

R. Treiber 1

Singapore

Compt. Cent

PATENT SPECIFICATION (11)

1 583 634

1 583 634

- (21) Application No. 6797/78 (22) Filed 21 Feb. 1978 (19)
 (31) Convention Application No. 773 713 (32) Filed 2 March 1977 in
 (33) United States of America (US)
 (44) Complete Specification published 28 Jan. 1981
 (51) INT. CL.⁸ H04B 3/03 H04M 3/00
 (52) Index of acceptance

H4K 1H13 1L 1U1 1U7 BL
 H4R LH



(54) SUBSCRIBER LINE/TRUNK CIRCUIT

(71) We, INTERNATIONAL STANDARD ELECTRIC CORPORATION, a Corporation organised and existing under the Laws of the State of Delaware, United States of America, of 320 Park Avenue, New York 22, State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to subscriber line/trunk circuits, such as used in telephone exchanges.

In many known telephone exchanges, the problem caused by the differing impedance and transmission characteristics of different types of telephone line have been handled by balancing the line impedance and the switching network by inserting components on a "per line" basis to achieve a compromise characteristic. Unfortunately this results in a loss of as much as 2 decibels in the transmission direction and 2 decibels in the receiving direction. Further if the problem is approached by individually balancing each line, each line has to be tested individually, which is expensive and time-consuming.

An object of the present invention is to minimise or overcome the above disadvantages in an economical manner.

According to the present invention there is provided a circuit for providing an interface between a two-wire subscriber line or trunk conveying bi-directional analog communication signals and a four-wire digital circuit having separate go and return channels, wherein the circuit includes means for providing two-wire to four-wire conversion between the analog line or trunk and the digital circuit, wherein due to imperfections in the two-wire to four-wire conversion the interface circuit is subject to undesired return signals from the return channel to the go channel, wherein the interface circuit includes analog-to-digital conversion means for converting the analog signals to digital signals, and digital signal processing means adapted to attenuate the digital signals

coupled thereto from the analog-to-digital conversion means in accordance with line or trunk parameters and to subtract from the attenuated digital signals the said undesired return signal, such that a composite digital output signal is derived from said attenuated digital signals and said undesired signal returns, which composite digital signal is representative of said analog signals substantially without the presence therein of said undesired return signals, and wherein means is provided to couple the composite digital output signal to the digital circuit.

In a preferred embodiment of the invention, the processing means is a microprocessor, and the operations which it performs include sending a tone on the line, measuring the tone on its return, and storing data concerning the transfer function in a memory. The data is used by a system of digital filters to compensate for line attenuation, and to reduce unwanted return signals generated due to the two-wire to four-wire conversion to an acceptable level. It will be appreciated that most subscriber circuits in known systems are of the "two-wire" type, which does not need two-wire to four-wire conversion, so that no undesired return signal is generated. In contrast the subtraction technique which we use achieves the desired compensation by programming of digital filters. Further, such bulky components as audio-frequency transformers and electro-mechanical filters are avoided. The avoidance of such bulky components, together with the relatively low (and decreasing) costs of micro-processors mean that an overall economy is achieved as compared with the prior art.

Naturally digital filters as such are well-known, and a description of the general design of such devices can be found in the book "Digital Processing of Signals", by B. Gold and C. Rader, Lincoln Laboratory Publication, McGraw-Hill, 1969.

A line circuit interface incorporating a power supply for interfacing the analog subscriber lines and trunks of a telephone system to the digital switching circuitry of a telephone exchange central office or to

other digital circuitry is described below, wherein all A/D and D/A conversion, two-wire to four-wire conversion, talking voltage, ringing voltage and other tone generation, measuring, testing and line monitoring are done by the subscriber circuit, thereby enabling a more efficient central office operation. Continuous feedback under microprocessor control for a signal generator is provided to derive a pulse duration modulated control signal in response to monitored load changes on the subscriber tip and ring lines. Also, in the same manner, ring trip and off-hook detection is accomplished without the need for external sensing devices. Current-sensitive equalization equipment as used in North America is effectively moved from the telephone subset to the central office. Except during programmable measuring and testing, the subscriber circuit is isolated and floating with respect to dc ground, which substantially eliminates the common power supply cross-talk problem of the known systems. Speech signal isolation is achieved under microprocessor control by filtering the unwanted signal returns from the speech signals such that there is no common audio impedance. As already mentioned, the apparent prodigality of providing, in the arrangements specifically described below, a micro-processor per line is more than compensated by the relatively large amount of work the micro-processor does. Further, micro-processors are currently fairly cheap, and their cost is likely to decrease in the future.

