16C1 TELEGRAPH REPEATER AND BALANCED LOOP APPLIQUE

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1. GENERAL

1.01 This section describes the 16C1 telegraph repeater and its associated balanced loop applique.

1.02 The 16C1 repeater is the electrical equivalent, with minor improvements, of the 16B1 repeater. With the 16B1, however, conversion from one type of operation to another required changes in soldered connections. The conversions caused delay, were expensive to make and were a cause of additional expense in some offices because of the provision of an abnormal number of spare repeaters, connected for different types of operation, in order that equipment in trouble might be quickly replaced. The 16C1 repeater allows the complete range of all operating adjustments and line and transmission options to be traversed by means of front-of-panel rotary switches and screwdriver-operated potentiometers.

1.03 The repeater was designed for operation, through a 144-type coupling unit, with Nos. 2 and 9B service boards. It is not arranged for use with the No. 1 service boards. For balanced loop operation at testboard offices, an applique unit, described herein, is required.

1.04 The 16C1 repeater provides for the following methods of operation:

(a) Differential Duplex - half or full duplex.

Line or line battery normal or reversed.

(b) Type A Polarential - half duplex only.

Polar sending or polar receiving.

(c) Type B Polarential - half duplex only.

Polar sending or polar receiving.

Note 1: For all of these methods, provision is made for reversing the loop and loop battery.

Note 2: Full-duplex operation is practicable only on lines on which a suitable balance can be maintained.

Note 3: No provision is made for 2-path polar operation.

1.05 The repeater, arranged as above, may be used on the following types of line facilities:

(a) One-wire on a grounded basis (Note 1).

(b) Two-wire operation with neutralizing wire.

Note 1: The 16C1 repeater is not recommended for use on small-gauge 2-wire telephone composited cable facilities exceeding about 40 miles in length because of the excessive thump and flutter which it would cause in the associated telephone circuit. If another telegraph circuit operates on the other wire of the pair, cross fire will limit the length to less than 40 miles. Type A composite sets should be used.

1.06 The 16C1 repeater will operate with other repeaters or stations as follows:

Differential Duplex Operation

Any other standard polar duplex repeater on single or 2-wire basis or with the line terminated in a grounded battery and potentiometer (upset operation).

Polarential Operation

Another 16C1 or 16B1 Repeater
Modified 12 or 16A1 Repeater
128B2 Station Set - polar receiving
Teletypewriter direct (polarential A)

1.07 Fig. 1 shows a front view of the repeater and Fig. 2 a front view of the balanced loop applique.

Working Limits

Telegraph coefficients are the same for 16C1 repeaters as for 16B1. Maximum resistances for the lines, including composite sets, are as follows:

Differential duplex operation 2750 ohms
Type A polarential operation 2750 ohms
Type B polarential operation 1650 ohms

In the case of 2-wire operation, the above limits apply to either line 1 or line 2.

In Type B polarential circuits, the minimum shunt resistance to ground is 1200 ohms, if leakage is uniformly distributed; it should not be less than 5000 ohms if the leakage is entirely between either terminal and the "compensation point" (a point one-third the line length from the polar-sending terminal).

2. DESCRIPTION OF OPERATION

(A) Differential Duplex Operation

2.01 Fig. 3 shows two 16C1 repeaters arranged for differential duplex operation with the normal arrangement of opposing line batteries. For 1-wire operation the circuit of the upper half of the figure is used. When studying the operation of this circuit, it is helpful to consider the current in any member as made up of the algebraic sum of two currents, the current which would exist if the distant battery were replaced by a short circuit plus that which would exist if the home battery were short-circuited. Taking first the 1-wire case with the lower two windings of the two REC relays disconnected from the circuit, assume that the east batteries are

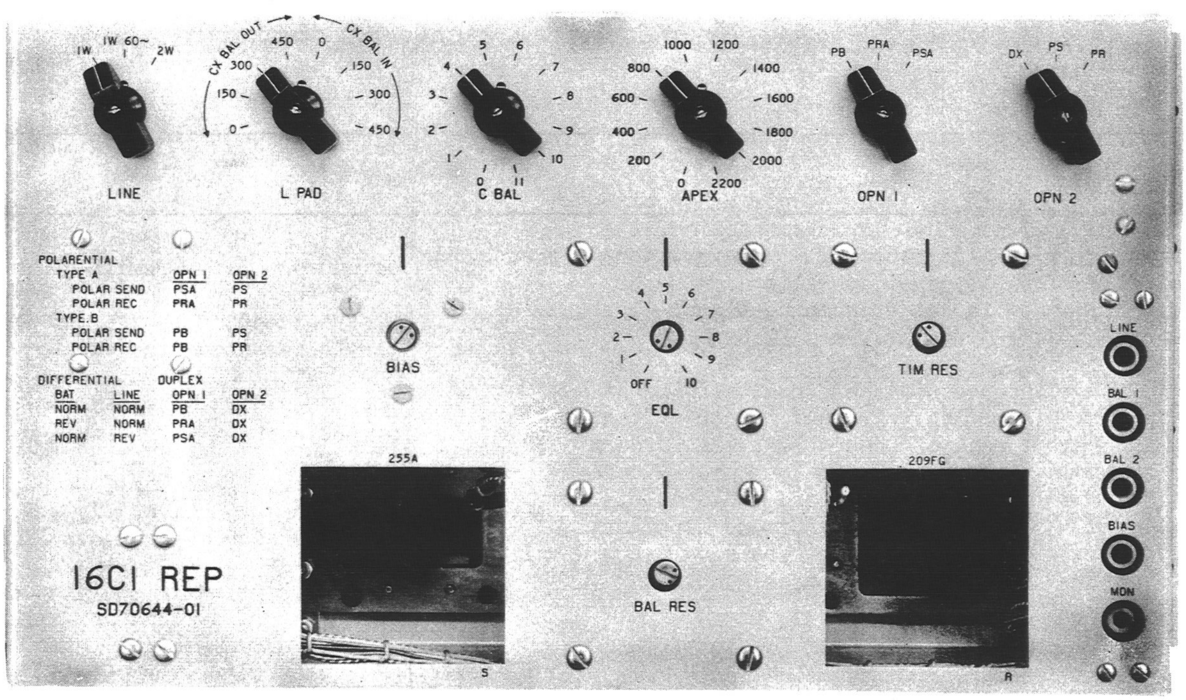


Fig. 1 - 16C1 Repeater

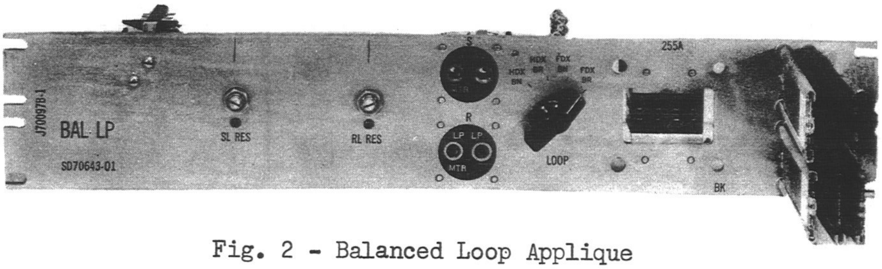


Fig. 2 - Balanced Loop Applique

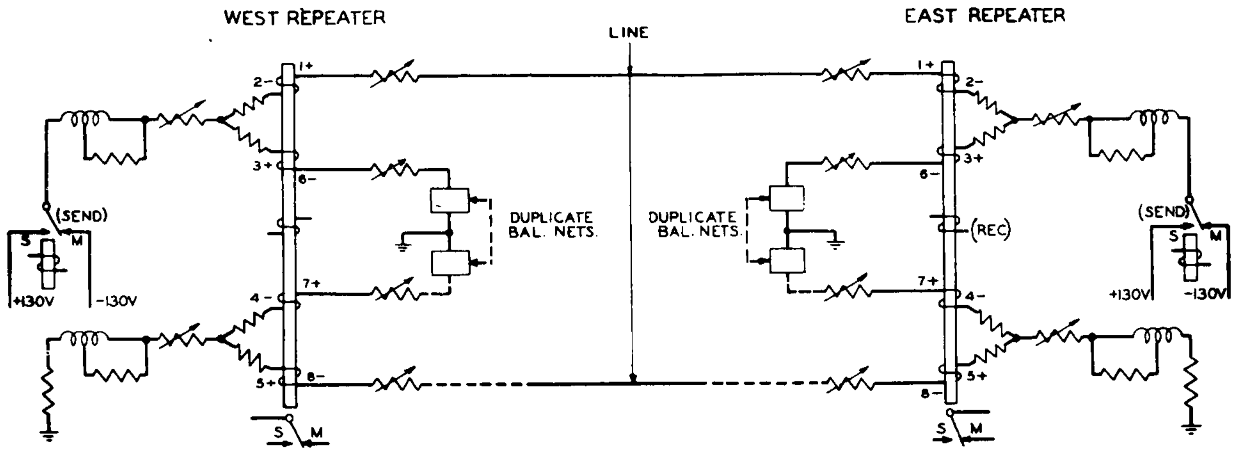


Fig. 3 - Differential Duplex - Opposed Line Batteries

replaced by short circuits and that both balances are perfect, i.e., that each balancing network has the same impedance as the line plus distant termination for currents of all frequencies which might affect relay operation. Signals from the west SEND relay will cause equal currents to flow in the line and balancing network of the west repeater and the west REC relay will not be affected. At the east repeater, the line current traverses the line winding of the REC relays and divides, part going through the APEX resistance and part through the network winding and network to ground. The two relay windings are in series aiding and so the relay follows the signals.

