower reading would suggest a receiver amplifier fault, and this should be changed.

3.2.2.4 Duplex Systems are set by switching on one channel at a time and observing the input level at the particular receiver. If there are no line amplifiers provided, then the system will have been designed to ensure adequate receiver input levels; however each received channel level may be reduced if necessary, by the addition of series resistance between the appropriate receiver and the line.

3.2.2.5 The final test is to ensure that each receiver operates correctly, when switched on and off again, and that the background signal, when the appropriate transmitter is switched off, causes no appreciable d.c. voltage (i.e. max of 0.2 volts) across the follower relay, measured on the d.c. range of an Avometer.

All transmitters are to be switched on. One team proceeding from the relay room observes receivers and follower relays in the field as the relay room team switch off individual transmitters, and also switches each transmitter in the field in turn for the inside team to observe the receivers and follower relays at their end.

Following the successful completion of these the reed systems should be cleared of all test straps and will then be available for through signalling testing.

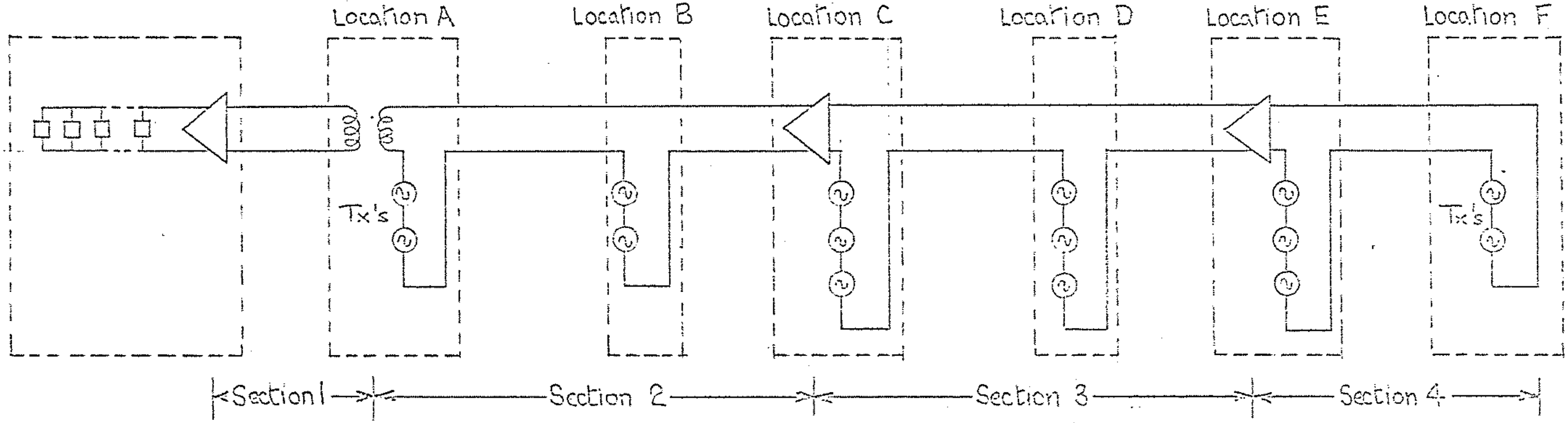


Fig. 3.2.2–1
Indication System.

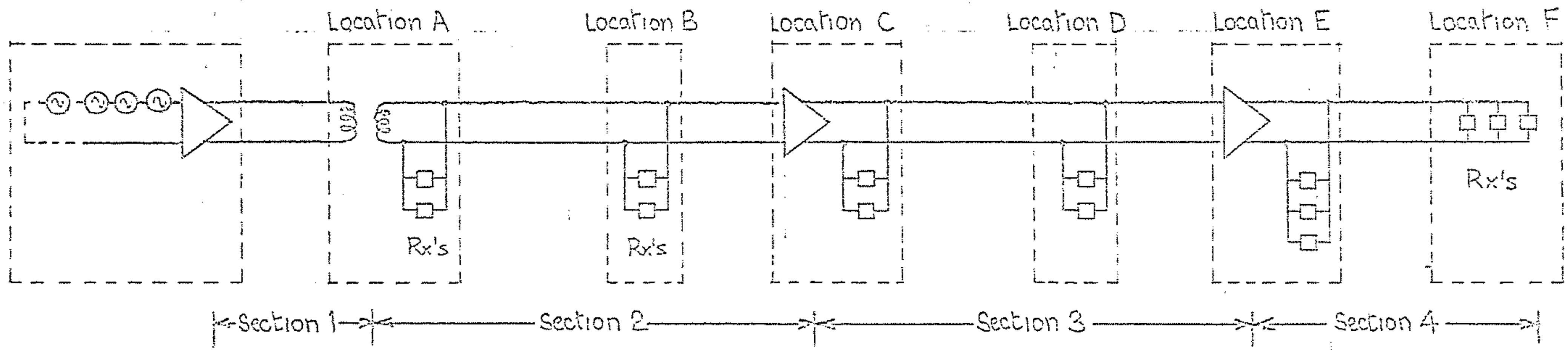


Fig. 3.2.2–2
Control System

3.2.3 Equivalent metric cable sizes.

Cable sizes have been specified in this section in Imperial units, in order to correspond with existing practice.

Where equivalent metric sizes are required, they should be to British Railways Specification no. 872. Recommended equivalent sizes for those which are mentioned in this section are given below.

Imperial (inch)	metric (millimetre)
1/.044	1/1.13
1/.036	1/0.85
9/.012	9/0.30
14/.0076	

4. MAINTENANCE AND FAULT FINDING INSTRUCTIONS

4.0.1 Contents of section 4:

4.1 Introduction to maintenance

The Type RR System is built up of basic plug-in easily replaced units, and site maintenance, apart from the routine monitoring of the performance of the system, involves only the speedy tracing of the unit causing any fault which occurs, and its replacement to ensure rapid restoration of the system to normal operation.

Fault finding and rectification within the units themselves is a workshop function, and should not be attempted on site. It is important that the fault report on any unit replaced in the course of maintenance should give as much detail as possible regarding the symptoms and circumstances of the failure.

The detachable amplifier portion of the transmitter is a common unit for all frequencies, and the number of spare transmitter amplifiers to be held will be related to the total number of transmitters in the installation, probably varying from 5% in large installations to 10% in smaller ones. The same applies to the detachable amplifiers of receivers.

The filter portion of transmitters and receivers can only be replaced by an identical filter of the same frequency and type number, a non-interchangeability pin code ensuring this feature. Consequently it will be necessary to hold at least one filter of each frequency transmitter and receiver used on the installation. Receiver filters and transmitter filters of the same frequency are not interchangeable.

All type RR equipment should be stored under dry conditions and when handled and transported should be treated with similar respect to that given to safety relays. Until actually installed, the equipment should continue to be housed in the individual packs in which it is supplied. Labels on the packs identify the contents fully.

4.2 TAKING MEASUREMENTS

The most suitable instruments for taking measurements on Type RR systems are the Model 8 Avometer and a transistorised voltmeter similar to the Farnell Instruments Ltd. Type TM1 or the Levell Transistorised A.C. Microvoltmeter Type TM3A. A heavy duty technician's Avometer should only be used in emergency, and then only for taking d.c. measurements and the a.c. output of the transmitter or T.R.U.

