CHAPTER 17

VOICE FREQUENCY REPEATERS

17.1 INTRODUCTION

A modern voice frequency repeater is an arrangement of electron tube or solid state amplifiers and associated apparatus capable of receiving a voice frequency current and from either side and retransmitting it, without appreciable distortion, at a greater magnitude. The energy required to produce the output currents is obtained from local sources at the repeater and is released under the control of the received currents. A repeater, then, is a two-way amplifier with some associated circuitry.

Telephone repeaters are an essential factor in our present system of long distance telephone communication. They are used:

1. To extend the range of transmission.
2. To provide a more economical means of transmission by employing inexpensive lines with repeaters instead of expensive lines without repeaters.
3. To improve the standards of volume and quality over long distance telephone lines.

For satisfactory telephone communication, there must be sufficient energy transmitted over the line to provide adequate sound volume at the receiving end. If we attempted to transmit energy over a 1,000 mile 19H44 cable circuit of approximately 480 db loss without any means of boosting the transmitted power along the line, an input power of one milliwatt at the sending end would be attenuated to 10^{-51} watt at the receiving end. If we were to attempt to increase the power received to a value equal to that of the power sent (one milliwatt) by means of a single amplifier or repeater inserted anywhere in the circuit, we would have to use a device capable of amplifying power by 10^{48}. Such an amplifier is, of course, a practical absurdity. However, by placing repeaters on cable circuits at intervals of about 50 miles, the power may be restored by each one in steps of practicable size.

The first successful telephone repeater was invented by a Bell System engineer, H. E. Shreeve, and was tried out successfully on a circuit between Amesbury, Mass.

and Boston in 1904. An improved form of this mechanical repeater, consisting of an amplifier made up of mechanically coupled receivers and transmitters, was commercially operated in the latter part of the same year on a circuit between New York and Chicago. Since the invention of the vacuum tube the use of repeaters has steadily increased, resulting in the economical extension of telephone service over distances which previsously could not be connected satisfactorily at all.

17.2 TYPES OF TELEPHONE REPEATERS

Repeaters can be divided into three types:
(a) through line repeaters; (b) switched-in line repeaters; and (c) cord circuit repeaters. Through line repeaters are permanently associated with a particular toll line; switched-in repeaters are automatically associated with a particular toll line as the result of special operations; cord circuit repeaters, before becoming obsolete, could be associated with any connection for which they were specified by the toll board operator by means of switch-board cords.

In general, telephone repeaters use two one-way amplifiers to provide transmission gain and are equipped with regulating devices for adjusting gain to meet operating requirements. Hybrid coils are used for adapting one-way amplifiers to two-way transmission. A balancing network is employed to approximate closely the impedances of each line of the circuit and its transmitted associated frequency band, thereby maintaining the degree of balance required for the proper functioning of the hybrid coil. That is, energy (at voice frequencies) from the output of one amplifier of a repeater must be prevented from reaching the input of the other. This would impair the quality of the transmission, or even cause "singing." Filters are used to filter out unwanted frequencies. Other miscellaneous apparatus and circuit features are used to adapt the repeater circuit to standard operating practices and become more or less a part of the repeater.

The function of such equipment is to: match impedance; connect 2-wire to 4-wire lines; compensate for unequal attenuation at different frequencies; adjust for variations in attenuation due to varying conditions; by-pass low-frequency or d-c signaling; and device phantom channels separately. The selection of this apparatus is sometimes determined more by the line to which it is assigned than by the amplifier with which it is used. For example, the repeater is designed to have a nominal impedance (e.g. 600 ohms), so the repeat coils (for matching impedance of repeaters and lines)

have different ratios because of different line impedances. Also, low-frequency ringing does not pass through the amplifier at all, so that means of deriving the signaling circuits are controlled by the line not by the amplifier.

The maximum overall gain of repeaters is limited by the amplifiers used, but adjustments, for example, by means of the slide-wire potentiometer and resistance pads, can bring this overall gain to any lower value. It is well to remember, however, that one-half of the energy is lost each time it must pass through a hybrid coil circuit. This means that the actual gain of each amplifying element must be at least 6 db greater than the overall gain required. This is recognized in the calibration of the repeater potentiometers.

The various types of through line repeaters used by the Bell System are as follows:

1. Reading - high impedance repeater for heavy loaded H245-155 facilities; initially used at Reading, Pa.; mostly floor type, but some of later ones were relay rack type. Obsolete

2. 21 - one-amplifier repeater for 2 directional use at exact mid-point of a two-wire circuits; used for service observing boards. Also obsolete.

3. 22A1 - two-amplifier repeaters for use on two-wire circuits. Superseded by V3.

4. 22A2 - two-amplifier repeater for use on high cut-off two-wire facilities, especially B88-50 facilities; modified 22A1. Superseded by V3.

5. 24A1 - two-amplifier repeater for use on 2-wire to 4-wire circuits. Superseded by V3.

6. 44A1 - four-amplifier repeater for use on four-wire circuits. Superseded by V3.

7. V1 - two one-way amplifiers with repeating coil hybrids for use as a 2-wire repeater, 4-wire repeater, or as a 2-wire to 4-wire repeater. Superseded by V3.

8. V2 - similar to V1, except for use with 48 volt filament and plate supply at small installations in offices having no 130-volt power plant.

9. V3 - two small compact, plug-in type amplifiers designed to replace the V1.

10. V4 - two transistorized plug-in amplifiers with associated plug-in terminating sets and equalizers designed to replace the V3.

11. E1 - miniature single amplifier, two-way negative impedance repeater for use primarily on exchange area trunks and special services.

12. E2 - an equipment redesign of the E1 employing plug-in type units as series elements.

13. E3 - a plug-in unit similar to the E2 but used as a shunt element between the midpoints of the E2 coils or across the line at either side of the line winding of the series element.

14. E6 - a transistorized plug-in type, designed to replace the E23.

15. E7 - is a transistorized shunt type repeater intended for operation on 2-wire nonloaded lines for certain types of service.

