SIGNAL COUPLER USING HIGH VOLTAGE AND LOW VOLTAGE FILTERING

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ABSTRACT

A signal coupler is provided which decreases the number of discreet elements required to provide low pass filtering for the plain old telephone service (POTS). The low pass filtering is shifted to areas of the signal coupler circuit which do not operate with the high battery voltage present on telephone lines. The low voltage filtering reduces the need for components, which are capable of operating in the high voltage environment and therefore reduces the space on the circuit board, which is occupied by each of the signal couplers. In this way, the number of individual subscriber lines that a given circuit board can accommodate can be increased.
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[0001] This patent application is a continuation of pending patent application entitled SIGNAL COUPLER USING LOW VOLTAGE FILTERING, having a filing date of Apr. 9, 1998, and a Ser. No. of 09/057,953.

TECHNICAL FIELD OF THE INVENTION

[0002] The invention relates to a signal coupler for telephone lines containing both plain old telephone service (POTS) and digital signals where low voltage filtering is used in the POTS channel.

BACKGROUND OF THE INVENTION

[0003] Modem data networks commonly use complex digital signal processing (DSP) devices called modems to transport data over communication channels. Data is typically transported via an analog transmission signal, which is representative of a synchronous, constant rate bit stream. This form of communication channel is suitable for the transmission of real-time information such as voice or video.

[0004] Often it is desirable to transmit both Plain Old Telephone Service (POTS) and digital data, either by Asymmetric Digital Subscriber Line (ADSL) or some other method, over the same line. The POTS frequency spectrum ranges from 300 to 3400 Hz. The ADSL frequency spectrum ranges from 24 kHz to 1100 kHz.

[0005] As shown in FIG. 1, the data and POTS signals are transmitted over standard telephone lines between a central office and a subscriber's home. The subscriber may have several modems and a POTS service. The subscriber is typically connected to a central office by twisted copper wire pair. At the central office, a signal coupler is used to filter, split and digitize signals coming into the central office from a subscriber. The digital signals are processed through switching networks and then sent through another signal coupler to another subscriber. Alternatively, the digital signal may be transmitted to another central office before being sent through another signal coupler to another subscriber. The signal coupler converts the digital signals from the switching circuits into analog signals for transmission to the subscriber as well as converting the analog input from the subscriber into digital signals, which are sent to the switching circuits.

[0006] The transmission lines between the central office and the subscriber may be twisted copper pairs, as shown in FIG. 1. Other possibilities for transmission lines include fiber optics. In any case, the equipment at the central office and at the subscriber must be protected against power cross, lightning strikes, or other high voltage events and current surges on the telephone line. The main voltage protection is accomplished outside of the central office. However, secondary voltage protection is usually included in the signal coupler. In FIG. 2, the signal from the subscriber appears on the TIP and RING lines and the secondary voltage protection is shown as the circuit protection 101.

[0007] After the voltage and current protection is accomplished, the signal is split into data and voice lines. The data is sent at frequencies in the 20-50 kilohertz range and up while POTS voice information is nominally below 3000 Hz. The splitting, then, is normally done by using a high-pass filter for the data lines and a series of low-pass filters for the POTS lines. The series of filters is further required to remove the noise from the incoming telephone cable. FIG. 2 shows the typical filtering circuit for the POTS. In FIG. 2, the voice filtering is accomplished by a multistage filtering circuit. The typical low pass filter used in the multistage filtering circuit has two to four stages of filtering.

[0008] The POTS signal from the subscriber, after passing through the protection circuit 101, is filtered by the multistage low pass filter 102. The multiple stages allow for filtering of multiple orders (i.e., a first order filter has only one stage while a second order filter has two stages). The components of each stage include an inductor pair and a capacitor. Stage 1 in FIG. 2, for example, has inductor L1 connected in series with the TIP line after protection circuit 101 and inductor L2 connected in series with the RING line after the protection circuit. Capacitors C1 is connected across the TIP and RING lines after the inductor pair L1 and L2. The remaining stages have similar components. In addition, the low pass filter 102 includes resistors R1 and R2 connected in a series with the TIP and RING lines before they are connected to Stage 1 and resistors R3 and R4 connected in series with the TUP and RING lines after they exit stage N. In addition, the low pass filtering circuit may include an additional inductor pair acting as a common mode choke which rejects signals common to both input lines. The common mode choke is connected before stage 1 and is connected similar to inductor pair L1 and L2.

[0009] Each component of the filtering circuit (i.e., the resistors, inductors, and capacitors) must be capable of withstanding the high battery voltage (48 V) and high DC currents (typically 25 mA) used in the subscriber loop. This necessitates that each of the components in the filtering circuit be discrete components, which require a large amount of space on the circuit board. This space requirement restricts the number of lines that can be placed on a given circuit board. It is desirable, then, to reduce the amount of filtering which must be accomplished in the high voltage mode.