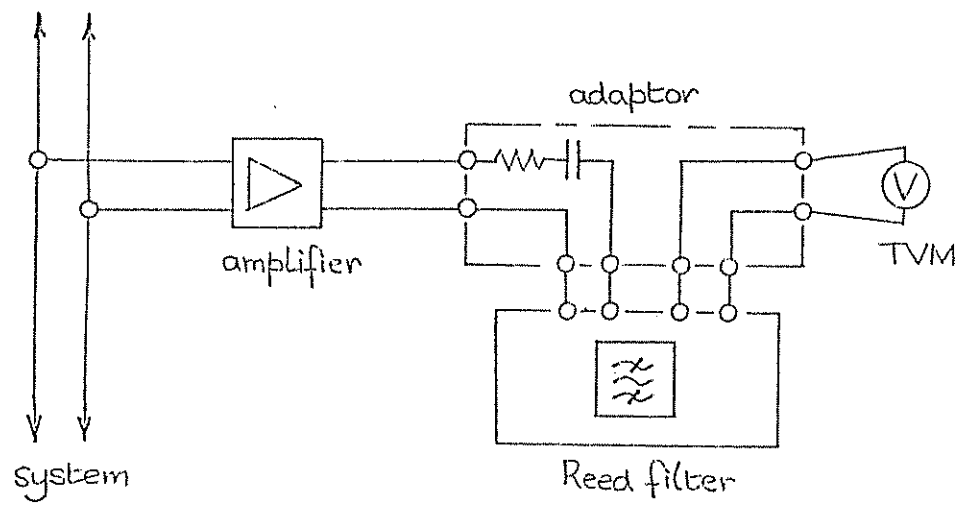
4.2.1 Line Measurements

Measurements of line voltage on the input and output of line amplifiers and line transformers can be taken using the 10-volt a.c. scale of a Model 8 Avometer. The loading of this range of the meter also makes it suitable for taking direct readings of line voltages with no other load on the line at that point, or for measuring the output voltage of an amplifier or transformer whose output terminals have been disconnected from the line. The reading obtained will have little exact significance, and with most working systems will be a rapidly varying one between 1 and 3 volts. It is, however, useful as an indicator of the presence of normal line signal.

Voltage measurements of individual frequencies on the line are only possible by using a Reed filter. A receiver filter, preferably with previously determined input/output calibration, can be used for this purpose, with a transistor voltmeter connected to the secondary side of the filter. To reduce the loading on the system, it is desirable to interpose a line amplifier set at 100% feed back between the line and the filter. To facilitate connections to the filter, a filter adaptor is provided. This takes the form of a dummy amplifier, and mounts on top of the filter to form a complete plug-in unit, in the same way as a normal receiver amplifier. However, the filter adaptor only contains links which connect the line input from the plugboard to the primary Reed filter coil, and the secondary coil to a pair of terminals on the front of the unit, to which the valve voltmeter can be conveniently connected. (In the case of a.c. immunised systems, the adaptor provided also contains a resistor and a capacitor, in series with the input from the line, to represent the fuse and capacitor used for immunisation in the receiver amplifier which is used in this case (see section 2.10.2),

4.2.1 (cont.)

and to attenuate the signal by the same amount, so that readings obtained with the amplifier correspond exactly to those occuring in the working system). The complete arrangement is as shown :



Readings of normal working levels taken by this method will be satisfactory; but caution should be observed in interpreting low values of signal due to noise generated within the system, or cross-talk from adjacent systems. If the readings are less than 6mV from the filter (equivalent to 15mV on line), the possibility that a significant proportion of this reading is due to stray pick-up or noise within the instrument should not be disregarded.

4.2.2 D.C. Supply

The d.c. supply to transmitters, receivers and T.R.Us. (if provided) may be measured on the 25-volt scale of the Model 8 Avometer, and should read between 12 and 13.4 volts.

4.2.3 A.C. To Power Supply Units

The a.c. supply to power supply units may be measured on the 250-volt scale of the Model 8 Avometer. The reading should be between 100 and 115 volts.

4.2.4 A.C. Supply To Line Amplifiers

The a.c. supply to line amplifiers should be measured on amplifier terminals 10 and 11 using the 100-volt scale of the Model 8 Avometer. The reading should lie between 22 and 26 volts, if the 24 volt tap is in use, and between 26 and 30 volts if the 28 volt tap is in use.

4.2.5 Transmitter and T.R.U. output

Measurements should always be made across the line resistor which is associated with the transmitter or T.R.U. and is mounted directly behind the plugboard. Using the 1 or 1.5 volt scale of the transistorised voltmeter or the 2.5 volt D.C. scale of the Model 8 Avometer, the reading should be between 0.59 and 0.68 volts A.C. when the D.C. input to the transmitter on terminals D3 and A3 is 12 volts. If the D.C. input voltage is above 12 volts the A.C. output will rise correspondingly to give an upper limit of 0.75 volts A.C. with 13.5 volts D.C. input. The corresponding limits for the T.R.U. are 0.57 to 0.69 volts at 12 volts D.C. input with an approximate limit of 0.77 volts with 13.5 volts D.C. input.

It should be noted that the reading across the line resistor is not appreciably affected by other channels which may be operating in the same system.

4.2.6 Receiver output and follower relay input

Using the 25-volt range of the Model 8 Avometer or the 75-volt range of the Technician's Avometer, measure the d.c. volts across terminals A1 and D1 of the receiver plugboard. The reading should lie between 9 and 16 volts. If a reading in excess of 20 volts is obtained, check for an open circuit between the receiver and the follower relay.

The d.c. input volts to the follower relay should be measured on terminals R1 and R4 of the relay plugboard. They should correspond to the output volts of the receiver.

4.2.7 Receiver background output

'Background' is the signal which can pass through the reed filter from the line when the corresponding transmitter is switched off. It arises from the effect of all the other frequencies present in the system, and from cross talk from other systems. It is measured in the same way as receiver output and will be a varying d.c. voltage well below 0.2 volt. It may well be too small to measure.

4.3 ROUTINE CHECKS AND RECORDS

It will assist in monitoring the performance of the systems if routine records are made of the operating levels of the systems at regular intervals. These checks might reasonably be made at monthly intervals for the first six months of a newly commissioned job, then at three monthly intervals.

Measurements should be made in the manner described in the previous section of the following :

Transmitter output when switched on (a.c.);

Transmitter d.c. supply volts;

Receiver output to follower relay (d.c.);

Receiver d.c. supply volts;

Background output from receiver to follower relay when corresponding transmitter not operating (d.c.).

Measurements requiring transmitters to be in the operated or unoperated condition would have to be taken as opportunity offered.

It will also be desirable to add comments as to temperature and any other extraneous factor which could have affected the results.

Measurements showing successive variations in the same direction, and exceeding 10% in magnitude, should be drawn to the attention of those responsible. Background measurements exceeding 0.1 volts should also be specially noted.

(On certain installations a monitoring trolley is provided to assist the system measurements and unit testing; See section 4.7 in this case).

4.4 PROCEDURE FOR CHECKING UNITS FOR SUSPECTED FAULTS

4.4.1 Checking a Transmitter

Step 1 - Measure output on line resistor

If correct - Unit O.K.
If low or zero - go to step 2.

Step 2 - Measure d.c. supply on terminals D3 (+) and A3

If correct - go to step 3
If low or zero - check power supply unit.

Step 3 - Remove the transmitter from plugboard and replace the same unit. Measure output on line resistor.

If correct - Unit O.K., but examine and if necessary clean plugboard contacts.
If low or zero - go to step 4.

Step 4 - Remove the transmitter from the plugboard and measure between plugboard contacts A2 and D2 and then between A4 and D4 on the xl resistance range of the Avometer.

If zero ohms - Switching circuit and link correct. Go to step 5.
If high reading - Unit probably O.K., but examine switching circuit or link for open circuit or high resistance contact.

Step 5 - Replace transmitter amplifier Type RR 1000 with a similar unit of the same type. Replace the complete transmitter on the plugboard. Measure output on line resistor.

If correct - Original transmitter amplifier was faulty. Report fault and return unit for workshop repair.
If low or zero - go to step 6.

Step 6 - Remove the transmitter from the plugboard and replace the transmitter filter with a similar unit of the same type. Replace the complete transmitter on the plugboard. Note that the transmitter filter type reference identifies the particular channel frequency and only a similar filter of similar frequency will plug home on the plugboard. Measure the output on line resistor.

If correct - Original transmitter filter was faulty. Report fault and return unit for workshop repair. Go to step 7.

If low or zero - Repeat tests with transmitter mounted on a separate test plugboard.

Step 7 - Recheck with original transmitter amplifier and new transmitter filter. Measure output on line resistor.

If correct - Original transmitter amplifier was O.K. Return spare to stock.

If low or zero - Original amplifier was faulty. Report and return unit for workshop repair. Replace with good spare transmitter amplifier.

