

## N3 CARRIER TELEPHONE TERMINAL COMPANDOR UNIT DESCRIPTION

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**1. GENERAL**

**A. System Function of Compandor**

**1.01** This section describes the compandor unit which is one plug-in component part of the channel equipment of the N3 carrier telephone terminal.

**1.02** A complete 24-channel terminal for the N3 carrier system will include 24 compandor units. Each compandor unit is a single plug-in assembly which provides two independent circuits, a compressor and an expander. A compressor is used in a message channel at the transmitting terminal to vary the gain in accordance with the speech volume of the talker. The volume of weak speech is raised relatively more than the volume of strong speech. An expander is used in a message channel at the receiving terminal to vary the gain in accordance with the compressed speech volume. The volume of weak speech is reduced relatively more than the volume of strong speech, thereby restoring the original speech volume.

**1.03** The inclusion of compandors in the terminal equipment of the N3 carrier telephone system yields an improvement in the amount of noise and crosstalk which can be tolerated in the transmission line. Weak speech volumes, being most susceptible to system disturbances, are carried over the high-frequency carrier line at a relatively higher level when compandors are used.

**B. Description and Features**

**1.04** The compandor for the N3 carrier system is a single plug-in modular unit. For convenience, a compressor and an expander have been assembled together and share a plug and receptacle. These circuits function independently except for a common connection to the power supply. The compandor unit is shown in Fig. 1.

**1.05** Silicon transistors and diodes have been used to provide highly stable and precise performance, good service reliability, and small power requirements. Since long life is anticipated, the transistors and diodes are wired directly into the circuit.



Fig. 1 – Compandor Unit

1.06 Transformers, electrolytic capacitors, and other components have been reduced to minimum size, consistent with design objectives.

1.07 Circuit components are mounted on a printed circuit board which forms a sub-assembly. The printed circuit board is surrounded by a die-cast frame. All interconnecting wiring to and from the compandor enters via a 20-pin plug which is part of the printed wiring assembly. The OUT ADJ potentiometer for adjusting the expander gain, four pin jacks for testing, and a mechanical latch for locking the unit in position are located on the front panel.

### C. General Discussion of Compandors

1.08 Compandors have been incorporated in the N3 carrier telephone terminal because certain economies are produced by their use. For example, the amount of noise and crosstalk which can be tolerated in the transmission line is increased, thereby making possible longer repeater spacing and longer over-all system lengths, respectively. Also, crosstalk balancing of the cable pairs can be eliminated and the selectivity of channel-band filters is effectively enhanced. The grade of performance of a transmission system can be measured in terms of the ratio of signal power to the total noise interfer-

ence power, that is, the S/I ratio. In this ratio, S represents the wanted voice-frequency signal power, and I represents the total unwanted interference power including interchannel crosstalk, modulation distortion, and line noise. Thus, for any required channel S/I ratio and a given maximum total noise, there is a permissible signal range which lies between a load capacity ceiling and noise floor.

1.09 Compandors increase the S/I ratio; therefore, the use of compandors makes possible a longer repeater spacing on a particular line whenever the minimum acceptable S/I ratio is specified as a design objective. This important result is explained in Fig. 2, which shows the essential features of the action of a compressor and an expander with respect to signal levels.

1.10 The left-hand side of Fig. 2 shows the relationships between the input and output powers for an ideal compressor. These powers are assumed to be expressed in dbm as measured at a zero level point in the system. For convenience, the illustration shows input powers between +8 and -52 dbm, a range of 60 db. For the ideal compressor being considered, the output decreases 1 db for each 2-db decrease in the input. Assuming that the gain has been adjusted so that +5 dbm output corresponds to +5 dbm input, the illustration shows output powers between +6.5 and -23.5 dbm, a range of 30 db. For inputs exceeding a maximum power of approximately +10 dbm at zero level, the compressor output becomes distorted due to overloading in the amplifier. Therefore, a ceiling exists above which the performance deteriorates rapidly due to clipping and intermodulation distortion. The compressor will continue to produce an appropriately compressed output for input powers less than -52 dbm. The reason for restricting the input range to 60 db for this illustration will be given below in the discussion of the expander.

1.11 The right-hand side of Fig. 2 shows the input and output powers for an ideal expander. These powers are also expressed in dbm as measured at a zero level point in the system. The illustration shows compressed signals having powers between +6.5 and -23.5 dbm, the range of 30 db being consistent with the assumptions made in the preceding paragraph. For the ideal expander being considered, the output decreases 2 db for each 1-db decrease in the input.



