

COMMON SYSTEMS
"N2" CARRIER TELEPHONE
COMPANDOR CKT

CHANGES

B. Changes in Apparatus

B.1 The changes in apparatus depend upon the vintage of equipment being modified. Refer to issue 17B of the schematic.

D. Description of Changes

D.1 The AE, AF, and AG options were added to cover all of the apparatus changes necessary in order to repair existing field units. The J, K, L, M, N, Y, Z, and AE options are rated "Mfr Disc." and the AF and AG options are rated "AT&TCo Standard."

D.2 Note 105 was added.

D.3 The tables for record of figures, wiring, and apparatus changes and for figures and options were revised to include added options.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT 4724-NLM-OLW

COMMON SYSTEMS
"N2" CARRIER TELEPHONE
COMPANDOR CKT

CHANGES

D. Description of Changes

D.1 In Fig. 2, the following changes were made:

- (a) The KS-19606 List 1 potentiometer R48, which was incorporated in the J99272E units in 1964, is shown on a "line-out" basis to correct an error.
- (b) The KS-16752 List 6 potentiometer R48 is changed to a KS-16752 List 10 potentiometer on a "line-out" basis.
- (c) The KS-16752 List 6 and the KS-19606 List 1 potentiometers are rated "Mfr Disc."

Bell Telephone Laboratories, Incorporated

Dept 4724-LAF-OLW

CIRCUIT DESCRIPTION

CD-95294-01
Issue 2A
Appendix 13D
Dwg Issue 15D

COMMON SYSTEMS
"N2" CARRIER TELEPHONE
COMPANDOR CKT

CHANGES

D. Description of Changes

D.1 To change the rating of the drawing from
"AT&TCo Standard" to "Mfr Disc."

Bell Telephone Laboratories, Incorporated

Dept 2169-LAF-OLW

COMMON SYSTEMS
N2 CARRIER TELEPHONE
COMPANDOR CIRCUITCHANGESB. Changes in Apparatus

B.1 In Appendix 10B, Section B.1, options AA and AB were omitted from the list of changes in apparatus and should be added as follows:

<u>Apparatus</u>	<u>Removed</u>	<u>Replaced by</u>
R12, KS-13490, L1	5,100 ohms AA option	2,400 ohms AB option
R16, KS-13490, L1	10,000 ohms AA option	4,700 ohms AB option

D. Description of Changes

D.1 In Appendix 10B, Section D.2, option AC was erroneously referred to as AI.

D.2 Option AC (addition of RV1) which was covered in the previous drawing, 12B (Appendix 10B), is being upgraded to an AB change.

BELL TELEPHONE LABORATORIES, INCORPORATED
DEPT 2192-WPK-AJG

COMMON SYSTEMS
N2 CARRIER TELEPHONE
COMPANDOR CIRCUITCHANGESB. Changes in Apparatus

B.1	Apparatus	Removed	Replaced by
	J1, J2 Jacks	KS-14523, L1	KS-14523, L13
	J3, J4 Jacks	KS-14532, L1	KS-14523, L9
	R4 Res KS-13490, L1	20 ohms	30 ohms
	R5 Res KS-13490, L1	20 ohms	30 ohms
	R13 Res KS-13490, L1	2,400 ohms	1,100 ohms
	R14 Res KS-13490, L1	7,500 ohms	10,000 ohms
	R15 Res KS-13490, L1	3,600 ohms	8,200 ohms
	T1 Transf	2586E	2586M

B.2 Added

1 - 100D Var, RV1

D. Description of Changes

- D.1 Options AA and AB were added to cover the changes in resistors R13, R14, and R15. Option AA is rated Mfr Disc., and option AB is rated Standard.
- D.2 Option AI was added to cover the addition of RV1.
- D.3 Options Y and Z were added to cover the changes in resistors R4 and R5. Option Y is rated Mfr Disc., and option Z is rated Standard.
- D.4 Option AD was added to cover the change in transformer T1, option B was rated A&M Only, and option AD is rated Standard.
- D.5 Note 201 was changed to include the 434B diode.
- D.6 Note 203 was changed to include option Z.
- D.7 Note 205 was added to cover options AA and AB.
- D.8 Note 104 was changed to include option AD.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT 2192-WPK-AJO

COMMON SYSTEMS
N2 CARRIER TELEPHONE
COMPANDOR CIRCUIT

CHANGES

B. CHANGES IN APPARATUS

B.1	<u>Apparatus</u>	<u>Removed</u>	<u>Replaced by</u>
	R32,221A	38,300 ohm	56,200 ohm

D. DESCRIPTION OF CHANGES

D.1 This change has been made to provide optional connection of R32 to improve uniformity of fixed current through CR1.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT 2192-JHJ-AJG

COMMON SYSTEMS
"N2" CARRIER TELEPHONE
COMPANDOR CKTCHANGES

B. CHANGES IN APPARATUS

B.1	Apparatus	Removed	Replaced by
	C4 - KS-16390, L5	100 μ f	-
	C5	100 μ f KS-16390, L5	200 μ f KS-16390, L7
	Q1	12B	12M
	R79, 10,000 Ω	KS-13806, L12	KS-13806, L15

B.2 Apparatus Added

1 - C34, 542AA, 0.0215 μ f

D. DESCRIPTION OF CHANGES

D.1 Options P and Q were added to cover the change of R79. P was rated Mfr Disc., and Q was rated Standard.