It may be an advantage to carry out the above routine using a separate test plugboard drilled to receive all pin codes. Such a plugboard should be wired with a 12-volt smoothed constant voltage d.c. supply on terminals D3 (+) and A3 and an output resistor, 24 or 33 ohms, wired across terminals A1, D1. A link should be wired between A2 and D2, and a switch between A4 and D4. The switch should normally be 'on' for the above tests.

(Facilities for this test are provided on a monitoring trolley on certain installations - see section 4.7 in this case).

4.4.2 Checking a Transmitter Repeater Unit (T.R.U.)

Step 1 - Measure each output on corresponding line resistor.

If correct - Unit O.K.
If low or zero on all outputs - go to step 2.

Step 2 - Measure d.c. supply on terminals B3 (+) and A3.

If correct - go to step 3
If low or zero - check fuses in power supply circuit and corresponding power supply unit.

Step 3 - Remove T.R.U. from the plugboard and replace the same unit. Measure each output on corresponding line resistor.

If correct on all outputs - unit O.K., but examine and if necessary clean plugboard contacts.
If low or zero on one or more outputs - go to step 4.

Step 4 - Remove the T.R.U. from the plugboard and measure with x1 resistance range of the Model 8 Avometer between plugboard contacts A4 and A6, B4 and B6 or C4 and C6 as appropriate to check for continuity of switching circuit, when low or zero output has been measured on the A, B or C banks respectively.

If zero ohms - switching circuit and line correct. Go to step 5.
If high reading - examine switching circuit.

Step 5 - Replace T.R.U. with another unit of the same type. Check for correct outputs. Report defective unit for workshop repair.

(Facilities for testing a T.R.U. are provided on the monitoring trolley provided on certain installations - see section 4.7 in this case).

4.4.3. Checking a Receiver

Note that there are two types of receiver amplifier, RR2002 (silver case) and RR2003 (black case). The electrical connections to the two types differ ; for the terminal numbers, refer to section 2.4.2.

Step 1 - Check as far as possible for an input to the receiver. This cannot be done directly on a working system, so check if possible the corresponding transmitter for output, and the final line amplifier for line signal output. If this cannot be done at this stage, assume an input and go to step 2.

Step 2 - Measure d.c. output to follower relay on plug-board terminals.

If correct - Unit O.K.
If low or zero - go to step 3.
If high (over 20 volts) - check continuity of circuit to follower relay, looking especially for open contacts which should be closed.

Step 3 - Remove the receiver from its plugboard and replace it. Measure d.c. output to follower relay on plugboard terminals again.

If correct - Unit O.K., but examine switching and if necessary clean the plug-board contacts.
If low or zero - go to step 4.
If high (over 20 volts) - Proceed as in step 2.

Step 4 - Measure d.c. supply on plugboard terminals.

If correct - go to step 5.
If low or zero - check power supply unit.

Step 5 - Remove receiver from plugboard, replace receiver amplifier with a spare unit of the same type, and replace receiver on plugboard.
Measure d.c. output to follower relay on plugboard terminals.

If correct - original receiver amplifier was faulty. Report fault and return unit for workshop repair.

If low or zero - go to step 6.
If high (over 20 volts) - Proceed as in step 2.

4.4.3 (cont.)

Step 6 - Remove receiver and replace receiver filter with a spare unit of the same type reference. Replace complete receiver on plugboard. Note that the type reference identifies the particular channel frequency, and any other filter will not plug into the plugboard. Measure d.c. output to follower relay on plugboard terminals.

If correct - Original receiver filter was faulty. Report fault and return unit for workshop repair. Go to step 7.
If low or zero - It will be necessary to check associated transmitter and the intervening line circuit of the system. See also alternative below.
If high (over 20 volts) - Proceed as in step 2.

Step 7 - Re-check with original receiver amplifier and new filter. Measure d.c. output to follower relay on plugboard terminals.

If correct - Original receiver amplifier was O.K. Return spare to stock.
If low or zero - Original receiver amplifier was faulty. Replace with good spare receiver amplifier and report fault and faulty unit for workshop repair.
If high (over 20 volts) - Proceed as in step 2.

4.4.4 <u>Checking a Power Supply Unit</u>

Step 1 - Measure d.c. output.

If correct - Unit O.K.
If low or zero - go to Step 2.

Step 2 - Measure a.c. input.

If correct - Unit faulty. Report fault and return unit for workshop repair.
If low or zero - Check BX110 fuse and replace if necessary. Check main power supply.

4.4.5 <u>Checking a Line Amplifier</u>

Step 1 - Check whether an a.c. immunisation unit (see section 2.10.3) is fitted to the amplifier.

If no, go to Step 2.
If yes, short the immunisation unit out by connecting links from terminal 1 to terminal 11, 6 to 16 and 9 to 19 on it. Check whether the fault has now cleared.
If yes, the immunisation unit is faulty and requires changing and returning for workshop repair.
If no, remove the three links and go to step 2.

Step 2 - Check that the correct power supply is present between <u>either</u> terminals 10 and 11 (if an a.c. supply is in use) <u>or</u> terminals 8 (+ive) and 10/11 (-ive)(if a d.c. supply is in use). Note that a d.c. supply may be provided as a stand-by for a normal a.c. supply.

If yes, go to step 3.
If no, check the supply connections, the fuses, and the main supply.

Step 3 - Measure the d.c. voltage appearing across the 5ohm (or 4.7 ohm) resistor on the amplifier baseplate.

If it lies between 5V and 8V, go to step 4.
If it is outside this range, a transistor in the amplifier is probably defective, and the amplifier requires replacing (note that, if the transistors are functioning correctly, they are both warm; if one is faulty, it can often be felt to be cold).

4.4.5 (cont.)

Step 4 - Measure the input from the line between terminals 1 and 6, and the amplifier input between terminals 2 and 6. Check that these two readings correspond, making allowance for the resistor or link connected between terminals 1 and 2.

If both are normal, go to step 5.
If the line signal (1 and 6) is normal and the input (2 and 6) low, the resistor or link requires replacing <u>WITH ONE OF THE SAME VALUE</u>; note that possession of the system will normally be required before this can be done.
If the line signal (1 and 6) is low, go to step 8.

Step 5 - Measure the amplifier output between terminals 7 and 9, and check that it corresponds with the input reading between 2 and 6, making allowance for the setting of the feedback link between terminal 6 and one of 5, 4 and 3. The <u>approximate</u> values of gain to be expected are :

link between terminals	gain
6 - 5 (100%)	1
6 - 4 (75%)	1.3
6 - 3 (50%)	2

If the readings correspond, the amplifier is O.K. and the fault lies elsewhere.
If the output is low or zero, go to step 6.

Step 6 - Remove outgoing leads from terminals 7 and 9 and connect the Model 8 Avometer on its 10v a.c. scale across terminals 7 and 9, and measure line output voltage.

If it is normal, fault is not in line amplifier. Restore line connection to terminals 7 and 9, making sure that the lines have not been reversed. Proceed to check the line section ahead and the next line amplifier.
If it is low or zero, change the line amplifier and go to step 8.

Step 7 - Remove the coupler from the amplifier and measure the input from the line between terminals 1 and 6 on the coupler, using the 10v a.c. scale of the Model 8 Avometer.

If it is now normal, change the amplifier and go to step 8.
If it is still low or zero, the fault is probably in the preceding line section or previous line amplifier.

Step 8 - Check that the fault has now cleared. If it has not, go back to step 4.

4.5 CHECKING THE REED SYSTEMS

4.5.1 Reed System Faults

Reed failure will normally become evident either :

(i) through the apparent failure of one or more indications to respond as expected when a route is set up or other function operated, or

(ii) through the unexpected appearance of an incorrect indication or group of indications unrelated to any function being operated, or known train movement.

However,it should be appreciated that such symptoms may just as easily arise due to a failure of the signalling equipment itself, and the Reed system may still be correctly performing its function.

Failures of the first type, i.e. failure to respond to controls, may be due to a failure of the signalling equipment in the signal box, a failure of the Reed control system, a failure of the signalling equipment in the field, or a failure of the Reed indications system.

Failures of the second type, i.e. the appearance of spurious indications, will normally be due to failures of signalling equipment in the field or of the Reed indication system, but in certain instances may also be due to a control system failure.

