# TYPE N AND ON CARRIER REPEATERS — REPEATERED HIGH-FREQUENCY LINE DESCRIPTION — TYPE N1 LOW-HIGH TRANSISTORIZED REPEATER

## 1. GENERAL

**1.01** This circuit is used as a repeater in the high frequency line of a Type N1 Carrier System. It is one of two similar repeater circuits and is designated a Low-High (L-H) Transistorized Repeater.

**1.02** The signals are handled on a 4-wire basis throughout and the amplifier circuits for the two directions of transmission are identical. The input signals from the line pass through an input filter to remove unwanted frequencies. They are then modulated by a 304-kc carrier to change bands from the low group to the high group. The same oscillator is used to supply the 304-kc carrier in the H-L Repeater. The action whereby the repeater transmits a different frequency band than it receives is termed frequency frogging. It is also the basis for the repeater nomenclature Low-High (L-H). The modulator output is passed through the second filter to suppress carrier leak and the unwanted sideband. The output of this filter is applied to the input of the regulating feedback amplifier. This amplifier automatically adjusts the gain by a thermistor regulator to maintain an output power which is almost constant over the operating range of the input power.

**1.03** Only a small amount of equalization is accomplished by the repeater. Most of the equalization depends upon having approximately equal cable lengths between repeaters and the use of frequency frogging at each repeater. The residual slope equalization is adjusted by the (SLOPE ADJ) control in the amplifier.

## 2. DETAILED DESCRIPTION

**2.01** This part of the section gives the overall detailed description of the L-H repeater.

**2.02** ***Over-All Repeater.*** The N1 Transistorized Low-High Repeater Circuit consists of three major parts, the E-W (east-west) subassembly, the W-E (west-east) subassembly, and the oscillator subassembly.

**2.03** ***E-W and W-E Subassemblies.*** The E-W and W-E subassemblies are identical. They consist of:

(1) A modulator with input and output filters plus associated transformers.

(2) A 3-stage transistor amplifier with regulating thermistor, slope adjustment, and flat gain adjustment.

(3) A voltage regulating diode power supply.

**2.04** ***Oscillator Subassembly.*** The oscillator subassembly consists of:

(1) A 1-transistor crystal-controlled oscillator with an output level adjustment, plus a 1-transistor buffer amplifier and second harmonic rejection filter.

(2) A bias adjustment for the E-W and W-E ampliers.

(3) A current adjustment for the heaters of the two thermistors.

**2.05** ***Repeater Input Coil.*** The repeater input coil (T1) serves to match the impedance of the incoming 135-ohm line to that of the 3000-ohm filters. Capacitors (C1) and (C2) are shunted across the coil to improve the transmission characteristic. This input coil provides the simplex connection to the line for the purpose of obtaining or supplying power over the line. It also aids in maintaining an adequate longitudinal balance to the line to suppress longitudinal noise.

**2.06** ***Modulator Filters.*** The modulator filters used at the input and output of the modulator select the desired frequency groups. These filters are designated (FL1), (FL2), (FL3), and (FL4).

**2.07** The modulator input filter (FL1) passes signals of the incoming low group frequencies onto the modulator and rejects the unwanted high group signals that are present at the repeater input due to crosstalk between the cable pairs. This filter is a low pass filter with a configuration and characteristic (measured between 3000-ohm resistance), as shown in Fig. 1.

**2.08** The modulator output filters (FL2), (FL3), and (FL4), Fig. 2, select for transmission to the amplifier the lower sideband created by the modulator and reject the upper sideband, all other modulation products, and the signals of the frequency group applied at the input of the modulator. This output filter also includes a peak section to reject the 304-kc carrier that is present due to imperfect modulator balance.

**2.09** ***Modulator Pad.*** A 4-db pad, (R1), (R2), and (R3), is used between the modulator output coil and the modulator output filter. This pad improves the impedance match between the filter and modulator, materially improves the transmission characteristic, and stabilizes the changes with temperature.

