(12) UK Patent Application (19) GB (11) 2 060 315 A

(21) Application No **8028777**
(22) Date of filing **11 Oct 1978**
Date lodged **5 Sep 1980**
(30) Priority data
(31) **841009**
(32) **11 Oct 1977**
(33) **United States of America (US)**
(43) Application published
29 Apr 1981
(51) **INT CL[3]**
H04M 19/00 1/58 1/76
(52) Domestic classification
H4K 1A10 1A11 1A12 1A2 1A5Z 1A8 BL
(56) Documents cited
GB 1538017
GB 1530089
GB 1489143
GB 1481750
GB 1434239
GB 1409299
GB 1361739
(58) Field of search
H4K
H4R
(60) Derived from Application No. 40123/78 under Section 15(4) of the Patents Act 1977

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(54) Interface circuit for telephone extension lines

(57) A telephone line circuit includes current sources (43, 44) for providing DC power to the telephone set, which are modulated by an audio signal (V_R) received from the four wire switching system, and a high impedance amplifier (52) connected to the two wire cable for providing an output signal which has a DC component and an AC component both of which are functions of the cable resistance, and therefore of the cable length. The DC component is used to control the current sources so that a constant current flows in the line, independent of the variations in line impedance, and the AC component is used to control the speech (AC) signal in the line so that they are rendered independent of line length.

Differential optical coupling circuits are used to couple the audio signal from the switching system to modulate the current sources and also to couple the microphone signal voltage to the four wire switching system.

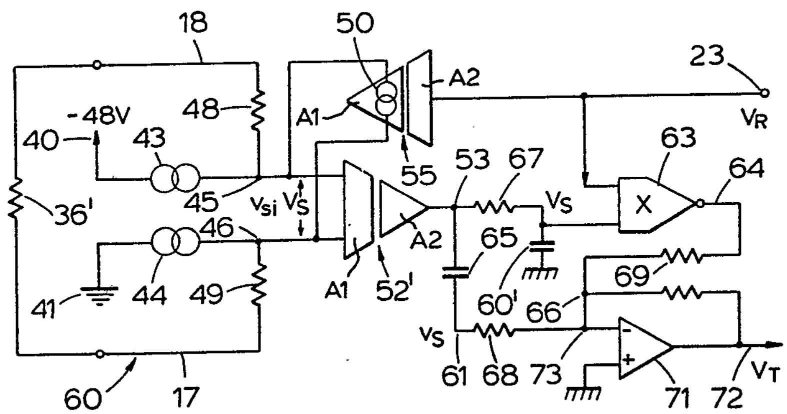

Fig.4

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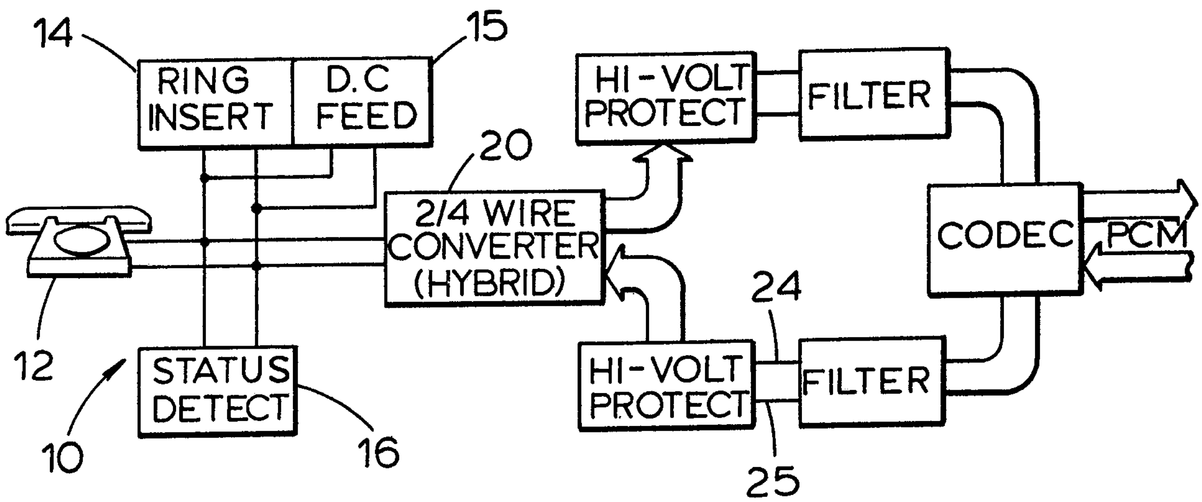
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INSERT
D.C
FEED
20
HI-VOLT
PROTECT
FILTER
2/4 WIRE
CONVERTER
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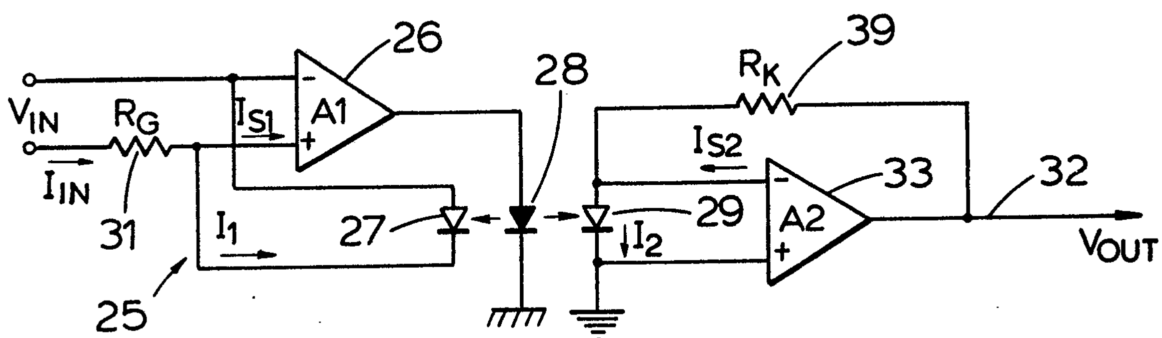
CODEC
PCM
24
12
STATUS
DETECT
HI-VOLT
PROTECT
FILTER
10
16
25