SUMMARY OF THE INVENTION

[0010] Accordingly, the present invention provides a signal coupler circuit, which provides the circuit protection and the filtering in a way that allows conservation of space on the circuit board at the central office. This is done by filtering the voice lines, at least in part, in a portion of the circuit where the high battery voltage is no longer present.

[0011] An analog signal capable of containing both POTS and data signals is present between the TIP and RING lines. The TIP and RING lines are lines which are components of a standard twisted pair configuration of telephone service. The invention, however, is not restricted to these lines and is useful for any transmission method of telephone service.

[0012] The signal between TIP and RING is first inputted to a voltage surge protection circuit. The surge protection circuit limits voltage spikes and current surges, which could damage other components. The main voltage and current surge protection is connected to the transmission line outside of the central office so that the protection required on the circuit board inside the central office is secondary circuit protection.
The output signal from the protection circuit is inputted to a low-pass filter. The low-pass filter occupies a minimal amount of space while being capable of accommodating the high voltage telephone lines. In the preferred embodiment, only one stage of filtering is used. More stages of filtering could be used at this point but, because of the high battery voltage, these stages utilize a great deal of circuit board space.

The output signal from the low-pass filter is then sent to a standard subscriber loop interface circuit (SLIC) device. The SLIC is a standard chip, which splits the two incoming lines into four lines, a pair of receive lines and a pair of transmit lines.

The transmit lines are finally filtered after the SLIC chip to remove the remainder of the noise. When the filtering is done after the signal is passed through the SLIC component, the high battery voltage is no longer present. The filtering components, then, can exist on a single chip and will take up much less space on the circuit board. Alternatively, some of the filtering may be accomplished digitally after the signal has been digitized by the CODEC.

The present invention provides a way of dispensing with the multistage high-voltage filtering which typically occurs before the SLIC in favor of low voltage, and therefore smaller and more compact, filtering on the transmit lines after the SLIC. The resulting savings in space will allow more signal couplers to exist on a given circuit board.

**TABLE 1**

<table>
<thead>
<tr>
<th>V_peak (V)</th>
<th>Pulse (us)</th>
<th>I_peak (A)</th>
<th>Reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>10/1000</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>1000</td>
<td>10/360</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>100</td>
<td>10/1000</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>2500</td>
<td>2/10</td>
<td>500</td>
<td>50</td>
</tr>
</tbody>
</table>

In a typical subscriber loop, the battery voltage across TIP 10 and RING 11 is 48 V and the loop may typically carry a current of from 23-35 mA. Although the current is nominally 25 mA, it could range as high as 120 mA.

The output signal from the protection circuit 101 on lines 12 and 13 is sent to low pass filter 109. It is a good practice to use different numbers for components that are different (particularly when one is prior art and one is part of the invention). In addition, the lines DSLT 12 and DSLR 13 are inputted to high pass filter 106. Low pass filter 109 passes the POTS signal while not passing the data signal. High pass filter 106 does not pass the POTS signal while passing the data signal. In this way, the data path is separated from the POTS path.

In addition to splitting the POTS signal and the data signal, low pass filter 109 also provides enough filtering to prevent overloading of the subscriber loop interface circuit (SLIC) 103. This requires that the low pass filter 109 have at least one stage. In the preferred embodiment, low pass filter 109 has only one stage of filtering. The output of low pass filter 109 is PTIP 14 and PRING 15. Signals PTIP 14 and PRING 15 are inputted to SLIC 103.

The subscriber loop interface circuit (SLIC) 103 is a standard integrated circuit which includes the function of splitting two lines which carry both transmit and receive signals (i.e., bi-directional transmission) into four lines, two of which carry the transmit signal and two of which carry the receive signal. The SLIC 103 must also handle the 48 volt battery voltage supplied by the central office and 25 mA of current or more, as opposed to the typically 5 V commonly handled by such circuits. SLIC chips are standard chips and may be purchased, for example, from Lucent Technologies, AMD, Harris, or Mitel. The Lucent Technologies chip L7855 is the preferred component used with this invention. With the use of the standard SLIC chip, the filtering circuit shown in FIG. 3 will appear identical to a standard prior art filtering circuit for compatibility with existing equipment.
central office for transmission through the signal coupler 100, to the subscriber. Lines TIP 10 and RING 11 will carry both the transmit and the received signals, the transmit signals being those that are received into the coupling circuit 100 and the receive signals being those that are received out of the coupling circuit 100.