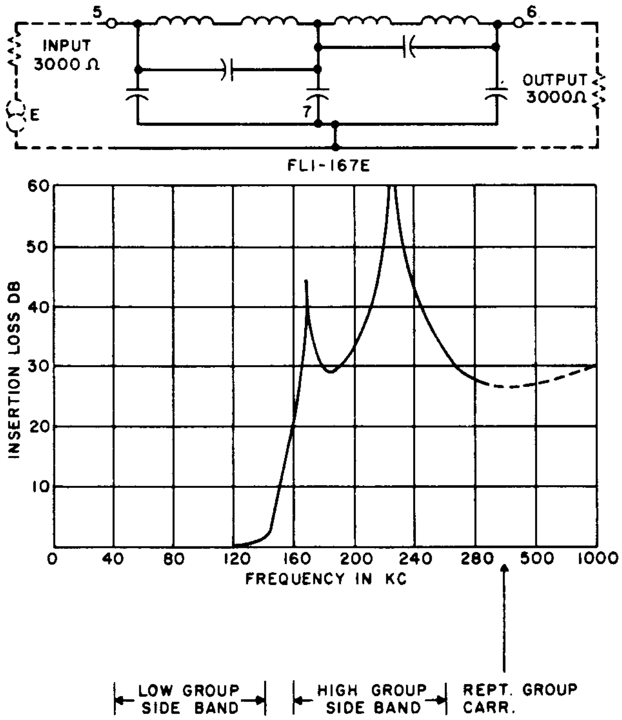


**Fig. 1 – Schematic and Insertion Loss Characteristic of (FL1) Filter**

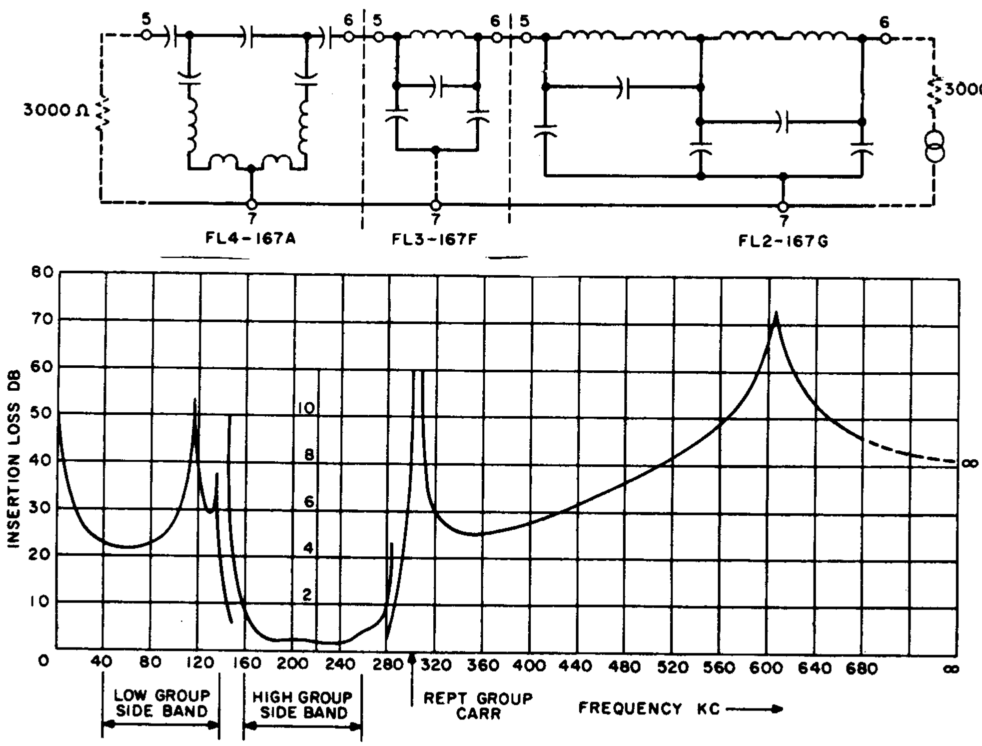


**Fig. 2 – Schematic and Insertion Loss Characteristic of (FL2), (FL3), and (FL4) Filters**

**2.10** ***Modulator.*** The modulator receives the low frequency group and modulates it with the group carrier (304 kc) to produce the high frequency group. Of the modulation products produced by the modulator, only the lower sideband is desired. The modulator is of the double-balanced type (input signal and carrier both balanced from the output). It consists of a copper-oxide varistor (CR1) connected between two repeating coils (T2) and (T3).