Fig.1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V_{IN}
R_G
I_{S1}
A1
I_{S2}
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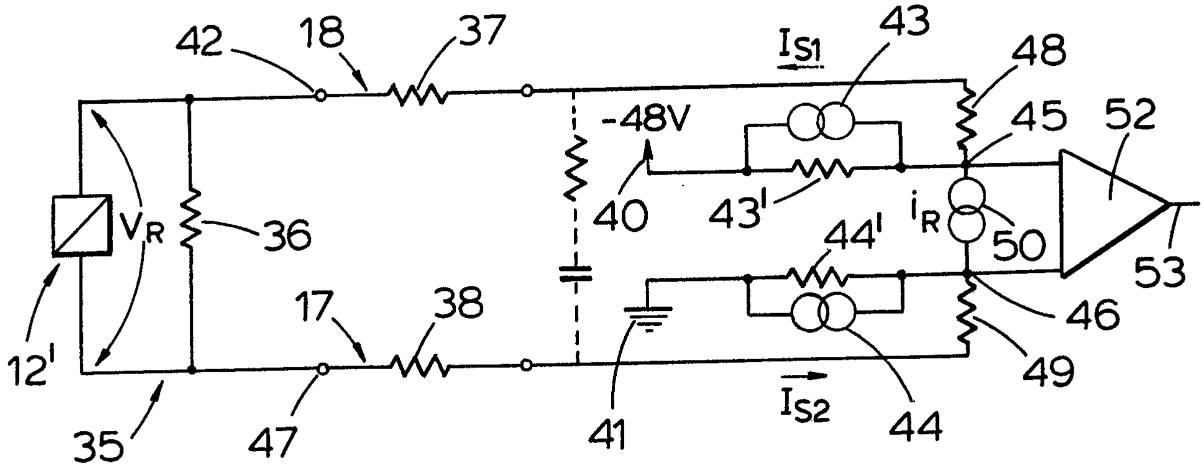
I_1
27
29
I_2
A2
V_{OUT}
25

Fig.2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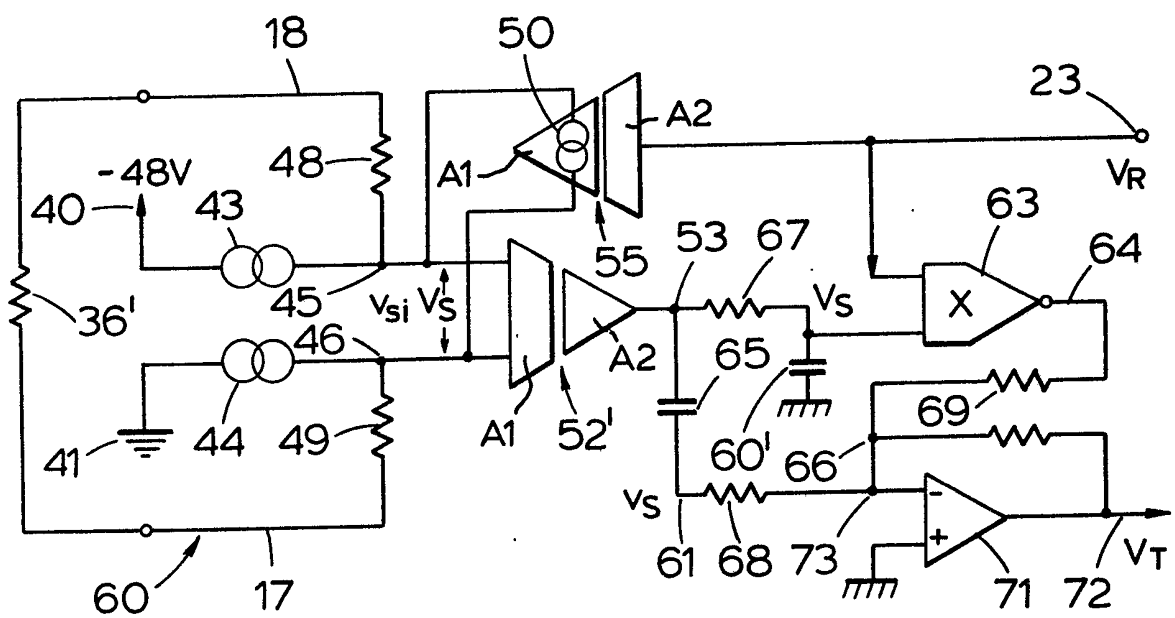
18
37
I_{S1}
43
48
-48V
45
52
V_R
36
40
43'
i_R
50
44'
53
46
17
38
12'
49
35
47
41
I_{S2}
44