An embodiment of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a line circuit of known type illustrative of a typical interface between a subscriber telephone set and a digital local exchange.

Figure 2 is a block diagram showing the implementation of two-wire to four-wire conversion using digital filtering techniques internal to the microprocessor, as used in an embodiment of the invention.

Figure 3 is a block and circuit diagram illustrative in greater detail the line circuit excluding the microprocessor system of an embodiment of the invention.

Figure 4 is a schematic diagram of the signal generator used in Figure 3, showing the generator and driver circuits.

The signal generator of Figure 4 is separately claimed in our Application No. 26786/78 (Serial No. 1,583,635), which has been divided from this application.

Referring now to Figure 1, a typical subscriber line circuit of the prior art is shown, the line circuit providing an interface between the analog telephone lines and the digital portions of a local exchange, such as its switching matrix. The incoming analog

signals on a two-wire line 10 from a typical subscriber telephone set are converted to a four-wire PCM encoded signal for connection to a digital local switching matrix via speech line 12 and signalling line 14. Input signals on line 16 and output signals on line 18 are isolated from each other by a two-wire to four-wire converter 20, a circuit which does not compensate for the imperfect impedance match at the two-wire line interface. A compromise balance circuit 21, typically 900 ohms and two micro-farads in series, is used to attempt to balance the wide variation in two-wire line impedances. Due to its less than perfect action some of the signal 16 is transmitted back on line 18, which forms an undesired return signal.

In a typical connection between two line circuits via the switching matrix their signals can cause an instability or near singing condition resulting in poor perceived transmission by the subscriber. The prior art seeks to resolve this problem by inserting an extra 2 db of loss in the four-wire path. Switches 22, 24, 26, 28 and others permit the switching in of direct voltage for tip and ring signals, test signals, dc power supply, such line monitoring signals as test signals via lines 30 and 32, a talking battery or other direct voltage via line feed loop detector 46, and a ringing supply via line 36 to a ring trip detector 38 and return dc via line 34. These switches, detectors, connections and lines when multiplied by the number of telephone subscriber sets in a typical telephone system are expensive and, in fact, the subscriber line circuits typically represent as much as eighty percent of the equipment cost of telephone exchanges; hence, simplification thereof represents a substantial cost saving. The aforementioned switches, test lines, detectors, and the two-wire to four-wire converter 20 are replaced when applying the principles of this invention. A coder-decoder (codec) 40 may perform the analog-to-digital and digital-to-analog conversion. One such technique first encodes the analog signal into digital format using linear A/D conversion techniques, whereafter the digital signal is companded. Analog filtering is provided by filters 42 and 44 which are expensive bulky audio components. A line feed loop detector 46 provides the D.C. talking battery to the line and supplies a sensing signal to signalling logic, relay drivers and power switches 48, which serve to couple the digital output of the codec 40 to the speech lines 12 and the various signal tones to the signalling lines 14.

Referring now to Fig. 2, the two-wire to four-wire portion and the analog-digital conversion portion of the line circuit for interfacing a two-wire analog line or trunk to a digital system is illustrated generally at 100. The two-wire to four-wire conversion;

which is effected without the use of the conventional type of two-wire to four-wire conversion, involves some imperfections as a result of which the return signal reaching Fig. 2 over the line 13 finds its way into the go signal output via line 12, albeit with a reduced amplitude. Such an undesired signal return is cancelled out at least partially by a subtraction technique which is implemented under the control of a microprocessor indicated at 126. This is, in effect, a digital filtering technique applied to the intelligence signal to be conveyed over the line 12.