2.02 Now if the batteries are restored to the east repeater, and they have the same voltages as the west batteries, the line current when the repeaters are both marking or both spacing is the sum of two equal and opposite currents and, therefore, equal to zero. Likewise when one repeater is marking and the other spacing, the line current is twice the current from either repeater alone. The balancing network current is not one-half this value due to the current supplied by the distant battery. It is greater than or less than the one-half value, depending on whether the batteries have alike or unlike polarities at the two repeaters. There can be no interference between the two directions of transmission, however, when a perfect balance exists at each end. If the marking batteries or the APEX resistances in the two repeaters have somewhat different magnitudes, or if there is line leakage, the marking line current is not exactly zero. This residual current is called "override current" and has no effect on telegraph transmission with perfect balance. As in other differential duplex circuits, the bias of signals will be affected by changes in line impedance due to temperature or leakage variations unless a compensating adjustment is made in the balancing networks. With opposing line batteries the unbalance caused by decreased line resistance causes spacing bias.

Note: In Fig. 3 and other figures, the usual convention is followed by designating at the end of a polar relay winding the polarity of battery which, connected to it, would tend to operate the relay to the spacing contact.

2.03 When a neutralizing wire is employed, the lower two windings of the REC relays are connected as shown in the lower half of Fig. 3. In the 1-wire case, a 60-cycle resonant circuit is connected across terminals 1-6 of the receive relay when 60-cycle interference is excessive. This is indicated in Figs. 5 and 6.

2.04 Fig. 4 shows two 16C1 repeaters connected with aiding line batteries. This arrangement is used on half-duplex circuits to permit operation of an intermediate subscriber station in series with the line. Signals are transmitted from the intermediate station by upsetting the balance of the terminal repeaters. Override current caused by different voltages at the two repeaters is undesirable, as it causes bias to the intermediate station signals. The neutralizing function in this case is effective in through transmission only and will not apply to transmission to and from the intermediate station unless special arrangements are provided for this purpose at the station. With aiding line batteries the unbalance caused by leakage or decrease in line resistance causes marking bias and

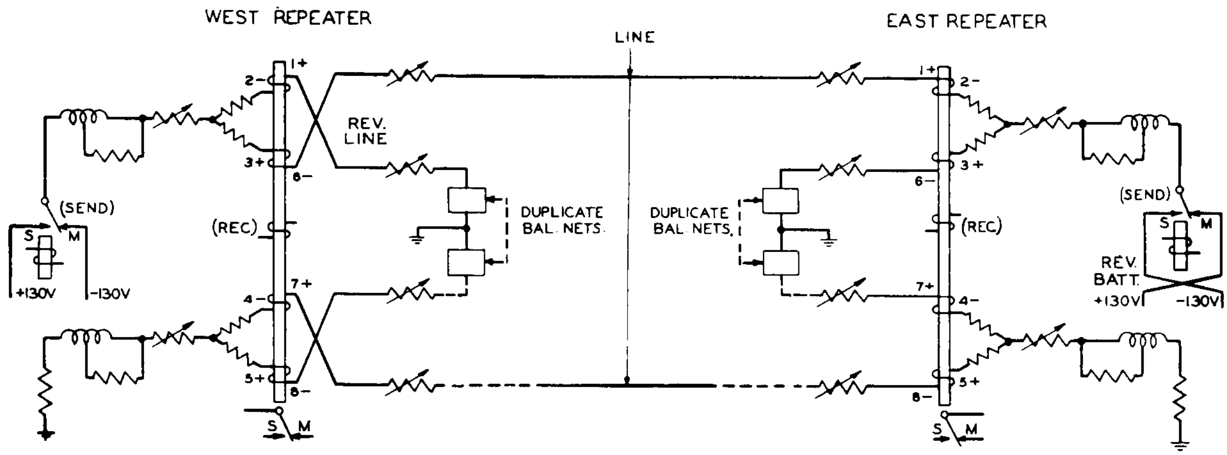


Fig. 4 - Differential Duplex - Aiding Line Batteries

therefore this arrangement may be used in alternate line sections, so that the effects of weather in one section will tend to be canceled in the succeeding section.

(B) Type "A" Polarential Operation

General

2.05 A Type A polarential system is shown in Fig. 5. Although 16C1 repeaters may be used at both ends of the line, they are arranged differently. As shown in the figure, the west repeater is arranged for polar sending and the east for polar receiving. The 128B2 set has transmission circuits similar to those of the east repeater.

Operating Principles

2.06 Transmission from west to east takes place as follows. Operation of the send relay at the west repeater will apply negative and positive voltages to the line for the marking and spacing conditions, respectively. Current will pass over the line, through the receiving relay of the east repeater, and thence to ground. This latter relay will operate, therefore, on a polar basis. When the line leakage changes or when the line resistance is changed, the amount of current received by the east repeater will be changed equally for both marking and spacing conditions and there will be no bias introduced. However, if the leakage is large enough the receiving relay will fail to operate properly because of insufficient current.

2.07 The receiving relay of the west repeater, in addition to its line and balancing windings, is provided with biasing windings. When the repeater is balanced, the outgoing currents from the contacts of the sending relay will divide equally. Half of this current will flow over the line and the other half will pass through the balancing network to ground. Since the windings are poled

