TELEPHONE SET TRANSMITTING AMPLIFIERS

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1. GENERAL

1.1 This section is intended to provide REA borrowers, consulting engineers, contractors, and other interested parties with technical information for use in the design, construction, and operation of REA borrowers' telephone systems. It discusses, in particular, the design and application of an amplifier for the transmitting branch of a telephone circuit which can be furnished where needed to meet transmission objectives on "long loops." The amplifier discussed is not an "extra charge" device but is considered to be a component of the telephone set. This section does not include other types of amplifiers, such as receiving amplifiers for hard-of-hearing sets, amplifiers for hands-free operation, or for loud-speaker operation.

1.2 Telephone set transmitting amplifiers are available as an applique device for converting standard telephone sets (500 Type) into "high-gain" or "long-loop" sets. These devices consist of a single-stage fixed-gain transistor amplifier assembled on a small printed circuit board which is designed to be mounted in the base of a telephone set or to the plastic transmitter cup in the transmitter cavity of a standard handset. They produce an effective gain in the transmitting branch of about 7 db.

1.3 The recommended model of this device includes a polarity guard diode bridge. The diode bridge insures proper battery polarity on the transistor at all times. This makes it possible to use the amplifiers with central office switching equipment which reverses battery to the calling subscriber when the called party answers. Models which do not include the polarity guard can be used only with switching equipment which does not reverse polarity at any time. Most long-line adapters do not reverse battery.

1.4 These amplifiers operate from normal loop currents ranging from about 35 to 15 ma. The gain is largely independent of the d.c. current. A lower limit of 7 ma. per set applies when two telephone sets on a line are in use, as in the case of an extension, an eaves-dropper on a party line, or a reverting call. This lower limit of 7 ma. cannot be used for loop design because other factors are limiting. Noticeable distortion can be produced in the amplifier output if operated with appreciably more than 35 or less than 7 ma. d.c., or if acoustically overloaded at low-loop currents. Drop out (complete loss of transmission) occurs at about 3 ma. Within its normal operating range, the amplifier does not contribute significantly to the total distortion of the telephone set.

1.5 The measured transmitting gain produced by amplifiers averages about 10 db. This gain, however, is accompanied by a substantial increase in sidetone. The measured gain is therefore penalized at the rate of 1 db. per 3 db. increase in sidetone, based on subjective studies. It is because of this penalty that the effective transmitting gain for design purposes is rated at only 7 db. The sidetone response of some telephone sets on certain loops may have a peak which, when an amplifier is applied in the transmitting branch, may result in an unacceptably high sidetone level. Telephone sets currently on our "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers" are acceptable from this standpoint, although some sets are better than others.

1.6 No gain is produced in the receiving branch of a telephone equipped with one of these amplifiers. The amplified transmitted energy, however, is received by the other party at the amplified level. The effects of this are discussed in paragraph 7.

1.7 The effective gain for design purposes is therefore taken as (T+R)/2 = (7+0)/2 = 3.5 db. with respect to a standard 500 Type set. In other words, a loop can be designed to exceed transmission objectives by 3.5 db. effective, and this deficiency can be made up by adding amplifiers as needed in the telephone sets. An effective attenuation of 3.5 db. in a long loop is roughly equivalent to a 1000 c.p.s. insertion loss of 3.5 db. The length of various facilities corresponding to 3.5 db. insertion loss at 1000 c.p.s. is as follows:

Facility Gauge	Loading	Miles	Kilo Feet
19	D-66	8.2	43.2
22	D-66	4.4	23.2
24	D-66	2.9	15.3

2. APPLICATION GUIDELINES

2.1 Telephone amplifiers may be used beyond the point where transmission objectives can be met with loading and 500 Type telephone sets to offset the attenuation of additional loop plant as indicated above. Their use is recommended where the subscriber distribution and service requirements are such that significant initial and annual cost savings can be realized.