All measurement and testing of analog signals associated with the speech path from a subscriber set is monitored and measured by the described microprocessor implemented line circuit. The two-wire line 102 couples input analog speech signals via a summing impedance 122 to an analogue-to-digital converter 104 which performs a digital coding function. The coder 104 may comprise a voltage controlled oscillator for converting the incoming analog signal to non-amplitude sensitive dc outputs. The dc encoded output is processed by microprocessor 126, within which microprocessor digital filters 106 and 124 and summation circuit 110 are implemented digitally. After filtering by digital filter 106, which processes the coder 104 output with a stored and/or programmable algorithm according to known digital filtering techniques, a coded signal output on line 108 is derived. This signal is summed at a junction 110 with an inverted version of the output on line 13, which inverted value is applied to the junction 110 via the line 112. This is implemented by microprocessor 126 which includes a standard microprocessor such as an Intel 8080 augmented with a high speed arithmetic capability for digital filtering, such that the microprocessor 126 and in particular the digital filters 124 and 106 implemented therein perform all signal processing. In addition, the digital filter 106 provides for variation of and compensation for subscriber line transmission parameters under program control. Further, ac signalling may be detected by digital filtering techniques.

The digital input signal corrected by subtraction of the unwanted signals is coupled from summing junction 110 via line 114 to the digital portions of the system, which may comprise a digital switching matrix such as that disclosed in our copending application No. 1786/78 (Serial No. 1,560,192).

The large audio components associated with the two-wire to four-wire conversion have been eliminated, particularly the audio transformer associated with this function.

Since the digital filter (106) can compensate for line loss, the current-sensitive equalizer often needed at a subset may be moved

from the telephone subset to the central office, since a selective frequency attenuation is added into the line circuit under microprocessor control to insure that the total loss will be equal for all transmitted frequencies and distances from the central office. A typical equalizer circuit of the prior art and description thereof appears in *Basic Carrier Telephony*, David Talley, revised second edition, Hayden Book Co., at page 121 thereof.

Functions which have hitherto normally needed separate access, i.e. talking batteries, ringing voltages, test measurements, tone dial pulse coding, etc. have been eliminated and these functions can be performed without separate access, as shown in Figure 3. Thus the line/trunk circuit is quite separate from the switching matrix and modularity thereof on a per line basis is provided, thus providing a standard interface to the switching system independent of the type of transmission circuit from which signals must be processed. The programmability of the microprocessor provides the flexibility for program modification for adapting to different characteristics and requirements of the line/trunk circuit, vis-a-vis the input lines, such as line 102. The digital return signal is coupled via line 116 to a decoder 118 which performs the digital-to-analog conversion and which may comprise any suitable digital-to-analog convertor such as the well-known weighted resistive network type D/A converter. After the analog filtering by filter 120, the analog speech signal is coupled through summing impedance 122 out onto the two-wire line 102.

The microprocessor 126 has memory capacity for program storage accessible as needed, and a high speed data bus (not shown). A permanent storage of data which may be accomplished by a read-only memory incorporated within the microprocessor provides for the storage of programs not readily transferred to the line circuit on an as-needed basis. However, the storage requirement is minimized by the use of the high-speed data bus, since the memory associated with each line circuit must exist for all line circuits; hence any cost savings associated with reduced memory capacity results in a substantial cost saving when considered in the light of the system as a whole. Typically, however, the central storage of non-easily accessible programs would be associated with a 64 line block of subscriber line circuits; that is, one central memory serves 64 two-wire lines, such as line 102, in an actual telephone system implementation.

Referring now to Figure 3, a hardware implementation of the more generalized subscriber line circuit illustrated by the block diagram of Figure 2 is illustrated generally at 200. The key element is a signal

generator 202 for generating the subscriber line circuit alternating and direct voltages as required under microprocessor control. Essentially, the incoming analog signals, including the tip and ring signals on lines 204 and 206 of the two-wire line 102, are coupled through a suitable over-voltage protection circuit 208 to the aforescribed coder 104 (shown as 218 in Figure 3) which senses the instantaneous voltage on the tip and ring lines 204 and 206, respectively; digitizes the sensed voltage and routes the digitized voltage through the microprocessor. There a pulse duration-modulated drive signal is generated and fed back via driver 210 to the signal generator 202 to generate the required talking battery and ringing voltages. In addition, control is provided to some switches, as will be described, and with a resultant minimization of system hardware requirements. In effect, the coder is an efficient means to control such a voltage source having dc continuity and ac and dc isolation characteristics even though the coder is transformer coupled. This is accomplished by modulating the signal including the dc component and transformer coupling the output. Demodulation is accomplished by recovering the digital signal in the microprocessor wherein a digital control signal for driving the signal generator is derived.