It is necessary to adopt a logical approach to narrow down the possible causes of failure, bearing in mind that all likely possibilities in the relay room should be checked before proceeding into the field.

First priority is to check whether the failt is in the Reed equipment or the signalling equipment, and, if it is in the Reed, whether it is in the control or the indication system. It will normally be possible to check in this way by operating controls and observing the corresponding indications on the control panel, before carrying out tests in the field.

In addition to failure being classifiable by the likelihood that either indication or control systems, or only indication systems, are affected, they may also be classified as follows.

4.5.1.1 Single-channel Faults

One indication or its associated control appears faulty, or possibly two or three such controls or indications without there being any obvious geographical or technical association between them. The failure would be expected to be 'right side', i.e. such that a Reed signal that should be present had disappeared, in view of the inherent integrity of the equipment.

If the fault is on the Reed system, control or indication, then it is most likely to be associated with a particular Reed channel, and the transmitter, receiver, or individual power supply unit associated with that channel should be checked.

4.5.1.2 Geographical Group Faults

Failure of a group of channels associated with a particular location, while channels to nearer and more distant locations were still operating, would suggest a failure of the signalling equipment, or of the Reed power supplies at that location.

4.5.1.3 System Group Faults

Failure of a group of channels related sequentially in a particular system, would normally indicate failure of common equipment or of the line. Checking should commence with the line amplifier and its power supply at the last location to which the system appears to be working, since a failed line amplifier will permit the system to work up to its input, but may fail the system beyond its output (although, under certain circumstances, a system may continue to work beyond a failed line amplifier, because of the equipment's tolerance of a wide range of line levels).

The line itself should be checked carefully, with attention being paid to through-crimps and terminals.

An open line would:

(i) fail all indications up to the line amplifier or isolating transformer on the box side of the break;

(ii) fail all controls beyond the location immediately on the box side of the break.

A short-circuited line would :

(i) fail all indications up to the location on the box side of the fault;

(ii) fail all controls up to the location on the box side of the short.

4.5.1.4 Complete System Faults

The failure of all channels on a system can be due to failure of :

(i) power supplies feeding transmitters/receivers for that system in the box;

(ii) the line amplifier in the box;

(iii) a line amplifier or its power supply in the field;

(iv) a cable fault, or a faulty connection, in the part of the line which carries all the functions in the system. (Beware of intermittent faults, which can be caused by faulty crimps, terminals, etc.).

4.5.1.5 Multi-System Faults

If all systems fail simultaneously, check the main power supply. Failure of several systems in one geographical direction would indicate a local power failure, or a severed cable; it can be located by checking which functions are still working.

In installations employing master transmitters and t.r.u's, failure of the same channel number in just three systems would indicate a fault in the appropriate t.r.u. in the relay room; failure of the same channel number in many systems would indicate a master transmitter fault.

If a group of functions in the same geographical location, but on different systems, fails, check the local power supplies, and the possibility of lightning or similar damage.

4.5.2 Summary Chart - System Fault Finding

This chart is arranged to show the quickest way to the most likely cause of failure. Decide first which category of fault fits the circumstances and then check units in the order suggested, continuing until the faulty unit or condition is discovered and replaced or rectified. If none of the suggested checks reveals the fault, consider the next most likely category, and so on. Refer to section 4.4 for details of unit checking.

REMEMBER, The Reed will show you SIGNALLING FAILURES. IT IS NOT NECESSARILY THE REED WHICH IS AT FAULT.

<table>
<tr><th rowspan="2"></th><th rowspan="2">Indication Only Faults</th><th colspan="2">Indication or Control Faults</th></tr>
<tr><th>Indication System</th><th>Control System</th></tr>
<tr><td>INDIVIDUAL FAULT.</td><td><u>In Box</u>
1 Check Receiver
<u>In Field</u>
2 Check Transmitter
3 Check Power Supply Unit.</td><td><u>In Box</u>
2 Check Receiver
<u>In Field</u>
3 Check Transmitter
4 Check Power Supply Unit.</td><td><u>In Box</u>
1 Check Master Transmitter/TRU
<u>In Field</u>
5 Check Receiver
6 Check Power Supply Unit.</td></tr>
<tr><td rowspan="3">GEOGRAPHICAL GROUP FAULT.</td><td><u>In Box</u></td><td><u>In Box</u></td><td><u>In Box</u></td></tr>
<tr><td colspan="3">1 Check that the failed receivers or transmitters do not have any common circuitry or power supply which could be the cause.</td></tr>
<tr><td><u>In Field</u>
2 Check Location Power Supply Units.
3 Check Transmitters. If several faulty, look for signs of lightning damage.</td><td><u>In Field</u>
2 Check Location Power Supply Units.
3 Check Transmitters. If several faulty, look for signs of lightning damage.</td><td><u>In Field</u>
4 Check Receivers.</td></tr>
</table>

<table>
<tr><th rowspan="2"></th><th rowspan="2">Indication Only Faults</th><th colspan="2">Indication or Control Faults</th></tr>
<tr><th>Indication System</th><th>Control System</th></tr>
<tr><td rowspan="4">SYSTEM GROUP FAULT</td><td><u>In Field</u></td><td><u>In Field</u></td><td><u>In Field</u></td></tr>
<tr><td colspan="3">1 Go to line amplifier on box side of first failed indication or control receiver. Check line amplifier and power supply. Check for open circuit line.</td></tr>
<tr><td colspan="2">2 Check next line amplifier out from box for open circuit on output.</td><td>2 Check next line amplifier out from box for short circuit on input.</td></tr>
<tr><td>3 Check line for open circuit.</td><td>3 Check line for open circuit.</td><td>3 Check line for open circuit or short circuit beyond last operating control receiver.</td></tr>
<tr><td rowspan="3">SYSTEM FAULT</td><td><u>In Box</u>
1 Check power supply unit feeding system receivers</td><td></td><td><u>In Box</u>
1 Check for discontinuity in line circuit connecting output resistors of T.R.Us.</td></tr>
<tr><td rowspan="2"><u>In Field</u>
2 Work outwards from box checking line amplifiers, amplifiers power supply units, & line continuity until the first transmitter is reached or the fault found.</td><td colspan="2"><u>In Box</u>
2 Check power supply unit feeding system receivers</td></tr>
<tr><td colspan="2"><u>In Field</u> / <u>In Field</u>
3 Work outward from box checking line amplifiers line amplifier power supply units and line continuity until the first transmitter * is reached or the fault found.
(* receiver in the case of control systems)</td></tr>
<tr><td>ALL-SYSTEM FAILURES (COMPLETE)</td><td colspan="3">1 Check for major power supply failure in box or in field.
2 Check for severed multicore cable affecting all systems.
3 Check power supply to line amplifiers at box and at all locations where these occur on all systems.</td></tr>
<tr><td>(PART)</td><td></td><td></td><td>4 If same channel numbers fail in all systems, check master transmitter power supply.
If same channel numbers fail in some systems only, check T.R.U. power supplies.</td></tr>
</table>

5. SPARES AND RE-ORDERING REFERENCES

5.1 SPARES

5.1.1 Spares for transmitters and receivers

The detachable amplifier portion of the transmitter is a common unit for all frequencies, and the number of spare transmitter amplifiers to be held will be related to the total number of transmitters in the installation, probably varying from 5% in large installations to 10% in smaller ones. Exactly corresponding considerations apply to the detachable receiver amplifier.

The filter portion of a transmitter or receiver can only be replaced by an identical filter of the same frequency and type number; this is ensured by a non-interchangeability pin code (as for standard signalling relays etc.). Consequently it is necessary to hold at least one spare transmitter and receiver filter for each frequency used in the installation (note that transmitter and receiver filters of the same frequency are not interchangeable).

5.1.2 Storage and transport

All type RR equipment should be stored under dry conditions, and, when being handled and transported, should be treated with the same respect given to safety relays. Until actually installed, the equipment should continue to be housed in the individual packs in which it is supplied; labels on the packs identify the contents fully.

In certain instances, special carrying boxes are provided for technicians to carry spare transmitter and receiver amplifiers to field locations in, for fault-finding and possible replacement of faulty units. Where provided, these boxes should always be used, in order to minimise the chance of damage in handling.