D.2 Option R and S were added to cover change of C4 and C5. R was rated Mfr Disc., and S was rated Standard.

D.3 Option U and V were added to cover change of Q1 from a 12B to a 12M. U was rated Mfr Disc., and V was rated Standard.

D.4 Option T was added to cover capacitor C34 which was added.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT 2192-WFK-AJG

CIRCUIT DESCRIPTION

CD-95294-01
Issue 2A
Appendix 7AR
Dwg Issue 9AR

**COMMON SYSTEMS
"N2" CARRIER TELEPHONE
COMPANDOR CKT**

CHANGES

B. CHANGES IN APPARATUS

<u>B.1 Apparatus</u>	<u>Removed</u>	<u>Replaced by</u>
1 - Transistor Q6	24B	24A

All other headings under CHANGES, no change.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT 2192-WPK-AJD

COMMON SYSTEMS
 "N2" CARRIER TELEPHONE
 COMPANDOR CKT

CHANGES

B. CHANGES IN APPARATUS

B.1

Apparatus	Removed	Replaced by
C2 KS-14056,L2	6.8 uuf	20 uuf
CR1	434A-II	434B-II
CR5	434A-I	434B-I
R7, 221A	0.121 meg	0.107 meg
R52, 221A	3320	3480
R81	8200 KS-13490,L1	
R82	33,000 KS-13490,L1	
R83	68,000 KS-13490,L1	
R85	16,000 KS-13490,L1	

B.2 Apparatus Added

- 1 - R78, 3600 ohms, KS-13490, L1
- 1 - R79, 10,000 ohms, KS-13806, L12

B.3 Apparatus Changed

All resistors previously designated KS-13490, L1 are now KS-16645, L1 except:

Resistors R50, R51, R56, R57, R62, R73, and R75.

D. DESCRIPTION OF CIRCUIT CHANGES

D.1 Options "M" and "N" were added to cover the change of CR1 and CR5. "M" was rated Mfr Disc. and "N" was rated Standard.

D.2 Option "L" was rated Mfr Disc. and was previously replaced by option "N".

D.3 Note 102 was changed to correspond to the apparatus changes under B3.

D.4 A manufacturing circuit adjustment provided by straps M1, M2, and M3 with resistors R81, R82, R83, and R85 was rated Mfr Disc. (option "M") and replaced by the potentiometer R79 and resistor R78 (option "N").

All other headings under CHANGES, no change.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT 2192-WPK-AJO

COMMON SYSTEMS
 "N2" CARRIER TELEPHONE
 COMPANDOR CKT

CHANGES

B. CHANGES IN APPARATUS

<u>B.1 Apparatus</u>	<u>Removed</u>	<u>Replaced by</u>
1 - R46 Res	221A 127 ohms	221A 100 ohms
1 - R51 Res	KS-13490, L1 5600 ohms	KS-13490, L1 7500 ohms
1 - R54 Res	221A 4220 ohms	221A 3320 ohms

D. DESCRIPTION OF CIRCUIT CHANGES

D.1 "L" option was added to cover B.1 above. "K" option was previously shown and is now rated Mfr Disc.

D.2 Notes 203 and 204 were added.

All other headings, no change.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT 2192-WPK-AJG

CIRCUIT DESCRIPTION

CD-95294-01
Issue 2A
Appendix 4B
Dwg Issue 6B

COMMON SYSTEMS
"N2" CARRIER TELEPHONE
COMPANDOR CIRCUIT

CHANGES

B. CHANGES IN APPARATUS

B.1	<u>Apparatus</u>	<u>Removed</u>	<u>Replaced by</u>
1	- R46 Res	KS-13490 L1 160 ohms	221A 127 ohms
1	- R51 Res KS-13490 L1	4700 ohms	5600 ohms
1	- R54 Res 221A	5110 ohms	4220 ohms

D. DESCRIPTION OF CIRCUIT CHANGES

D.1 "J" and "K" options were added to cover B.1 above. "J" was previously shown and now rated Mfr Disc.

All other headings, no change.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT 2192-WPK-AJO

COMMON SYSTEMS
"N2" CARRIER TELEPHONE
COMPANDOR CKT

CHANGES

B. CHANGES IN APPARATUS

B.1 Superseded	Superseded by
1-Res(R68) 6190 221A	1-Res(R68) 5620 221A

D. DESCRIPTION OF CIRCUIT CHANGES

D.1 "G and H" options were added to cover
B.1 above. "G" option only was pre-
viously shown and not rated "Mfr. Disc."

All other headings, No change.

WEST TELEPHONE LABORATORIES, INCORPORATED

DEPT. 2172-WFK-AJG-TB

COMMON SYSTEMS
"N2" CARRIER TELEPHONE
COMPANDOR CKT.