All testing is done by appropriately controlling the signal generator and switches. The signal generator 202 is coupled to the remainder of the illustrated circuitry by a ferrite transformer, which provides dc isolation. The tip and ring lines are coupled via lines 212 and 214, respectively, to the digital-to-analog decoder 216 and to analog-to-digital coder 218 via lines 220 and 222, without the heretofore required two-wire to four-wire converter. A highly efficient feedback control with pulse width duration modulation is provided by the digital voltage control output from the microprocessor on line 224, which signal is applied as the base drive to transistor amplifier 226, the pulsed output of which is transformer coupled across a small ferrite transformer 228 to the signal generator 202. A polarity control signal is provided via lines 230 from the microprocessor and is transformer coupled to signal generator 202. A battery isolating impedance 231 and a line matching impedance 232 are provided.

The aforementioned microprocessor-generated pulse-duration modulated control signal is preferably in the range of 50 to 100 kHz. The signal generator control signal on line 224 is derived by first measuring the output of signal generator 202 in the coder circuit 218 wherein the incoming analog signal on lines 220 and 222 is converted to a non-analog sensitive digital output and

transformer coupled via transformer 234 to the microprocessor. The instantaneous value of this transformer-coupled digital signal is then compared with a reference value stored internally in the microprocessor, such that any deviation therefrom generates a corrective increase or decrease, as the case may be, within the microprocessor. This varies the pulse duration of the signal output from the microprocessor on line 224. Thus, the microprocessor functions as a feedback regulator circuit to vary the pulse duration of the base drive for driver 226 to generate the desired signal according to the internal reference stored in the microcomputer. One way to generate such a pulse duration signal is by counting down a preset value stored in a counter associated with the microprocessor. When such stored value reaches zero, the pulse, to be transmitted on line 224, is terminated. Of course, the preset counter is controlled by the digital feedback increase/decrease information derived by the microprocessor from the measured dc output. Other techniques for controlling the preset values stored in such a counter, such as a look-up table stored in the microprocessor memory may also be used. The high frequency operation of the supply enables the generation of relatively smooth waveforms and the consequent use of small ferrite-type transformers and capacitors, which avoids the heavy and bulky battery feed coils and audio transformers used in known systems. An isolated dc-to-dc converter 236 of conventional design may serve as the power supply for decoder 216 and coder 218. Bipolar signals are obtained by a floating isolated bridge which reverses the polarity of the secondary output of the switching regulator.

The incoming speech signals thus pass from the two-wire line 102 through coder 218 to the microprocessor and to the receiver output for coupling to a suitable digital switching matrix, while the decoder 216 output is isolated from the transmissions through coder 218 but still passes through the circuit to lines 204 and 206 to enable the normal two-way telephone communication.

Switches S1 to S7 are used for testing operations. They provide for grounding either/or both sides of the line through S1 and S2, measuring current output (the voltage across 231) through S7, S4 and S3, and disconnecting the impedance 232 through S5 and S6, when line leakage type measurements are made. Test voltages are generated by the signal generator. While switches S1 to S7 are illustrated without control inputs thereto for simplicity of description, it is to be understood that such control inputs are coupled to these switches from microprocessor 126. Switches S1 to S7 may be imple-

mented in like manner as switches 320, 322, 324 and 326 described hereinafter with reference to Figure 4, with any desired switching sequence being obtainable from the microprocessor.