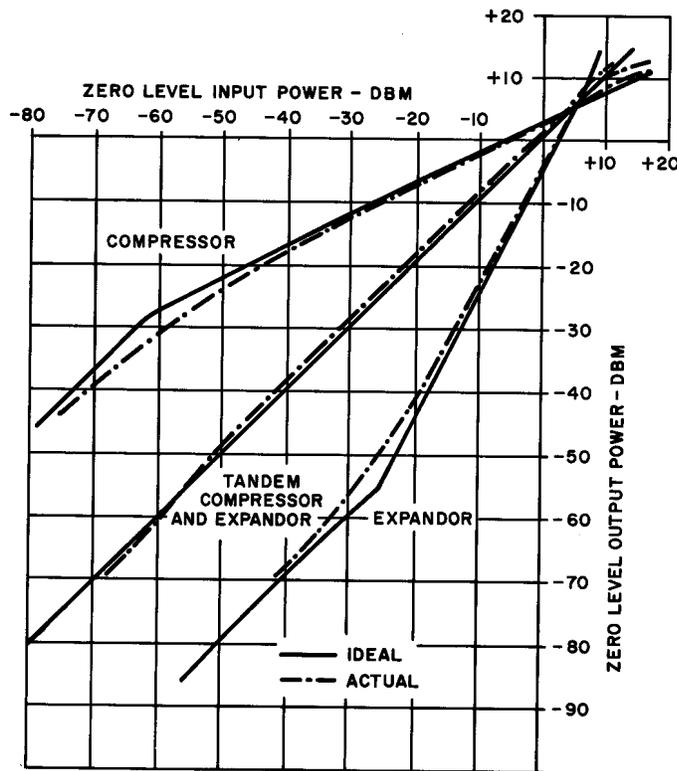


Fig. 3 – Input-Output Load Characteristics for N3 Compressor

1.14 The functions performed by either a compressor or an expander have been described in 1.02. The way in which the required action is achieved can be explained quite easily by referring to the block diagrams shown in Fig. 4, 5, and 6. The forward transmission path has been drawn with heavy lines to emphasize the fact that each circuit consists of a variable attenuator, called a variolossor, followed by an amplifier. The net gain of the circuit is equal to the gain of the amplifier reduced by the loss inserted by the variolossor.

gain of the amplifier reduced by the loss of the attenuator. Assume that the gain of the amplifier remains unchanged and that the loss of the attenuator can be adjusted manually to any de-

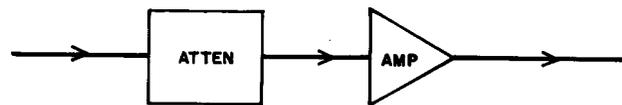


Fig. 4 – Simple Block Diagram

1.15 The compressor and the expander are automatic gain control devices, and the functions described in 1.02 are performed without manual adjustment or intervention. However, it is instructive to observe the sequence of adjustments which could be made manually to simulate either compression or expansion. First consider the simple block diagram shown in Fig. 4. It consists of an attenuator, or loss pad, and an amplifier. The net gain of the circuit is equal to the

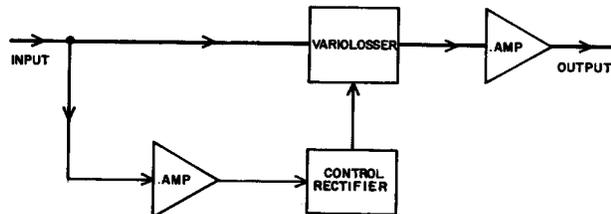


Fig. 5 – N3 Expander Block Diagram

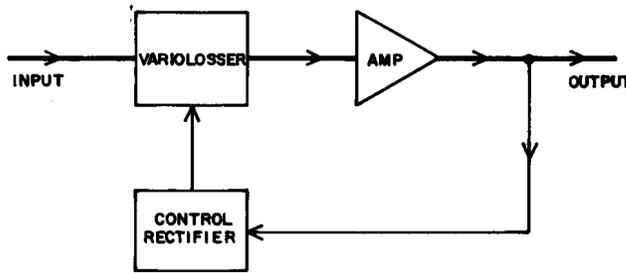


Fig. 6 - N3 Compressor Block Diagram

sired value. To adjust the attenuator to satisfy either the requirements for a compressor or the requirements for an expander as stated in 1.02 is explained below.

1.16 The expander principle being easier to understand, first consider what happens in the expander circuit when the input is a single tone, say 1000 cps. If the input is increased 1 db and the attenuator loss is not changed, the output increases 1 db. If the attenuator loss is decreased 1 db and the input is not changed, the output increases 1 db. Thus, the output increases 1 db either when the input increases 1 db or when the loss of the attenuator is decreased 1 db. If, simultaneously, the input is increased 1 db and the loss of the attenuator is decreased 1 db, the output will increase 2 db. This is exactly the relationship which was specified for an ideal expander.

1.17 Although 1-db changes have been used in this example, the same conclusion would be reached with any other number, that is, expander action requires that the net gain of the circuit shall increase by the same number of decibels that the input signal increases. The design specification for an expander can be stated as follows: The change in loss of the attenuator must be equal to the change in magnitude of the input signal and in the opposite sense.

1.18 Let  $P_{10}$ ,  $P_{20}$ ,  $L_0$ , and  $G$  represent the input power, output power, loss in the attenuator, and gain of the amplifier for an initial reference condition. Also, let  $P_1$ ,  $P_2$ ,  $L$ , and  $G$  represent the same quantities for any other condition. If all quantities are expressed in decibels,

the transmission equations for the two conditions can be written as follows:

$$P_{20} = P_{10} + G - L_0 \quad (1)$$

$$P_2 = P_1 + G - L \quad (2)$$

The change in output power can be related to the change in input power and the change in attenuation, thus,

$$(P_2 - P_{20}) = (P_1 - P_{10}) - (L - L_0). \quad (3)$$

Using the same notation, the design specification for an ideal expander can be written as

$$(L - L_0) = -(P_1 - P_{10}). \quad (4)$$

That is, the change in loss is in the opposite sense (indicated by the negative sign) and equal in magnitude to the change in input power. The transmission equation for the expander can be obtained by substituting equation (4) in equation (3), hence

$$(P_2 - P_{20}) = 2(P_1 - P_{10}). \quad (5)$$

An attenuator, the loss of which can be made to vary in accordance with the magnitude of a control signal, is called a variollosser. If the control is derived from the input signal, the circuit is said to be forward-acting. Thus, the expander is essentially a variollosser having a forward-acting control circuit. A block diagram of the expander is shown in Fig. 5.