**2.11** The modulator action may be considered as a double-pole, double-throw switch inserted in the signal path between the input and output coils. This switch action is activated by the plus and minus voltages of the carrier applied longitudinally through the transformers (T2) and (T3). When the carrier voltage is positive at (JE9) and negative at (JE10), the carrier current flows through the two outer rectifying elements. Their impedance is then made low. A signal present in the input will then flow directly through the modulator to the output transformer. During the next half cycle of carrier, the carrier potential is reversed and the current flows through the inner rectifying units, making their impedance low. This is equivalent to reversing the path for signal voltages from the input to the output transformer.

**2.12** This double-pole, double-throw switch action of the balanced modulator has the inherent function that many of the modulation products formed do not appear at the output terminals of the circuit. If the symbol $v$ represents the incoming group of signals and $c$ represents the 304-kc carrier, the modulation products formed within the modulator may be considered in four sets. These sets are:

$$n_o c \pm n_o v$$
$$n_o c \pm n_e v$$
$$n_e c \pm n_o v$$
$$n_e c \pm n_e v,$$

where $n_e$ represents even integers and $n_o$ represents odd integers. Of these modulation products only the odd order set, $n_o c \pm n_o v$, appears at the output terminals of the modulator; all the other sets of modulation products are theoretically balanced out. Of the odd order set the simple difference (c-v) is the modulation product desired,

$$304 - (36 \longleftrightarrow 140) = (164 \longleftrightarrow 268).$$

The other components of this order are rejected by the filters following the modulator. As perfect modulator balance is not achieved, some energy from the other sets of modulation products does appear at the output terminals. This is composed principally of the input signals $v$, which are suppressed about 20 db, and the 304-kc carrier $c$, which is suppressed about 40 db.

**2.13** ***Modulator Repeating Coils.*** A low group sideband coil (T2) is used at the input to the modulator and a high group sideband coil (T3) at the output of the modulator. These coils have an impedance ratio of 3000:130 ohms and serve to match the impedance of the filters to that of the modulator and to change from an unbalanced filter circuit to a balanced modulator circuit. A capacitor (C3) is shunted across the low impedance side of the (T2) coil to improve the transmission characteristic. To maintain the proper balance in this circuit, it is important that the only ac ground connection to this modulator circuit be at (T3) as indicated. These same two coils are used for the H-L repeater but in reverse circuit positions.

**2.14** ***304-KC Carrier Oscillator.*** The carrier frequency used at each repeater is supplied by the 304-kc crystal oscillator. This oscillator employs a 16A transistor (Q40) and a 33DA quartz crystal (Y40) to form the oscillating circuit. A buffer amplifier consisting of one 20A transistor (Q41) drives the two modulator circuits in parallel through a step-down transformer (T40). This amplifier is necessary in order to obtain sufficient carrier power; it also serves to isolate the oscillator from the nonlinear modulator load. The transformer is followed by a rejection filter composed of components (L41), (C47), (C49), and (C50) in order to suppress the second harmonic of 304 kc.

**2.15** The frequency of oscillation is stabilized by the crystal (Y40) to 304 kc with a maximum deviation of approximately ±20 cps over a temperature range of −40 C to +60 C. The output voltage is 0.55 volts ±0.2 volts and the second harmonic level is at least 55 db below the fundamental.

**2.16** The frequency of oscillation is set by crystal (Y40) and is trimmed slightly by capacitor (C41). The low pass filter (C43), (C44), and (L40) matches the output of the oscillator to the input of the buffer amplifier and also provides the proper phase shift for the feedback loop. The variable inductor (L40) provides fine tuning to compensate for the initial output capacitance tolerance of transistor (Q40). It is factory adjusted to yield the proper output voltage. Resistors (R40), (R41), (R42), and (R43) are biasing resistors for transistor (Q40); capacitor (C42) is the emitter bypass.

**2.17** The oscillator is coupled to the buffer amplifier through capacitor (C45). Resistors (R45), (R46), (R47), and (R49) are biasing resistors for transistor (Q41); capacitor (C46) is the emitter bypass. The degeneration introduced by resistor (R47) compensates for the initial gain tolerance of transistor (Q41). This stage is biased to produce symmetrical clipping at maximum oscillator output. The dc voltage for both stages is obtained from a 22-volt regulating diode (CR2, W-E) and they are decoupled from the power supply by resistor (R50) and capacitor (C48).