17.3 22-TYPE REPEATER

Figure 17-1 is a schematic of a telephone repeater known as the 22-type. As will be observed, the amplifier units in this arrangement are triodes connected with transformers in both input and output circuits. The drawing also shows the connections of the hybrid coil output transformers with their balancing networks; and the potentiometers in the input circuits for controlling the amplifier gains. Equalizing networks are inserted at the midpoints of the low-impedance sides of the input transformers; and low-pass filters are included in the output circuits to prevent the passage of high frequencies not essential for voice transmission. The maximum overall gain of this repeater is approximately 19.5 db when the potentiometers are on top step, but the gain of the amplifying units themselves must be higher than this to overcome the losses in the hybrid coils and other circuit elements. The gain is essentially flat over the frequency range from about 200 to 3,000 Hertz.
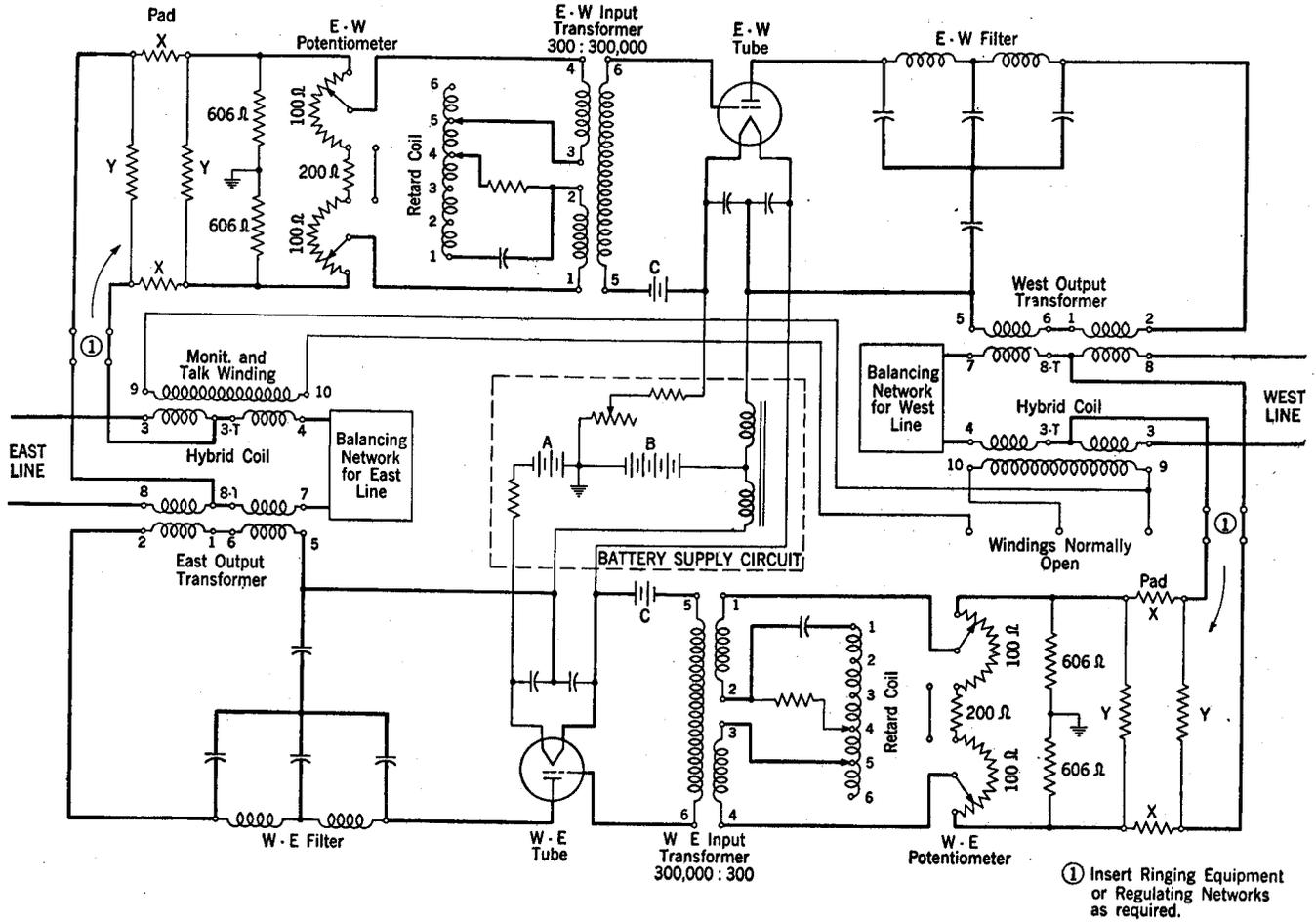
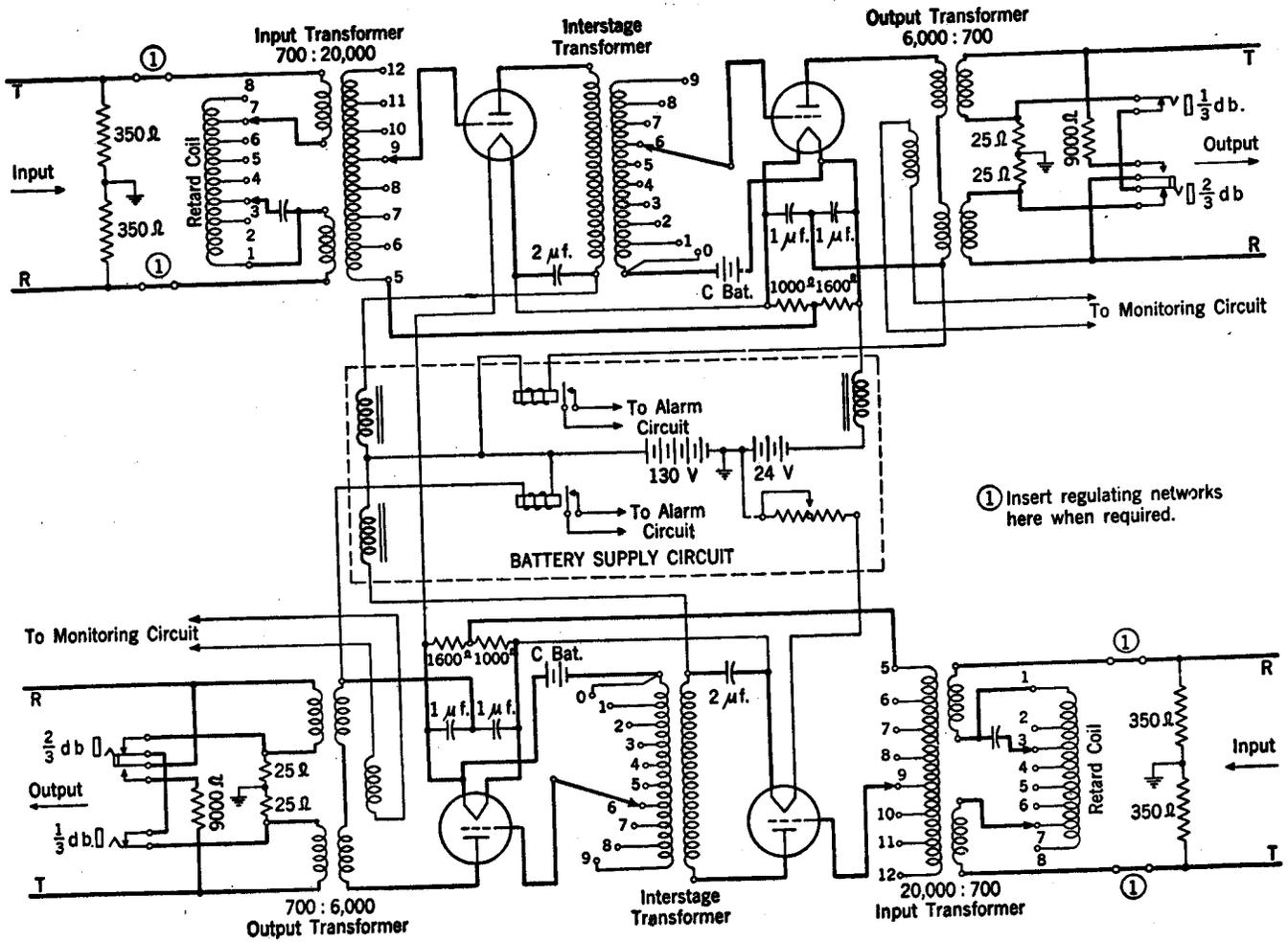Figure 17.1   22-Type Telephone Repeater Circuit

Figure 17.2   44-Type Telephone Repeater Circuit

17.4 44-TYPE REPEATER

For 4-wire circuits, the repeater corresponding to the 22-type repeater is known as the 44-type. In this case, the circuit itself is double-tracked so that there is no necessity for using hybrid coils except at the circuit terminals where the 4-wire circuit is converted to a 2-wire for connection to the switchboard. There is therefore no need for line balancing networks at repeater points, and little possibility of a "singing" path around the individual repeater. For this reason, 4-wire repeaters may generally be operated at higher gains than 2-wire repeaters.