CHANGES

B. CHANGES IN APPARATUS

B.1 Superseded	Superseded by
1-Transistor (Q4) 12B	1-Transistor (Q4) 12M
1-Transformer (T1) 2586A	1-Transformer (T1) 2586E
1-Transformer (T2) 2586B	1-Transformer (T2) 2586F

D. DESCRIPTION OF CIRCUIT CHANGES

D.1 Note 202 was added to describe transistor (Q4) change.

D.2 "A", "B" and "E", "F" options were added to cover B.1 above. "A" and "E" options only were previously shown and not rated "Mfr. Disc."

D.3 Note 104 was added

All other headings, No change.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT 2172-WPK-AJG-BD

COMMON SYSTEMS
"N2" CARRIER TELEPHONE
COMPANDOR CKT.

CHANGES

B. CHANGES IN APPARATUS

B.1 Removed

1-Res. (R7)
145A
0.121 Meg Ω

1-Res. (R12)
KS-13490, L1
20,000 Ω

1-Res. (R18)
KS-13490, L1
10 Ω

1-Res. (R28)
221A
3830 Ω

1-Res. (R50)
KS-13490, L1
20,000 Ω

Replaced by

1-Res. (R7)
221A
0.121 Meg Ω

1-Res. (R12)
KS-13490, L1
5,100 Ω

1-Res. (R18)
KS-13490, L1
33 Ω

1-Res. (R28)
221A
9090 Ω

1-Res. (R50)
KS-13490, L1
5,100 Ω

Removed

1-Res. (R81)
KS-13490, L1
11,000 Ω

1-Res. (R84)
221A
38,300 Ω

Replaced by

1-Res. (R81)
KS-13490, L1
8,200 Ω

1-Res. (R84)
221A
31,600 Ω

B.2 Added

1-Res. (R85)
KS-13490, L1
16,000 Ω

D. DESCRIPTION OF CIRCUIT CHANGES

D.1 Strap M3 was added.

D.2 Note 201 was added.

D.3 Note 101 was revised to include Strap M3.

All other headings, No change.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT 2172-WPK-AJG-ED

COMMON SYSTEMS
"N2" CARRIER TELEPHONE
COMPANDOR CKT

SECTION I - GENERAL DESCRIPTION

1. GENERAL

1.1 The Compandor is a single plug-in apparatus unit which comprises two complementary devices, a Compressor and an Expander, which function independently except for a common connection to the power supply. These devices each have the property that the gain of the circuit is made to vary in accordance with the voice frequency signal. The slowly varying envelope of the signal wave rather than the instantaneous value controls the gain in a prescribed way.

1.11 The Compressor reduces the volume range of the voice frequency signal, the action being such that the output power increases 1 db for each 2 db increase in the input power. The changes occur at the syllabic frequency rate of the voice frequency signal.

1.12 The Expander increases the volume range of the voice frequency signal, the action being such that the output power increases 2 db for each 1 db increase in the input power. The changes occur at the syllabic frequency rate of the voice frequency signal.

1.13 Both compression and expansion are accomplished by inserting in the circuit a Variolossor. This device is a variable attenuator which causes the voice frequency signal to be attenuated as required above. The action is controlled by a slowly varying current derived from the envelope of the voice frequency signal.

1.14 The Compandor is energized by an external power supply which is regulated to -21 volts. The -24 volt plant battery is the primary source of power. A regulated -15 volt source with additional noise filtering for a quiet bias supply is an integral part of the unit.

2. FUNCTIONAL CHARACTERISTICS

2.1 The inclusion of Compandors in the terminal equipment of the "N2" Carrier Telephone System yields an improvement in the amount of noise and crosstalk which can be tolerated in the transmission medium. Weak speech volumes, being most susceptible to system disturbances, are carried at a relatively higher level over the intervening

noisy medium. Strong speech volumes need less increase in proportion to the volume. Thus, the need for crosstalk balancing of the line is eliminated; filter discrimination requirements can be reduced; and signal levels can be raised without undue interference.

2.11 The Compressor reduces the volume range of the voice frequency signal before modulation in the transmitting terminal. It receives inputs within the range 250 to 3250 cps from a trunk circuit through a 4 wire terminating network and delivers an output having a compressed volume range to the channel modulator. The input to the Compressor is a balanced 600 ohm impedance suitable for connection to the hybrid transformer. The unit accepts voice frequency signals having power levels between -8 dbm and -68 dbm measured at the input transformer terminals and delivers a voice frequency signal having a volume range of 30 db after compression.

2.12 The Expander increases the volume range of the voice frequency signal after demodulation in the receiving terminal. It receives inputs within the range of 250 to 3250 cps from a channel demodulator through a band pass filter, and delivers an output to a trunk circuit through a 4 wire terminating network. The Expander restores to the original volume range the voice frequency signal, thus complementing the action of the Compressor. The output of the Expander is a balanced 600 ohm impedance suitable for connection to the hybrid transformer. The unit accepts voice frequency signals having a compressed volume range of 30 db and delivers a voice frequency signal having power levels between +18 dbm and -42 dbm measured at the transformer terminals.