**2.18** ***Amplifier.*** A high group amplifier is used in the L-H repeater. The amplifier uses three transistor stages with hybrid feedback connections at both the input and the output. The first two stages are 16A transistors; the last stage is two 20A transistors in parallel. The amplifier contains a thermistor-regulated output, a flat gain adjustment and a slope control adjustment.

**2.19** The input to the amplifier is coupled to the modulator output filter by a hybrid transformer (T4). The input impedance of the first transistor (Q1) does not balance the transformer; however, feedback ensures that the input impedace of the transformer is 3000 ohms, matching the modulator output filter. The impedance seen by the first stage looking back into the transformer is 500 ohms. This value is the optimum generator impedance for a 16A transistor to minimize the noise figure. The hybrid tap is placed so that the ratio between turns on the secondary is 9:1. This turns ratio ensures that the noise figure of the amplifier will be degraded by less than 0.5 db due to the hybrid connection. It also ensures that variations in impedance seen looking into the feedback network will have little effect on the transmission through the hybrid. Resistor (R4) is the hybrid termination and sets the impedance level seen at the other hybrid terminals. Resistor (R25) ensures that the feedback network is fairly well matched to the hybrid for all conditions of the feedback network.

**2.20** The amplifier output is coupled to the line by a hybrid transformer (T5). The output impedance of the last stage does not balance the transformer; however, feedback ensures that the output impedance of the transformer is 125 ohms, matching the line impedance. The impedance seen by the last stage is 400 to 500 ohms and depends on the state of the thermistor. The hybrid tap ratio is 9:1, which is chosen to supply the correct amount of power to the thermistor. The autotransformer (T6) transforms the high impedance of the thermistor to the relatively low impedance level of the output hybrid. Resistor (R18) is the hybrid termination and sets the impedance level seen at the other hybrid terminals.

**2.21** The three transistor stages are direct coupled to conserve bias current. Temperature stability and stability with respect to component variations are achieved by minimizing the dc gain per stage and judiciously placing diodes so that the temperature effects of diodes and transistors tend to cancel. The emitter voltages of the two transistors in the last stage (Q3) and (Q4) are the most critical points in the circuit because they set the current in these transistors and therefore set the clipping level. The emitter voltage of transistor (Q3) is factory set to 3.0 volts by adjusting the potentiometer in the collector of the second stage, (R53) for the W-E amplifier and (R57) for the E-W amplifier. After these voltages are factory set, they become a good indication of the condition of all transistors and diodes.

**2.22** The voltage at the base of the first stage (Q1) is regulated to about 3.0 volts, see 2.36 of this section. The emitter current is set by the emitter resistor (R5) to about 2 ma to obtain a good noise figure. Resistor (R7) and diode (CR3) set the collector voltage of the first stage and the base voltage of the second stage (Q2). Diode (CR3) is used to reduce the resistance value of resistor (R7) and therefore reduce the dc gain. The emitter current in the second stage is set by resistor (R9), while resistors (R12), and (R53) or (R57) set the collector voltage. Diode (CR4) sets the base voltage of the last stage (Q3) and (Q4). The biasing current for diode (CR4) is provided through resistor (R10) which also lowers the dc gain. Resistors (R14) and (R15) set the emitter current in transistor (Q3) and resistors (R16) and (R17) set the emitter current in transistor (Q4). Resistors (R14) and (R16) ensure that the two transistors in the output stage share the ac signal equally.

**2.23** Low frequency stabilization of the feedback loop involves the four emitter bypass capacitors (C5), (C9), (C15), and (C17), and the dc blocking capacitors (C18), (C19), and (C25). High frequency stabilization is accomplished by the interstage network components (C6), (R6), and (L2), plus capacitor (C22) which bypasses the output hybrid, the autotransformer, and the thermistor at high frequencies, and capacitor (C23) which bypasses the remainder of the feedback network at high frequencies.

**2.24** To prevent crosstalk and 304-kc carrier leak through devious ground paths, capacitor (C4) ties the amplifier circuit ground to true ground.

**2.25** ***Flat Gain Adjustments.*** The gain of the amplifier is determined by the loss in the feedback network between the input and output hybrid taps. The feedback network consists of the autotransformer (T6), the thermistor (RT1), and a pi network. The slope-adjust network constitutes one shunt leg of the pi; resistor (R25) is the other shunt leg; and resistors (R21), (R22), and (R23) make up the series leg. Resistors (R21), (R22), and (R23) provide 1-db gain adjustment steps for use in manufacture to compensate for the accumulated variations due to all the circuit components.