The circuit arrangements of the 44-type repeater are illustrated schematically by Figure 17-2. It will be noted that each amplifier has two triode stages, the first tube acting as a voltage amplifier and the second as a power amplifier. Transformers are used for interstage coupling, as well as in the input and output circuits. The gain is controlled by adjustable steps on the secondary windings of both the input and interstage transformers. The shape of the gain-frequency characteristic is controlled by an equalizing network connected in series at the midpoint of the primary of the input transformer. The maximum overall gain of this repeater is 42.7 db and is flat to frequencies well above 3,000 Hertz.

Where extremely stable amplifier operation is required, as for example in the repeaters of telephotograph circuits, the 44-type repeater may be modified for operation with negative feedback. This reduces the maximum overall gain to about 38 db. Feedback is from an output unit made up of capacitors and resistors inserted between the second-stage tube and the output transformer, to a similar input unit inserted between the input transformer and the first-stage tube.

17.5 V-TYPE REPEATER - GENERAL

Another and more recent design of the voice-frequency telephone repeater is known as the V-type. It differs from the 22- and 44-types considerably, both with respect to the amplifiers themselves and the associated equipment arrangements. Figure 17-3 shows a comparison of the 22A1 and the V1 repeater arrangements in block form. Hybrid coils, equalizers, filters and regulating networks are associated with the line equipment instead of with the amplifiers, so that the repeater proper

consists only of the amplifiers themselves. All repeaters are thus essentially identical and this makes it possible to transfer them freely from one circuit to another, as may be required for maintenance purposes. It also makes possible the use of the same repeaters for either 2-wire or 4-wire operation.
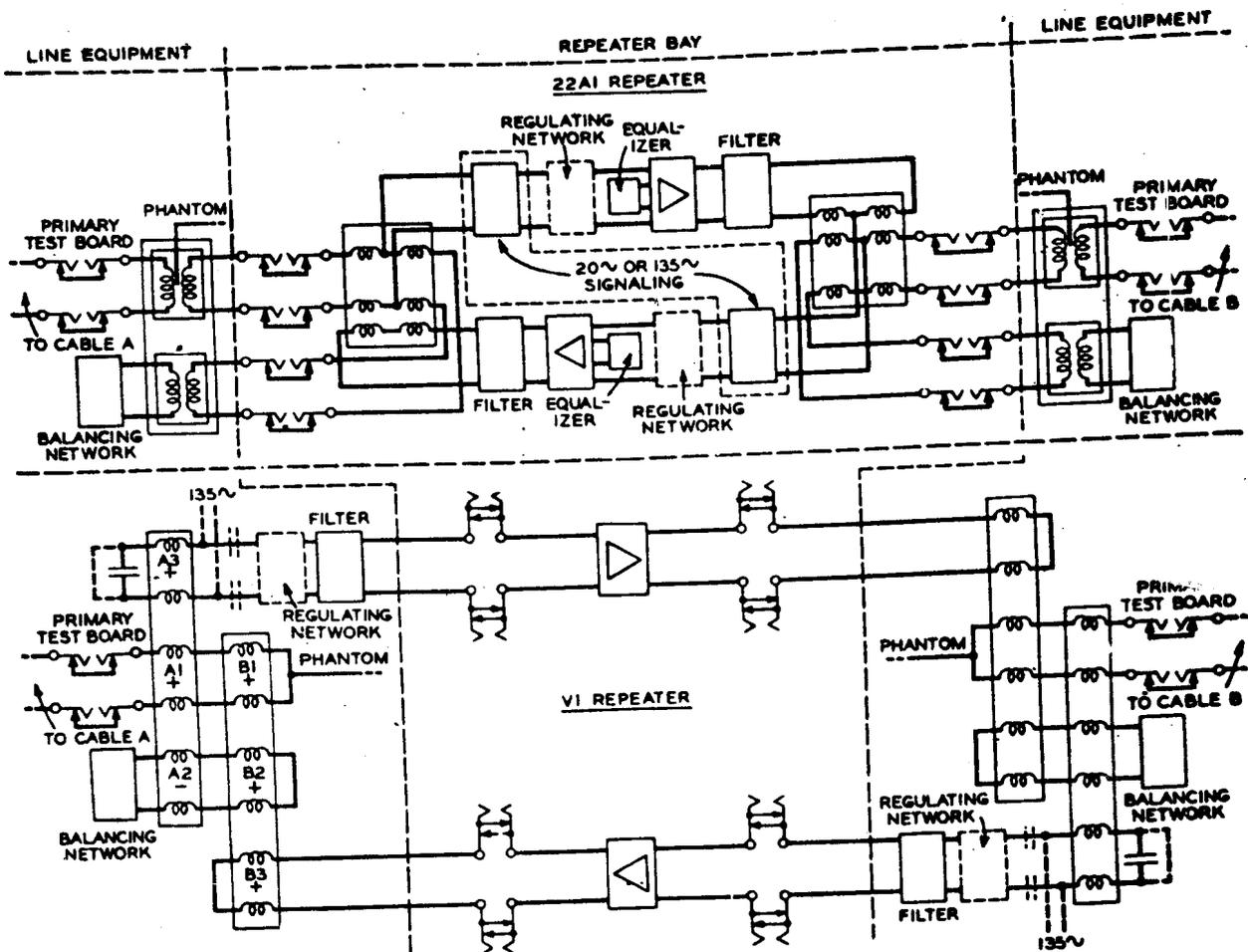

Figure 17-3 (above) - Block Schematic of an Intermediate
22A1 Repeater;
(below) - Block Schematic of a V1 Repeater.

The V-type repeater consists fundamentally of two one-way amplifiers, including talking and monitoring features. A schematic of one amplifier of a V-type repeater is shown in Figure 17-4.

A. V1 Repeater

It will be noted that the amplifying element is a pentode rather than a triode. This permits a maximum net gain of about 35 db, even though the feedback circuit causes a reduction of approximately 10 db.

The amplifier employs negative feedback which reduces gain fluctuations with changes in potentials applied to the vacuum tube. As a result, the variations in gain, due to battery fluctuations, are only one-third of those in the 22A1 repeater. The gain frequency characteristic of the amplifier varies less than 1 db over a range of about 250 to 4,000 Hertz. Feedback is derived from an extra winding on the output transformer and resistances in the cathode circuit. These latter parts include a potentiometer, which, together with taps on the secondary winding of the input transformer, serves to control the gain. The amount of effective feedback changes with the setting of the potentiometer.

The gain change resulting from a movement of the potentiometer contact arm is due to the combined effects of a change in feedback voltage and a change in the amplification of the vacuum tube due to the change in grid bias. This method permits a continuous control of gain over a range of about 5 db. For both direction of transmission, two amplifiers are required of the type shown in Figure 17-4, as this figure only provides amplification in one direction.
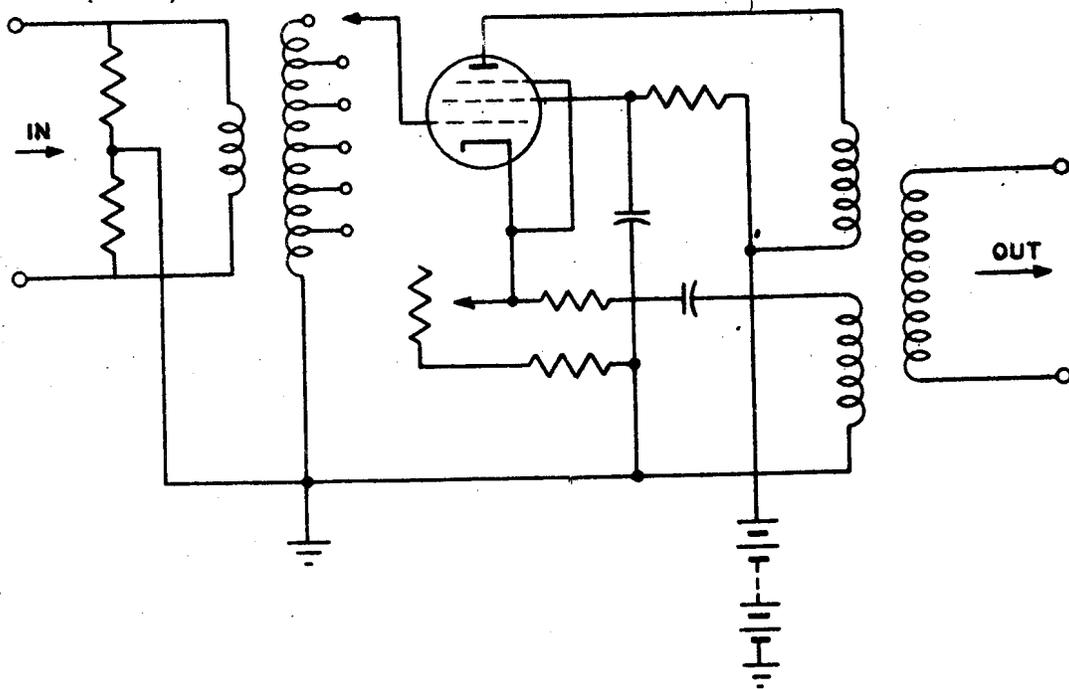
Figure 17-4   One Half Of V Type Repeater