Fig. 3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A2
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A1
V_R
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43
55
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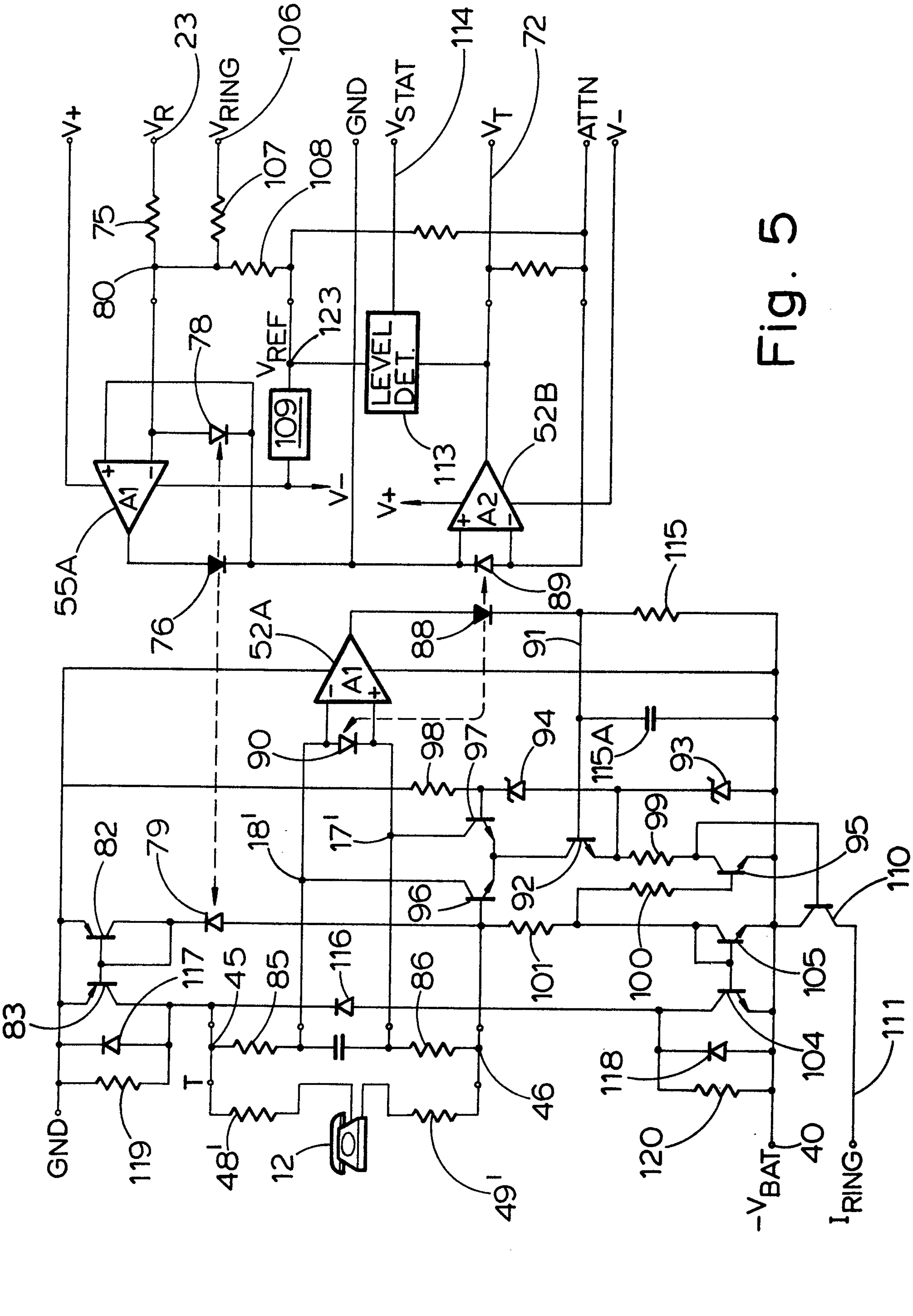
V_S
V_S
X
36'
46
65
A2
69
60'
66
41
44
49
A1
52'
V_S
V_T
61
68
73
71
72
60
17

Fig. 4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75
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55A
76
89
88
52A
91
115
90
98
97
94
115A
93
82
79
18'
17'
96
92
99
95
110
83
117
45
85
116
86
101
100
105
104
111
119
48'
12
49'
46
118
120
40
Fig. 5

SPECIFICATION

Interface circuit for telephone extension lines

The invention relates to telephone extension line circuitry and techniques for conversion of bi-directional signals on a two wire cable to uni-directional signals for a four wire switching system.