Referring now to Figure 4, the signal generator 202 is illustrated. The circuit provides a floating isolated bridge for switching the circuit on the secondary output 302 of ferrite transformer 300. For a given value of V_{cc} applied to the primary 304 of transformer 300 and to drive transistor 306 of driver 226, and for a generation of a fixed direct voltage at the output of signal generator 202, the pulse duration coupled to the base of transistor 306 is constant. Should the load change on the output (tip and ring lines 204 and 206, respectively), the sensing of such change causes the pulse duration of the base drive to vary correctively, as described. This enables the detection of changes in hook status of the subscriber telephone. Further, for ring-trip detection, the average value of the pulse duration (the equivalent dc value) may be used to measure changes in line direct current. Switches 308 and 310 may be used to ground either side of the line (tip or ring) for test purposes, while inductor 312 isolates the relatively low impedance power supply and signal generator from the line. Monitoring of gain stability is accomplished internally in the microprocessor by sensing the line voltages.

Operationally, the primary 304 stores energy in accordance with the well known relationship $E = \frac{1}{2}LI^2$. When transistor 306 is ON (the indicated positive polarity dots become negative polarity), diode 314 does not conduct. When transistor 306 is OFF, diode 314 conducts, charging shunt capacitor 316 and transferring the energy stored in primary 304 to the secondary 302, i.e., to capacitor 316. Capacitor 316 also serves as a ripple voltage filter. Energy transfer from primary 304 to secondary 302 is controlled by the switching of transistor 306 while the amount of energy transferred, i.e., the effective output voltage, is controlled by the duty cycle of the switching of transistor 306, which in turn is controlled by the pulse duration modulated signal applied to the base thereof from the microprocessor. A regulated energy feedback power supply is thus provided, but at a high enough frequency (100 KHz) to avoid the costly and bulky audio transformer and relays of the prior art.

Switches 320, 322, 324 and 326, which may be VMOS, DMOS, bipolar or other semiconductor switches of known configuration, are driven by isolated, transformer coupled microprocessor controlled switching pulses under the control of the microprocessor programming. To generate an ac signal, a half-wave rectified signal and ap-

propriate switch is thus employed. When switches 320 and 322 are ON, switches 324 and 326 are OFF and vice versa. Illustratively, when switches 320 and 322 are ON, the negative polarity from capacitor 316 is coupled to the tip line 204 and the positive polarity from capacitor 316 to the ring line 206. Conversely, when switches 324 and 326 are ON, the tip has coupled thereto the positive polarity from capacitor 316 and the ring has coupled thereto the negative polarity from capacitor 316. An ac signal from the signal generator under microprocessor control is thus generated from a dc signal. The effect is significant, since the heretofore required ac power supply and switches for switching the ac power into the circuit of the prior art are eliminated. The present circuit generates all of the subscriber line alternating and direct voltages required for tones, operation and testing.

WHAT WE CLAIM IS:—

1. A circuit for providing an interface between a two-wire subscriber line or trunk conveying bi-directional analog communication signals and a four-wire digital circuit having separate go and return channels, wherein the circuit includes means for providing two-wire to four-wire conversion between the analog line or trunk and the digital circuit, wherein due to imperfections in the two-wire to four-wire conversion the interface circuit is subject to undesired return signals from the return channel to the go channel, wherein the interface circuit includes analog-to-digital conversion means for converting the analog signals to digital signals, and digital signal processing means adapted to attenuate the digital signals coupled thereto from the analog-to-digital conversion means in accordance with line or trunk parameters and to subtract from the attenuated digital signals the said undesired return signal, such that a composite digital output signal is derived from said attenuated digital signals and said undesired signal returns, which composite digital signal is representative of said analog signals substantially without the presence therein of said undesired return signals, and wherein means is provided to couple the composite digital output signal to the digital circuit.
2. A circuit in accordance with claim 1, and including: a digital-to-analog conversion device for converting return digital communication signals from said digital circuit to return analog communication signals; means for coupling said return analog communication signals from said digital-to-analog converter to said subscriber channel thereby providing bi-directional communication.

3. A circuit in accordance with claim 1 or 2, wherein said analog communication signals are speech signals.



mented in like manner as switches 320, 322, 324 and 326 described hereinafter with reference to Figure 4, with any desired switching sequence being obtainable from the microprocessor.