B. V3 Repeater

The V3 repeater consists of two amplifiers and supersedes the V1 telephone repeater. The amplifiers composing the V3 are of the miniature type arranged on an 11-pin plug-in base. The overall size of the V3 repeater is 1/6 that of the V1. This has been accomplished principally by the use of a small combined input-output transformer in a single can, a small carbon composition potentiometer for gain adjustment, a small 1 uf capacitor, and a small vacuum tube.

The "miniature" technique is used primarily for space saving purposes, and the overall characteristics of the amplifier are approximately the same as for the V1 repeater. The vacuum tube used has about twice the transconductance and substantially the same output power as the tube employed in the earlier V-type amplifier. The entire amplifier unit is of the plug-in type which provides for quick replacement of defective units and facilitates testing and maintenance.

The gain may be varied continuously from a maximum of about 36 db to a small loss by a logarithmically tapered potentiometer having approximately 40 db range connected across the secondary of the input transformer. Feedback is obtained by coupling from the output to the input through a cathode resistance and a feedback winding on the output transformer. The total amount of feedback over the voice frequency band from the output to the input is about 14 db and is independent of gain adjustment. This is about 6 db more than the V1 and stabilizes the gain better against tube and battery variations.

C. V4 Repeater

The V4 telephone repeater consists of two 227 type transistorized voice frequency amplifiers and their associated equipment. The repeaters have been designed primarily for use between 600- or 900-ohm central office equipment and H88 loaded exchange cable, 600-ohm equipment, or nonloaded cable, by utilizing miniature repeating coils. The associated equipment consists of 1-type terminating sets, 359-type equalizers, and 849-type networks. These various equipments have been designed as plug-in units to facilitate field maintenance, line-up and monitor procedures, and unit replacement as the demand for a particular circuit arrangement changes. Balanced center tap input and output coils built into the amplifier units provide simplex signaling legs without the use of additional repeating coils. If no provision for simplex signaling is needed, these center taps can be used to match the 150- or 300-ohm impedance of nonloaded cable sections or to provide over the line power to intermediate repeater stations.

The V4 operates from either a 48- or 24-volt source. Power consumption is reduced because of solid-state design. For example, each amplifier uses no more than one watt. The V4 will perform substantially longer without maintenance than repeaters previously available. Since all the equipment for a single telephone circuit is contained in one shelf, repeaters may be placed economically and without complex wiring on a customer's premises. In many cases, the V4 offers an approximate 4 to 1 size reduction over V3. Contributing to this efficient use of central office space are the built-in line coils which save additional space on the relay rack and distributing frame.

D. 24V4 Repeater

The 24V4 repeater is used to terminate a four wire circuit at a Central Office as an exchange area trunk or to extend a four-wire circuit in a two wire line to a distant office or PBX. Figure 17-5 is a typical circuit configuration and equipment arrangement of this repeater. The repeater consists of a mounting shelf which holds a terminating set, two amplifiers or networks, an equalizer, and includes a jack field and power supply arrangements. This repeater, therefore, furnishes equalization, amplification and transition from two-wire to four-wire using V4 repeaters. These repeaters are also used in Traffic Service Position Systems using one repeater for every local position at the base unit.

17.6 AMPLIFIER UNITS

The 227-type amplifiers are of the miniature type employing transistors. A 227-type amplifier is available for use in telephone circuits served by underground cable where lightning protection is normally not required. Another 227-type amplifier has essentially the same transmission characteristics but has built-in protection against lightning surges. The input and output transformers of both types are designed primarily to provide either 600- or 1,200-ohm line impedances with a highly balanced center-tap connection for simplex signaling. These amplifiers may be connected directly to the line without the use of repeating coils. By using a center tap for connection to one side of the line, additional input and output impedances of 150 and 300 ohms can be obtained for special applications. The simplex must be sacrificed in order to do this.

Figure 17-6 is a schematic of a 227-type amplifier, which employs two transistors, an input and output transformer capable of working directly into the line, gain controls, and feedback. For descriptive purposes, the circuit can be divided into three parts:

(a) Input Circuit
(b) Output Circuit
(c) Feedback Loop

The input circuit comprises a terminated transformer, a continuous gain control potentiometer of approximately 15 db range, and an 11 db pad that can be inserted, when required, to reduce the gain. The line winding of the input transformer is center-tapped for
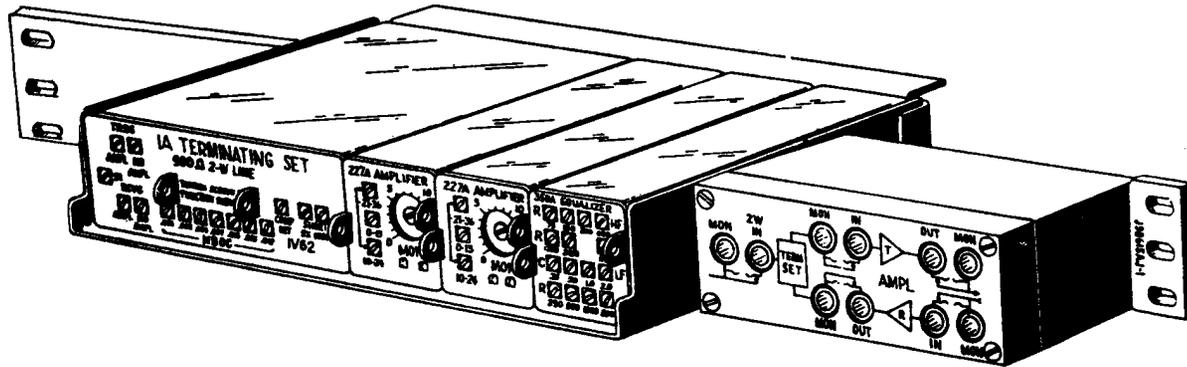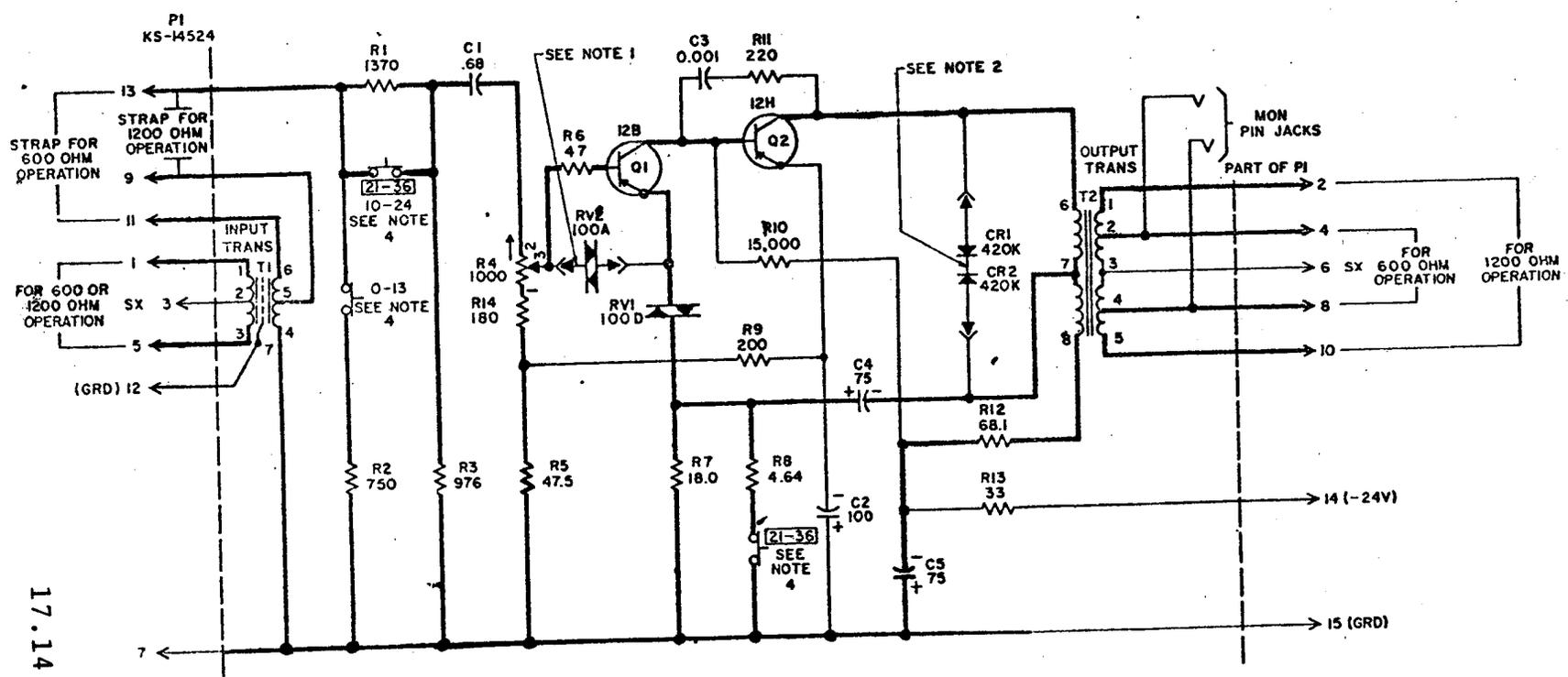
(A) 24V4 Equipment Arrangement
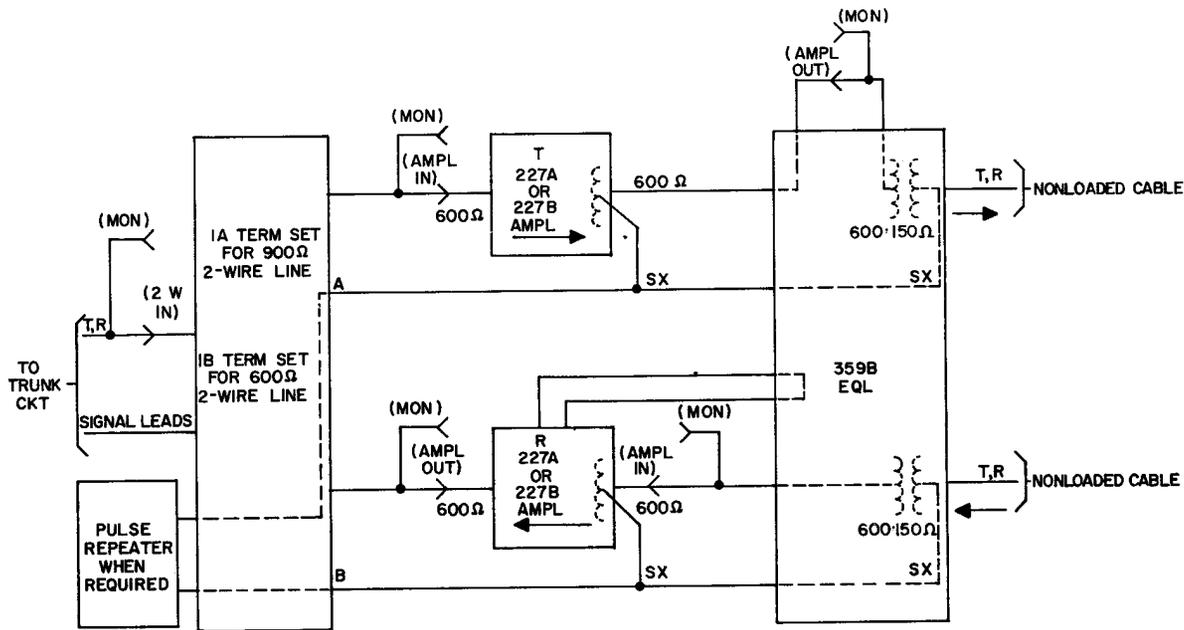
(B) 24V4 Repeater Arranged for Non-Loaded
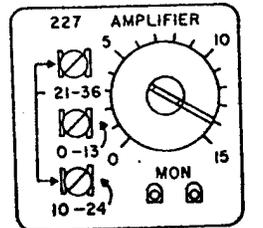Cable Requiring Gain and Loop Signaling

Figure 17-5

NOTES:
1. OMIT VARISTOR, RV2, FOR 227A.
2. OMIT DIODES, CRI AND CR2, FOR 227A.
3. UNLESS OTHERWISE SPECIFIED ALL RESISTANCE VALUES ARE IN OHMS AND ALL CAPACITANCE VALUES ARE IN MICROFARADS.
4.

RANGE DB	SCREW POSITIONS		
	21-36	0-13	21-36,10-24
21 → 36	CLOSED	OPEN	CLOSED
10 → 24	OPEN	OPEN	CLOSED
0 → 13	OPEN	CLOSED	OPEN

227 AMPLIFIER

MON

227 AMPLIFIER FACE PLATE

Figure 17-6 Schematic 227-Type Amplifiers

balanced-to-ground operation, and an electrostatic shield is provided. The secondary winding is tapped to provide either 600- or 1,200-ohm termination for the line. The secondary side of the input coil is brought out to terminals, so that a network can be inserted to equalize for loaded cable.

The output circuit comprises a multiple winding transformer used in an unbalanced hybrid connection for feedback, a line-balancing network, and a feedback network. The line winding is center-tapped for balanced operation and taps are provided for connection to either 600- or 1,200-ohm lines. The primary winding is tapped for 10:1 impedance division to minimize power loss to the line. The output impedance is generated by feedback action, thus avoiding power loss in a terminating resistance.

The feedback system comprises two essential loops, one being effective for voice-frequency currents, and the other being effective for bias currents, which are essentially direct currents serving to stabilize the operating point for the transistor. In one loop, voice-frequency current from the hybrid transformer is fed back through a resistor in series with the input circuit. By shunting this resistor with one of lower value, the feedback may be changed to increase the gain by approximately 11 db. The collector current for the output transistor is stabilized by a common emitter resistance. A fraction of the current is diverted to the base circuit of the first transistor to stabilize the collector voltage of the input transistor.