2.2 <u>Application to one- and two-party lines:</u>

2.21 Telephone amplifiers may be applied to loaded one- and two-party loops of various gauges of cable and noncable-type facilities whose resistance ranges are listed below. The capacitance of noncable-type end sections must not exceed the capacitance specified for cable end sections.

Type of Loading	Approximate Limiting Resistance Ranges of Buried Plant Loops at 68° F. - Ohms			
	Short End Section [2]		Long End Section [3]	
	Minimum	Maximum [1]	Minimum	Maximum [1]
D-66	2000	2700	1700	2300
H-88	1500	2300	1500	2300

[1] Decrease values 15% for aerial plant.

[2] A short D-66 end section of cable ranges from not less than 1 KF to not more than 4.5 KF. A short H-88 end section of cable ranges from not less than 2 KF to not more than 6 KF.

[3] A long end section of cable is not more than 12 KF with D-66 loading or 9 KF with H-88 loading.

2.22 In addition to the requirements of paragraph 2.21, on two-party lines, a minimum current of 7 ma. must be maintained in the most distant set during a reverting call. In order to insure 7 ma. in the most distant set, the difference in loop resistance between the two sets must not exceed the values specified in Table I.

2.23 Three examples illustrating how to calculate the difference in loop resistances of reverting call subscribers on two-party lines are shown in the sketches on Table I.

2.231 Sketch A of Table I shows a two-party line having an outside plant loop resistance to the most distant subscriber ("B") of any value within the range of resistances included in Column (1). The other subscriber ("A") on this line is assumed to be connected directly to the main line and to be 150 ohms closer to the central office than subscriber "B". The difference in loop resistance between "A" and "B" is x = m - n = 150 - 0 = 150 ohms. Reference to Table I will show that, if the total loop resistance is 1700 ohms, satisfactory reverting calls with amplifiers could be made with either a 48- or a 72-volt battery supply from the CDO. If the total loop resistance were 2300 ohms, a difference in loop resistance between "A" and "B" of 150 ohms would not be satisfactory with a 48-volt CDO because the division of d.c. loop current between the two sets would be such that set "B" would not get 7 ma. Adequate current would result in set "B" on a 2300-ohm loop, however, if 72-volt CDO battery is provided.

2.232 Sketch B of Table I is similar to Sketch A, except that subscriber "A" is assumed to be located at the end of a 100-ohm bridged tap "n". In this case, the resistance "m" from "B" to the branch tap "O" is assumed to be 150 ohms. The difference in resistance "x" between "A" and "B" would be x = m - n = 150 - 100 = 50 ohms. Reference to Table I shows there would be no problem in meeting limits with a 48-volt CDO up to a 2400-ohm loop, and no problem with a 72-volt CDO up to and beyond a 2700-ohm buried loop.

2.233 Sketch C of Table I shows an extreme case of a bridge tap where each subscriber is 600 ohms from the branch point "O". The difference in loop resistance in this case is x = m - n = 600 - 600 = 0 ohms, which means that the available loop current would divide equally between the two branches. The loop resistance regarding this aspect of revertive calls would not be limiting because any value of loop resistance up to 2900 ohms (48-volt CDO), or 4650 ohms (72-volt CDO), would produce a loop current of 14 ma. which would insure a minimum of 7 ma. in each set.

2.34 Table I, Column (1), is based on 68° F. temperature; therefore, the values in Columns (4) and (5) have been reduced 15% for aerial cable to allow for the increase in loop resistance with temperature.

2.3 Four- and eight-party lines:

2.31 Amplifiers should not be applied to eight-party lines, and their application to four-party lines is not recommended. The reason for this is that, as the number of parties per line increases, the application and administration of the reverting call limitations become more difficult, and the economic advantages decrease.

3. LOOP DESIGN CONSIDERATIONS

3.1 Loops should be designed to meet the transmission requirements of TE & CM-424, except that the appropriate resistance limits specified herein may be used with amplifiers instead of those in TE & CM-424, Issue No. 1, dated July 1963, provided it has been determined that the central office equipment to be used will be capable of signaling, ringing, ring tripping, and supervising over the proposed loops.