2.13 Both the Compressor and the Expander require Variolossors to achieve the required compression and expansion of the signal volume. A Variolossor being a non-linear device, a low volume for the voice frequency signal is necessary in order to avoid introducing intolerable harmonic and intermodulation distortion due to its non-linear elements. The Variolossor in the Expander receives signals at the required low level, but the Variolossor in the Compressor is preceded by a fixed attenuator which reduces the signal to the appropriate low level. In both the Compressor and the Expander, the Variolossor is

followed by a high-gain negative feedback amplifier. These amplifiers compensate for the losses introduced by the fixed pad and by the transmission medium, respectively; and restore the voice frequency signal to the proper level.

SECTION II - DETAILED DESCRIPTION

1. GENERAL

Although a complete design theory for either a Compressor or an Expander requires precise mathematical relationships, the essential features can be placed in evidence by describing three parts separately:

- (1) Variolossor
- (2) Control Circuit
- (3) Amplifier

1.1 Variolossor

1.1.1 A Variolossor is a network having a varistor, i.e., 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 whose magnitude depends upon the bias current rather than the signal current.

(1) Varistor

A silicon diode has a nonlinear relationship between the current and the voltage across the terminals, i.e.,

$$I = I_s \left[\exp\left(\frac{q}{kT} V\right) - 1 \right]$$

If the voltage drop, V, is positive and greater than a few tenths of a volt, a satisfactory approximation is to assume that V is proportional to Log I and the significance of the several constants is not important.

When the total current is a combination of a relatively large unidirectional bias current and a small voice frequency signal current, the ac resistance of the varistor is inversely proportional to the bias current. (The ac resistance is the ratio of the incremental change in voltage to the small change in current that produced it; i.e., it is the slope of the V vs. I characteristic at a point determined by the bias current.)

If R_0 and I_0 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

$$\left(\frac{R}{R_0}\right) = \left(\frac{I_0}{I}\right) \tag{1}$$

(2) The Compressor employs a Variolossor having the varistor connected as a shunt element. If R represents the ac resistance of a varistor shunted across a voice frequency signal circuit, and if Z_1 and Z_2 represent the input and output signal 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 db, is

$$X \approx 10 \text{ Log}_{10} \left| \frac{Z_1}{R} \right|^2$$

If X_0 and R_0 represent Variolossor attenuation in db and varistor resistance in ohms for an initial reference condition, and if X and R represent the same quantities for any other condition, the loss equation is

$$(X-X_0) = 10 \text{ Log}_{10} \left(\frac{R_0}{R}\right)^2$$

Since R and R_0 are related to the control current according to equation (1), the equation for the loss introduced by the Variolossor in the Compressor is

$$(X-X_0) = + 10 \text{ Log}_{10} \left(\frac{I}{I_0}\right) \tag{2}$$

(3) The Expander employs a Variolossor having the varistor connected as a series element. If R represents the ac resistance of a varistor inserted in a voice frequency signal circuit, and if Z_1 and Z_2 represent the input and output signal circuit impedances, respectively,

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

COMMON SYSTEMS
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COMPANDOR CKT

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1.14 The Compandor is energized by an external power supply which is regulated to -21 volts. The -24 volt plant battery is the primary source of power. A regulated -15 volt source with additional noise filtering for a quiet bias supply is an integral part of the unit.

2. FUNCTIONAL CHARACTERISTICS

2.1 The inclusion of Compandors in the terminal equipment of the "N2" Carrier Telephone System yields an improvement in the amount of noise and crosstalk which can be tolerated in the transmission medium. Weak speech volumes, being most susceptible to system disturbances, are carried at a relatively higher level over the intervening

noisy medium. Strong speech volumes need less increase in proportion to the volume. Thus, the need for crosstalk balancing of the line is eliminated; filter discrimination requirements can be reduced; and signal levels can be raised without undue interference.

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2.13 Both the Compressor and the Expander require Variolossors to achieve the required compression and expansion of the signal volume. A Variolossor being a non-linear device, a low volume for the voice frequency signal is necessary in order to avoid introducing intolerable harmonic and intermodulation distortion due to its non-linear elements. The Variolossor in the Expander receives signals at the required low level, but the Variolossor in the Compressor is preceded by a fixed attenuator which reduces the signal to the appropriate low level. In both the Compressor and the Expander, the Variolossor is

followed by a high-gain negative feedback amplifier. These amplifiers compensate for the losses introduced by the fixed pad and by the transmission medium, respectively; and restore the voice frequency signal to the proper level.

SECTION II - DETAILED DESCRIPTION

1. GENERAL

Although a complete design theory for either a Compressor or an Expander requires precise mathematical relationships, the essential features can be placed in evidence by describing three parts separately:

- (1) Variolossor
- (2) Control Circuit
- (3) Amplifier

1.1 Variolossor

1.1.1 A Variolossor is a network having a varistor, i.e., 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 whose magnitude depends upon the bias current rather than the signal current.

(1) Varistor

A silicon diode has a nonlinear relationship between the current and the voltage across the terminals, i.e.,

$$I = I_s \left[\exp\left(\frac{q}{kT} V\right) - 1 \right]$$

If the voltage drop, V, is positive and greater than a few tenths of a volt, a satisfactory approximation is to assume that V is proportional to Log I and the significance of the several constants is not important.