The amplifier may be operated from a 24-volt battery or from a 48-volt battery with a series dropping resistor of 1,400 ohms. The gain of the amplifier is 0 to 36 $\pm$ 1 db in three overlapping ranges of about 15 db each. Range is selected by making screw-down contacts at the front of the amplifier. Gain within any range is smoothly adjustable by potentiometer. Gain is down about 0.5 db at 300 and 12,000 Hertz.

17.7 ASSOCIATED PLUG-IN APPARATUS UNITS

The one-type terminating set used with the 24V4 repeater provides the transition between four-wire lines and two-wire lines or drops. Each set is made up of a two coil hybrid transformer, series blocking capacitors, compromise network, building-out capacitors and two optional impedance improving networks for each direction of transmission.

The 359-type equalizers serve to compensate for
the transmission-frequency characteristics of the line
facilities with which they are used.

Where gain is not needed in the repeaters, the
849-type network is used in lieu of the amplifiers. In
special cases, both amplifiers are replaced by these
networks. Electrically, each network is the equivalent
of a 1C pad, plus a transformer when needed, for matching
the pad to line facilities. The pad part is adjusted by
means of 89-type plug-in resistors.

17.8 44V4 REPEATER

The 44V4 repeater is a four-wire voice frequency
repeater usually inserted at an intermediate point in a
long trunk to provide gain and equalization for low loss
circuits on loaded or nonloaded lines. It consists of two
amplifiers, two equalizers and a jack field. Figure 17-7
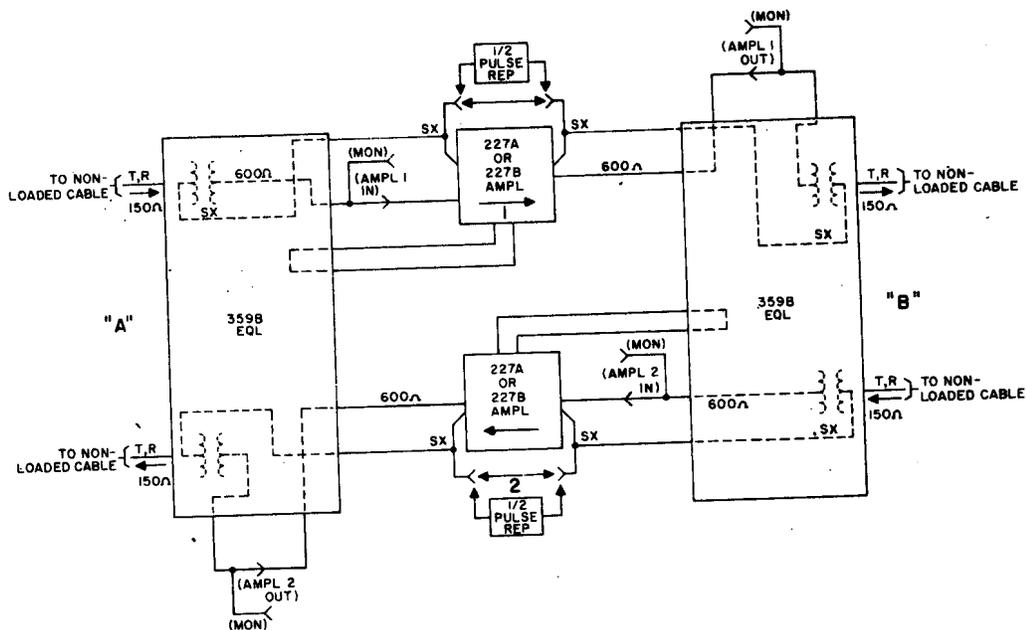shows a typical circuit configuration of this repeater.

Figure 17-7   44V Repeater Plug-In Units Arranged
For Non-Loaded Cable Requiring Gain,
Equalization, and Simplex Signaling

17.9 E-TYPE REPEATERS

A. E1 Repeater

An interesting and rather remarkable design of voice-frequency repeater circuit is illustrated in Figure 17-8. This device is sometimes known as a negative-impedance repeater or converter, but is coded in the Bell System as an E-type telephone repeater. Instead of being inserted in the line as in the case of other types of telephone repeaters, the amplifier is coupled to the line through a transformer without breaking the line continuity This transformer may be viewed as both an input and output transformer. As indicated in the drawing, the amplifier circuit employs a dual-triode connected in a push-pull arrangement. The grounded grid connection of the tubes results in a very large feedback because the input and output are in a common circuit. The secondary windings of the transformer are included in the output (plate to cathode) circuit as well as in the input circuit, and plate to cathode current thus flows through both the output and input circuits. Plate to cathode current changes accordingly tend to set up induced voltages in the primary side of the transformer.
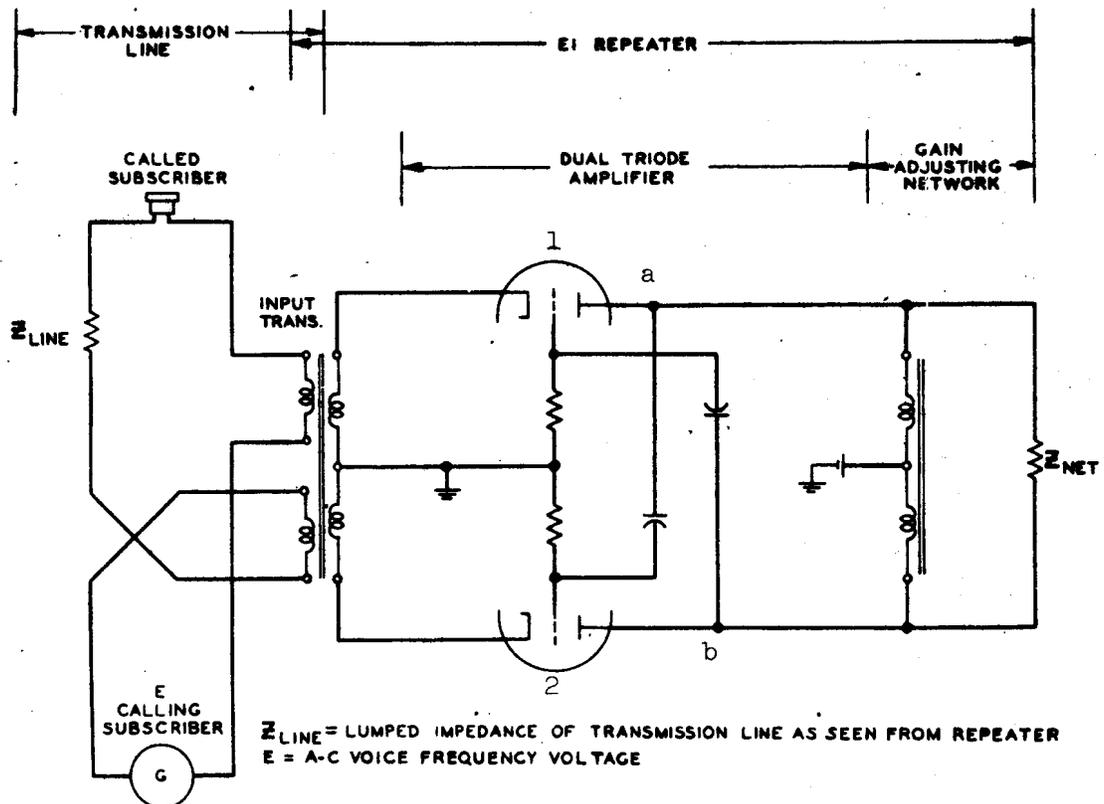

Figure 17-8 Simplfied Schematic of E1 Repeater

At first glance it might appear that this circuit arrangement would have practically no effect on the transmission line because current flowing in the line would induce voltages in the transformer secondary, which would be applied across the cathode-grid circuit of the tubes to cause corresponding currents in the plate-cathode circuits that would flow through the transformer secondaries and set up voltages that would counteract the original applied voltages. This would be true if it were not for the capacitors which couple the plate of each tube to the grid of the other tube. The potential at the grid of Tube 2 is thus determined not alone by the input voltage, but also by the potential at point a. This potential depends on the amount of current flowing in the circuit of Tube 1 and the resultant voltage drops across the retardation coil and the elements of the gain adjusting network. Similarly, the grid potential of Tube 1 is controlled by the potential at point b.