3.2 The selection of the most economical cable gauge is affected by the ability to serve critical subscribers by means of finer gauge cable conductors because of the 3.5 db. greater attenuation which the use of amplifiers permits. The circuits in which amplifiers can be used usually require long-line adapters and often booster battery. A subscriber distribution which involves a cluster of subscribers beyond the point where long-line adapters are required but with relatively few subscribers in between, offers the greatest opportunities for savings by applying amplifiers.

3.3 The cost of additional long-line adapters is usually the most important factor in attempting to design a lead to use amplifiers. The installed first cost per amplifier of $15.00 each ($3.25 annual costs) and the proportionate share of the cost of booster battery attributable to the amplifier design are not usually controlling economic factors.

3.4 If one or more extension stations are associated with a main station which requires an amplifier, the extension station, or stations, must also be equipped with amplifiers. Amplifiers are not required in the sets of both parties on a two-party line unless both parties are beyond normal transmission limits, but the resistance limitation between parties still applies.

3.5 Amplifiers are recommended where their use results in both first and annual cost savings as compared with other means, such as voice frequency repeaters, coarser gauge cable, long-line adapters, or carrier. Addendum 3 to Section 218, dated June 1965, shows an example of how economies can be achieved by the use of finer gauge cable in conjunction with amplifiers. Where a number of negative resistance repeaters of present design are contemplated for achieving transmission objectives, significant savings can be realized by substituting amplifiers for V.F. repeaters where the objectives can be met with a (T+R)/2 gain of 3.5 db.

4. APPLICATION TO EXISTING SYSTEMS

4.1 General application of amplifiers should be considered at the time an existing multi-party system is being upgraded to one-party or to one- and two-party service.

4.2 Application of amplifiers to a particular station or stations on any line of a working system to correct "can't be heard" complaints should be considered, provided the loop resistance is within the range specified in paragraph 2.21 and is properly designed and constructed. If a maintenance man has been sent to a subscriber's premises in response to such a complaint, and if his inspection and tests do not disclose any obvious defects, it may be possible to correct the trouble by installing an amplifier if the poor transmission is caused by a naturally weak talker.

4.21 Amplifiers should not be used instead of replacing defective components, nor instead of performing needed maintenance work. However, if it has been determined that a design or construction error that would be difficult and costly to correct has been built into the plant, amplifiers may offer an inexpensive temporary solution. An example of the type of construction error referred to would be a greater length of 24-ga. cable built into a lead, than intended in the design.

4.22 If "can't be heard" complaints occur because of an inadequate signal-to-noise ratio on a circuit, an amplifier at the transmitting station may overcome the problem because this would result in improved signal-to-noise ratio for the station receiving a message from the station equipped with an amplifier. All of the transmitting gain is signal-to-noise ratio gain.

5. INSTALLATION

5.1 The schematic circuit of a typical amplifier with polarity guard diode bridge is shown in Figure 1 which also shows how it is connected in a typical telephone set circuit. It should be noted that installation involves only the disconnection of two handset leads in the telephone set, the connection of those two leads to the amplifier terminals and the connection of the two amplifier leads to the two terminals from which the handset leads were removed.

5.2 Amplifiers can be installed in a few minutes by regular station installers after a very brief period of instruction.

5.3 No electrical protection measures are needed other than the normal station protection.

6. MAINTENANCE

6.1 Amplifiers are basically "go" and "no-go" devices. They either operate as intended or don't operate at all. Damaged or inoperative amplifiers should be discarded because repair is not practical. Failure rates to date have been negligible. Amplifiers should not be tested on zero or very short loops.