When the total current is a combination of a relatively large unidirectional bias current and a small voice frequency signal current, the ac resistance of the varistor is inversely proportional to the bias current. (The ac resistance is the ratio of the incremental change in voltage to the small change in current that produced it; i.e., it is the slope of the V vs. I characteristic at a point determined by the bias current.)

If R_0 and I_0 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

$$\left(\frac{R}{R_0}\right) = \left(\frac{I_0}{I}\right) \quad (1)$$

(2) The Compressor employs a Variolossor having the varistor connected as a shunt element. If R represents the ac resistance of a varistor shunted across a voice frequency signal circuit, and if Z_1 and Z_2 represent the input and output signal 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 db, is

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

If X_0 and R_0 represent Variolossor attenuation in db and varistor resistance in ohms for an initial reference condition, and if X and R represent the same quantities for any other condition, the loss equation is

$$(X - X_0) = 10 \text{ Log}_{10} \left(\frac{R_0}{R} \right)^2$$

Since R and R_0 are related to the control current according to equation (1), the equation for the loss introduced by the Variolossor in the Compressor is

$$(X - X_0) = + 10 \text{ Log}_{10} \left(\frac{I}{I_0} \right) \quad (2)$$

(3) The Expander employs a Variolossor having the varistor connected as a series element. If R represents the ac resistance of a varistor inserted in a voice frequency signal circuit, and if Z_1 and Z_2 represent the input and output signal 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 db, is

$$X = 10 \log_{10} \left| \frac{R}{Z_2} \right|^2$$

If X_0 and R_0 represent variolossler attenuation in db and varistor resistance in ohms for an initial reference condition, and if X and R represent the same quantities for any other condition, the loss equation is

$$(X - X_0) = 10 \log_{10} \left(\frac{R}{R_0} \right)^2$$

Since R and R_0 are related to the control current according to equation (1), the equation for the loss introduced by the Variolossler in the Expander is

$$(X - X_0) = -10 \log_{10} \left(\frac{I}{I_0} \right)^2 \quad (3)$$

1.2 Control Circuit

1.2.1 The Control Circuit for the Variolossler employs a peak-type rectifier which charges a capacitor to the peak voltage of the voice frequency signal. If the capacitor is charged through a relatively low resistance circuit and is allowed to discharge through a high resistance, the charging and discharging time constants can be adjusted so that the output current is proportional to the voltage of the envelope of the voice frequency signal. Thus, the derived control current is proportional to the square root of the signal power. If P_0 and I_0 represent the signal power in db and the control current in amperes for an initial reference condition, and if P and I represent the same quantities for any other condition, the equation describing the action of the Control Circuit is

$$10 \log_{10} \left(\frac{I}{I_0} \right)^2 = (P - P_0) \quad (4)$$

Since the Variolossler requires very low signal levels to avoid intolerable intermodulation distortion, both the input and the output power are small. Therefore, amplification is necessary between the Variolossler and the rectifier in the Control Circuit.

(1) Variolossler and Control Circuit

The important properties of a Variolossler and its Control Circuit in combination can be placed in evidence in the following simple way:

Let P_{10} , P_{20} and X_0 represent the input power, output power and variolossler attenuation for an initial reference condition. Also let P_1 , P_2 and X represent the same quantities for any other condition. If all quantities are expressed in db, the transmission equation for the Variolossler is

$$(P_2 - P_{20}) = (P_1 - P_{10}) - (X - X_0) \quad (5)$$

(2) Compressor

The Compressor having a backward acting control circuit, the changes in attenuation in the Variolossler are dependent upon the changes in output power. The desired two-to-one compression can be achieved if the change in attenuation is in the same sense and is equal to the change in output power; i.e.,

$$(X - X_0) = + (P_2 - P_{20}) \quad (6)$$

Substituting this equation into equation (5), the transmission equation for the Compressor becomes

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

Equations (2) and (4) can be combined to form equation (6); therefore, a shunt type Variolossler in combination with a backward acting control circuit will have the desired two-to-one compression characteristic.

(3) Expander

The Expander having a forward acting control circuit, the changes in attenuation in the Variolossler are dependent upon the changes in input power. The desired one-to-two expansion can be achieved if the change in attenuation is in the opposite sense and is equal to the change in input power; i.e.,

$$(X - X_0) = - (P_1 - P_{10}) \quad (8)$$

Substituting this equation into equation (5), the transmission equation for the Expander becomes

$$(P_2 - P_{20}) = + 2(P_1 - P_{10}) \quad (9)$$

Equations (3) and (4) can be combined to form equation (8); therefore, a series type Variolossor in combination with a forward acting control circuit will have the desired one-to-two expansion characteristic.

1.3 Amplifier

1.31 The Compander unit includes three high-gain negative feedback amplifiers which increase the voice frequency signal power to the levels required in the system.

(1) Compressor Amplifier

(2) Expander Amplifier

(3) Control Amplifier

(1) Compressor Amplifier

The Compressor Amplifier receives the low level voice frequency signals from the Variolossor and develops voltages between 0.1 and 8.5 volts RMS across the modulator input terminals. This amplifier also functions as a control amplifier since the backward acting control circuit required for the Variolossor is connected to the Compressor Amplifier output rather than the Variolossor output.