The important functions and elements of extension-line circuits include the following (see Fig. 1 of the accompanying drawings). High voltage protection devices capable of transferring voice signals to and from the four wire switching system are required to protect the electronic switching system (i.e., the PABX). The two bi-directional signals on the two wire telephone cable must be separated by means of a two-to-four wire converter 20. A power circuit 15 is required to feed DC power to the telephone set 12. The DC feed circuit must be protected against short circuits of the two wire cable. Ring insertion circuitry 14 is required which activates the ringing device in the telephone set when a ring command is sent from the electronic switching system. Finally, a means of status detection 16 is required for indicating changes in the status of the telephone set, such as on-hook and off-hook transitions.

It has been suggested to use modulated current sources to provide the DC feed to the two wire cable and to produce the incoming voice signal to provide the signal to be received by the earphone of the telephone set. However, the suggested system uses a 600 ohm cable termination, causing attenuation of the microphone output signal as a function of cable length. The previously suggested system uses optical couplers whose signal transmission characteristics are directly proportional to the light emission efficiency of light emitting diodes therein. These systems are incapable of operating within the required tolerance for telephone extension systems because of the inherent instability of presently available light emitting diodes.

An extension line interface circuit requires low echo return, which occurs when any part of the voice signal received from the electronic switching system is fed back to that four wire electronic switching system as a component of the microphone output transmitted to the electronic switching system.

Ordinarily, expensive high voltage relays are used to isolate the interface circuit from the two wire cable to allow a ring voltage to be impressed upon the ringing circuit of the telephone set in response to a ring command from the four wire switching system. The voltage applied to the ringing circuitry is ordinarily approximately 90 volts RMS at 20 Hz and may reach 120 volts in magnitude, so the high voltage relays are necessary to prevent the ringing signal from damaging the interface circuit. Static discharges on the line which would arc across the relays must be kept out of the switching circuits. According to the present invention there is provided an interface circuit for coupling a two wire cable connected to a telephone set to an electronic switching system, the interface circuit comprising means for producing a first AC signal on the two wire cable proportional to the length of the two wire cable in response to a first signal transmitted to the interface circuit by the electronic switching system; means for producing a DC voltage on the two wire cable proportional to the length of the two wire cable; means for receiving a microphone signal from the telephone set on the two wire cable; means responsive to the first signal coupled to the two wire cable for producing an AC cancellation signal proportional to the DC voltage, the cancellation signal being out of phase with the first AC signal; means responsive to the cancellation means for summing the cancellation signal, the first AC signal, and the microphone signal, thereby effecting cancellation of the first AC signal from the two wire cable and producing a signal which includes the microphone signal, but is substantially free of any components due to the first signal; and means responsive to the summing means for transmitting the microphone signal to the electronic switching system, wherein the echo return loss of the first signal is maximized.

The invention can be used to provide a telephone interface circuit of reduced size and reduced cost for interfacing between a standard telephone set in an electronic switching system. A preferred circuit uses optical couplers which have improved stability and which transmit signals independently of the emission efficiency of light emitting diodes of the optical couplers. The invention can reduce the echo return, and can be provided with simplified, reduced cost ring insertion circuitry and status and detection circuitry which operates without the use of relays.

A preferred embodiment of the invention is a semiconductor interface circuit for transmitting and receiving information between a telephone set and a switching system. The interface circuit includes current sources for providing DC power to the telephone set through a two wire cable. The current sources are modulated by an audio signal received from the four wire switching system. A high impedance amplifier is connected to the two wire cable for providing an output signal which has a DC component and an AC component both of which are functions of the cable resistance, and therefore of the cable length. The audio signal received from the switching system and the output signal of the amplifier provide inputs to an inverting analog multiplier. The output of the analog multiplier circuit represents a signal equal to the complement of the signal from the switching system multiplied by a factor which is proportional to the cable resistance. The output of optical couplers which have improved stability and which transmit signals independently of the emission efficiency of light emitting diodes of the optical couplers. The invention reduces the echo return, and can be provided with simplified, reduced cost ring insertion circuitry and status and detection circuitry which operates without the use of relays.

A preferred embodiment of the invention is a semiconductor interface circuit for transmitting and receiving information between a telephone set and a switching system. The interface circuit includes current sources for providing DC power to the telephone set through a two wire cable. The current sources are modulated by an audio signal received from the four wire switching system. A high impedance amplifier is connected to the two wire cable for providing an output signal which has a DC component and an AC component both of which are functions of the cable resistance, and therefore of the cable length. The audio signal received from the switching system and the output signal of the amplifier provide inputs to an inverting analog multiplier. The output of the analog multiplier circuit represents a signal equal to the complement of the signal from the switching system multiplied by a factor which is proportional to the cable resistance. The output of the amplifier circuit includes a component derived from the audio signal which is received from the switching system and has an amplitude proportional to the cable length. The output of the multiplier circuit and the output of the ampifier are coupled to a summing node of an operational amplifier so that the component of the audio signal from the switching system is cancelled at the summing node. Differential optical coupling circuits are used to couple the audio signal from the switching system to modulate the current sources and also to couple the microphone signal voltage to the four wire switching system. A DC ring insertion control signal from the switching system is coupled from the four wire switching system to an output of the interface circuit through one of the differential optical couplers to turn off the current sources, isolating the rest of the interface circuit from the cable. DC status signals from the telephone set are conducted through the other differential optical coupling circuit to the switching system.