5.2 REFERENCES FOR ORDERING SPARES AND REPLACEMENTS

This section relates only to complete units supplied by AEI-General Signal Ltd. The AGS type reference, which is generally an adequate and complete description of the article, should be quoted on all correspondence, enquiries or orders.

Reference should be made to section 2 for detailed description of the units.

5.2.1 Transmitters

The transmitter is described in section 2.3. It has blue labels.

5.2.1.1 Transmitter amplifier (detachable top portion of complete unit) - order reference, type RR 1000.

5.2.1.2 Transmitter filter (lower portion of complete unit) - order reference depends upon frequency. The order references, frequencies and pin-codes for the various channels are given in the following table.

Order Ref.	Frequency No.	Frequency Hz.	Period Secs.x 10^{-9}	Code	Pins
RR1010	f1	879.5	1137009	1061	D E G H L
RR1020	f2	876	1141552	1063	D E G K L
RR1030	f3	887.5	1126760	1065	D E H K L
RR1040	f4	803.25	1244942	1067	D F G H L
RR1050	f5	797.75	1253525	1069	D F G K L
RR1060	f6	792.75	1261431	1071	D F H K L
RR1070	f7	788.25	1268633	1073	D G H J L

5.2.1.2 (cont.)

Order Ref.	Frequency No.	Hz.	Period Secs.x 10^{-9}	Code	Pins
RR1080	f8	784.25	1275103	1075	D G J K L
RR1090	f9	779.75	1282462	1077	D E F G M
RR1100	f10	774.75	1290738	1079	D E F J M
RR1110	f11	768.75	1300813	1081	D E F L M
RR1120	f12	811.75	1231906	1083	D E G J M
RR1130	f13	714	1400560	1085	D E G L M
RR1140	f14	711	1406469	1087	D E H K M
RR1150	f15	706.5	1415428	1089	D E J K M
RR1160	f16	702.5	1423487	1091	D E K L M
RR1170	f17	697.5	1433691	1093	D F G J M
RR1180	f18	692	1445086	1095	D F G L M
RR1190	f19	687	1455604	1097	D F H K M
RR1200	f20	682.5	1465201	1099	D F J K M
RR1210	f21	678.5	1473839	1101	D F K L M
RR1220	f22	674	1483679	1103	D G H K M
RR1230	f23	667	1499250	1105	D G J K M
RR1240	f24	622.25	1607071	1107	D G K L M
RR1250	f25	616.25	1622718	1109	D H J L M
RR1260	f26	611.75	1634654	1111	D J K L M
RR1270	f27	607.75	1645413	1113	D E F H N
RR1280	f28	598.25	1671541	1115	D E F K N
RR1290	f29	587.75	1701403	1117	D E F M N
RR1300	f30	574.75	1739886	1119	D E G J N
RR1310	f31	569.75	1755155	1121	D E G L N
RR1320	f32	525	1904762	1123	D E H J N
RR1330	f33	519.5	1924927	1125	D E H L N
RR1340	f34	514.5	1943644	1127	D E J K N
RR1350	f35	510	1960784	1129	D E J M N
RR1360	f36	505	1980198	1131	D E K M N
RR1370	f37	499.5	2002002	1133	D F G H N
RR1380	f38	493.5	2026342	1135	D F G K N
RR1390	f39	488	2049180	1137	D F G M N
RR1400	f40	483	2070393	1139	D F H K N
RR1410	f41	478.5	2089864	1141	D F H M N
RR1420	f42	473.5	2111932	1143	D F J L N
RR1430	f43	468	2136752	1145	D F K L N
RR1440	f44	463	2159827	1147	D F L M N
RR1450	f45	415.25	2408188	1149	D G H K N
RR1460	f46	424.75	2354326	1151	D G H M N
RR1470	f47	419.75	2382370	1153	D G J L N
RR1480	f48	410.25	2437538	1155	D G K L N
RR1490	f49	404.75	2470661	1157	D G L M N
RR1500	f50	399.75	2501563	1159	D H J L N
RR1510	f51	395.25	2530044	1161	D H K L N
@*RR1710	f71	757.75	1319696		X Y
@+RR1720	f72	458.5	2181025		X Y
@RR1810	f81	383.25	2609262	1221	E G L M N
@RR1820	f82	430.25	2324230	1223	E H J K N
@RR1830	f83	446	2242152	1225	E H J M N
@RR1840	f84	533.75	1873534	1227	E H K M N
@RR1850	f85	544	1838235	1229	E J K L N
@RR1860	f86	632	1582280	1231	E J L M N
@RR1870	f87	719	1390821	1233	F G H J L
@RR1880	f88	736.75	1357313	1235	F G J K L
@RR1890	f89	748.25	1336451	1237	F G H J M
@RR1900	f90	815.25	1226620	1239	F G H L M
@RR1910	f91	836.5	1195460	1241	F G J L M
@RR1920	f92	842	1187650	1243	F H J K M

Note :

* Universal spare for use only on systems where this is acceptable and plugboards are drilled to correspond. Colour coded WHITE.

\+ Universal spare for use only on systems where this is acceptable and plugboards are drilled to correspond. Colour coded RED.

@ Not for use on vital circuits on systems designed to be immune to 50Hz. interference.

5.2.2. Receivers

The receiver is described in section 2.4 It has Yellow labels.

5.2.2.1 Receiver amplifier(detachable top portion of complete unit) - order reference type RR2002 or RR2003 as appropriate (see section 2.4). The correct type must be used; the electrical connections to the unit would prevent a unit of the wrong type from functioning, if it were to be plugged in accidentally (the two types have different power supply connections).

5.2.2.2 Receiver filter (lower portion of complete unit) - order reference depends upon frequency. The order references, frequencies and pin-codes for the various channels are given in the following table.

Order Ref.	Frequency No.	Frequency Hz.	Period Secs.x 10^{-9}	Code	Pins
RR2010	f1	879.5	1137009	1062	D E G J L
RR2020	f2	876	1141552	1064	D E H J L
RR2030	f3	887.5	1126760	1066	D E J K L
RR2040	f4	803.25	1244942	1068	D F G J L
RR2050	f5	797.75	1253525	1070	D F H J L
RR2060	f6	792.75	1261431	1072	D F J K L
RR2070	f7	788.25	1268633	1074	D G H K L
RR2080	f8	784.25	1275103	1076	D H J K L
RR2090	f9	779.75	1282462	1078	D E F H M
RR2100	f10	774.75	1290738	1080	D E F K M
RR2110	f11	768.75	1300813	1082	D E G H M
RR2120	f12	811.75	1231906	1084	D E G K M
RR2130	f13	714	1400560	1086	D E H J M
RR2140	f14	711	1406469	1088	D E H L M
RR2150	f15	706.5	1415428	1090	D E J L M
RR2160	f16	702.5	1423487	1092	D F G H M
RR2170	f17	697.5	1433691	1094	D F G K M
RR2180	f18	692	1445086	1096	D F H J M
RR2190	f19	687	1455604	1098	D F H L M
RR2200	f20	682.5	1465201	1100	D F J L M
RR2210	f21	678.5	1473839	1102	D G H J M
RR2220	f22	674	1483679	1104	D G H L M
RR2230	f23	667	1499250	1106	D G J L M
RR2240	f24	622.25	1607071	1108	D H J K M
RR2250	f25	616.25	1622718	1110	D H K L M