A careful analysis of the voltages throughout the circuit when an a-c input signal is applied, will show that amplified voltages are set up in the secondary windings, and that these voltages are of such phase as to induce voltages in the primary windings that add to the line signal voltages so as to increase the current in the line in either direction. The net amount of amplification secured is controlled by the gain adjusting network by virtue of its control over the potentials at points a and b. In practice, the gain adjusting networks are designed so that the connections of their elements can be adjusted in various specified ways depending upon the characteristics of the line facilities in which the repeater is used. The network connections thus determine not only the overall gain of the repeater, but provide equalization to match the loss-frequency characteristics of the line.

Transmission-wise, it is convenient to consider the E repeater as an impedance converter, which makes the positive impedance of the gain adjusting network appear as a negative impedance coupled in series with the line by the transformer. For this reason, it is frequently called a "negative impedance repeater." When current passes through a positive impedance, a voltage difference IZ, is developed across the impedance. The voltage will be directly proportional to the current, as long as the impedance is not changed. A negative impedance also produces a voltage across its terminals which is proportional to the current which it carries.

However, this voltage will have a polarity that aids the flow of current. So a negative impedance will tend to cancel the "opposition" to current flow offered by a positive impedance in series with it. It is in this way that the E repeater overcomes a portion of the attenuation of the transmission line to which it is connected.

Repeaters of this type provide gains up to 8 or 10 db over the voice-frequency range of approximately 300 to 3,500 Hertz. The application of E repeaters is generally to Exchange telephone plant, where they may be used effectively to improve transmission on long trunks or subscriber lines. They can be applied either at terminals or intermediate points of such lines or trunks.

B. E23 Repeater

Since the equivalent circuit of any transmission line is a T-network, a connected device that is not to be a source of reflections must have an equivalent circuit with both a series and a shunt component. The E repeater is in effect only a negative impedance in series with the line, and it is inherently a source of echo.

This unfortunate characteristic has generally restricted the El's use to interlocal trunks where the echo problem is usually less critical. This limitation brought about the introduction of two new negative impedance repeaters, the E2 and E3. The E2 is electrically the same as its predecessor, the E1, differing only in equipment arrangements. However, center taps are provided on the line windings of the E2 transformer to permit connection of a shunt element. The circuit of the E3 is materially different from that of the E2, but it performs the same function. It makes the positive impedance of its network appear as a negative impedance between the line terminals of the repeater. However, this negative impedance is designed to be bridged across the line. Normally this connection is made between the center taps on the line windings of an E2. Such a combination is termed an E23 repeater and can be seen in Figure 17-9. The E23 can be viewed as an artificial transmission line having an impedance which matches that of the real circuits with which it is associated, but having a negative attenuation constant so that it which replaces some of the energy lost in the real line.

17.19

Since the E23 can provide appreciable gain without introducing objectionable echo, it is finding increasing application in toll connecting trunks as well as inter-local trunks and special service lines.
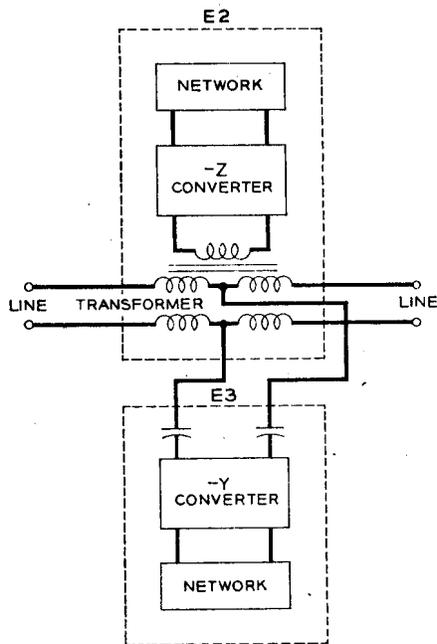
Figure 17-9   Block Diagram
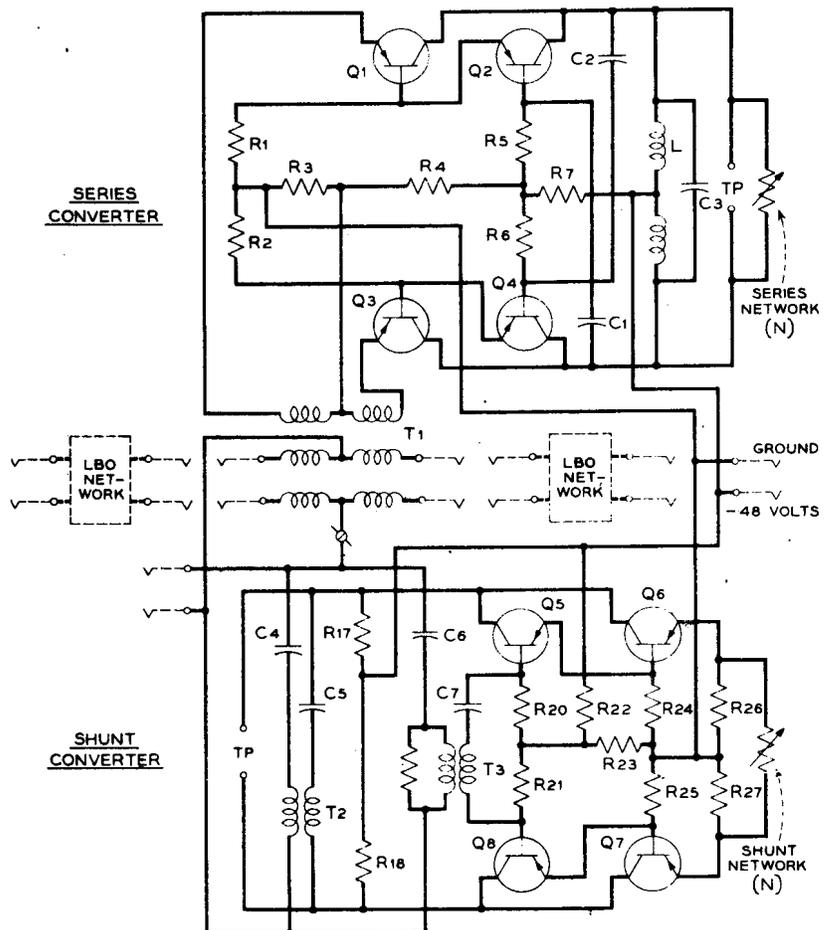   E23 Repeater

Figure 17-10   Complete Schematic
                 of E6 Repeater

17.20

C. E6 Repeater

The E6 is a transistorized two-wire, voice-frequency repeater of the plug-in type. The repeater consists of an 831A network and two line-building-out (LBO) networks. Figure 17-10 shows the schematic of an E6 repeater.

The 831A network is composed of a series converter and a shunt converter which change component resistive networks to negative impedances. These negative impedances form the arms of a gain pad designed to work with the LBOs which match the repeater to the line. The LBO contains elements to build out the line with regard to length, gauge, loading, capacitance, and whether the repeater is to be used at a terminal or intermediate location. Adjustments of the LBO and of repeater gain are made by screwdriver-operated screws which short out or connect in the various components as required.