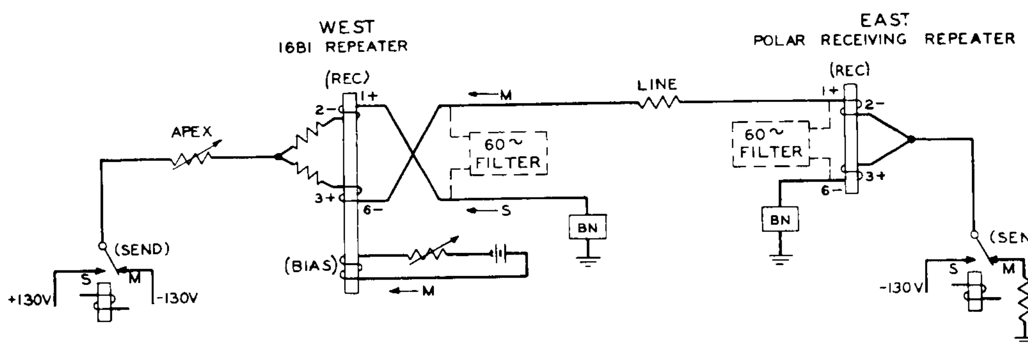


Fig. 5 - **Type "A" Polarential System**

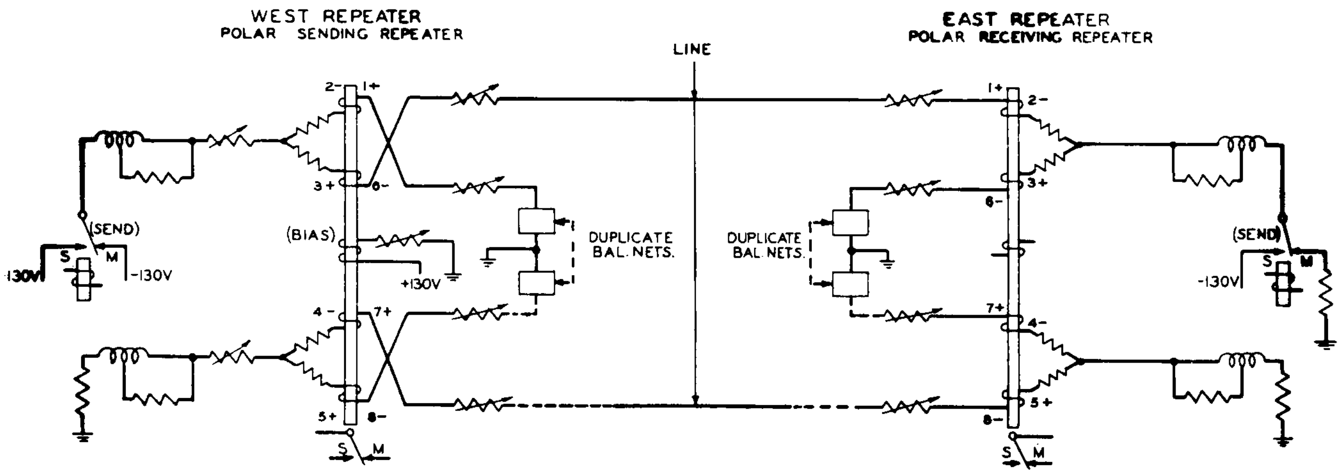


Fig. 6 - 16C1 Repeaters Arranged for Type "A" Polarential Operation

oppositely, there will be no net operating ampere turns on the relay. The relay will be held to marking by a third winding which is designated BIAS in the figure. This bias current is adjusted to make transmission unbiased from the east terminal.

2.08 Transmission from east to west takes place as follows. The sending relay of the east repeater is operated by telegraph signals and it connects the line to ground for marking and applies to the line a negative 130-volt battery for spacing. Assuming good balance in the east balancing network, these signals can not affect the east receive relay, and so the part of the relay current supplied by the east spacing battery may be neglected. The relay is held on its marking contact by steady marking current from the west.

2.09 When the sending relay at the east repeater is operated to spacing, the line current reverses. This overcomes the effect of the BIAS winding and the west R relay operates to spacing.

Bias Due to Changes in Line Resistance

2.10 Transmission from west to east over this circuit is polar and changes in line resistance have no effect on bias. Transmission from east to west is not true polar and changes in the line resistance will cause a bias unless the repeater is lined up in a particular manner. It can be shown that by adjusting the values of the resistances of the balancing network and apex branches of the west repeater so that the line currents are made equal and opposite for marking and spacing, transmission from east to west will be made free from bias due to line resistance variations. Bias in received signals due to changes in line resistance will then be neutralized by an equal and opposite bias caused by unbalance current in the balancing network. The required equality of marking and spacing effects will be obtained when the resistances of the apex and balancing network branches are approximately equal, assuming that the battery voltages at both ends of the line are equal. It is often impracticable with single wire operation to obtain this 1:1 ratio of resistances without reducing the line operating currents below allowable limits. In the case of 2-wire operation as shown in Fig. 6 this ratio can be maintained over longer lines than for operation over 1-wire, since a lower operating line current can be tolerated with the lower interference level which this operation affords.

2.11 The Type "A" polarential system is recommended for cable circuits where line resistance variations are the controlling factor. For such circuits, Type "A" operation is likely to be more satisfactory than either differential duplex or Type "B" polarential. The Type "A" polarential system is more subject to bias due to the effects of line leakage than a differential duplex system. It is accordingly much less satisfactory for open-wire operation than a Type "B" polarential system.

(C) Type "B" Polarential Operation

General

2.12 A Type "B" polarential system is shown in Fig. 7. Although 16C1-type repeaters may be used at both ends of the line these two repeaters will be different, as shown in the figure. The west repeater is arranged for polar sending, the east for polar receiving. The 128B2 teletypewriter subscriber set has transmission circuits similar to the east repeater.

Operating Principles

2.13 Transmission from west to east is similar to that for Type "A" polarential which is covered in Paragraphs 2.06 and 2.07.

2.14 Transmission from east to west takes place as follows. The sending relay of the east repeater is operated by telegraph signals and connects ground to the line for marking and applies positive 130-volt battery for spacing. The currents through the receiving relay windings of the west repeater are in the directions shown by the arrows for the marking and spacing conditions indicated. With a mark sent from the east, the west receiving relay will be operated to marking by its bias current. When the east sending relay operates to spacing, current in the line will be increased to a value somewhat less than three times the current for the marking condition and will be in the same direction as this current, thus producing a spacing effect on the west receiving relay. The balancing network current will be reduced because of the presence of the common apex resistance but will continue in the marking direction. To produce unbiased signals the effect on the relay of the bias plus balancing network currents must be equal and opposite to that of one-half the sum of the marking and spacing line currents.

2.15 For transmission from east to west the line currents for marking and spacing both tend to hold the receiving relay of the east repeater to marking. From this it might appear that no balancing network would be required at the east repeater. However, when the east send relay is in the spacing condition the capacitance of the line and composite set is charged to a positive potential by the spacing battery. Subsequently, when the relay returns to marking, the capacitance discharges through the line winding of the receiving relay to ground in a direction opposite to the marking current and tends to operate the relay to spacing. This particular kick-off of the receiving relay is prevented by providing a network to balance the line, including the composite sets.

Bias Due to Changes in Line Leakage

2.16 Transmission from west to east in the simplified Type "B" polarential circuit of Fig. 7 is polar and changes in line leakage have no effect on bias. Transmission from east to west, however, is not true polar and unless the system is lined up in a definite manner leakage will cause bias. This bias is minimized for a Type "B" polarential system by adjusting the apex resistance at the polar sending repeater in a certain relation with that of the line circuit. Instructions for making this adjustment are given in another section of Bell System Practices. The characteristics of the Type "B" system are such that when this adjustment is properly made the unbalance current in the balancing network caused by leakage nearly neutralizes the bias which the leakage tends to cause.

2.17 Type "B" polarential is recommended only for use over open-wire circuits and it is likely to be less satisfactory than a differential duplex or a Type "A" polarential

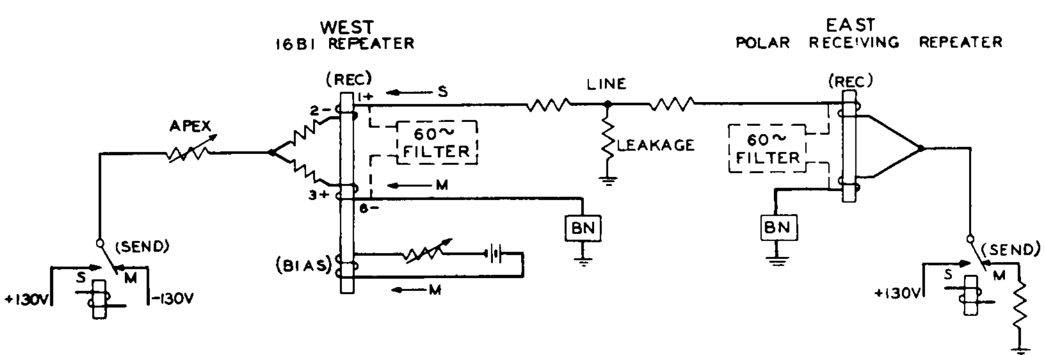


Fig. 7 - Type "B" Polarential System

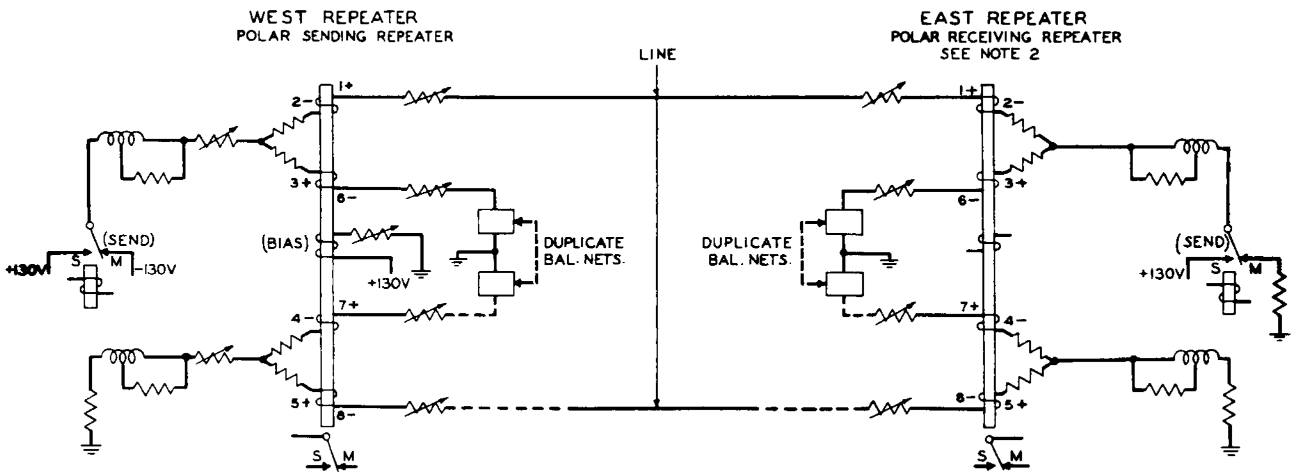


Fig. 8 - 16C1 Repeaters Arranged for Type "B" Polarential Operation

system when operated over cable circuits, particularly when line resistance variations are a factor.