In the accompanying drawings:

Fig. 1 is a functional block diagram of an extension line circuit (described above);

Fig. 2 is a simplified schematic diagram of a differential optical coupling system which is used in the circuits of Figs. 4 and 5;

Fig. 3 is a simplified schematic diagram of a DC line feed system and voice sensing system used in the invention;

Fig. 4 is a simplified block diagram of an interface circuit according to an embodiment of the invention; and

Fig. 5 is a schematic diagram of an embodiment of the invention.

Before describing the preferred embodiments of the invention, it may be helpful to explain the concept of differential optical coupling. The basic differential optical coupling system of Fig. 2 permits replacement of the costly, bulky transformers presently used in two-to-four wire converters. The differential optical coupler of Fig. 2 provides an output voltage V_{out} which is a replica of the input voltage V_{in}. However, V_{out} is completely isolated from V_{in}, so that a large voltage surge induced on the inputs of operational amplifier 26 will not cause damage to circuitry connected to node 32.

The operation of the differential optical coupler is as follows. Light emitting diode 28 is driven by operational amplifier 26. Photodiodes 27 and 29 are matched photodiodes which are positioned to receive equal amounts of light emitted by light emitting diode 28. Photodiode 27 is used to close a feedback loop around operational amplifier 26 such that operational amplifier 26 drives increasing amounts of current through light emitting diode 28 until $I_{in} = I_1$. I_{S1} is very nearly equal to zero since the operational amplifier 26 has nearly infinite input impedance.

Photodiode 29 is used to feed a current equal to the current through photodiode 27 to operational amplifier 33, which in conjunction with feedback resistor 39 functions as a current-to-voltage converter. The output voltage V_{out} rises or falls until I_2, the current through photodiode 29, equals the current through feedback resistor 39, so that I_{S2} is equal to zero, at which point V_{out} is stabilized. It may be readily determined that the transfer function of the differential optical coupler of Fig. 2 is given by the equation

$$V_{out} = (R_k/R_g)V_{in}.$$

Since this above equation does not contain a term proportional to the light emission efficiency of light emitting diode 28, the stability of light emitting diode 28 is not critical to the signal transmission characteristics of the differential optical coupler of Fig. 2.

Fig. 3 illustrates the basic concept of electronic implementation of the DC feed function to power the telephone set. Current sources 43 and 44, each having an output impedance of several Kilohms, represented by resistors 43′ and 44′, respectively, provide a constant DC component of current through cable wires 18 and 19, respectively, to provide power to telephone set 12′. Reference numeral 12′ actually represents the earpiece and the microphone of the telephone set. The microphone and the earpiece are interconnected and have a combined DC resistance of approximately 200 ohms, represented by resistor 36. Current source 43 is connected to a −48 volt power supply connected to terminal 40, while current source 44 is connected to earth conductor 41. Resistors 48 and 49, which couple current sources 43 and 44 to wires 18 and 19, respectively, are power resistors which protect the electronics coupled to nodes 45 and 46 from surge voltages and ringing voltages induced on or applied to lines 18 and 19. The cable resistances are represented by resistors 37 and 38, and may vary from 0 to 500 ohms, since the maximum permitted cable resistance in telephone extension lines is 1000 ohms.

Use of current sources to provide a constant DC component to the telephone set provides a stable

DC voltage to the telephone set across nodes 42 and 47. This result in uniformly low power dissipation both in the telephone set and in the DC feed circuitry. The previously mentioned large effect of variations in cable resistance on the DC voltage and on power dissipation at the telephone set is thereby avoided.

Fig. 3 also illustrates an equivalent circuit which shows how the voice signal received from the four wire switching system is fed into the two wire cable 18, 19. This function is accomplished by means of an equivalent AC current source 50, which is connected between nodes 45 and 46. In contrast, the usual approach is to feed the voice signal from a 600 ohm voice signal source in the four wire switching system into the primary of a transformer having a secondary winding coupled between nodes 45 and 46.

Utilization of equivalent current source 50 to provide an AC voice current signal I_R into the two wire cable 18, 19 eliminates current variation due to variations in the cable resistance 37 and 38. Thus, a uniform and stable voltage signal is received at the telephone set regardless of cable length. The value of the current i_R should be set such that it produces the same signal strength at the earpiece as is produced by a conventional transformer audio feed system. A value of $i_R = 1.29$ milliamps (RMS) corresponds to a signal level of OdBm in the conventional 600 ohm system.