**2.26** When the repeater is used as an alternate repeater in the transistorized repeater switching set or during maintenance tests, a fixed gain without regulation is desired. This condition is obtained by using the 20,000-ohm resistor (R19) in place of the thermistor regulator. This resistor provides 6 db more repeater gain than that provided by the thermistor at its mean operating value. The resistor is also used for manufacturing and repair testing. It is normally replaced by the thermistor for field installation.

**2.27** ***Repeater Gain and Regulation.*** The repeater gain is controlled by the loss of the feedback circuit. The fixed gain condition is provided by use of the fixed resistor (R19). The regulated gain condition is provided by use of the thermistor regulator (RT1) which functions to hold the repeater output nearly constant for a considerable range of inputs. This regulated gain is essentially flat with frequency. The thermistor is activated in proportion to the total power at the output of the repeater. This power is nominally +12 dbm and the thermistor holds this output power to within ±1 db for a change in input level of ±8 db. This regulation performance in terms of change of output from a mean condition versus change in input is shown in Fig. 3.

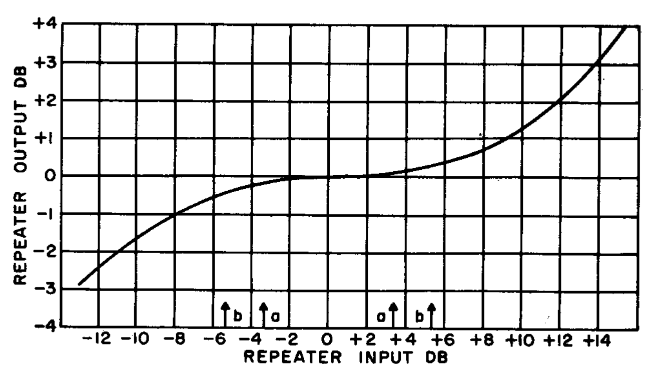


**Fig. 3 — Regulation Characteristic of Low-High Transistorized Repeater**

**2.28** The thermistor regulator reaction time is plotted in Fig. 4 in terms of the time required for the regulator to attain a given percentage of its ultimate change after a transmission alteration. This reaction time is different in the two directions of regulator change. The regulator decreases output three to five times as fast as it increases it. This reaction time materially influences field use in that, after any transmission change, a waiting period is required before the circuit will stabilize within any desired measuring accuracy. This waiting period is plotted in Fig. 5 in terms of stabilization within 1/4 db and also 1/10 db. The OUTPUT INCREASED curves apply for changes which have increased the output above normal and which the regulator restores to normal by decreasing the repeater gain; the OUTPUT DECREASED curves apply for decreased changes in output which the regulator restores to normal by increasing the repeater gain. Thus an increase in input of 2 db would require a wait of about 4 minutes for 1/10-db measuring accuracy, whereas a decrease in input of 2 db would require a wait of about 14 minutes. A cold repeater when inserted is at high gain and for a normal input will have a high output, so to obtain 1/4-db accuracy of stabilization output requires about 6 minutes wait. Accuracy within 1/10 db requires a wait of 15 to 20 minutes.