2.18 A neutralizing line wire can be employed for polarential operation in the same manner as described in Paragraph 2.03 for differential duplex as a means for minimizing the effects of interference. This neutralizing wire, together with its balancing network is shown dotted in Figs. 6 and 8 which apply to Type "A" and Type "B," respectively. For convenience the balancing networks of the regular and neutralizing circuits are adjusted by common controls, so that their impedances are the same at all times.

Connection to Nos. 2 and 9B Service Boards

2.19 Fig. 9 indicates the circuit arrangement used to connect a 16C1 repeater to a No. 2 or 9B service board through a 144A1 coupling unit. No provision is made for connection to other types of service boards. Signals from the send hub cause the 144A coupling unit to send polar ±7.5 milliampere signals (positive for marking) into the send relay of the repeater, its two windings being connected series aiding. The receive relay sends approximately +27 ma and -32 ma into the control circuit for marking and spacing signals, respectively; the resulting potentials at the receiving hub of the service board are +60 and -30 volts for mark and space, respectively.

Loop Arrangements

2.20 Half and full-duplex loop connections are shown schematically in Figs. 10 and 11, respectively, when the repeaters are used with appliques. The loop noise killers shown are not a part of the applique but must be provided externally when required. The loop balancing network is not adjustable.

3. CIRCUIT ARRANGEMENTS

General

3.01 Figs. 12-14 show schematically the circuit of the 16C1 repeater arranged for connection to a 144A1 coupling unit in a No. 2 or 9B service board office, as follows:

Fig. 12 Differential Duplex
Fig. 13 Polarential - polar sending
Fig. 14 Polarential - polar receiving

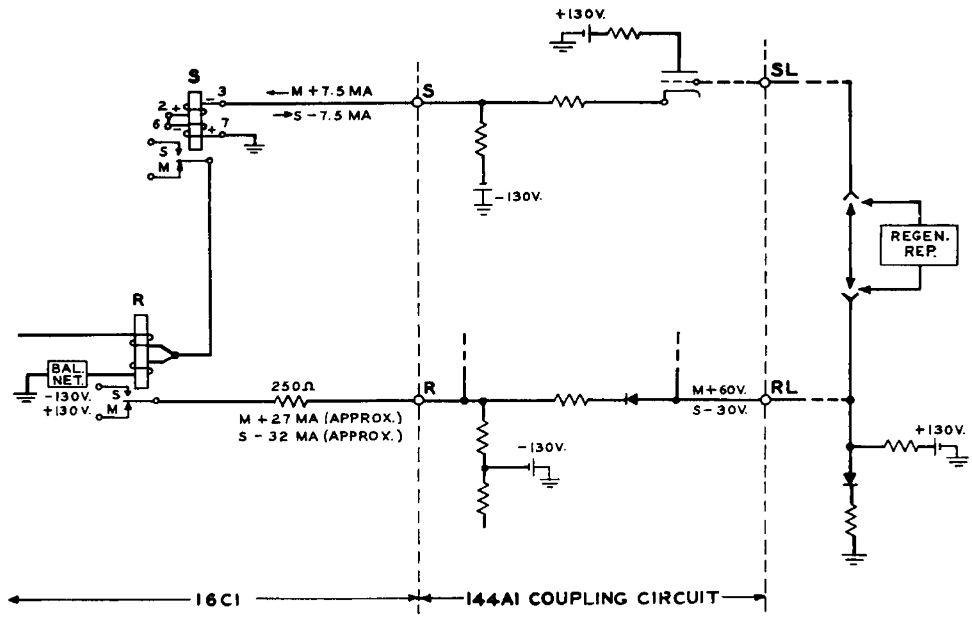
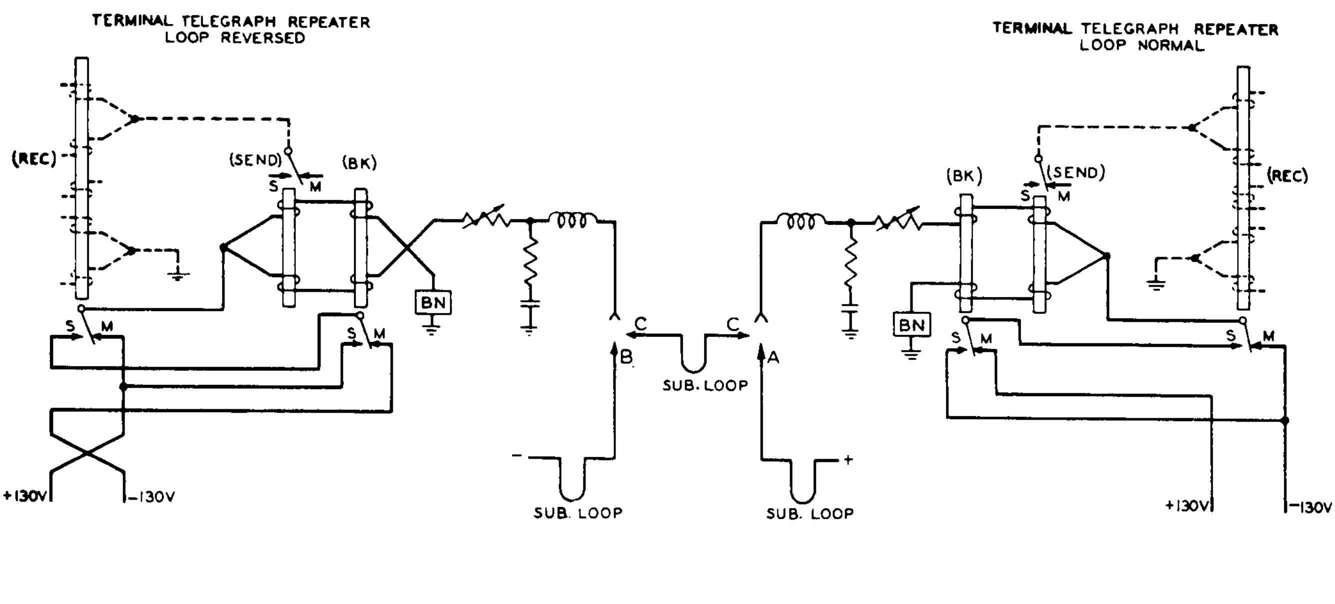


Fig. 9 - Connection to Nos. 2 or 9B Service Board



NOTES
1 "A" WIRING - TERMINAL REPEATER BATTERY NORMAL.
"B" WIRING - TERMINAL REPEATER BATTERY REVERSED.
"C" WIRING - INTERMEDIATE REPEATER WITH LOOP.