(2) Expander Amplifier

The Expander Amplifier receives low level voice frequency signals from the demodulator through the Variolossor, and delivers power to the line at levels between +18 dbm and -42 dbm.

(3) Expander Control Amplifier

The input to the Variolossor is very low level and a Control Amplifier is necessary in the forward acting control circuit for the Expander. This amplifier receives power from the line and develops sufficient voltage across the rectifier to provide the necessary control current for the Variolossor.

(4) Stability of Amplifiers

The speech amplifiers are high-gain negative feedback amplifiers. The loop gain is provided by three transistors used in the common emitter connection. Since the current gain of a transistor may vary between wide limits, i.e., -50% to +200%, the provision of a loop that is always stable in the Nyquist sense is essential.

In general, the slope of loop gain (db vs. $\log f$) must be controlled below as well as above the voice frequency band. The low-frequency cutoff is shaped by choosing appropriate capacitors to by-pass the emitter and base bias resistors. The high-frequency cutoff is shaped by adding two RC shunts, one on transistor (Q2) and one on transistor (Q3). The design objective is to obtain 45 degrees phase margin and 20 db attenuation margin.

2. SPECIFIC

The Compander schematic circuit drawing has been presented as two figures for convenient reference although all components have been assembled as a single apparatus unit.

(1) Compressor Circuit

Fig. 1, Fig. 101

(2) Expander Circuit

Fig. 2, Fig. 102

2.1 Compressor Circuit, (Fig. 1, Fig. 101.)

2.11 Voice frequency signals from a balanced pair are received via terminals (3,5) and are transmitted to the modulator via terminals (7,13) of the plug (P1) which is located at the rear of the unit. Pin jacks (C1 and C2), (J1, J2) are located on the front panel and can be used to monitor and measure the voice frequency input.

2.12 Power to energize the transistors is received from the Power Supply Unit via terminals (11,13) of plug (P1). The nominal voltage for terminal (11) is -21 volts dc measured with respect to ground on terminal (13). A source of reduced voltage having relatively low noise components is provided as part of the Compander equipment. Resistor (R38) and avalanche diode (CR2) form a voltage regulator which reduces the -21 volt supply to approximately -15 volts. In combination with capacitor (C18) and resistor (R20), this circuit reduces the noise from the main power supply.

2.13 Two terminals are used for factory testing: terminal (2) is the Diode Test point which is used to measure the output voltage of the Control Rectifier; and terminal (8) is the Bias Test point which is used to measure the emitter voltage on transistor (Q3). Straps (A1) and (A2) may be cut to change the base bias voltage for (Q1), thereby adjusting the emitter current in transistor (Q3) to the optimum value. The metal frame of the subassembly is connected to terminal (1) so that the shield ground and the signal ground can be connected at the desired point in the system.

(1) Variolosses

(1a) Voice frequency signals are transmitted as a transverse voltage from the line terminals (3, 5) in plug (P1) through transformer (T1) to the balanced attenuator. The balanced attenuator consists of resistors (R1), (R2) and (R3) and the varistor circuit which includes varistor (CR1), resistors (R4) and (R5) and bypass capacitor (C1). Transformer (T2) is terminated by resistor (R6) and transmits the voice frequency signal to the amplifier input. Transformers (T1) and (T2) increase the impedances presented to the varistor by the source and load so that the desired compression characteristic can be achieved. The amount of attenuation depends upon the resistance provided by the varistor (CR1).

(1b) The Variolosses control current which is unidirectional and which contains the envelope frequency of the speech waveform is transmitted as a longitudinal current through the symmetrical varistor elements (CR1) to ground at the center-tap of transformer (T2). Resistors (R36) and (R37) make the current independent of the varistor resistance. A small bias current flowing through resistors (R34) and (R35) maintains a threshold resistance for the varistor when no voice frequency signals are being received from the line. Resistors (R28) and (R32) form a fractionating network which is used to adjust the bias current.

(1c) Transformer (T2) is well balanced with respect to the grounded center-tap and is provided with an electrostatic shield. It is essential that the balance be adequate to prevent the longitudinal control current from producing a transverse voltage across the voice frequency circuit. A feedback loop through the main amplifier and the control circuit would be unstable and would produce a "singing" condition.

(2) Amplifier

(2a) The forward gain circuit of the Compressor amplifier consists of three transistors (Q1), (Q2) and (Q3) which are all used in the common emitter connection. Resistors (R13) and (R14), together with resistors (R12) and (R16) if required, provide base bias for (Q1). Resistors (R17), (R22) and (R23) provide the proper emitter voltages for transistors (Q1), (Q2) and (Q3) respectively. Capacitors (C3), (C4), (C5), (C8) and (C11) bypass these emitter resistances at voice frequencies. These capacitors have been selected so that the transmission around the feedback loop will have a suitable phase margin to prevent instability at low frequencies. Resistors (R15), (R19) and (R21) provide the proper collector voltages for (Q1) and (Q2). Capacitor (C9) in combination with (R21) acts as a noise filter for power supply noise.