Fig. 3 also illustrates an improved electronic implementation of the function of sensing the voice signal generated by the microphone of the conventional telephone set 12′. A high impedance differential amplifier 52 has its inputs connected to nodes 45 and 46. It is ordinarily desirable that differential amplifier 52 perform a high voltage protection function, so that circuitry connected to output 53 will not be damaged by surges which may occur on the two wire cable 18, 19. Use of high input impedance amplifier 52 permits elimination of the usual 600 ohm termination resistance used in conventional transformer systems. As a result a significant improvement in the variation in the microphone output signal between nodes 45 and 46 is achieved. The improvement occurs because there is no voltage division between the cable resistance and the eliminated 600 ohm termination resistance. Consequently, the influence of cable length and associated cable resistance (shown by resistors 37 and 38) is eliminated. The effects of eliminating the 600 ohm transmission line termination are relatively insignificant for cable lengths up to several miles, since the wave length of the highest frequency signal, 3.4 kilohertz, in the pass band is 53 miles. The cross-talk expressed in dB below the voice signal will remain unchanged because both voice and pick-up levels will increase equally on long cables.

A simplified equivalent circuit diagram of the features of the invention which provide for minimum echo return are shown in Fig. 4. In the circuit of Fig. 4, compensation for echo return is based on cable length, i.e., on the value of cable resistances represented by resistors 37 and 38 in Fig. 3. In Fig. 4, the cable resistances 37 and 38 and the resistance of the telephone set 36 are all lumped together and represented by resistor 36′. Resistors 48 and 49 in Fig. 4 are the surge protection resistors also shown in Fig. 3 by the same reference numerals. In Fig. 4 the microphone signal voice sensing amplifier is provided by using a differential optical coupler 52′, which is constructed using the concept illustrated in Fig. 2 and explained above. Fig. 4 also illustrates in more detail the manner in which the signal v_R received from the four wire switching system is converted to provide the received audio feed signal i_R represented by the current source 50 in Fig. 3.

Actually, Fig. 3 merely represents an equivalent circuit viewpoint. The actual construction is more clearly shown in Fig. 4 which illustrates a second optical coupler 55 having its input connected to node 23, to which signal v_R, which is the voice signal received from the four wire switching system, is applied. The second stage amplifier A2 of differential optical coupler 55 is actually a current-to-current amplifier and performs the function of generating current source 50 which sends the received voice signal in the form of current i_R to the telephone set over two wire cable 18, 19.

It should be noted that in Fig. 4 that the two wire cable 17, 18 provides bi-directional signal flow. The signal v_R received from the four wire switching system is converted to a current which is sent through two wire cable 17, 18, to the earphone of the telephone set. The voice signal generated by the microphone of the telephone set is transmitted along wires 17 and 18, where it is sensed by amplifier 52′. The echo return is minimized by cancelling out any component of v_R on the cable. The voice signal V_T is transmitted by means of conductor 72 to the four wire switching system. The signals on conductors 23 and 72 are uni-directional. The earch conductors are not shown in Fig. 4, but it is to be understood that the circuitry of Fig. 4 incorporates the two-to-four wire converter, with the two wires which are earthed being implied to be present.

The operation of the equivalent circuit of Fig. 4 to minimize the echo return signal, i.e., the feed through of v_R through differential optical coupler 55, differential optical coupler 52′ and the remaining circuitry to conductor 72, is as follows. The DC feed voltage V_S between nodes 45 and 46 is amplified by differential optical coupler 52′, as explained above with respect to Fig. 2. Since the impedance of analog multiplier circuit 62 is high, and since differential optical coupler circuit 52′ is designed to have unity gain, and since it operates both as an AC amplifier and a DC amplifier, a voltage equal to V_S appears on node 60. Conductor 23 is connected to the other input of analog multiplier 63, so the magnitude of the voltage appearing at the output thereof is equal to the product of v_R and v_S, except that it is inverted with respect to V_R and is therefore 180 degrees out of phase with V_R. The magnitude of V_S is clearly proportional to the cable resistance represented by resistors 37 and 38 in Fig. 3, since the DC currents I_{S1} and I_{S2} are constant. The out-of-phase signal at node 64 is therefore multiplied by a factor which directly reflects the cable length, or cable resistance, to the telephone set.

Capacitor 60′ and resistor 67 filter the voice signal components of the cable voltage out of the cable signal to produce a DC signal at node 66. However, the AC components of the signal at node 53 are coupled directly to node 61 by means of capacitor 65, while the DC component is blocked by capacitor 65. Resistors 68 and 69 are selected so that the component of v_R between nodes 45 and 46, which is reproduced at node 53, is coupled to node 61, and finally is cancelled out at node 73 by the signal produced at analog multiplier output 64. Since the inverted signal produced at node 64 has been obtained by multiplying v_R at node 23 by a DC voltage which varies with cable resistance in exactly the same way that the component of v_R at node 61 varies with the cable resistance, the cancellation at summing node 73 is precise over a wide range of cable lengths. Consequently, the voice signal v_T transmitted on conductor 72 represents only the microphone output signal from the telephone set 12.

A more detailed implementation of the interface circuit of the invention is illustrated in Fig. 5 which shows the audio signal V_R received on conductor 23 from the four wire switching system being transmitted by means of input gain resistor 75 to node 80, to which is connected an input of operational amplifier 55A. Operational amplifier 55A, light emitting diode 76, diodes 78 and 79, and the circuitry including current mirror transistors 82 and 105 and current source transistors 83 and 104 form a differential optical coupling system similar to the one shown in Fig. 2. However, the second amplifier A2 of Fig. 2 which acts as a current-to-voltage converter is replaced in Fig. 5 by one acting as a current-to-current converter.