Fig. 10 - Loop Arrangements for Half-Duplex Service

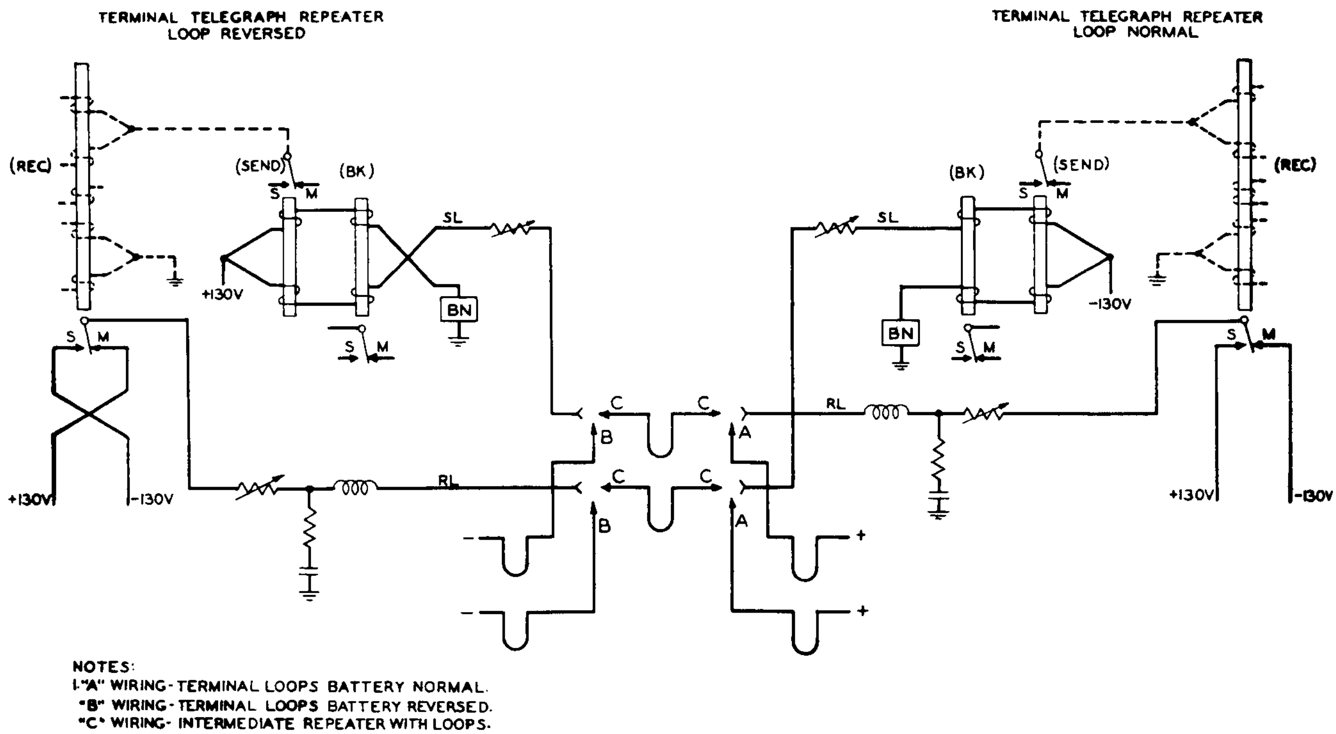


Fig. 11 - Loop Arrangements for Full-Duplex Service

The positions of the various switches are indicated. For instance, "PB, PRA" indicates that the connection shown is made when the OPN 1 switch is in either the PB or PRA positions. The switch connections are indicated by arrows and dots, and are designated by a code indicating the switch, section and contact number.

3.02 A 209FG relay is used for receiving signals from the line. One of the four balanced windings is for use in series with each line conductor and one is for use in each of the two balancing networks. The two auxiliary windings are connected in series and serve as a biasing winding for use at the polar sending end for polarential operation.

3.03 The two apex circuits are arranged so that their impedances will always be the same. This is accomplished by providing duplicate series resistances in each circuit and employing a switch for adjusting the resistances of both circuits simultaneously. The resistance of each branch is adjustable from zero to 2000 ohms in 200-ohm steps. Fig. 15 shows schematically the connection made by the APEX switch. The noise killer consists of two units, one in each apex, and each employs a 149E retard coil and a 160 and a 2990-ohm resistance. For economy the 149E coil used in the noise killer unit of the neutralizing line circuit is also employed in the 60-cycle filter as these circuits are never used simultaneously.