(2b) Resistors (R7) and (R8), together with (R9), (R10) and (R11) if required, form the feedback path which is used to adjust the gain to the required value. Resistor (R18) and capacitor (C7) are used to control the phase margin for the feedback loop. Resistor (R24) and capacitor (C13) serve a like purpose and also serve to bypass transformer (T3) at frequencies well above the voice frequency range. Capacitor (C2) removes loss from the feedback circuit at high frequencies. These capacitors have been selected so that the transmission around the feedback loop will have a suitable phase margin to prevent instability at high frequencies.

(3) Control Circuit

(3a) Transformer (T3) steps up the signal voltage before rectification. It also presents an appropriate load impedance to transistor (Q3) to insure maximum power output. Diodes (CR3) and (CR4) in combination with capacitors (C15) and (C16) and the control circuit resistance form a voltage doubling rectifier circuit which delivers a control current proportional to the envelope of the voice frequency wave. Capacitor (C12) blocks a small dc voltage which might otherwise affect the modulator.

2.2 Expander Circuit, (Fig. 2, Fig. 102).

2.21 Voice frequency signals from the demodulator are received via terminals (17), (19) and are transmitted to a balanced line via terminals (9, 15) of the plug (P1) which is located at the rear of the unit. Pin jacks (E1 and E2), (J3, J4) are located on the front panel and can be used to monitor and measure the voice frequency input.

2.22 Three terminals are used for factory testing: terminal (14) is the Bias Test point which is used to measure the emitter voltage on transistor (Q6); terminal (18) is the Bias Test point which is used to measure the emitter voltage on transistor (Q8); and terminal (20) is the Diode Test point which is used to measure the output voltage of the Control Rectifier. Straps (P1) and (P2) may be cut to change the base bias voltage for (Q4), thereby adjusting the emitter current in transistor (Q6) to the optimum value. The base bias voltage for (Q7) is not adjustable, but the emitter voltage for (Q8) should be measured to assure that the emitter current is within appropriate limits.

(1) Variolosses

(1a) Voice frequency signals are transmitted as a transverse voltage from the input terminals (17, 19) in plug (P1) through transformer (T4) to the balanced attenuator. Transformer (T4) also transmits the voice frequency signals to the

control amplifier circuit. The balanced attenuator consists of resistors (R41), (R42), (R43) and (R44) and the varistor circuit which includes varistor (CR5), transformer (T5) and bypass capacitor (C19). Transformer (T5) is terminated by resistor (R45) and transmits the voice frequency signal to the amplifier input. Transformers (T4) and (T5) decrease the impedances presented to the varistor by the source and load so that the desired expansion characteristic can be achieved. The amount of attenuation depends upon the resistance provided by the varistor (CR5).

(1b) The Variolossor control current which is unidirectional and which contains the envelope frequency of the speech waveform is transmitted as a longitudinal current through transformer (T5) and the symmetrical varistor elements (CR5) to ground at the junction of resistors (R44). Resistors (R88) and (R89) make the current independent of the varistor resistance. A small bias current flows through the varistor as a result of introducing a voltage between the rectifier and ground. This voltage is obtained from the voltage divider formed by (R84) and a selected parallel combination of (R81), (R82) and (R83). Straps (M1) and (M2) may be cut as required to produce the desired bias voltage.

(1c) Transformer (T5) is well balanced with respect to ground and is provided with an electrostatic shield. It is essential that the balance be adequate to prevent the longitudinal control current from producing a transverse voltage across the voice frequency circuit. A feedback to the input of the control amplifier would form an unstable loop and would produce a "singing" condition.

(2) Main Amplifier

(2a) The Expander Amplifier for voice frequency signals consists of a forward gain circuit having three transistors (Q4), (Q5) and (Q6) each being used in the common emitter connection, and a feedback circuit. The feedback from the output is obtained from the unbalanced hybrid transformer (T6). The feedback is attenuated by the voltage divider formed by resistor (R32) and the combination of (R46), (R47) and (R48). The voltage fed back is added to the voltage delivered to (R45) by transformer (T5) and inserted in the base-emitter mesh. Thus, the amplifier has a hybrid output and a series input connection. The (OUT ADJ) variable resistor (R48) provides a change in gain having approximately 4.0 db range.

(2b) Resistors (R53) and (R51) together with resistors (R50) and (R56) if required, provide base bias for (Q4).

Resistors (R57), (R59) and (R64) provide the proper emitter voltages for transistors (Q4), (Q5) and (Q6) respectively. Capacitors (C20), (C21), (C24) and (C27) bypass these emitter resistances at voice frequencies. These capacitors have been selected so that the transmission around the feedback loop will have a suitable phase margin to prevent instability at low frequencies. Resistors (R55), (R62) and (R63) provide the proper collector voltages for (Q4) and (Q5). Capacitor (C26) in combination with (R63) acts as a noise filter for power supply noise. Resistor (R58) and capacitor (C23) are used to control the phase margin for the feedback loop. Resistor (R61) and capacitor (C25) serve a like purpose. Capacitor (C28) bypasses transformer (T6) at frequencies well above the voice frequency band and removes loss from the feedback path. These capacitors have been selected so that the transmission around the feedback loop will have a suitable phase margin to prevent instability at high frequencies.