1.19 The compressor principle can also be established by referring to Fig. 4 and considering what happens in the compressor circuit when the input is a single tone, say 1000 cps. If the input is increased 1 db and the attenuator is not changed, the output increases 1 db. If the input is increased 1 db and the attenuator loss is increased 1 db, the output remains unchanged. If, simultaneously, the input is increased 2 db and the attenuator loss is increased 1 db, the output will increase 1 db. This is exactly the relationship which was specified for an ideal compressor. Although simple numbers have been used in this example, the same conclusion would be reached with any numbers in the same proportion, that is, compressor action requires that the net gain of the circuit shall decrease by the same number of decibels that the output signal

increases. The design specification for a compressor can be stated as follows: The change in loss of the attenuator must be equal to the change in magnitude of the output and in the same sense.

1.20 Using the notation defined in 1.18, the design specification for an ideal compressor can be written as

$$(L - L_0) = +(P_2 - P_{20}). \quad (6)$$

That is, the change in loss is in the same sense (indicated by the positive sign) and equal in magnitude to the change in output power. The transmission equation for the compressor can be obtained by substituting equation (6) in equation (3), hence

$$(P_2 - P_{20}) = \frac{1}{2}(P_1 - P_{10}). \quad (7)$$

Thus, the compressor is essentially a variolossor having a backward-acting control circuit. A block diagram of the compressor is shown in Fig. 6.

## 2. COMPRESSOR

### A. Circuit Description

2.01 The compressor decreases the volume range of the voice-frequency signal before modulation in the transmitting terminal, the action being such that the output power increases 1 db for each 2-db increase in the input power. The input terminals of the compressor present a balanced 600-ohm impedance suitable for connection to the voice-frequency circuit. The unit accepts voice-frequency signals having powers between -8 and -68 dbm as measured at the input transformer terminals. The compressor delivers to the modulator a voice-frequency signal having a volume range of 30 db after compression, that is, a volume range of 60 db at the input is reduced to 30 db at the output.

2.02 The compressor achieves the desired compression of the signal volume by means of a variable attenuator, or variolossor, a fixed-gain amplifier, and a control rectifier circuit. A block diagram, Fig. 6, shows the compressor circuit, and the essential relationships can be demonstrated by analyzing the three components separately.

### B. Variolossor

2.03 The term variolossor is used to designate a class of circuits having a particular property in common, that is, the transmission loss is made to vary in accordance with changes in the magnitude of a control signal. In general, in compandor circuits, it is not the instantaneous value of the speech wave which controls the loss introduced by the variolossor, but is a somewhat more slowly varying quantity, such as the envelope of the speech wave. Variolossors used in compandors are controlled by the speech power averaged over an interval corresponding to the syllabic frequencies of typical speech.

2.04 The essential properties of a circuit capable of producing the action required of a compressor were described in Part 1. For simplicity, a manually adjusted attenuator was assumed. The variolossor designed for the N3 compressor performs the same operation automatically under control of a current derived from the speech being transmitted. A circuit which provides variable attenuation controlled by a slowly varying unidirectional current is shown in Fig. 7.

2.05 The circuit includes a varistor RV1 which limits transients caused by signaling relay operations; a transformer T1 which raises the impedance level; a fixed pad comprised of resistors R1, R2, and R3 which decreases the signal level to the desired magnitude to prevent signal distortion by the variolossor and also acts as a buffer between the variable resistance element and the input terminals; and a transformer T2 which lowers the impedance level to a convenient magnitude for connection to the amplifier. The shunt circuit, including the pair of silicon diodes CR1-A and CR1-B, resistors R4 and R5, and capacitor C1, forms the variable element which enables the variolossor to perform its function. The control current is introduced through resistors R36 and R37; a fixed bias current is introduced through resistors R34 and R35. Since the control circuit elements are bypassed by capacitor C1, these resistors can be ignored when considering the voice-frequency transmission loss of the variolossor. Resistors R28, R29, and R32 form a fractionating network which is used at the factory to adjust the bias current.