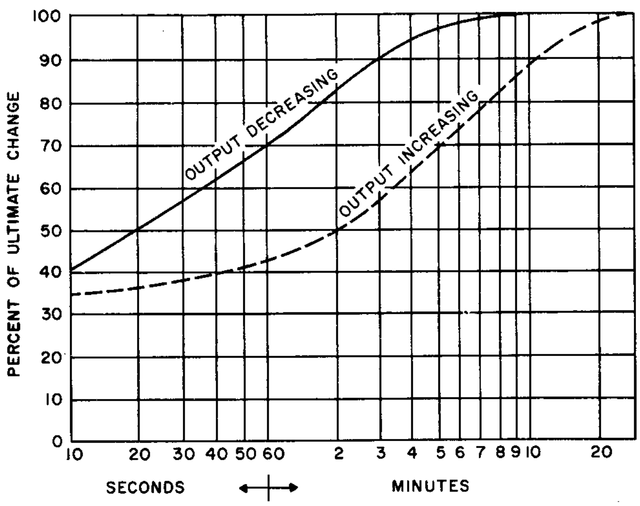


**Fig. 4 — Thermistor Regulating Time**

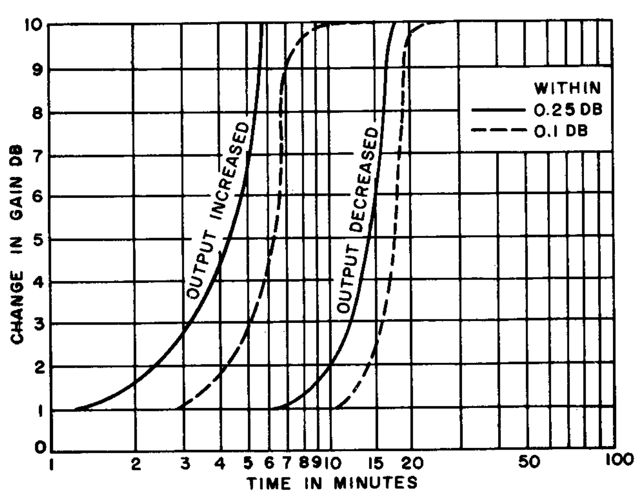


**Fig. 5 — Stabilization Time (Within 0.25 DB and 0.1 DB of Final Value**

**2.29** The thermistor unit (RT1) consists of a thermistor pellet and the associated ambient temperature control for this pellet. The thermistor pellet is a negative temperature coefficient resistance unit that normally varies from about 1,000 ohms to about 20,000 ohms. Under abnormal transmission conditions, it may vary from a few hundred ohms to upwards of 40,000 ohms. For a repeater having the nominal gain the thermistor resistance will be about 9,000 ohms. This value is referred to as the design value.

**2.30** Because the thermistor changes its resistance with temperature, changes in the ambient temperature would affect the resistance values. Hence a heater is built around the pellet and the pellet is maintained at a temperature above normal ambients. The temperature at which it is held by the heat from this ambient compensation heater is adjusted in manufacture so that with +12 dbm output from the repeater, the pellet resistance is 9,000 ohms. This thermostated temperature in general is between 135 F and 185 F. This temperature compensation is obtained by a disc thermistor in the heater network which varies the power dissipated in the pellet heater with the ambient temperature. This ambient temperature control permits the regulating thermistor to be used at operating temperatures between —20 F and +130 F without appreciable change in its operating performance. Beyond these temperature extremes the regulating level will vary with increasing temperature, producing decreasing repeater output level. However, this change is not cumulative from one repeater to the next and so in general is not vital to operating performance.

**2.31** *Slope Adjustment.* The amplifier slope adjustment provides the manual control of the amplifier frequency characteristic to obtain the desired slope across the band. The slope changes are produced by varying the amplifier feedback as shown in Fig. 6. The adjustment is in three steps designated A, B, and C, providing slopes of about +2 db, 0 db, and −2 db of gain, respectively, for channel 12 with respect to channel 1. These adjustments are so arranged that for each setting the repeater has the same power output. Thus a change in slope setting may be made on an operating system without affecting the thermistor regulating action. The slope adjustment network is a shunt across the feedback circuit. In position A the shunt consists of a series resonant circuit (C20), (L3), and (R26) in parallel with the series combination of resistors (R27) and (R29). In position B the shunt consists of resistors (R27) and (R28) and does not provide shaping. In position C the network consists of a parallel resonant circuit (C20), (L3), and (R28) in series with resistor (R27). The networks associated with positions A and C are designed to give the proper in-band slope while having a negligible effect on the out-of-band feedback. The latter ensures amplifier stability for all slope position.

**2.32** *Power Arrangement.* The power connections to the cable pairs are made at the center tap of the appropriate repeater input and output transformers through the choke coils (L1) and (L4). Capacitors (C40) and (C53) with choke coils (L1) and (L4) provide power supply filtering.