The current flowing through light emitting diode 76 has both a DC component and an AC component. The DC component is determined by a DC bias current flowing into node 80 from voltage reference circuit 109, which may be constructed in a number of ways, such as by use of common zener diode reference voltage circuits. Resistor 108 controls the DC biasing current generated from node 123 by reference circuit 109 to node 80, thereby controlling the DC component of the output voltage of operational amplifier 55A, and thereby also controlling the DC component of the current through light emitting didode 76. The light emitted by light emitting diode 76 activates photodiodes 78 and 79, causing them to produce a DC current. Photodiode 78 closes the loop around operational amplifier 55A, as explained previously with respect to Fig. 2, and stabilizes the DC component of the output voltage of operational amplifier 55A and thereby also stabilizes the current through photodiode 79.

The current through photodiode 79 flows through current mirror transistors 82 and 105, thereby establishing proportional DC current components in transistors 83 and 104, respectively. The collectors of transistors 83 and 104 are respectively coupled to nodes 45 and 46. Exemplary values of the currents through transistors 83 and 104 are 20 and 24 milliamps. This results in a voltage difference between nodes 45 and 46 of from four to twenty-four volts, depending on whether the total cable resistance is very close to zero for a short cable or is very near 1000 ohms for a maximum length cable. The above DC voltage difference is symmetrically centered about −24 volts, which is the mid-range point for the usual −48 volt power source used in telephone systems.

A portion of the voice signal v_R applied to node 80 is controlled by input gain setting resistor 75. In response to the AC voltage component on node 80, operational amplifier 55A modulates the voltage at its output and thereby modulates the previous established DC current through light emitting diode 76, which in turn modulates the current through photodiode 79. Consequently, the modulated currents through current mirrors 82 and 105 causes modulation of the current in the two wire cable 17, 19 in accordance with the received voice signal v_R. A corresponding variation in the voltage between nodes 45 and 46 occurs.

Thus, it can be seen that the AC current in the two wire cable generated by current source 50 in Figs. 3 and 4 is provided in the circuit of Fig. 5 by modulation of the DC currents through the DC current sources 43 and 44, which corresponds to transistors 83 and 104 in Fig. 5.

The audio voltage at nodes 18′ and 17′ includes both the voice signal generated by the microphone of telephone set 12 and the component due to v_R caused by the modulation of the currents through transistors 83 and 104. This audio voltage is applied to the inputs of operational amplifier 52A.

Operational amplifiers 52A and 52B, light emitting diode 88 and photodiodes 89 and 90 form a second differential optical coupler. Operational amplifier 52A causes a current having a DC component representative of the DC voltage difference between nodes 45 and 46 and AC components representative of both the microphone output voltage and v_R to flow through light emitting diode 88. The magnitude of the current is controlled by the output of operational amplifier 52A. Photodiode 90 absorbs the current supplied through resistors 85 and 86 and closes the feedback loop around operational amplifier 52A, as explained previously with respect to Fig. 2 to stabilize the current through light emitting diode 88. An equal amount of current flows through light emitting diode 89, which drives amplifier 52B to produce the output voltage v_T, which represents the voice signal generated by the microphone of telephone set 12. The voltage

v_T is then transmitted to the four wire switching system via conductor 72.

The echo return is minimized by means of circuitry including zener diodes 93 and 94, and the differential amplifier including transistors 96 and 97. Transistors 96 and 97 inject a cancellation current into photodiode 90. The cancellation current cancels the portion of the AC signal between nodes 45 and 46 due to v_R. The operation of the cancellation circuitry is analogous to the operation of the cancellation circuitry in Fig. 4, but its actual construction in Fig. 5 is considerably different. The operation of the cancellation circuitry of Fig. 5 is as follows.

The current through light emitting diode 88 is proportional to both the AC and DC components of the voltage difference between nodes 45 and 46. The DC current through light emitting diode 88 is sensed by resistor 115, and is proportional to the cable length, i.e., to the cable resistance, of conductors 17 and 18 (and also the resistances at resistors 48′ and 49′). The voltage across resistor 115 is therefore directly proportional to the DC voltage difference between conductors 17 and 18. The voltage across resistor 115 is then used to control the base of transistor 92, which operates as a current source for the differential amplifier which includes transistors 96 and 97. Therefore, the greater the cable resistance, i.e., the longer the cable, the greater the common mode current that flows through the differential amplifier.

One side of the differential amplifier is biased by a fixed voltage established by the sum of the voltage drops across zener diodes 93 and 94. The voltage applied to the other side of the differential amplifier, to the base of transistor 96, is developed across resistor 101 by the current through photodiode 79, which, as previously explained, controls the DC and AC components of voltage on cable 17, 18, in response to both the reference voltage supplied by circuit 109 and to the received signal v_R. The values of the various resistors, including resistors 101, 99, and 115 and the geometry of the various transistors may be selected so that transistors 96 and 97 operate to cancel the component of voltage due to v_R between nodes 45 and 46, thereby minimizing or eliminating the echo return. The differential amplifier including transistors 96 and 97 plays the same role in the circuit of Fig. 5 as multiplier 63 plays in the circuit of Fig. 4. The gain characteristics (gm) of differential amplifier transistors 96 and 97 are controlled by the current through current source transistor 92 and thus by the DC voltage difference between nodes 45 and 46, and thereby by the cable length.