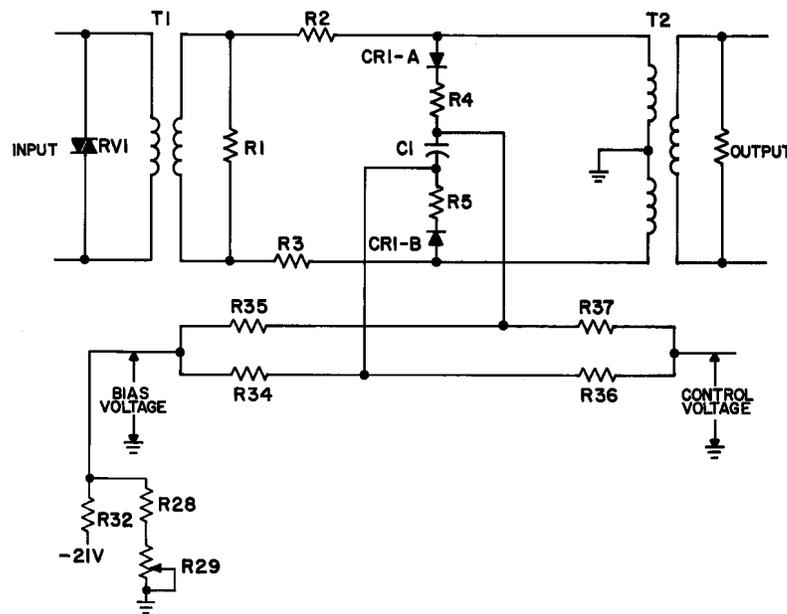


Fig. 7 - N3 Variollosser for Compressor

**2.06** In the compandor, the variollosser varistors, that is, variable resistances are the controlling elements. Voice-frequency signals are attenuated by amounts dependent upon the magnitude of the variable resistance. If the varistor is a silicon diode, the resistance can be varied by changes in the value of a unidirectional bias current. When the voice-frequency signal current is small in comparison with the bias current, the impedance presented by the varistor is a resistance, the magnitude of which depends upon the bias current rather than the signal current.

**2.07** The voltage-current characteristic of a varistor (or a resistor) considered as a 2-terminal circuit is useful in presenting the relationship that exists when the varistor forms a branch of a circuit. A resistor has a linear terminal characteristic, that is, the current through the resistor is a linear function of the voltage across its terminals. A silicon diode has an exponential terminal characteristic, that is, the current through the diode is an exponential function of the voltage across its terminals. Fig. 8 shows graphically the terminal characteristics of a resistor (constant resistance) and a silicon varistor (variable resistance).

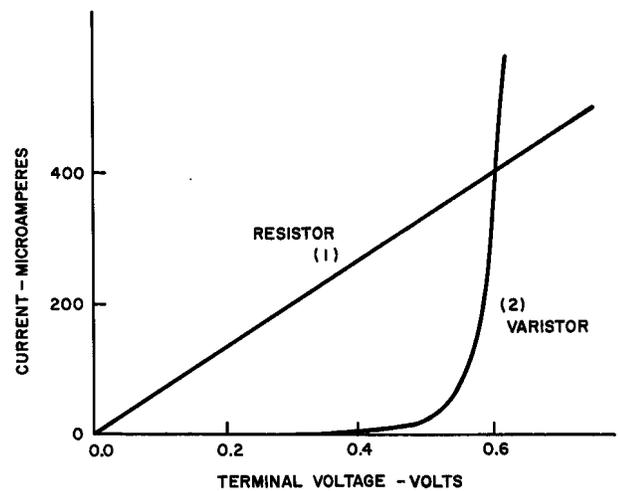


Fig. 8 - N3 Terminal Characteristic

**2.08** When the total current through a branch of a circuit is a combination of a relatively large unidirectional bias current and a small voice-frequency signal current, the ac resistance presented by the branch to the small voice-frequency signal current can be determined. The ac resistance is the ratio of the incremental change

in voltage to the small change in current produced by it, that is, it is the slope of the voltage-versus-current characteristic at a point determined by the large bias current. The terminal characteristic for the resistor is a straight line [(1) of Fig. 8], and since the slope does not depend upon the current, the ac resistance is the same for all bias currents. The terminal characteristic for the varistor is a curve [(2) of Fig. 8]. Since the slope is different for different bias currents, the ac resistance depends upon the bias current, the resistance becoming smaller as the bias current becomes larger. The terminal characteristic for a silicon diode can be represented by the exponential equation,

$$I = I_s \left[ \exp \left( \frac{qV}{kt} \right) - 1 \right].$$

The significance of this equation is not essential for this discussion, but the equation for incremental resistance (which can be derived from it) is necessary. The small signal ac resistance is inversely proportional to the large bias current. Theoretical considerations and experimental measurements of the silicon diode used in the N3 compandor show that the ac resistance is related to the unidirectional bias current approximately by the equation,

$$r = \frac{0.045}{I}$$

where I is in amperes and r is in ohms.

**2.09** The shunt varistor circuit shown in Fig. 7 includes the pair of diodes CR1-A and CR1-B connected in series. The effects of the two small resistors R4 and R5 and the capacitor C1 can be neglected for the present. If  $R_o$  and  $I_o$  represent the ac resistance in ohms and the control current in amperes for an initial reference condition, and if R and I represent the same quantities for any other condition, the equation describing the action of a varistor is

$$\left( \frac{R}{R_o} \right) = \left( \frac{I_o}{I} \right). \tag{8}$$

**2.10** The compressor employs a variolossor having the varistor connected as a shunt element. If R represents the ac resistance of the varistor shunted across a voice-frequency circuit, and if  $Z_1$  and  $Z_2$  represent the input and output circuit impedances, respectively,

$$\frac{E_{in}}{E_{out}} = Z_1 \left[ \left( \frac{1}{Z_1} + \frac{1}{Z_2} \right) + \frac{1}{R} \right].$$

If R is small in comparison with the parallel combination of  $Z_1$  and  $Z_2$ , a good approximation for the attenuation, expressed in decibels, is

$$L = 10 \text{ Log}_{10} \left| \frac{Z_1}{R} \right|^2.$$

If  $L_o$  and  $R_o$  represent variolossor attenuation in decibels and varistor resistance in ohms for an initial reference condition, and if L and R represent the same quantities for any other condition, the loss equation is

$$(L - L_o) = 10 \text{ Log}_{10} \left( \frac{R_o}{R} \right)^2.$$

Since R and  $R_o$  are related to the control current according to equation (8), the equation for the loss introduced by the variolossor in the compressor is

$$(L - L_o) = +10 \text{ Log}_{10} \left( \frac{I}{I_o} \right)^2. \tag{9}$$

**C. Control Circuit**

**2.11** The control circuit for the variolossor employs a peak-type rectifier which charges a capacitor to the peak voltage of the voice-frequency voltage wave. Since large voltages are required to produce the necessary control currents through the diodes in a variolossor circuit having the desired time constant, a type of rectifier which doubles the voltage is used in the N3 compandor. The circuit is shown in Fig. 9.