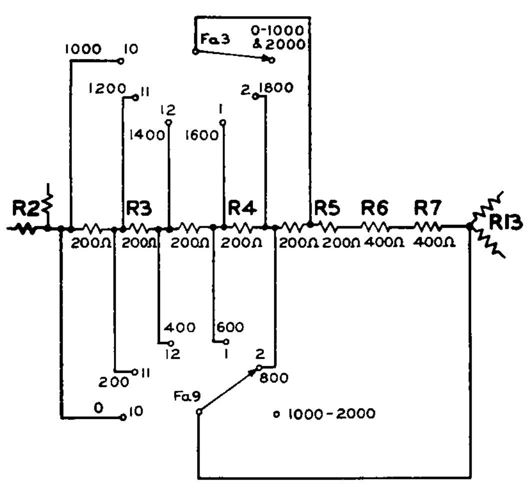


Fig. 15 - Apex Switch

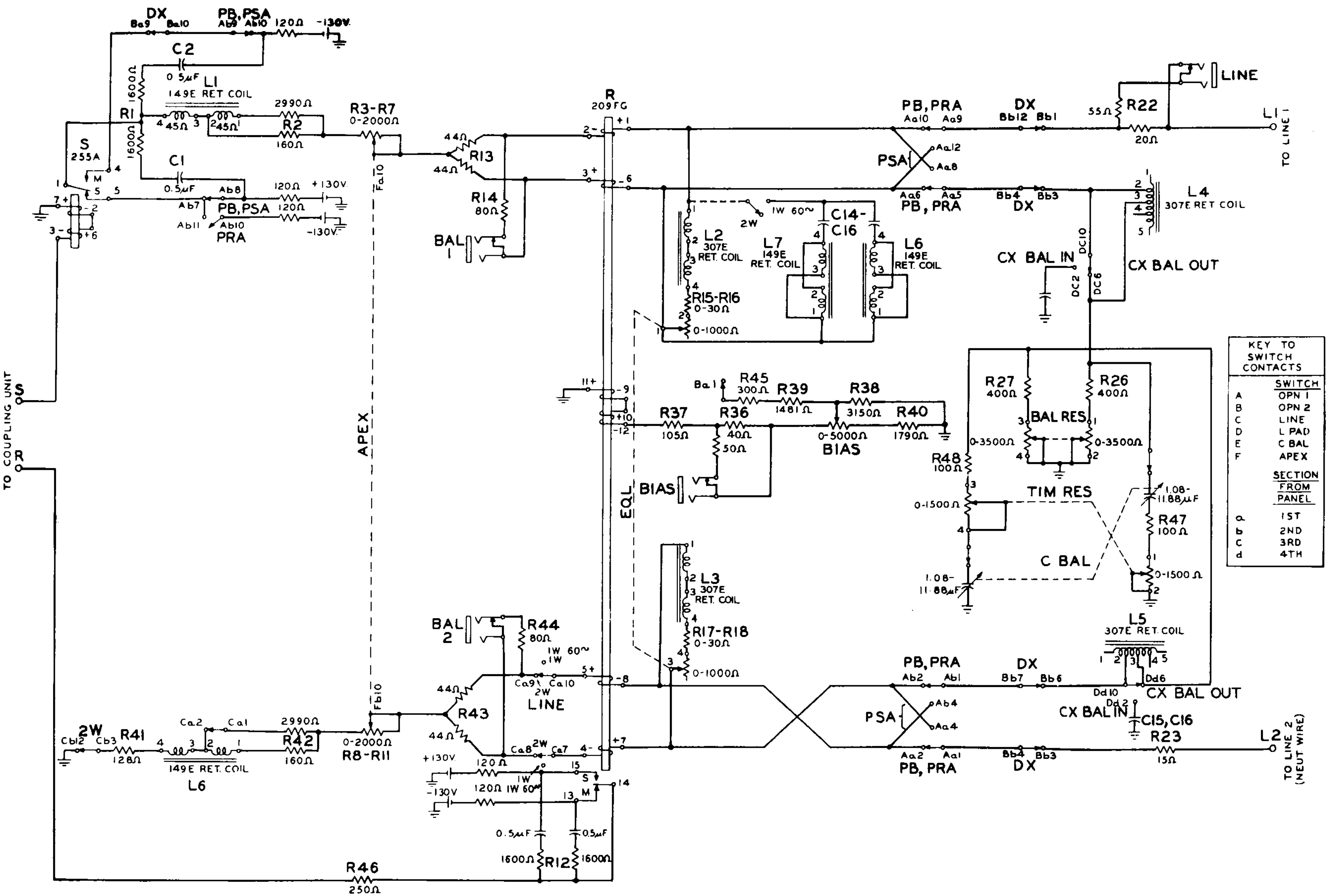


Fig. 12 - Differential Duplex Battery and Line Normal

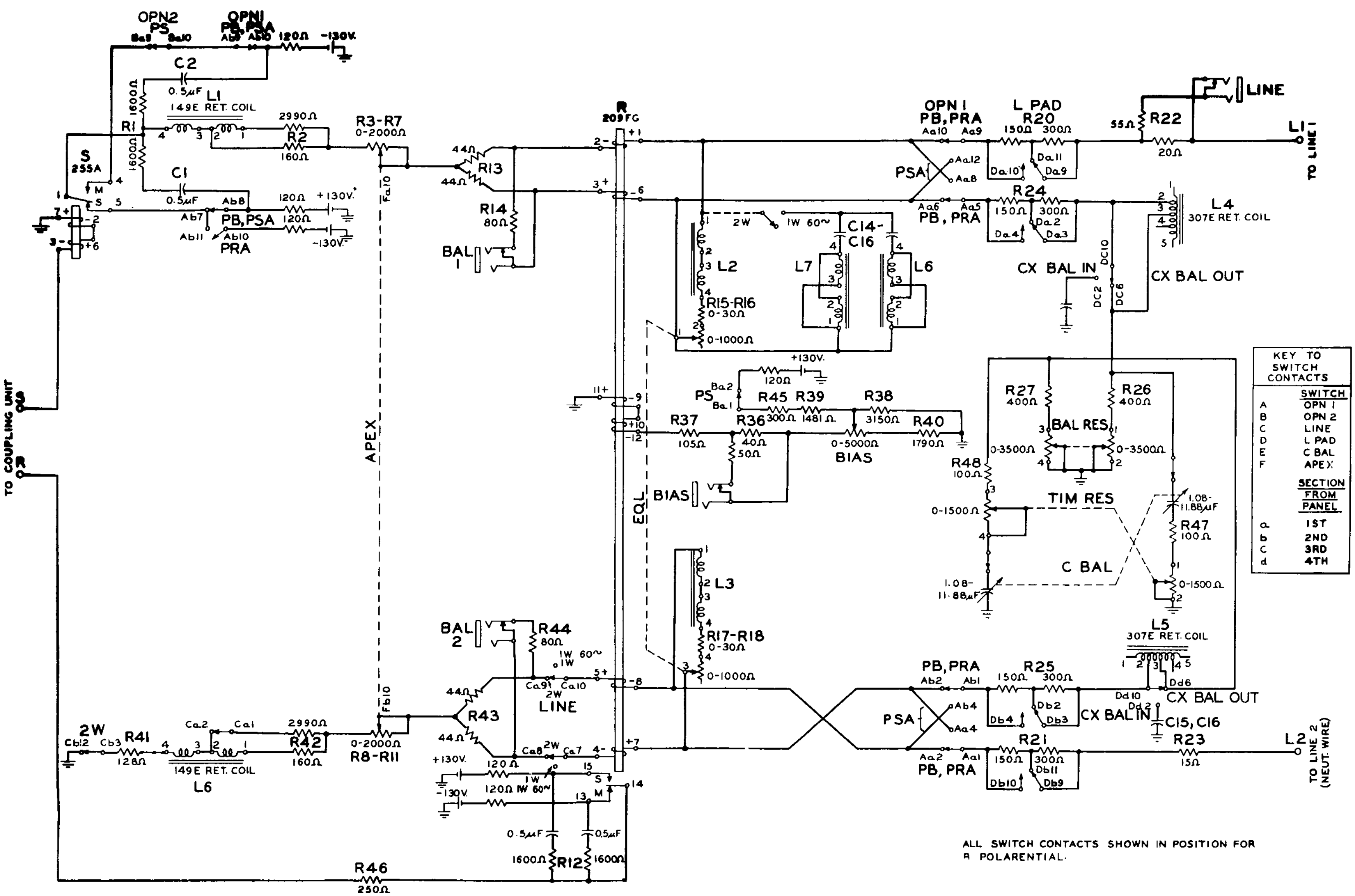


Fig. 13 - Polarential Polar Send

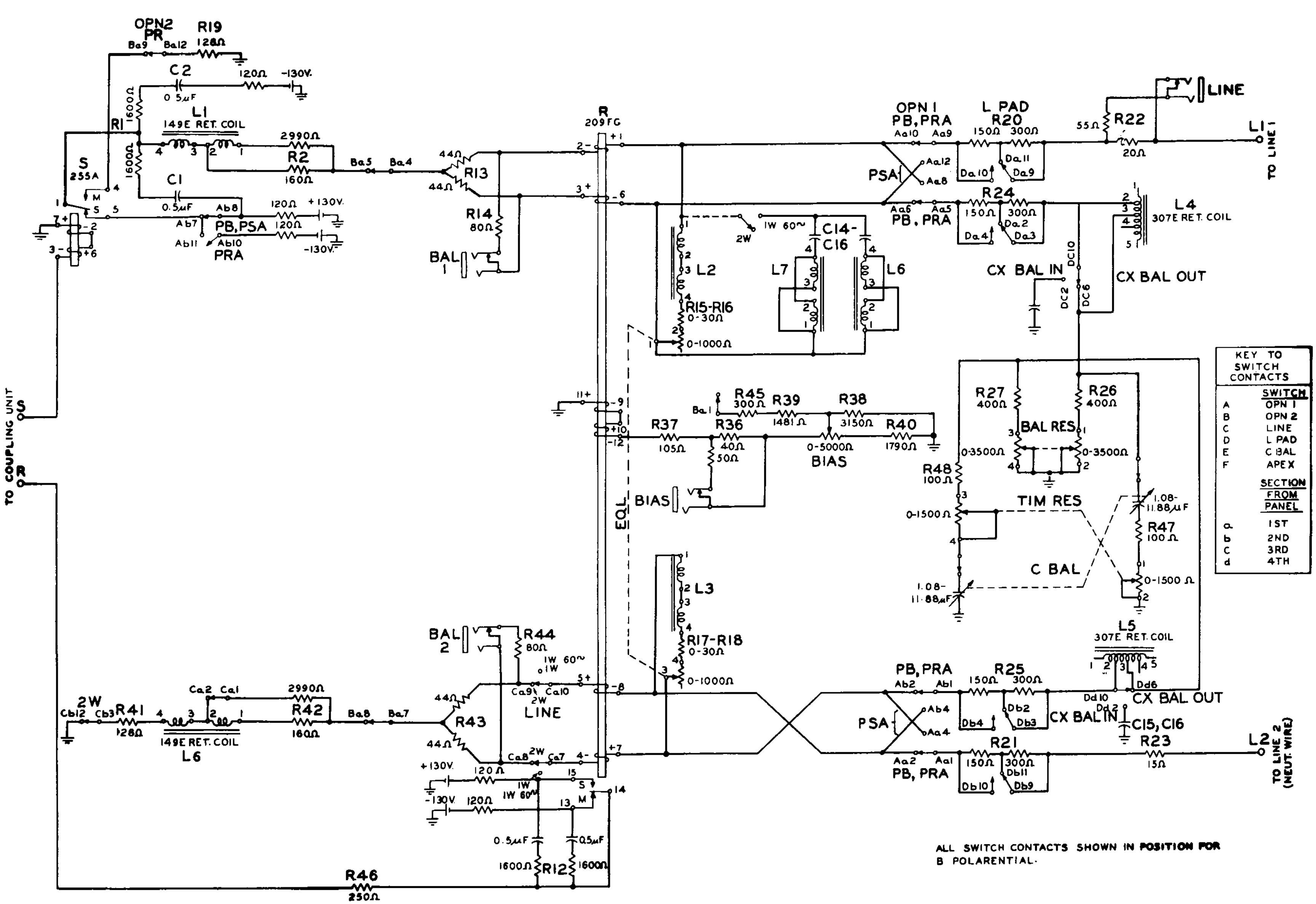
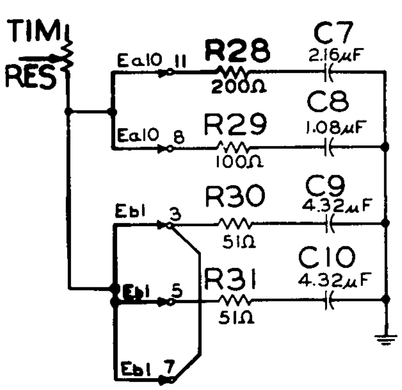


Fig. 14 - Polarential Polar Receiving

Balancing Network

3.04 The capacitance and resistance of the line circuit can not be exactly duplicated in the balancing network without having many adjustable members. In the case of operation with a neutralizing wire, capacitance coupling between the regular and neutralizing line circuits is not duplicated between the two balancing networks, and the use of a single winding meter such as that provided with the 163-type test unit may introduce some error in the a-c balance adjustment. In cases where a more accurate balancing network adjustment is required, telegraph transmission measurements may be made and the capacitance balance adjustment varied until best operation is obtained.