Order Ref.	Frequency No.	Hz.	Period Secs.x 10^{-9}	Code	Pins
RR2260	f26	611.75	1634654	1112	D E F G N
RR2270	f27	607.75	1645413	1114	D E F J N
RR2280	f28	598.25	1671541	1116	D E F L N
RR2290	f29	587.75	1701403	1118	D E G H N
RR2300	f30	574.75	1739886	1120	D E G K N
RR2310	f31	569.75	1755155	1122	D E G M N
RR2320	f32	525	1904762	1124	D E H K N
RR2330	f33	519.5	1924927	1126	D E H M N
RR2340	f34	514.5	1943634	1128	D E J L N
RR2350	f35	510	1960784	1130	D E K L N
RR2360	f36	505	1980198	1132	D E L M N
RR2370	f37	499.5	2002002	1134	D F G J N
RR2380	f38	493.5	2026342	1136	D F G L N
RR2390	f39	488	2049180	1138	D F H J N
RR2400	f40	483	2070393	1140	D F H L N
RR2410	f41	478.5	2089864	1142	D F J K N
RR2420	f42	473.5	2111932	1144	D F J M N
RR2430	f43	468	2136752	1146	D F K M N
RR2440	f44	463	2159827	1148	D G H J N
RR2450	f45	415.25	2408188	1150	D G H L N
RR2460	f46	424.75	2354326	1152	D G J K N
RR2470	f47	419.75	2382370	1154	D G J M N
RR2480	f48	410.25	2437538	1156	D G K M N
RR2490	f49	404.75	2470661	1158	D H J K N
RR2500	f50	399.75	2501563	1160	D H J M N
RR2510	f51	395.25	2530044	1162	D H K M N
@*RR2710	f71	757.75	1319696		X Y
@+RR2720	f72	458.5	2181025		X Y
@ RR2810	f81	383.25	2609262	1222	E G L M N
@ RR2820	f82	430.25	2324230	1224	E H J L N
@ RR2830	f83	446	2242152	1226	E H K L N
@ RR2840	f84	533.75	1873534	1228	E H L M N
@ RR2850	f85	544	1838235	1230	E J K M N
@ RR2860	f86	632	1582280	1232	E K L M N
@ RR2870	f87	719	1390821	1234	F G H K L
@ RR2880	f88	736.75	1357313	1236	F H J K L
@ RR2890	f89	748.25	1336451	1238	F G H K M
@ RR2900	f90	815.25	1226620	1240	F G J K M
@ RR2910	f91	836.5	1195460	1242	F G J K M
@ RR2920	f92	842	1187650	1244	F H J L M

Note:

* Universal spare for use only on systems where this is acceptable and plugboards are drilled to correspond. Colour coded WHITE.

\+ Universal spare for use only on systems where this is acceptable and plugboards are drilled to correspond. Colour coded RED.

@ Not for use on vital circuits on systems designed to be immune to 50 Hz. interference.

5.2.2.3. Immunisation units (where 50Hz a.c. immunisation is required) : the type references are as follows :

type RR8510 - Colour code GREEN

type RR8520 - Colour code BROWN

type RR8530 - Colour code WHITE

(See section 2.10 for details of the use of the immunisation units).

5.2.3 <u>Transmitter repeater unit (t.r.u.)</u>

The transmitter repeater unit described in section 2.6. It has <u>green</u> labels. It is independent of frequency, and is mounted in a case similar to that used for the AGS type Z relay, conforming fully to BR 930 relay module size.

Order reference - type RR1990.

5.2.4 <u>Reed follower relay</u>

Only the correctly matched safety relay should be used on the output of the receiver. This is an AGS type M relay with special coil and operating figures, but which otherwise conforms to BR930 (see section 2.5).

Order reference - type ZS2411.

5.2.5 <u>Plugboards for above</u>

The basic plugboard is the same as for the BR930 series relays, but employs a special retaining clip in the case of the reed transmitter and receiver.

Basic plugboard moulding: Order ref. D6/26696.

Non-reversible terminal connector : Order ref. D3/26929.

The plugboard may be supplied pre-drilled for any of the various units described above.

<u>Plugboard Order Reference.</u>

Unit	Normal	Special to accommodate universal spare.
RR1010	RY1061	RY1361
RR1020	RY1063	RY1363
RR1030	RY1065	RY1365
RR1040	RY1067	RY1367
RR1050	RY1069	RY1369
RR1060	RY1071	RY1371.

5.2.5. (cont)

Unit	Normal	Special to accommodate universal spare
RR1070	RY1073	RY1373
RR1080	RY1075	RY1375
RR1090	RY1077	RY1377
RR1100	RY1079	RY1379
RR1110	RY1081	RY1381
RR1120	RY1083	RY1383
RR1130	RY1085	RY1385
RR1140	RY1087	RY1387
RR1150	RY1089	RY1389
RR1160	RY1091	RY1391
RR1170	RY1093	RY1393
RR1180	RY1095	RY1395
RR1190	RY1097	RY1397
RR1200	RY1099	RY1399
RR1210	RY1101	RY1401
RR1220	RY1103	RY1403
RR1230	RY1105	RY1405
RR1240	RY1107	RY1407
RR1250	RY1109	RY1409
RR1260	RY1111	RY1411
RR1270	RY1113	RY1413
RR1280	RR1115	RY1415
RR1290	RY1117	RY1417
RR1300	RY1119	RY1419
RR1310	RY1121	RY1421
RR1320	RY1123	RY1423
RR1330	RY1125	RY1425
RR1340	RY1127	RY1427
RR1350	RY1129	RY1429
RR1360	RY1131	RY1431
RR1370	RY1133	RY1433
RR1380	RY1135	RY1435
RR1390	RY1137	RY1437
RR1400	RY1139	RY1439
RR1410	RY1141	RY1441
RR1420	RY1143	RY1443
RR1430	RY1145	RY1445
RR1440	RY1147	RY1447
RR1450	RY1149	RY1449
RR1460	RY1151	RY1451
RR1470	RY1153	RY1453
RR1480	RY1155	RY1455
RR1490	RY1157	RY1457
RR1500	RY1159	RY1459
RR1510	RY1161	RY1461
RR1710	-	RY1360
RR1720	-	RY1360
RR1810	-	RY1221
RR1820	-	RY1223
RR1830	-	RY1225
RR1840	-	RY1227
RR1850	-	RY1229
RR1860	-	RY1231
RR1870	-	RY1233
RR1880	-	RY1235
RR1890	-	RY1237
RR1900	-	RY1239
RR1910	-	RY1241
RR1920	-	RY1243

5.2.5. (cont)

Unit	Normal	Special to accommodate universal spare
RR2010	RY1062	RY1362
RR2020	RY1064	RY1364
RR2030	RY1066	RY1366
RR2040	RY1068	RY1368
RR2050	RY1070	RY1370
RR2060	RY1072	RY1372
RR2070	RY1074	RY1374
RR2080	RY1076	RY1376
RR2090	RY1078	RY1378
RR2100	RY1080	RY1380
RR2110	RY1082	RY1382
RR2120	RY1084	RY1384
RR2130	RY1086	RY1386
RR2140	RY1088	RY1388
RR2150	RY1090	RY1390
RR2160	RY1092	RY1392
RR2170	RY1094	RY1394
RR2180	RY1096	RY1396
RR2190	RY1098	RY1398
RR2200	RY1100	RY1400
RR2210	RY1102	RY1402
RR2220	RY1104	RY1404
RR2230	RY1106	RY1406
RR2240	RY1108	RY1408
RR2250	RY1110	RY1410
RR2260	RY1112	RY1412
RR2270	RY1114	RY1414
RR2280	RY1116	RY1416
RR2290	RY1118	RY1418
RR2300	RY1120	RY1420
RR2310	RY1122	RY1422
RR2320	RY1124	RY1424
RR2330	RY1126	RY1426
RR2340	RY1128	RY1428
RR2350	RY1130	RY1430
RR2360	RY1132	RY1432
RR2370	RY1134	RY1434
RR2380	RY1136	RY1436
RR2390	RY1138	RY1438
RR2400	RY1140	RY1440
RR2410	RY1142	RY1442
RR2420	RY1144	RY1444
RR2430	RY1146	RY1446
RR2440	RY1148	RY1448
RR2450	RY1150	RY1450
RR2460	RY1152	RY1452
RR2470	RY1154	RY1454
RR2480	RY1156	RY1456
RR2490	RY1158	RY1458
RR2500	RY1160	RY1460
RR2510	RY1162	RY1462
RR2710	–	RY1360
RR2720	–	RY1360
RR2810	–	RY1222
RR2820	–	RY1224
RR2830	–	RY1226

5.2.5. (cont)

Unit	Normal	Special to accommodate universal spare
RR2840	–	RY1228
RR2850	–	RY1230
RR2860	–	RY1232
RR2870	–	RY1234
RR2880	–	RY1236
RR2890	–	RY1238
RR2900	–	RY1240
RR2910	–	RY1242
RR2920	–	RY1244

Plugboard pre-drilled for reed follower relay: Order Ref: ZY133

Retaining clip for relays and T.R.Us: Order Ref: D3/26697.