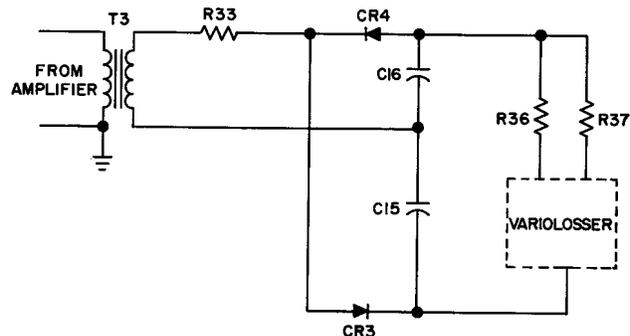


Fig. 9 - N3 Control Rectifier

**2.12** If the capacitor is charged from a relatively low-resistance source, such as transformer T3 driven by a low output impedance feedback amplifier, and if the capacitor is allowed to discharge through a high-resistance load, such as the circuit which includes resistors R36 and R37, the charging and discharging time constants can be adjusted so that the output current  $I$  is proportional to the voltage of the envelope of the voice-frequency signal. Since the signal power is proportional to the square of the voltage, the derived control current is proportional to the square root of the signal power. Resistor R33 serves two purposes: it limits peak current for a suddenly applied signal and controls the compressor attack time.

**2.13** If  $P_{20}$  and  $I_{20}$  represent the signal power in dbm and the control current in amperes for an initial reference condition, and  $P_2$  and  $I_2$  represent the same quantities for any other condition, the equation describing the action of the control circuit rectifier is

$$10 \text{ Log }_{10} \left( \frac{I_2}{I_{20}} \right)^2 = (P_2 - P_{20}). \quad (10)$$

**2.14** Since the variolossor requires very low signal levels if the signals are not to be subject to intolerable intermodulation distortion, a fixed attenuator precedes it in the circuit. A high-gain negative feedback amplifier follows the variolossor and increases the voice-frequency signal power to the levels required in the system. The control circuit rectifier is connected to the output of the amplifier, rather than to the output of the variolossor, because a relatively large control current through the varistor is necessary.

**2.15** The important properties of a variolossor and its control circuit in combination can be explained in the following simple way. Using the symbols defined in 1.18 and combining equations (9) and (10), it can be seen that

$$(L - L_0) = +(P_2 - P_{20})$$

which is the design specification for an ideal compressor given as equation (6) in 1.20.

#### D. Compressor Characteristics

**2.16** The analysis given in Part 2 under B, Variolossor, for a varistor connected as a shunt element in a variolossor, showed that the

loss in decibels increased as the control current increased according to the relation designated equation (9).

**2.17** The analysis given in Part 2 under C, Control Circuit, for an amplifier and rectifier connected to the output of a variolossor, showed that the control current increased as the output power increased according to the relation designated equation (10). Using appropriate subscripts and combining equations (9) and (10), equation (11) is obtained, thus

$$(L - L_0) = +(P_2 - P_{20}). \quad (11)$$

This equation states that the change in loss expressed in decibels is in the same sense and is equal to the change in output power expressed in decibels.

**2.18** Having related the change in loss to the change in output power, the transmission equation for the variolossor and amplifier, which was given by equation (3), yields the basic compressor characteristic. The change in output power expressed in decibels is equal to one half the change in input power expressed in decibels.

$$(P_2 - P_{20}) = \frac{1}{2} (P_1 - P_{10}).$$

#### E. Amplifier

**2.19** An amplifier is required to provide sufficient power for the control rectifier circuit and to deliver the required voice-frequency signal to the modulator in the modem unit. A simplified schematic drawing of the negative feedback amplifier used in the compressor of the N3 compandor is shown in Fig. 10.

**2.20** The amplifier employs three transistors, each being connected in the common-emitter configuration. The input signal is introduced via transformer T2. A fraction of the output voltage provided by resistors R7 and R8 is also fed back to the input circuit. Negative feedback action produces an over-all voltage gain determined almost entirely by the ratio of resistors R7 and R8. The required gain is achieved by trimming resistor R8 as a factory adjustment. Adjustment of the bias currents of the transistors is also made during factory tests.