Referring now to Figure 4, the signal generator 202 is illustrated. The circuit provides a floating isolated bridge for switching the circuit on the secondary output 302 of ferrite transformer 300. For a given value of V_{cc} applied to the primary 304 of transformer 300 and to drive transistor 306 of driver 226, and for a generation of a fixed direct voltage at the output of signal generator 202, the pulse duration coupled to the base of transistor 306 is constant. Should the load change on the output (tip and ring lines 204 and 206, respectively), the sensing of such change causes the pulse duration of the base drive to vary correctively, as described. This enables the detection of changes in hook status of the subscriber telephone. Further, for ring-trip detection, the average value of the pulse duration (the equivalent dc value) may be used to measure changes in line direct current. Switches 308 and 310 may be used to ground either side of the line (tip or ring) for test purposes, while inductor 312 isolates the relatively low impedance power supply and signal generator from the line. Monitoring of gain stability is accomplished internally in the microprocessor by sensing the line voltages.

Operationally, the primary 304 stores energy in accordance with the well known relationship $E = \frac{1}{2}LI^2$. When transistor 306 is ON (the indicated positive polarity dots become negative polarity), diode 314 does not conduct. When transistor 306 is OFF, diode 314 conducts, charging shunt capacitor 316 and transferring the energy stored in primary 304 to the secondary 302, i.e., to capacitor 316. Capacitor 316 also serves as a ripple voltage filter. Energy transfer from primary 304 to secondary 302 is controlled by the switching of transistor 306 while the amount of energy transferred, i.e., the effective output voltage, is controlled by the duty cycle of the switching of transistor 306, which in turn is controlled by the pulse duration modulated signal applied to the base thereof from the microprocessor. A regulated energy feedback power supply is thus provided, but at a high enough frequency (100 KHz) to avoid the costly and bulky audio transformer and relays of the prior art.

Switches 320, 322, 324 and 326, which may be VMOS, DMOS, bipolar or other semiconductor switches of known configuration, are driven by isolated, transformer coupled microprocessor controlled switching pulses under the control of the microprocessor programming. To generate an ac signal, a half-wave rectified signal and ap-

propriate switch is thus employed. When switches 320 and 322 are ON, switches 324 and 326 are OFF and vice versa. Illustratively, when switches 320 and 322 are ON, the negative polarity from capacitor 316 is coupled to the tip line 204 and the positive polarity from capacitor 316 to the ring line 206. Conversely, when switches 324 and 326 are ON, the tip has coupled thereto the positive polarity from capacitor 316 and the ring has coupled thereto the negative polarity from capacitor 316. An ac signal from the signal generator under microprocessor control is thus generated from a dc signal. The effect is significant, since the heretofore required ac power supply and switches for switching the ac power into the circuit of the prior art are eliminated. The present circuit generates all of the subscriber line alternating and direct voltages required for tones, operation and testing.

WHAT WE CLAIM IS:—

1. A circuit for providing an interface between a two-wire subscriber line or trunk conveying bi-directional analog communication signals and a four-wire digital circuit having separate go and return channels, wherein the circuit includes means for providing two-wire to four-wire conversion between the analog line or trunk and the digital circuit, wherein due to imperfections in the two-wire to four-wire conversion the interface circuit is subject to undesired return signals from the return channel to the go channel, wherein the interface circuit includes analog-to-digital conversion means for converting the analog signals to digital signals, and digital signal processing means adapted to attenuate the digital signals coupled thereto from the analog-to-digital conversion means in accordance with line or trunk parameters and to subtract from the attenuated digital signals the said undesired return signal, such that a composite digital output signal is derived from said attenuated digital signals and said undesired signal returns, which composite digital signal is representative of said analog signals substantially without the presence therein of said undesired return signals, and wherein means is provided to couple the composite digital output signal to the digital circuit.

2. A circuit in accordance with claim 1, and including: a digital-to-analog conversion device for converting return digital communication signals from said digital circuit to return analog communication signals; means for coupling said return analog communication signals from said digital-to-analog converter to said subscriber channel thereby providing bi-directional communication.