Retaining clip for transmitters and receivers: Order Ref: SK.1780.890

4-Stem moulded terminal block mounted behind plugboards for line terminals or line resistor. Order Ref: PM2322.

Line resistors (one required per transmitter or t.r.u. output) –

Current type : Electrosil type TR-6, 24 ohm, 5% (1W metal-oxide);
Maintenance type : Welwyn type F75, 33 ohm (4W wire-wound).

5.2.6 Line amplifier

The line amplifier is described in section 2.7.

Current type : order ref. type RR8101 (this unit can use either 24V a.c. or 24V d.c. power supplies);
Obsolete type : Order ref. type RR8100 (this unit can use 24V a.c. power supplies only);
Non-standard type : order ref. type RR8110 (this is a special version of type RR8101, designed to operate from a 12V d.c. supply).

Type RR8100 was universally used on all new installations up to 1970. It may now be replaced for maintenance purposes by type RR8101.

5.2.7 Line amplifier supply transformer

Transformer to supply 1 line amplifier : for outline see fig. 5.2 – 1; 110/28-24-20V, 50Hz, 35VA; order ref. type RR9210.

Transformer to supply 10 line amplifiers : for outline see fig. 5.2-2; 110/28-24-20V, 50Hz, 350VA; order ref. type RR9220.

(Type RR9220 may be used as a replacement for type RR9210 for maintenance purposes).

Transformers for other primary voltages can be supplied, but are non-standard.

5.2.8 Line isolating transformer

The line isolating transformer is described in section 2.8, and an outline is given in fig. 5.2 - 3.

Order ref: type RR8200.

5.2.9 Power supplies

The Reed power supplies give a smoothed and stabilised d.c. output voltage of 12.5V from a 50Hz a.c. input at 110V, and are used to feed transmitters, receivers and transmitter repeater units. There are two types, as follows:

(i) 600mA unit, type ref. RR9120 - will feed up to six receivers or ten transmitters;

(ii) 5A unit, type ref. RR9130 - used in the signal box to supply all the transmitters or receivers.

(Note : type RR9130 can be used as a spare for type RR9120, providing sufficient space is available).

The units are described in detail in section 2.9.

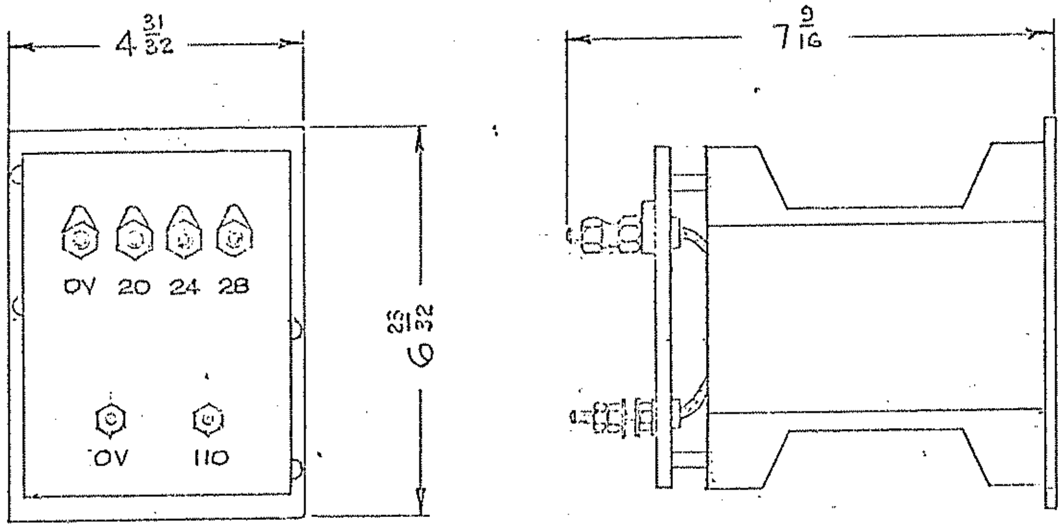


Fig. 5.2-1 : Line amplifier supply transformer, RR 9220

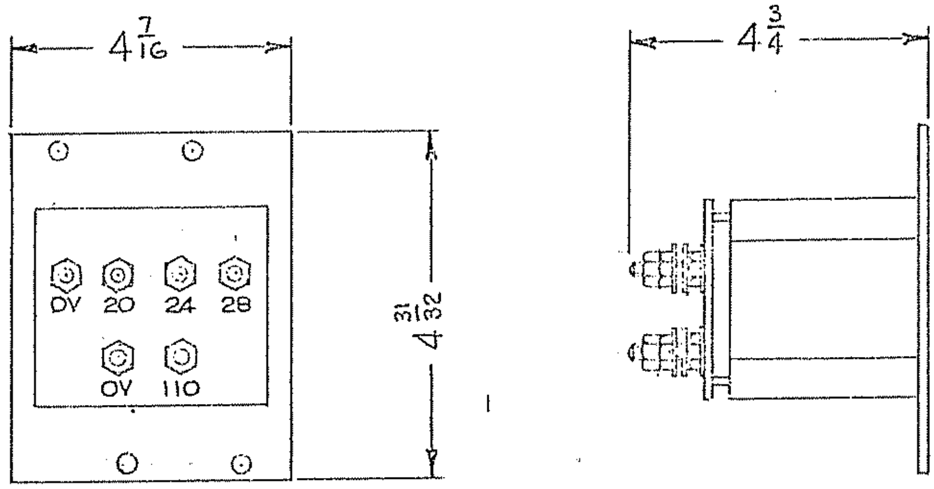


Fig. 5.2-2 : Line amplifier supply transformer, RR 9210

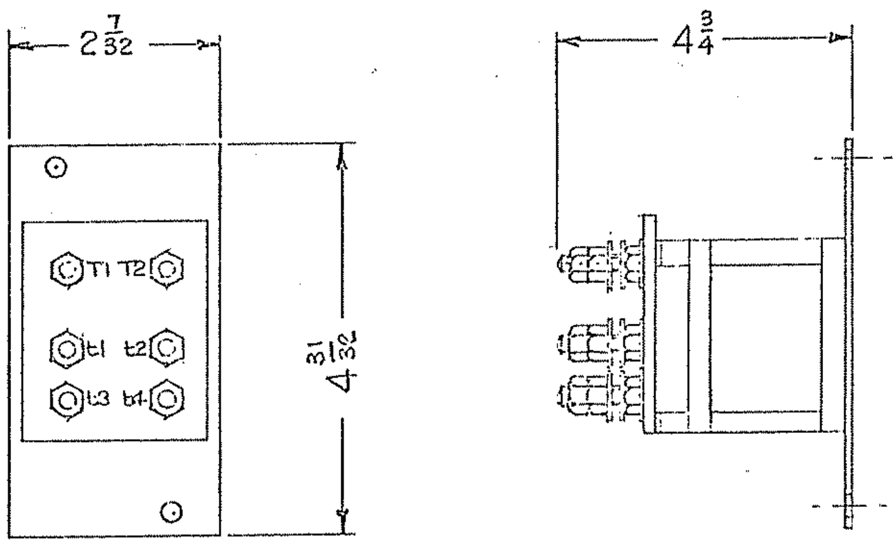


Fig. 5.2-3 : Line isolating transformer, RR 8200.