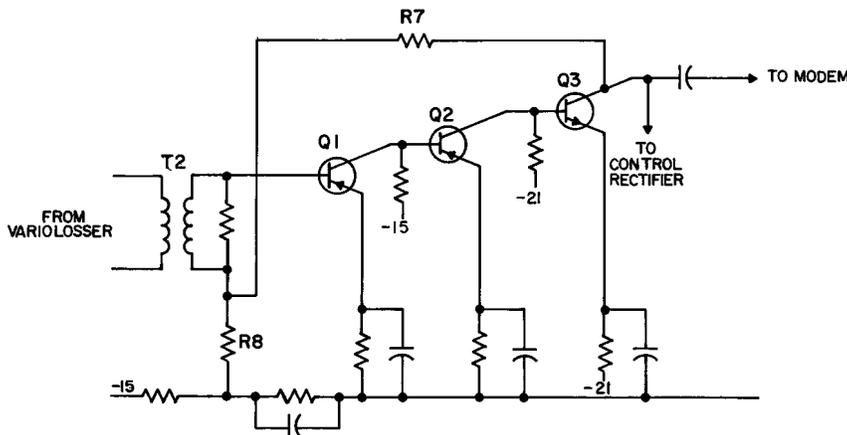


Fig. 10 – N3 Amplifier for Compressor

### 3. EXPANDOR

#### A. Circuit Description

**3.01** The expander increases the volume range of the compressed voice-frequency signal recovered from the line signal by demodulation in the receiving terminal, the action being such that the output power increases 2 db for each 1-db increase in input power. The expander restores the compressed voice-frequency signal to its original volume range, thus complementing the action of the compressor. The output terminals of the expander present a balanced 600-ohm impedance suitable for connection to the voice-frequency circuit. The unit accepts, from the demodulator, compressed voice-frequency signals; and for an input having a volume range of 30 db, it delivers an output voice-frequency signal having powers ranging between +15 and -45 dbm measured at the transformer terminals, that is, a volume range of 30 db at the input is increased to 60 db at the output.

**3.02** The expander achieves the desired expansion of the signal volume by means of a variable attenuator or variollosser, a control circuit which includes an amplifier and a rectifier, and a voice-frequency signal amplifier. A block diagram, Fig. 5, shows the expander circuit, and the essential relationships can be demonstrated by analyzing the three components separately.

#### B. Variollosser

**3.03** The variollosser used in the expander belongs to the class of circuits that was described in 2.03. The transmission loss is made to vary in accordance with changes in received speech volume.

**3.04** The essential properties of a circuit capable of producing the action required of an expander, were described in Part 1. For simplicity, a manually adjusted attenuator was assumed. The variollosser designed for the N3 expander performs the same operation automatically under control of current derived from the compressed speech being received from the modem unit. A circuit which provides variable attenuation controlled by a slowly varying unidirectional current is shown in Fig. 11.

**3.05** The circuit includes transformer T4 which lowers the impedance level to the desired magnitude; a fixed pad comprised of resistors R41, R42, R43, and R44 which decreases the signal level to the desired magnitude and acts as a buffer between the variable resistance element and the input terminals; and a transformer T5 which raises the impedance level to a convenient magnitude for connection to the amplifier. The series circuit including the pair of silicon diodes CR5-A and CR5-B and the capacitor C19 form the variable element which constitutes the variollosser. The control current is introduced through resistors R88 and R89.

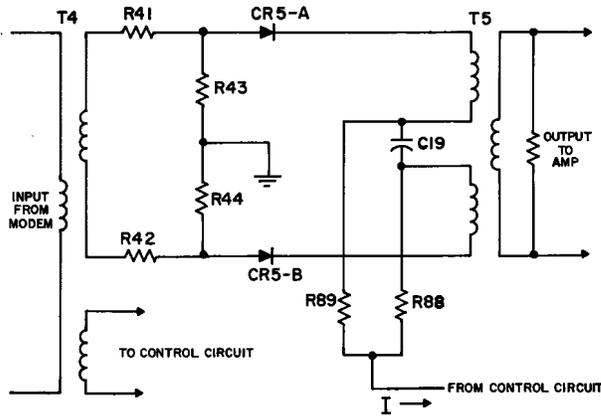


Fig. 11 - N3 Variolossor for Expander

**3.06** A variolossor is a network having a varistor, that is, a variable resistance as an element. Voice-frequency signals are attenuated by amounts dependent upon the magnitude of the resistance. If the varistor is a silicon diode, the resistance can be varied by changes in a unidirectional bias current. When the voice-frequency signal current is small in comparison with the bias current, the impedance presented by the varistor is a resistance, the magnitude of which depends upon the bias current rather than the signal current.

**3.07** The terminal characteristic of a varistor was described in 2.08, where the ac resistance was shown to vary inversely with the bias current.

**3.08** The expander employs a variolossor having the varistor connected as a series element. If  $R$  represents the ac resistance of a varistor inserted as a series element in a voice-frequency signal circuit, and if  $Z_1$  and  $Z_2$  represent the input and output circuit impedances, respectively,

$$\frac{E_{in}}{E_{out}} = \frac{Z_1 + Z_2 + R}{Z_2}$$

If  $R$  is large in comparison with the series combination of  $Z_1$  and  $Z_2$ , a good approximation for the attenuation, expressed in decibels, is:

$$L = 10 \text{ Log}_{10} \left| \frac{R}{Z_2} \right|^2$$

If  $L_0$  and  $R_0$  represent variolossor attenuation in decibels and varistor resistance in ohms for an initial reference condition, and if  $L$  and  $R$  represent the same quantities for any other condition, the loss equation is

$$(L - L_0) = 10 \text{ Log}_{10} \left( \frac{R}{R_0} \right)^2$$

Since  $R$  and  $R_0$  are related to the control current according to equation (8), the equation for the loss introduced by the variolossor in the expander is

$$(L - L_0) = -10 \text{ Log}_{10} \left( \frac{I}{I_0} \right)^2 \quad (13)$$

**C. Control Circuit**

**3.09** The control circuit for the variolossor used in the expander employs a rectifier circuit just like the one used in the compressor which was described in Part 2 under C, Control Circuit. An amplifier ahead of the rectifier circuit is necessary to provide the large control current required by the variolossor. The amplifier circuit is shown in Fig. 12.