3. A circuit in accordance with claim 1 or 2, wherein said analog communication signals are speech signals.



4. A circuit in accordance with claim 1, 2 or 3, wherein said digital circuit includes a switching matrix.
5. A circuit in accordance with claim 1, 2, 3, or 4, wherein said composite digital output signals are pulse code modulated signals.
6. A circuit in accordance with claim 1, 2, 3, 4 or 5, wherein said line or trunk is a two-wire telephone line and wherein said signal processing means includes equalizing means for providing an impedance match for a two-wire to four-wire conversion.
7. A circuit in accordance with claim 1, 2, 3, 4, 5 or 6, wherein said digital signal processing means includes a programmable microprocessor, wherein means is provided for sensing the transmission conditions of said line or trunk; and wherein means is provided for coupling signals representative of the sensed conditions to the microprocessor such that said attenuation of said digital signals is variable according to said sensed subscriber channel conditions.
8. A circuit in accordance with claim 7, wherein the microprocessor simulates digital filter means which includes means for detecting ac signalling.
9. A circuit in accordance with claim 4 or any claim appendent thereto, wherein said circuit is remote from said switching matrix.
10. A circuit in accordance with claim 7, 8, or 9, wherein said line or trunk carrying analog communication signals further carries alternating and direct voltages indicative of telephone signalling information.
11. A circuit in accordance with claim 10, and including signal generator means responsive to microprocessor control signals for deriving said alternating and direct voltages indicative of said telephone signalling information.
12. A circuit in accordance with claim 11, and including pulse duration modulated switching means responsive to pulse duration modulated signals derived from said microprocessor for deriving said microprocessor control for said signal generator; and transformer means for coupling said pulse duration modulated signal to said signal generator such that the output of said signal generator is variable in accordance with said pulse duration modulated control signal coupled thereto.
13. A circuit in accordance with claim 12, wherein one of said voltages generated by said signal generator is a ringing voltage.
14. A circuit in accordance with claim 12 or 13, wherein said sensing means includes means for sensing hook status conditions.
15. A circuit in accordance with claim 12, 13 or 14, wherein said sensing means includes means for sensing ring-trip conditions.
16. A circuit in accordance with claim 12, 13, 14 or 15, wherein said sensing means includes means for sensing direct current changes.
17. A circuit in accordance with claim 14, 15 or 16, wherein said sensing means includes means for sensing dial pulsing.
18. A circuit, as claimed in claim 12, and in which said signal generator includes signal processing means responsive to the digital output signal from said analog to digital converter means for comparing that signal with a reference and for deriving a pulse duration modulated feedback control signal in response to said comparison; and regulator means coupled to said two-wire line and responsive to said control signal for regulating said analog voltage on said two-wire line.
19. A circuit in accordance with claim 18, and in which said analog voltages on said two-wire line or trunk include telephone tip and ring voltages.
20. A circuit in accordance with claim 18, and wherein said generator generates on electrically isolated output voltage and wherein said regulator means include: switching circuit means having a duty cycle controlled by said feedback control signal and having a switched output signal; and transformer means for transferring energy from the primary thereof to the secondary thereof in response to said switched output signal from said switching circuit such that the amount of energy transferred from said primary to said secondary of said transformer is proportional to the duty cycle of said switching circuit.
21. A circuit in accordance with claim 20, and including for testing said two-wire line or trunk with test voltages generated by the signal generator.
22. A circuit in accordance with claim 20, whereas said regulator means further includes: signal isolation means for isolating the secondary of said transformer from said two-wire line, and wherein said switching circuit is a switching transistor.
23. A circuit in accordance with claim 22, wherein said transformer is a ferrite transformer and said isolation means includes a floating bridge circuit.
24. A circuit in accordance with claim 23, wherein said floating bridge circuit is comprised of a plurality of switches controlled by said microprocessor for controlling the generation of an output alternating voltage.
25. An interface for coupling a telephone

65

70

75

80

85

90

95

100

105

110

115

120

125



1,583,634

subscriber line to a digital telephone exchange, substantially as described with reference to the accompanying drawings.

For the Applicants:
S. R. CAPSEY,
Chartered Patent Agent.

Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1981.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY
from which copies may be obtained.