7. RECEIVING LEVELS

7.1 As previously indicated, the amplifiers produce only transmitting gain. The lack of receiving gain within the loop limits specified above is unimportant provided the efficiency of the receiving circuit and the receiver unit is equivalent to that of a standard

Table I

Resistance Limits for Reverting Calls

Outside Plant Resistance (Incl. Load Coils) to most distant subscriber 68° F. - Ohms	Permissible difference in loop resistance between nearest reverting call subscriber and most distant reverting call subscriber to maintain 7 ma. in most distant set ohms - (see note)			
	Buried		Aerial	
(1)	48 V CDO (2)	72 V CDO (3)	48 V CDO (4)	72 V CDO (5)
1500	215	---	183	---
1600	190	---	162	---
1700	169	360	144	306
1800	149	300	127	256
1900	132	278	112	236
2000	114	270	97	230
2100	98	257	84	218
2200	82	236	70	200
2300	72	217	61	185
2400	62	207	53	176
2500	51	190	43	162
2600	42	173	36	147
2700	30	150	26	128

$x = m - n$ ohms

Where: x = Difference in loop resistance between nearest reverting call subscriber "A" and most distant reverting call subscriber "B".

m = Resistance of main lead between subscriber "B" and branch point "O".

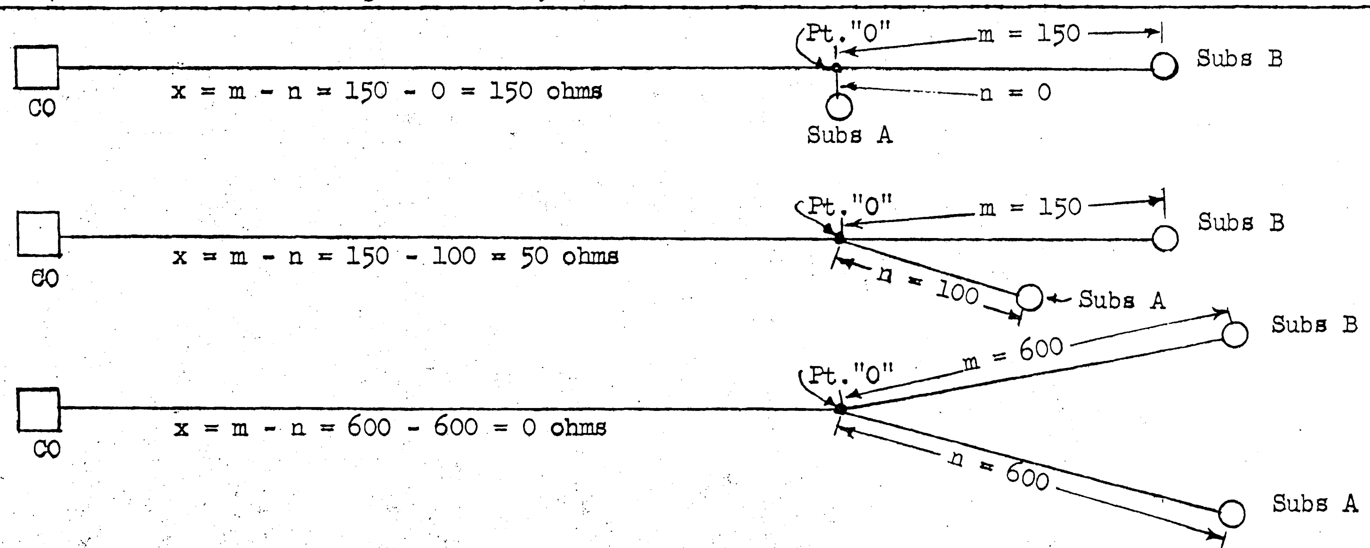
n = Resistance between branch point "O" and subscriber "A".

Examples are shown in Sketches A, B, and C.