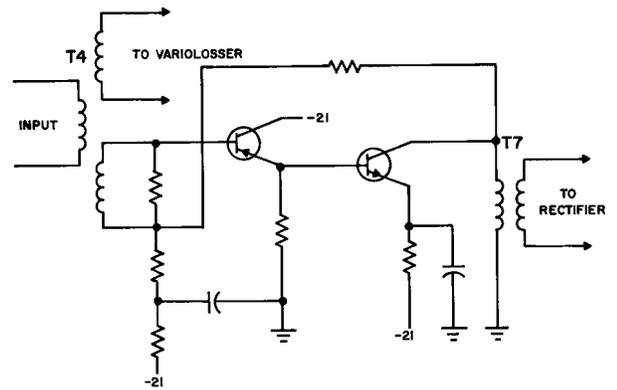


Fig. 12 - N3 Amplifier for Control Circuit

**3.10** The voice-frequency signal voltages at the output transformer T7 are almost the same as the voltages applied to the rectifier in the compressor. As described in Part 2 under C, Control Circuit, the derived control current is proportional to the square root of the signal power.

3.11 If  $P_{10}$  and  $I_{10}$  represent the signal power in dbm and the control current in amperes for an initial reference condition, and  $P_1$  and  $I_1$  represent the same quantities for any other condition, the equation describing the action of the control circuit is

$$10 \text{ Log}_{10} \left( \frac{I_1}{I_{10}} \right)^2 = (P_1 - P_{10}). \quad (14)$$

3.12 Since the variolossor requires very low signal levels if the signals are not to be subject to intolerable intermodulation distortion, a fixed attenuator precedes it in the circuit. The control circuit amplifier input is connected to the input of the variolossor.

3.13 The important properties of a variolossor and its control circuit in combination, can be placed in evidence in the following simple way. Using the symbols defined in 1.18 and combining equations (13) and (14), it can be seen that

$$(L - L_0) = -(P_1 - P_{10}) \quad (15)$$

which is the design specification for an ideal expander, given as equation (4) in 1.18.

#### D. Expander Characteristics

3.14 The analysis given in Part 3 under B, Variolossor, for a varistor connected as a series element in a variolossor, showed that the

loss in decibels decreased as the control current increased according to the relation designated equation (13).

3.15 The analysis given in Part 3 under C, Control Circuit, for an amplifier and rectifier connected to the input of a variolossor, showed that the control current increased as the input power increased according to the relation designated equation (14).

3.16 Having related the change in loss to the change in input power, the transmission equation for the variolossor and amplifier, which was given by equation (3), yields the basic expander characteristic. The change in output power expressed in decibels is equal to twice the change in input power expressed in decibels.

$$(P_2 - P_{20}) = 2(P_1 - P_{10}). \quad (16)$$

#### E. Amplifier

3.17 Because the signal level is low at the output of the variolossor, an amplifier is used to deliver adequate power to the voice-frequency circuit. A simplified schematic drawing of the negative feedback amplifier used in the expander portion of the N3 compander is shown in Fig. 13.

3.18 The amplifier employs three transistors, each being connected in the common-emitter configuration. The input signal is introduced via transformer T5. The output signal is de-

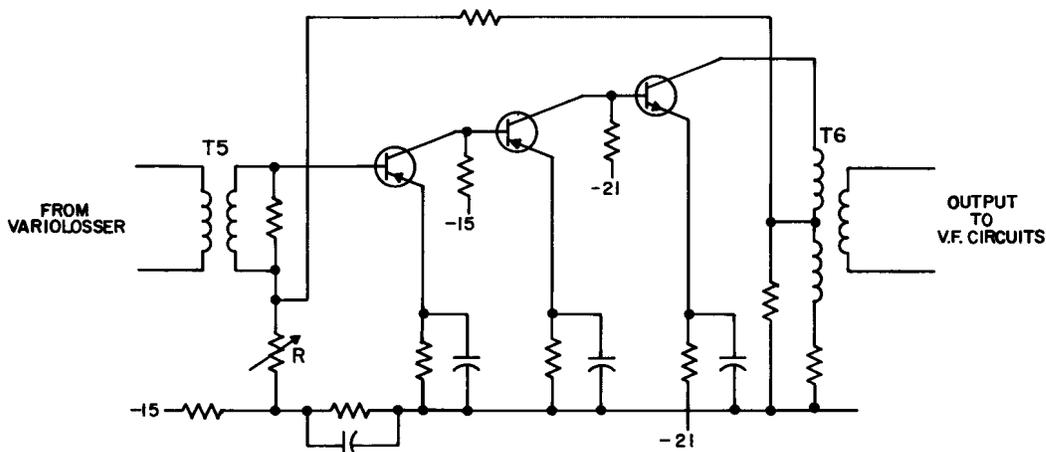


Fig. 13 - N3 Amplifier for Expander

livered to the voice-frequency circuit via transformer T6. To obtain a satisfactory output impedance with maximum transfer of power to the connected voice-frequency circuit, a hybrid transformer feedback connection is used. A fraction of the output voltage is fed back to the input circuit. Negative feedback action produces an over-all voltage gain determined almost entirely by the feedback circuit. The required gain is achieved by adjusting the OUT ADJ control which changes the magnitude of variable resistor R. This is a screwdriver adjustment which is made from the front panel. Adjustment of the bias currents of the transistors is made during factory tests.