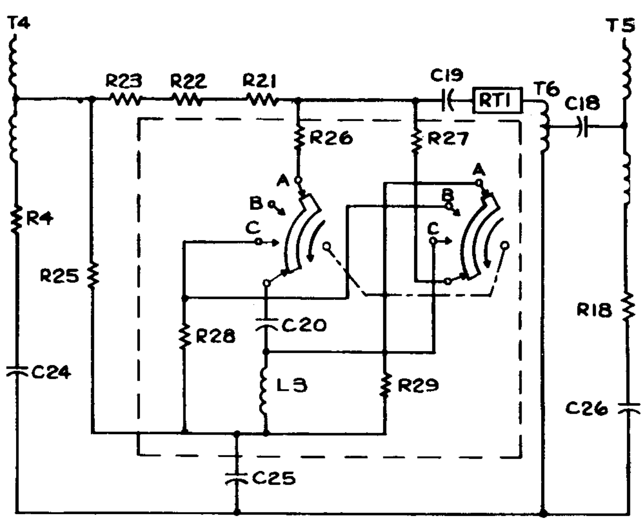


**Fig. 6 — Low-High Transistorized Repeater Slope Circuit**

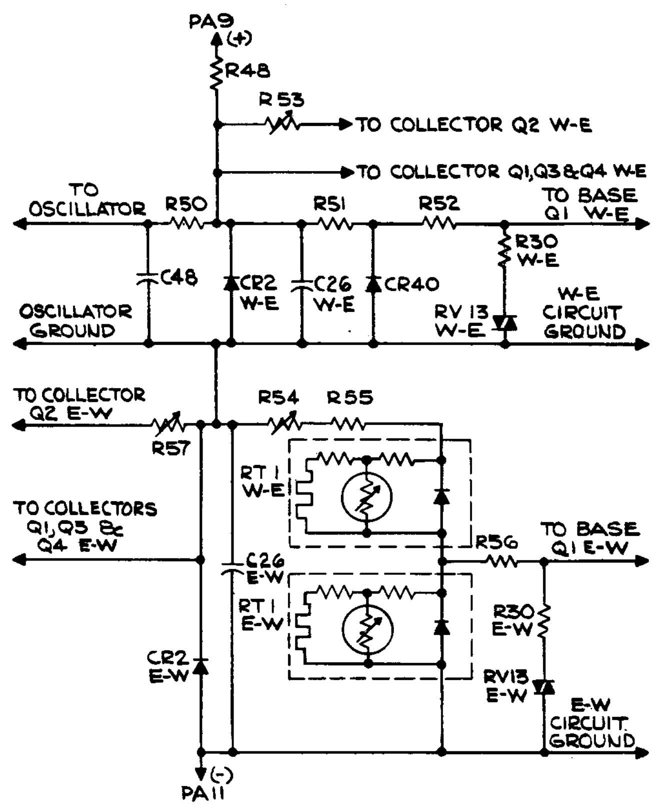


**Fig. 7 — Power Distribution Low-High Transistorized Repeater**

**2.33** The power used by a repeater is applied at jacks (PA9) and (PA11), and is distributed to the several components as shown in Fig. 7. The voltage applied to the amplifiers, oscillator, and thermistor heater circuit is regulated by two 22-volt regulation diodes (CR2, W-E) and (CR2, E-W). The W-E diode controls the oscillator and W-E amplifier, while the E-W diode controls the thermistor heater circuit and the E-W amplifier. Capacitor (C26) is a power supply filter which prevents crosstalk and 304-kc carrier leak.

**2.34** The two thermistor heaters are powered in series through potentiometer (R54) and resistor (R55). The current through the thermistor heaters is factory set to 18 ma by adjusting potentiometer (R54) and setting the voltage across resistor (R55) to 3 volts. The voltage across each thermistor heater is controlled by an internal 8.2-volt diode.

**2.35** The oscillator circuit is supplied through a decoupling network consisting of resistor (R50) and capacitor (C48). This network is necessary to reduce the 304-kc carrier leak.

**2.36** The voltage at the base of the first stage (Q1) of each amplifier is regulated to about 3.0 volts. The voltage regulating network for the W-E amplifier consists of components (CR40), (R51), (R52), (R30, W-E), and (RV13, W-E). This network together with capacitor (C24) provides decoupling from the power supply to prevent crosstalk and 304-kc carrier leak. The diodes (CR40) and (RV13) are also used to enhance the temperature stability. The voltage regulating network for the E-W amplifier consists of components (RT1, E-W), (R56), (R30, E-W), and (RV13, E-W). The internal diode in (RT1, E-W) performs the same function as (CR40). The collector supplies of all three stages are taken directly from the 22-volt diode without additional decoupling. The collector of the second stage is supplied through potentiometer (R53) for the W-E amplifier and (R57) for the E-W amplifier. These potentiometers are used to factory adjust the emitter of transistor (Q3) to 3.0 volts in each amplifier.