3.05 Duplicate resistance units are furnished in the line and balancing network circuits to facilitate current adjustments. Each of these current limiting resistances has 0-450 ohms in 150-ohm steps, under control of the L PAD switch. The pads are short-circuited by OPN 2 switch for differential duplex operation. Rheostats are provided for the adjustment of bias current (BIAS), condenser timing resistance (TIM RES) and d-c line resistance balance (BAL RES). The capacitance balance for each branch consists of condensers, adjustable in 1.08 mf steps from 0 to 11.88 mf, by operation of the C BAL switch. Fig. 16 shows schematically the switch connections, the numbers in the table indicating the switch positions for which the adjacent contacts are made. Resistances in series with the condensers protect the switch contacts from excessive currents. The TIM RES and BAL RES resistances are provided as duplicate rheostats for the balancing networks of the regular and neutralizing line circuits. These are made to give the same values by mechanical coupling between units.



SWITCH POSITIONS
2 3 6 7 10 11
1 3 5 7 9 11
6 7 8 9 10 11
8 9 10 11
4 5 10 11

Fig. 16 - C BAL Switch

3.06 Duplicate composite balancing units are provided in the balancing networks of both regular and neutralizing line wires. A 60-cycle filter is provided as optional equipment for use in suppressing 60-cycle interference when operating on a one-line basis. This filter is not employed when operating with a neutralizing circuit.

3.07 The repeater is equipped with five jacks which are used for patching the meter of the test unit into the various circuits of the repeater for purposes of adjustment. The 163A1 or A2 test unit is used when the repeater is equipped with an applique and the 163F1 with 144A1 coupling units. The MON jack is used only when the repeater is connected to a coupling unit. The circuits are arranged for use with this particular type of meter and the use of any other meter is likely to result in erroneous readings and adjustments. The meter has a 100-0-100 ma scale and 25 ma through the meter circuit produces full scale deflection.

Meter Indications

3.08 When patched in the BAL 1 jack the meter indicates the differential current in the line and balancing network. The shunt on the BIAS jack is such that the proper bias current is obtained when the bias meter reading is equal and opposite to the BAL 1 jack reading, when the line is balanced and a spacing signal is received. The meter indicates the true loop currents in the S and R loop meter jacks.

Equalizer Networks

3.09 The repeater is provided with equalizer networks, one of which is bridged across the R relay line and net windings of line 1 and the other across the line and net windings of line 2. Each consists of a 307E coil in series with a resistance unit connected as shown in Figs. 12-14.

3.10 The equalizer, including coil L2 and the 0-1000-ohm section A of tandem rheostat EQL, is connected across the receiving relay windings, from terminal 1 to terminal 6. This shunt is closed when the rheostat is moved away from the OFF position. Small resistors 0-30 ohms are for padding out the resistance of the coil, when necessary, to make the resistance equal to that of coil L2. This is done at the factory. If the repeater is otherwise in duplex balance the adjustment of the shunt has no effect on transmitted currents or on the duplex balance of the home repeater. It shunts the receiving relay in a manner which, in ampere turn effect, is the same as though the "apex" point were grounded and connected to the mid-impedance point of the shunt and to the mid-point of the 80-ohm bridge R14.

3.11 Because the shunt has considerably more inductance than the relay windings, it by-passes a relatively larger portion of the low frequency and direct current components of the received signal around the relay, the degree of discrimination increasing as the resistance is decreased by clockwise rotation of the rheostat. The operating wave received by the relay is modified in such a way as to tend to reduce negative characteristic distortion. This form of distortion ordinarily becomes important in 60-speed transmission only when the line conditions are severe.

3.12 At the lowest values of series resistance in the EQL rheostat the steady state signal delivered to the R relay may be so reduced that instability of relay operation will be a source of distortion. When the resistance is a maximum the effect of the shunt is very small. Between these extremes further compromise may be required because the equalizer may tend to worsen some forms of distortion. The optimum adjustment can be found only by transmission tests on the particular system. These tests should be made with predistorted teletypewriter signals when both repeaters on the line section are 16 type. Undistorted signals should be sent from a subscriber station for equalizing.

3.13 The equalizer rheostat is provided with a scale graduated into ten divisions, representing increasing degrees of frequency discrimination or equalization. These divisions have no specific quantitative significance, but are provided as a convenience to facilitate the comparison or reproduction of equalizer settings. The OFF position, in which the shunt is opened, is at the extreme counterclockwise end of the scale.

Balanced Loop Applique

3.14 For balanced loop applications an applique is associated with the repeater. Fig. 17 shows a schematic circuit of the applique and the connections to the repeater It provides 60 milliampere send and receiv loop terminations, a break relay, and jack for connecting the meter and key and sounde of the 163A2 (or 163A1) test unit in serie with the send or receive loop. A switch con ditions the circuit for half or full duplex normal or reversed batteries. The switch po sitions are designated on Fig. 17 adjacent t the switch contacts. The contacts are ope except for the switch position designated Some items are shown twice on the figure, t simplify the drawing. Bias battery for the l relay of the repeater, in polarential operation is supplied through the J lead (not shown in Fig. 17).

3.15 No loop noise killer is provided in the repeater or applique.

Break Relay

3.16 To facilitate interruption of the sending operator in half-duplex circuits a break relay is provided in the applique, operating simultaneously with the send relay. To understand its function, assume the loop to be open in order to "break" the distant operator; as soon as a marking signal is received from the line, the send relay armature will be moved to spacing due to current in the biasing winding and the absence of current in the loop. The break relay at the same time connects marking battery to the spacing contact of the receiving relay so that no matter what signal is subsequently received from the line the send relay will continue to send a steady space. If the break relay were not used, incoming signals would operate the sending relay and be repeated back to the line reversed. This would result in a slow and uncertain break.

3.17 On some long half-duplex circuits difficulty has been experienced due to two stations sending simultaneously so that a short message is sometimes lost. This may be minimized by connecting repeaters at intermediate points having no loop on a full-duplex basis so that the break relay is inoperative and the break is not held up to await an incoming mark. In considering any specific case the latest information on recommended practices should be obtained.