#### 4. TESTING AND MAINTENANCE FEATURES

##### A. N3 Carrier Compandor — External Connections

4.01 A complete 24-channel N3 carrier terminal may include 24 compandor units, each unit consisting of one compressor and one expander. The compandors are interchangeable plug-in units, all interconnecting wiring being made through a 20-contact plug which is part of the printed circuit board. The plug terminal assignments are shown in the following table:

PIN	ASSIGNMENT
1	Shield of frame ground
2 and 3	Compressor input pair
4, 5, and 6	No connection
7	Diode test, compressor
8	Bias test, compressor output transistor
9	Compressor output
10	No connection
11	-21 volts
12	No connection
13	Circuit ground
14	Bias test, expander output transistor
15 and 16	Expander output pair
17	Bias test, expander control amplifier output transistor
18 and 19	Expander input pair
20	Diode test, expander

##### B. Test Points and Adjustments

4.02 Relative to system "zero level," the level of the compressor input is -16 db, and the level of the expander output is normally +7 db. Two pairs of pin jacks mounted on the front panel permit observing transmission signals at these points while adjusting levels. A screwdriver adjustment, located on the front panel and marked OUT ADJ, can be used to adjust the gain of the expander amplifier and thus the output level.

##### C. Trouble-clearing Procedure

4.03 It is expected that a trouble found to arise in the compandor will be cleared by removing the unit assembly and replacing it with a trouble-free spare unit.

#### 5. TRANSMISSION PERFORMANCE

##### A. Frequency Characteristic

5.01 Several components contribute to the over-all voice-frequency transmission characteristic of an N3 channel. The transformers in the compressor and expander units contribute to the losses at frequencies below 100 cps. Fig. 14 shows the transmission characteristic of a typical unit at low voice frequencies for a compressor and an expander connected in tandem. The high-frequency response of a channel is determined by other circuits, such as the modem, and not by the compandor.

##### B. Input-Output Load Characteristic

5.02 An idealized pair of compressor and expander characteristics would be complementary, that is, the total transmission gain through the two devices connected in tandem would be constant. The extent to which this ideal is realized is shown by the transmission characteristics shown in Fig. 3. The departure of the over-all compandor characteristic from a straight line is called the tracking error. Fig. 15 shows a typical deviation from the ideal characteristic for a tandem combination of a compressor and an expander.

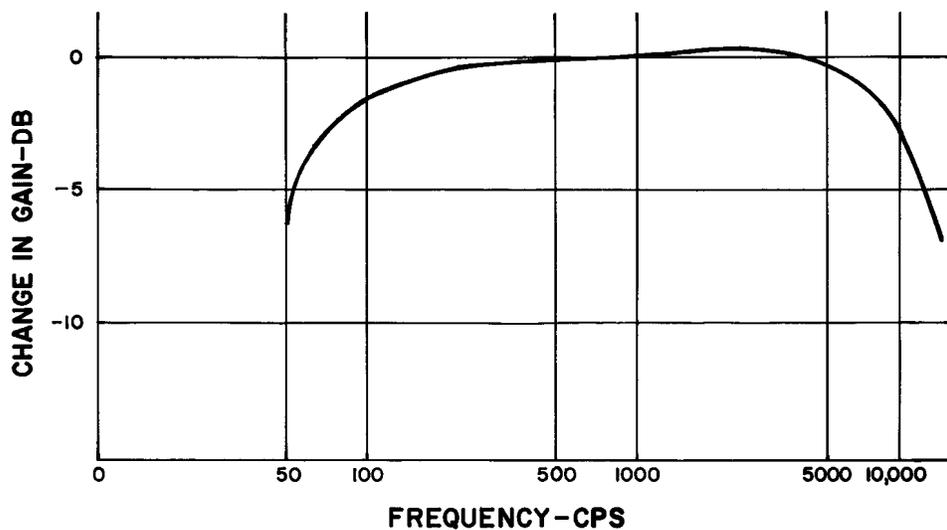


Fig. 14 - N3 Compressor Characteristic

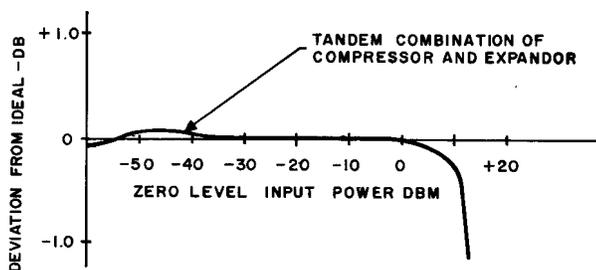


Fig. 15 - Typical Deviation from an Ideal N3 Characteristic

6. DRAWINGS

6.01 The following schematic drawings (not attached) provide detailed information.

TITLE	NUMBER
Compressor Circuit	SD-97174-01
	SD-97174-02

6.02 The following equipment drawing (not attached) provides detailed information.

TITLE	NUMBER
Compressor Unit	J99300AA-( )