**2.37** ***Lightning Protection.*** The repeater is partially protected from lightning surges induced in the transmission lines by carbon lightning protection blocks exterior to the repeater. These blocks are placed from each conductor to ground at both the input and output of the repeater, and limit surge voltages to approximately 500 volts. If the blocks break down at the far side of the repeater from a lightning surge, large longitudinal currents may flow through the power supply diodes (CR2, W-E) and (CR2, E-W). Resistor (R48) limits the current to a safe value. If the blocks at the near side of the repeater break down, transverse currents may flow through the input transformers. The input of the repeater is protected from transverse surges by the band limiting filters and the modulator. The output of the repeater is protected from transverse surges by diodes (RV1) to (RV12) which shunt the output transformer (T5). Twelve diodes are necessary to prevent modulation of the output signal. Resistors (R31) and (R32) limit the current through these diodes to a safe value.

**2.38** ***Testing Facilities.*** In order to facilitate the in-service detection of component variations, test points are provided on each subassembly. In the E-W and W-E subassemblies, the test points are located at the emitters of (Q1), (Q3), and (Q4) and at circuit ground. The test points in the oscillator subassembly are located at the emitter of (Q40), in the emitter circuit of (Q41), at both terminals of each 22-volt diode (one of which is the oscillator circuit ground), at true ground, and on both sides of resistor (R55) in the thermistor heater circuit. The voltage measured from an emitter test point to the appropriate circuit ground effectively measures the emitter current of that transistor. Any change in an emitter current indicates a change in current gain of that transistor or a change in other biasing component values due to aging or temperature change. The voltage from the emitter of (Q3) to amplifier circuit ground is especially sensitive to component degradation in the amplifier circuit. It is factory set to exactly 3 volts at room temperature and therefore is not affected by initial component tolerances. Its value will be affected only by component degradation, repeater temperature, and cable temperature. The voltage across the 22-volt diodes indicates the condition of the diode and the dc current in the cable. If this voltage drops below 20 volts, a trouble condition exists. The voltage across resistor (R55) indicates the current in the heater circuit. If this voltage drops below 2.2 volts, a trouble condition exists. All these voltages may be measured with a 20,000-ohms-per-volt meter while the repeater is in service. They are intended to indicate a trouble condition, not to specify the defective component.

**2.39** The test points are tabulated below:

| TEST JACK DESIGNATION | NUMBER JACK | TEST POINT |
|---|---|---|
| W-E TEST | JB1 | circuit ground W-E |
| | JB2 | emitter (Q1, W-E) |
| | JB3 | emitter (Q3, W-E) |
| | JB4 | emitter (Q4, W-E) |
| E-W TEST | JB1 | circuit ground E-W |
| | JB2 | emitter (Q1, E-W) |
| | JB3 | emitter (Q3, E-W) |
| | JB4 | emitter (Q4, E-W) |
| TEST | JC1 | true ground |
| | JC2 | emitter (Q40) |
| | JC3 | emitter circuit (Q41) |
| | JC4 | cathode (CR2, W-E) |
| | JC5 | anode (CR2, W-E), cathode (CR2, E-W), and oscillator circuit ground |
| | JC6 | anode (CR2, E-W) |
| Red | TP1 | across resistor (R55) |
| Black | TP2 | |

## 3. REFERENCE DATA

**3.01** ***Working Limits:***

Temperature: −40 F to +140 F.

DC Current: 85 to 200 ma.

Input Level: −35 dbm ±8 db.

**3.02** ***Functions.*** This repeater receives signals at low group frequencies (36 to 140 kc) from the line, translates them to high group frequencies (164 to 268 kc), and then suitably amplifies and regulates them for transmission at the desired output level. This repeater is used alternately along the cable with another repeater designated High-Low (H-L) Repeater.

**3.03** The repeater provides a transmission slope across the band adjustable to about +2, 0, or −2 db.

**3.04** Wiring adjustment is provided to obtain a fixed repeater gain in place of the regulated gain to be used when the repeater is used for testing or in the transistorized repeater switching set.

**3.05** The repeater provides means, when required, to transmit power over the cable in either or both directions to another repeater and to receive power in a like manner from another repeater.

**3.06** The repeater provides means for making component degradation tests.

**3.07** ***Connecting Circuits.*** "N1" Carrier Telephone — Application Schematic for "N1" Transistorized Repeater — SD-95124-02. — Not attached.