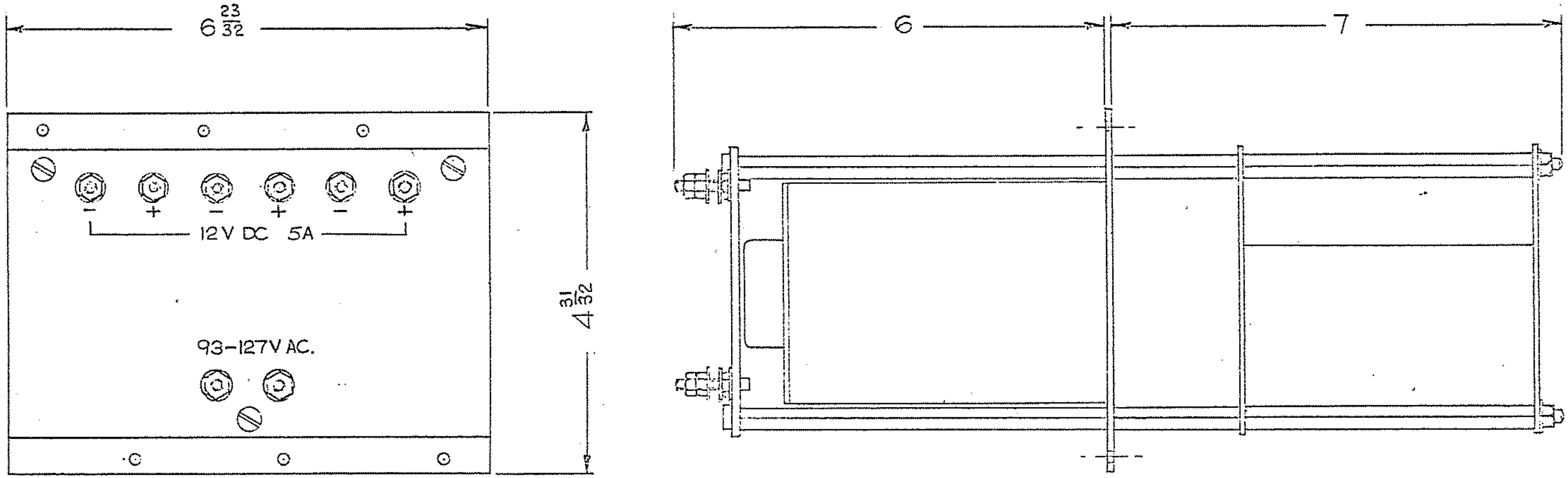


Fig. 5.2.-4 : Reed Power Supply Type RR 9130 (5A).

Dimensions :		X	Y
	RR 9110	5"	4.625"
	RR 9120	5.875"	6.125"

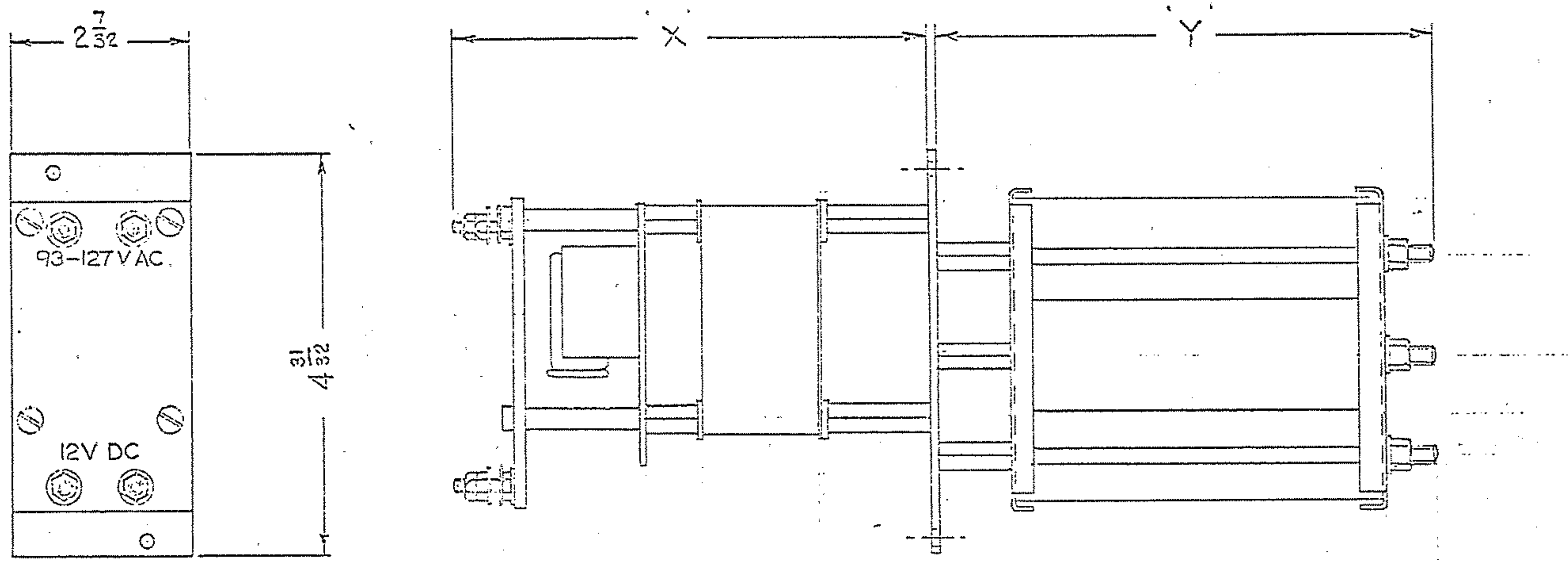


Fig. 5.2-5 : Reed Power Supplies Types RR 9110 (100mA), and RR 9120 (600mA).

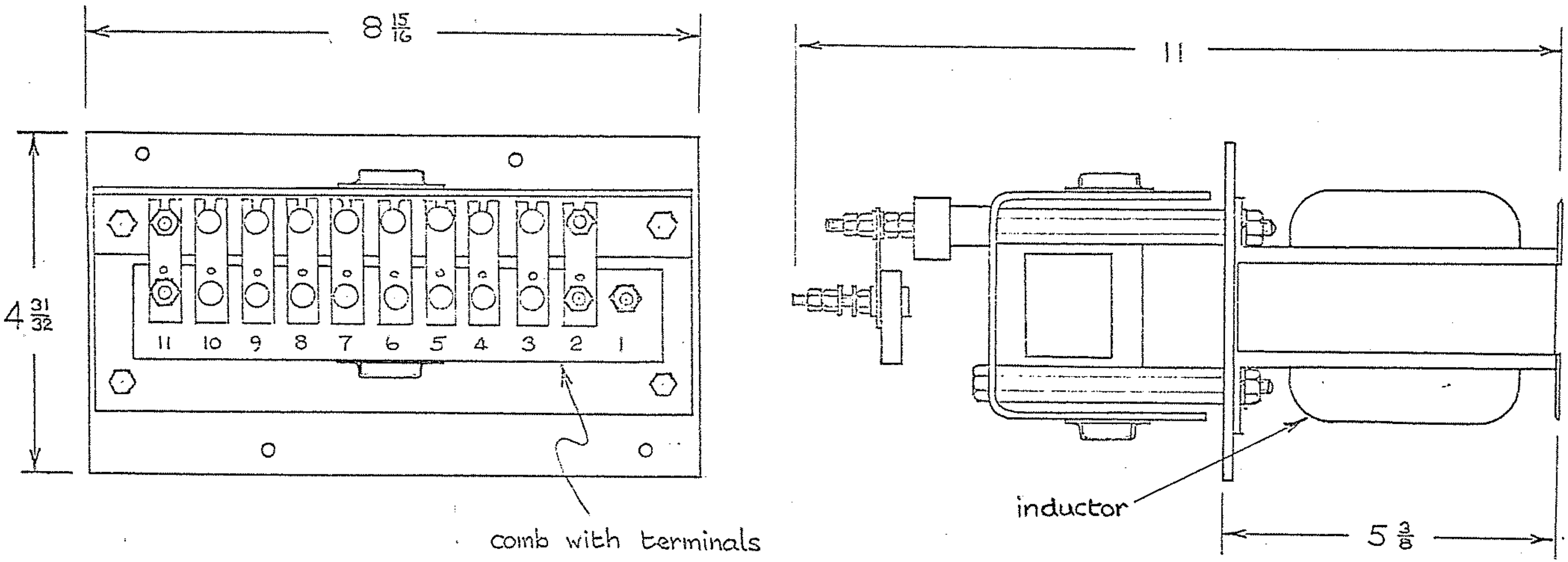


Fig. 5.2-6 : outline of line amplifier