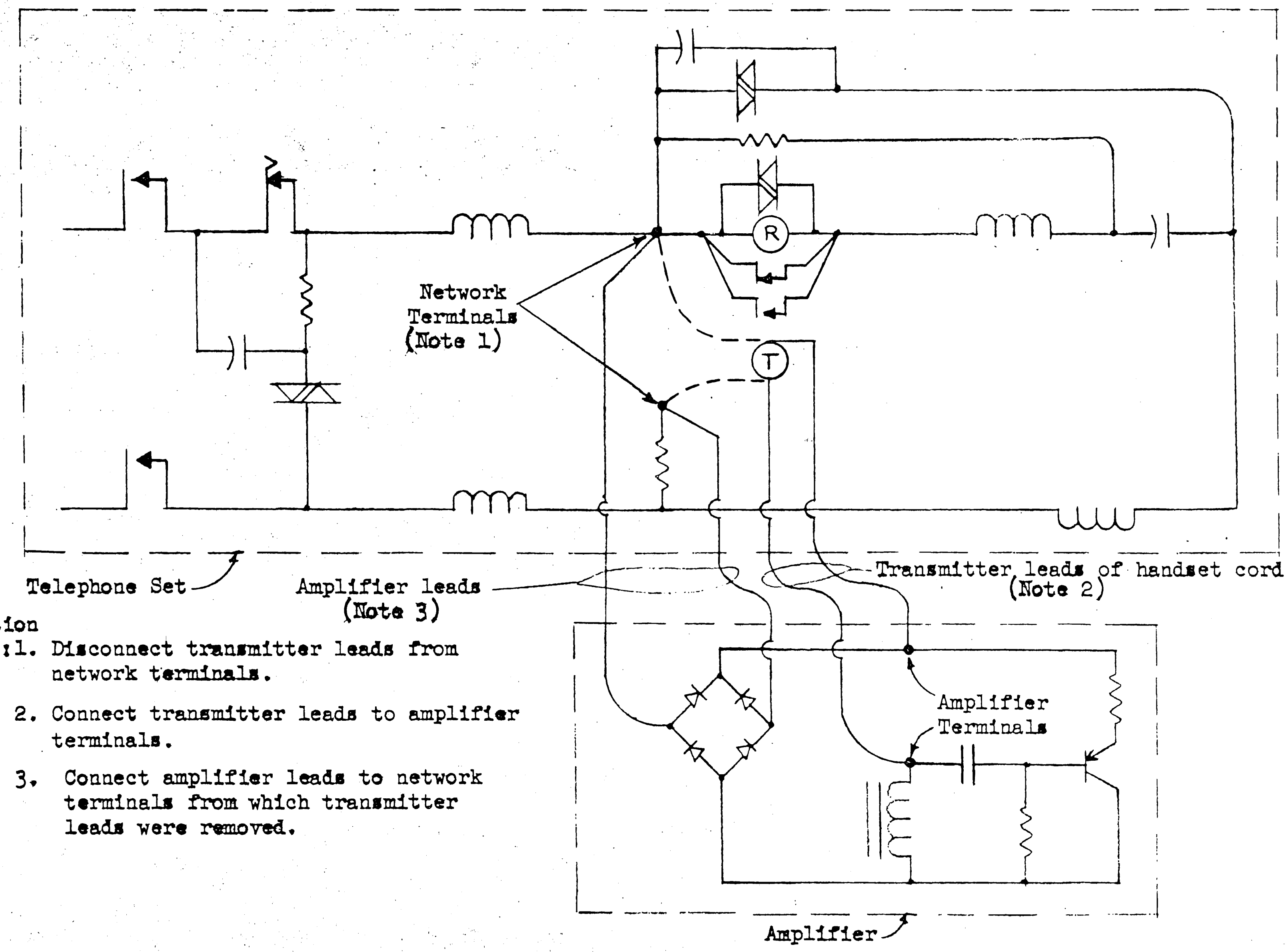
Sketch A

Sketch B

Sketch C



Schematic Diagram of Amplifier in Telephone Circuit



Installation

Notes: 1. Disconnect transmitter leads from network terminals.

2. Connect transmitter leads to amplifier terminals.

3. Connect amplifier leads to network terminals from which transmitter leads were removed.

Figure 1