Repeater gains up to approximately 12 db are possible in favorable cases. In a specific circuit, (12V, 6db) more gain can be realized from a repeater at or near the midpoint than from one at a terminal.

On certain types of circuits, more repeater gain is required than is normally obtainable without resultant singing during idle- or switching-circuit conditions. The greater gains are operable only with idle-circuit terminations or with repeater disablers of the loop-current-operated type. In many cases, the idle-circuit terminations cannot be used without adverse effect on signaling features, and in these cases, repeater disablers are required. The disablers must be located in the same bay with the associated repeaters in order to minimize the effect of capacitance of office cabling upon frequency characteristic of equipped facilities and to prevent interchannel crosstalk.

The E6 repeaters may be operated in tandem on the same circuit, provided the rules for maximum permissible gain are observed.

Combination of the series and shunt units, reduction in size of the line transformer, transistorization, and simplification of repeater networks result in space saving of about 50% over the E23 repeater, as seen in Figure 17-11. Combination of the two units also saves
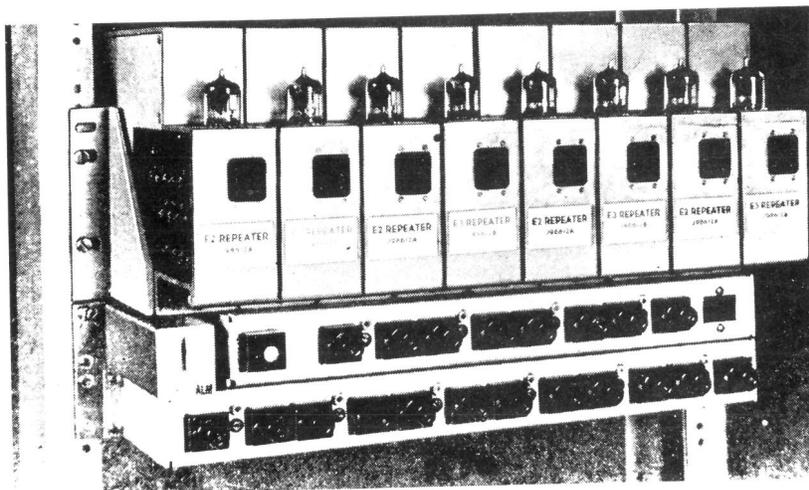
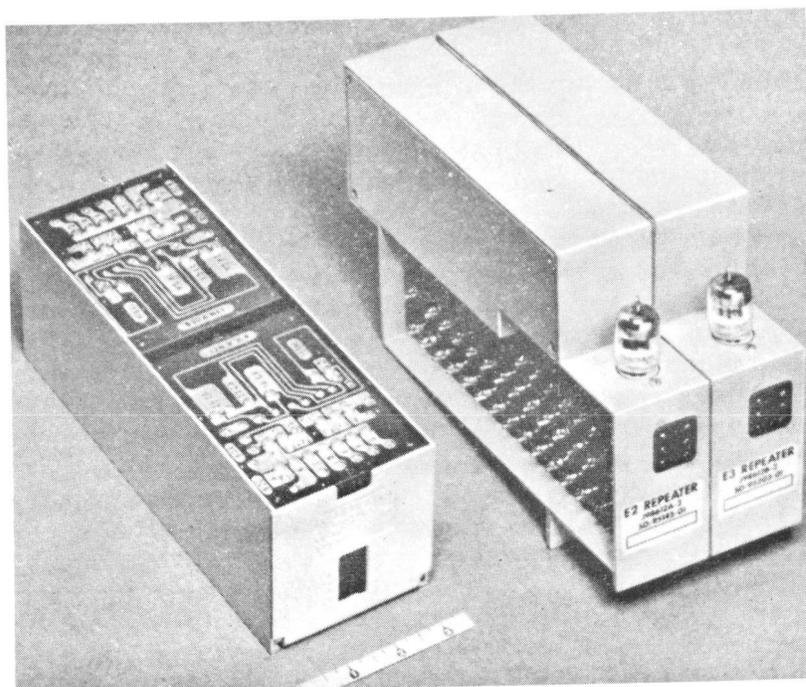Four E23 Repeater With Mounting Shelf

Figure 17-11   E23 and E6 Repeater

handling the time during installation and maintenance, and reduces the number of plug-in contacts.

The use of transistors in place of vacuum tubes frees the E6 repeater from the need for 130 volt battery. This permits easy application in outlying offices that have only 48-volt supply. It also reduces power consumption and the problem of heat dissipation. In the vacuum-tube repeater, filament-current adjustments were required; the use of transistors does away with filament currents.

D. E7 Repeater

The E7 repeater is a transistorized, two-wire, voice-frequency telephone repeater of the plug-in type. It is designed to be inserted between the central office and the subscribers nonloaded loop and used for TWX and Dataphone services, in the manner indicated in Figure 17-12. The repeater improves the loop return loss by modifying the impedance seen from the central office end, provides moderate gains at higher voice - frequencies to permit meeting return-loss and insertion-loss requirements, respectively, and inserts moderate losses at frequencies below 850 Hz as part of its equalization function.

The E7 repeater, although it uses the same mounting shelf arrangements and housing as the E6, has no counter-part among the other E type negative-impedance repeaters. The E7 repeater consists of three major parts:

(1) The Coupling Transformer
(2) The Negative-impedance Converter (NIC)
(3) The Adjustable Network

This repeater acts basically as a shunt repeater at high voice frequencies and a series repeater at low frequencies. As the E7 repeaters must improve the impedance matches between nonloaded loops, which can vary over a considerable range, and nominal office impedance of 900 ohms and 2 microfarads in series, they are necessarily unsymmetrical devices. To couple the office to the loop, a transformer with taps on the loop windings is employed. The converter is coupled to both the office and the loop by means of a fixed third winding.

The E7 repeater improves the transmission by decreasing the loop loss at the high-frequency end of the voice band and increasing it at the low-frequency end. The amount of the high-frequency gain introduced by the repeater is primarily determined by the coupling-transformer turns ratio and may be as high as 8 db. As the E7 is not designed to present a smooth-termination at the central office end of the loop it may reduce the return loss at the station end of the loop. Therefore, this repeater is restricted to terminal subscriber loops that do not switch the station end circuit.

The E7 repeater's negative-impedance converter is a shunt-type (short-circuit stable) negative-impedance converter which presents to the coupling transformer approximately the negative of the impedance of its adjustable network. The shunt converter employs compount-connected transistors in a balanced amplifier and keeps the gain essentially constant, regardless of normal variations of the transistors and of the power-supply voltage.
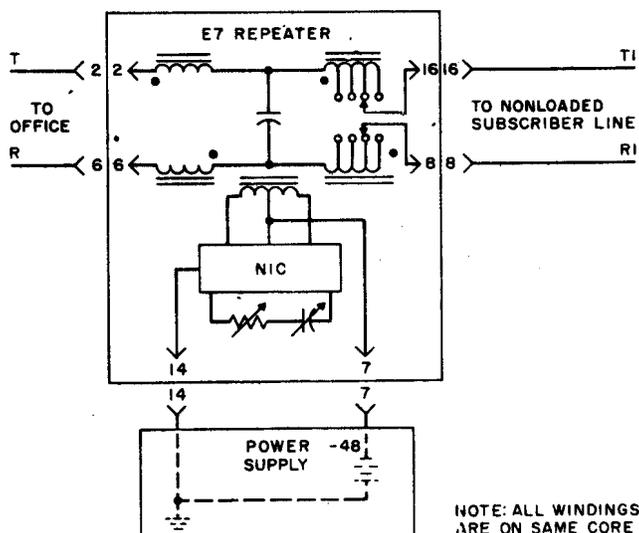

Figure 17-12 Simplified Schematic of E7 Repeater