The operation of the differential amplifier is that transistor 92 modulates the gm of transistors 96 and 97 such that the output voltage of operational amplifier 52A causes the corrent amount of DC current to flow through light emitting diode 88, so that the voltage drop produced across resistor 115 is equal to V_{Z2} plus the base-emitter voltage of transistor 92. This is accomplished with very small variations in DC current through light emitting diode 88, since very slight changes in base to emitter voltage produce the required change in collector current. This stabilizes the differential output current of differential amplifier 96, 97 at a lever proportional to the cable length. Any increase in the component of AC voltage between nodes 45 and 46 due to increase cable length is accompanied by an increase in gain (gm) of transistors 96 and 97. Thus, transistors 96 and 97 modulate their collector currents into nodes 17 and 18 proportionally to their gains (gm), thereby cancelling the AC component due to v_R from the cable 45, 46. Thus, the only AC voltage that gets transmitted via photodiode 89, operational amplifier 52B and conductor 72 to the four wire switching system is v_T, the microphone output signal. The echo return of v_R is eliminated regardless of cable length. Thus, with the proper scaling the above circuitry provides cancellation of the AC voltage across conductors 17 and 18 due to the AC current injected by transistors 83 and 104 in response to v_R. Capacitor 115A by-passes AC components to prevent the gain (gm) of transistors 96 and 97 from responding to AC signals.

Resistors 119 and 120 are provided to compensate for differences in the current in transistors 83 and 104 and to compensate for leakage currents between cable conductors 17, 18 and for external induced imbalances in order to maintain a common mode or lateral line voltage of approximately 24 volts.

Any transient voltages on the line exceeding earth voltage or −48 volts ($-V_{BAT}$) are absorbed by external protection resistors 48′ and 49′ and are clipped by protection diodes 117 and 118. Diode 116 prevents polarity reversal between conductors 17 and 18.

The ring command in telephone extension systems ordinarily causes an AC voltage of 20 Hz with a magnitude of the order of 90 volts to be impressed upon the cable 17, 18 to cause the telephone set to ring. In the circuit of Fig. 5, the ring command is supplied to input conductor 106 of the interface circuits. The voltage V_{RING} and resistor 107 cause a current greater than and opposite to the bias current provided by resistor 108 to be injected into node 80. (The voltage applied to conductor 106 could be a T^2L logic gate output). This voltage causes operational amplifier 55A to turn off, thereby turning off light emitting diode 76, and causing photodiode 79 to turn off. This in turn causes current source transistors 83 and 104 to be turned off and effectively disconnects cable 17, 18 from the earth and −48 volt conductors. The absence of current through photodiode 79 also causes transistor 95 to be turned off. This causes transistors 110 to be turned on by the current through resistor 99. The collector of transistor 110 may then be used to energize a triac or an ordinary inexpensive low voltage relay which is connected to cause the telephone to ring.

The status signalling function if performed as follows. It is necessary for the four terminal switching system to know whether the phone is on the hook. When the telephone receiver is "on the hook", the telephone set appears as an open circuit to cable conductors 17 and 18, and no signal current flows therein. It may be seen that if conductors 18 and 17 appear as an open circuit to the interface circuit of Fig. 5, the current through current source transistors 83 and 104 increases the DC voltage difference between nodes 45 and 46, which causes amplifier 52A to saturate. This greatly increases the current through light emitting diode 88, which in turn causes a large amount of current to flow through photodiode 89, thereby saturating operational amplifier 52B. This produces a high voltage at the output of operational amplifier 52B, which high voltage is detected by level detector circuit 113. Level detector circuit 113 may be implemented in a variety of ways, for example, by a Schmitt trigger. Level detecting circuit 113 produces a suitable output voltage on status output conductor 114, which voltage indicates the status of the telephone set. Dial pulses from the telephone set are processed entirely similarly and can also be sensed at status output conductor 114.

This application is divided out of application 40123/78 to which attention is directed.

CLAIMS

1. An interface circuit for coupling a two wire cable connected to a telephone set to an electronic switching system, the interface circuit comprising means for producing a first AC signal on the two wire cable proportional to the length of the two wire cable in response to a first signal transmitted to the interface circuit by the electronic switching system; means for producing a DC voltage on the two wire cable proportional to the length of the two wire cable; means for receiving a microphone signal from the telephone set on the two wire cable; means responsive to the first signal coupled to the two wire cable for producing an AC cancellation signal proportional to the DC voltage, the cancellation signal being out of phase with the first AC signal; means responsive to the cancellation means for summing the cancellation signal, the first AC signal, and the microphone signal, thereby effecting cancellation of the first AC signal from the two wire cable and producing a signal which includes the microphone signal, but is substantially free of any components due to the first signal; and means responsive to the summing means for transmitting microphone signal to the electronic switching system, wherein the echo return loss of the first signal is maximized.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1981. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.