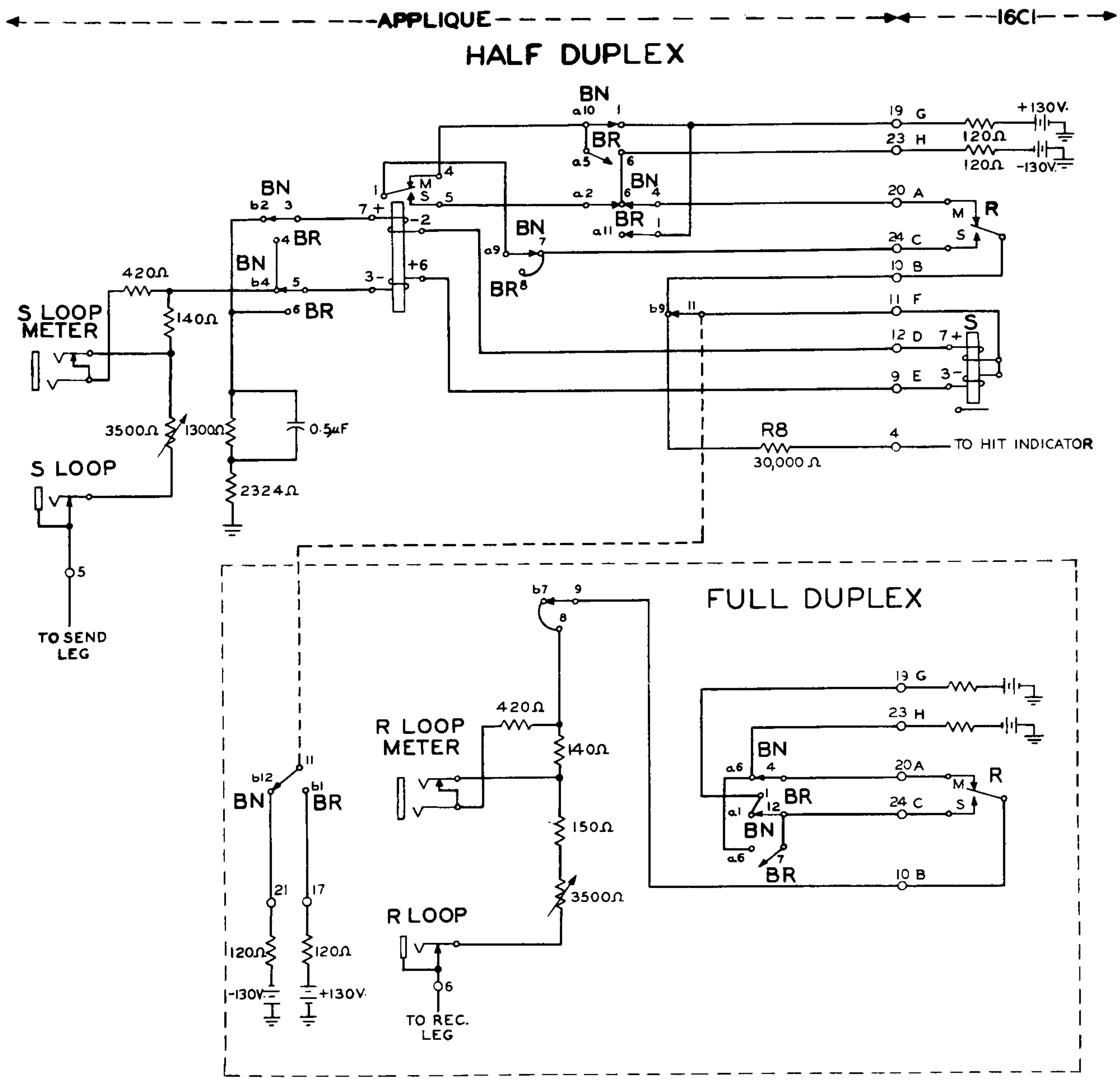


Fig. 17 - Applique Circuit

60-Cycle Filter

3.18 Figs. 18 and 19 show schematically how the LINE switch connects coil L6 in the 60∿filter when in the 1W 60∿position and in the noise killer circuit of LINE 2 in the 2W position.

4. DESCRIPTION OF EQUIPMENT

16C1 Repeater

4.01 A front view of the repeater is shown in Fig. 1. The 16C1 repeater is a self-contained shop-wired unit having a unit terminal strip for making external connections. The unit occupies the space of six 1-3/4" by 19" mounting plates and is arranged for mounting on channel or I-beam relay rack or cable duct-type bays. Eleven repeater units can be mounted on an 11'-6" bay. The unit consists of a main panel of the raised dishpan type containing the operating components with operating knobs, dials and jacks appearing on the front, and a supplementary panel containing the remaining apparatus components hinged to the rear of the main panel. All of the line and transmission options and operational adjustments are effected by means of the controls appearing on the front panel.

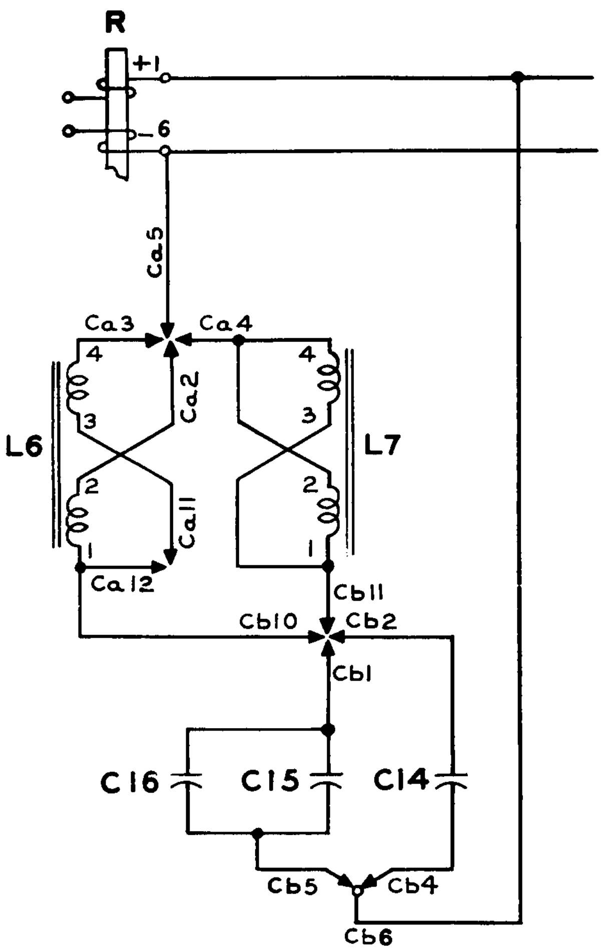


Fig. 18 - 1 Wl 60 Cycle

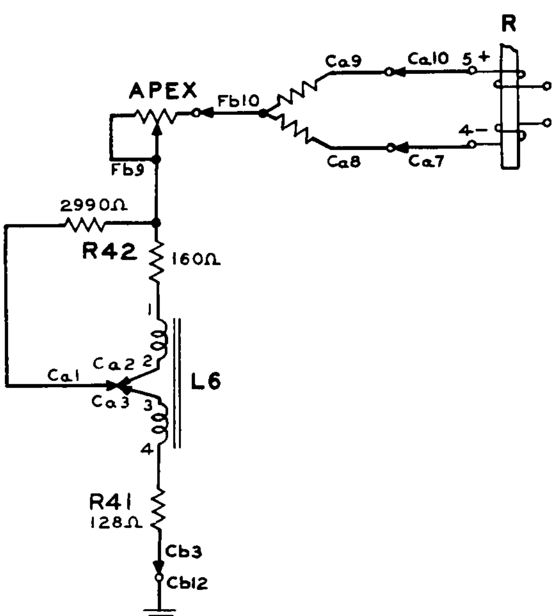


Fig. 19 - 2 Wl

Balanced Loop Applique

4.02 The applique is shown in Fig. 2. **It is** a self-contained shop-wired unit mounted on a flat panel. It occupies the space of two 1-3/4" x 19" mounting plates. The equipment is so mounted that when two applique units are vertically adjacent, mounting space is provided for the associated 163A2 test unit.

163A2 Test Unit

4.03 The monitoring equipment used with the applique is a 163A2 test unit, which is a portable unit consisting of a meter mounted on a bracket slotted to slip over the heads of two extended mounting plate screws. The test unit is designed to mount on the left side of two vertically adjacent applique units without interference in any way with the adjustment of the repeater. The bracket is also designed to accommodate a Morse key and sounder which are provided on an optional basis. The repeater is provided with jacks in the various circuits for connection to the test unit.

4.04 Means are provided for preventing injury to the meter in case it is accidentally connected to the jacks intended for the key and sounder circuit. This is accomplished by employing two-conductor jacks for the key and sounder circuit and three-conductor jacks for the meter. The meter is wired to the tip and ring conductors of its plug and as the ring of this plug does not make contact with the sleeve of the key and sounder jack, the meter cannot be connected in series with the loop circuit. The tip and sleeve conductors of the meter plug are strapped together so that the loop circuit would not be opened if the meter circuit were accidentally plugged into the key and sounder jack.

4.05 The meter cord is a three-conductor red colored cord, three feet in length, equipped with a three-conductor plug having a red shell. The key and sounder cord is a two-conductor green cord, three feet in length, equipped with a two-conductor plug having a black shell. The cords are of sufficient length to permit the test unit to be mounted in a bay adjacent to that on which the 16B1 repeater under test is mounted.

The 163A1 test unit does not differ materially from the 163A2 and may also be used.

163F1 Test Unit

4.06 Fig. 20 shows schematically how the 163F1 test set is used with the repeater when it is connected to a 144-type coupling unit. The meter circuit is the same as that of the 163A2. When it is required to send signals from the repeater, as for instance in adjusting the balancing networks, the 109-type plug is plugged into the monitoring jack of the repeater. (A 109-type plug is used so that the meter plug cannot be inserted in the MON jack.) With the telegraph key open, -130 volts is connected through 13,620 ohms to two windings of the send relay connected in series aiding; the resulting 9 ma current operates the relay to spacing. When the key is closed, a connection is added to +130 volts through 6800 ohms, causing 9 ma to flow in the opposite direction and operating the relay to marking. Space should be provided for mounting this test unit; it cannot be mounted on repeaters which are installed immediately adjacent, vertically, to each other.

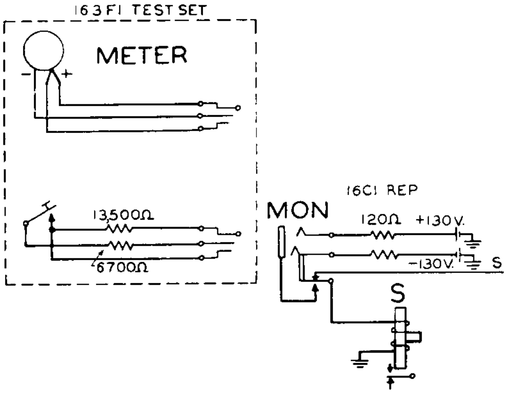


Fig. 20 - 163F1 Test Set