(3) Control Circuit Amplifier

(3a) The level of the voice frequency signal received by the Expander is low, and amplification is required before rectification. The amplifier comprises two transistors (Q7) and (Q8), the first stage being connected as a common collector and the second stage being connected as a common emitter.

(3b) Transformer (T4) steps up the voltage and injects it into the base circuit of (Q7) as a voltage across resistor (R66). The forward gain circuit delivers an output to transformer (T7). The voltage fed back to the input base mesh is fractionated primarily by the parallel combination of (R74) and (R75) and (R68). Resistor (R75) and capacitor (C32) serve to increase the gain at low voice frequencies to compensate for losses in other circuits.

(3c) Resistor (R76) carries the emitter current of transistor (Q7) and establishes the proper base voltage for transistor (Q8). Resistor (R77) carries the emitter current of transistor (Q8) and establishes the proper voltage and current for (Q8). Capacitor (C33) bypasses the resistor at voice frequencies.

(3d) Resistors (R73), (R68) and (R74) provide suitable base bias voltage for transistor (Q7). Capacitor (C29) bypasses the resistor and the power supply impedance at voice frequencies. This capacitor in combination with (R73) reduces the noise introduced into the input mesh from the power supply.

(4) Control Circuit Rectifier

(4a) Transformer (T7) receives voice frequency signals from the Control Amplifier and steps up the voltage before

rectification. This transformer also presents an appropriate load impedance to the transistor (Q8) to insure maximum power output.

(4b) Diodes (CR7) and (CR8) in combination with capacitors (C35) and (C36) and the control circuit resistance form a voltage doubling rectifier circuit which delivers a control current proportional to the envelope of the voice frequency wave.

SECTION III - REFERENCE DATA

1. WORKING LIMITS

1.1 The voice frequency signal input to the Compressor shall be between -8 dbm and -68 dbm measured at the input transformer terminals.

1.2 The voice frequency signal input to the Expander shall be such that the output is between +18 dbm and -42 dbm measured at the transformer output terminals when connected to a 600 ohm load.

1.3 The supply voltage shall be between the limits -21 volts $\pm 2\%$ measured at the terminals in plug (P1).

1.4 The ambient temperature shall be between +40°F and +140°F.

2. FUNCTIONS

2.1 The Compressor reduces the volume range of the voice frequency signal before modulation in the transmitting terminal. The volume range after compression is 30 db.

2.2 The Expander increases the volume range of the voice frequency signal after demodulation in the receiving terminal. The volume range after expansion is 60 db.

2.3 Both circuits transmit voice frequency signals within the range 250 to 3250 cycles.

2.4 When a Compressor is followed by an Expander, the original volume is restored within ± 0.5 db.

3. CONNECTING CIRCUITS

3.1 Appl Schem "N2" Carrier Telephone terminal Bay SD-97118-01

3.2 Channel Modem Ckt. SD-95299-01

3.3 Power Supply Ckt. SD-81544-01

SECTION IV - CHANGES

A. CHANGES IN FUNCTIONS

A.1 The 2600 cps Trap Circuits (Z1) and (Z2) were removed to satisfy equipment engineering requirements. The suppression of 2600 cps tone, formerly a function provided by networks (Z1) and (Z2) of the Compressor, will be accomplished elsewhere in the system.

B. CHANGES IN APPARATUS

B.1 Removed

2 - Nets (Z1) and (Z2)
40320

B.2 Removed

Replaced by

4 - Pin Jacks (TP1), (TP2), (TP3) and (TP4).
Selectro Corp.,
SKT-10

4 - Pin Jacks (C1), (C2), (E1) and (E2) respectively.
KS-14523, L5

1 - Transf (T7)
2585A

1 - Transf (T7)
2585C

20 - Res (R2)
R3, R36, R37, R6,
R7, R8, R34, R35,
R28, R32, R66, R89,
R88, R45, R52, R54,
R84, R74, R68
145A

20 - Res (R2)
R3, R36, R37, R6,
R7, R8, R34, R35,
R28, R32, R66,
R89, R88, R45,
R52, R54, R84,
R74, R68
221A

No change in value of resistance for the above resistors.

Removed

Replaced by

2 - Res (R41) and (R42)
227A
19.6 Ω

2 - Res (R41) and (R42)
227A
5.62

1 - Res (R16)
KS-13490, L1
39000 Ω

1 - Res (R16)
KS-13490, L1
10,000 Ω

1 - Res (R46)
145A
82.5 Ω

1 - Res (R46)
KS-13490, L1
160 Ω

1 - Res (R47)
145A
187 Ω

1 - Res (R47)
KS-13490, L1
2200 Ω

1 - Res (R56)
KS-13490, L1
39000 Ω

1 - Res (R56)
KS-13490, L1
10,000 Ω

B.3 Added

- 1 - Res (R20)
KS-13490, L1
120Ω

D. DESCRIPTION OF CIRCUIT CHANGES

D.1 Fig. 101 was revised to show arrows in proper direction.

D.2 Fig. 102 was revised to show transmission in proper direction.

D.3 Designation (LEVEL ADJ) was changed to (OUT ADJ) for the (R38) pot.

All other headings, under Changes, no change.

BELL TELEPHONE LABORATORIES, INCORPORATED

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