[0029] The transmit signals, on lines VTX 18 and VRTX 19, are input to a low voltage filter 104. Filter 104 finishes filtering the incoming transmit signals. The receive signals, RCVP 16 and RCVN 17, are not filtered in this circuit. These signals would be filtered in another circuit as transmit signals before being switched into the circuit illustrated here as receive signals. The other coupling circuits and the switching circuits are shown in FIG. 1.

[0030] The four lines—RCVP 16, RCVN 17, VTX 20 and VRTX 21—are connected to coder/decoder circuit (CODEC) 105. CODEC 105 receives the digital signal DRX 22 and outputs the analog receive signal between lines 16 and 17. CODEC 105 receives the filtered analog transmit signal between lines 20 and 21 and outputs the corresponding digital signal on DRT 23. CODEC 104 may also receive a clock signal 24 and a framing signal 25 in order to coordinate with a digital processing and switching circuit at the central office.

[0031] The high pass filter 106, in addition to filtering out the POTS signal, also filters the 48 V battery voltage from between lines DSLT 12 and DSLR 13. The output lines of high pass filter 106, lines 24 and 25, are connected to Hybrid 107. Hybrid 107 performs the same two-wire to four-wire function that SLIC 103 performs without the necessity of being capable of handling the high battery voltage or the associated high DC current. The Hybrid may need to operate with high current in higher frequency ranges. The four-wire side of Hybrid 107 includes receive signals on receive lines 26 and 27 and transmit signals on lines 28 and 29. The four-wires 26, 27, 28, and 29 are connected to CODEC 108. Codec 108 converts the analog transmit signals received on lines 28 and 29 to digital signals output on line 31 and the digital receive signals received on line 30 to analog signals output on lines 26 and 27. The digital lines 30 and 31 are connected to the digital processing and switching circuits at the central office (See FIG. 1).

[0032] FIG. 4 illustrates signal coupler 100 showing in greater detail the circuitry within the circuit protection circuit 101, the low pass filter 109 and the high pass filter 106.

[0033] The circuit protection 101 in FIG. 4 has two components, current protection and voltage protection. The current protection on TIP line 10 is accomplished by resistor R1 in series with fuse F1. On RING line 11, the current protection is accomplished by resistor R2 in series with fuse F2. The combination of resistor and fuse adheres to the Bellcore specifications, fuses F1 and F2 opening only in second level testing. In the embodiment shown in FIG. 4, R1 and R2 are both 5.6 Ohm resistors.

[0034] The voltage protection is provided by component Z, which acts as a triggered voltage shunt. Monolithic protection devices consisting of one or more SCR-type thyristors are commonly available under the trade names such as SURGECTAR (Harris, Inc.), SIDACTOR (Tecco, Inc.) and LB1201 SLIC Protector (Lucent Technologies, Inc.). Although any device which prevents the voltage between lines TIP 10 and RING 11 from exceeding the Bellcore standard could be used, devices such as the SIDACTOR have the advantage of being benign until they are triggered. Preferably, Z is a SIDACTOR. Component Z is connected across lines TIP 10 and RING 11 with an output leg attached to a protection ground GNDPN. After Z triggers, it shunts the voltage across it directly to GNDPN. Preferably, Z should be chosen so that it triggers at around 200 volts.

[0035] The low pass filter 109 in FIG. 4 is a single-stage LRC circuit. Line 12 is connected in series with resistor R3, inductor L1, and resistor R5. Line 13 is connected in series with resistor R4, inductor L2 and resistor R6. Capacitor C1 is connected across the two lines, from a point between inductor L1 and resistor R5 to a point between inductor L2 and resistor R6. Inductors L1 and L2 comprise a four terminal inductor with an iron core. In FIG. 4, R3 and R4 are 15 Ohm resistors, R5 and R6 are 20 Ohm resistors, L1 and L2 are 18 mH inductors and C1 is a 0.002 uF capacitor.

[0036] Although the low pass filter illustrated in FIG. 4 is the preferred embodiment, other embodiments will be apparent to one skilled in the art. For example, providing an initial coupled inductor as a common mode choke, adding further stages of filtering or using different combinations of resistors, capacitor and inductor in the filtering are options. The components of the low pass filter, however, operate with the 48 volt battery voltage provided at the central office and the inductors have to pass tens of milliamperes of current without saturation. As such, the components require a large amount of circuit board space.

[0037] The high pass filter 106 in FIG. 4 includes capacitor C2 and transformer T1. Transformer T1 has a first side and a second side. The first side is split and a first coil P1 and a second coil P2 of the first side are coupled through capacitor C2. An input lead of the first coil P1 is connected to line DSLT 12 and the opposite input lead of the first coil P1 is connected to a lead of capacitor C2. The opposite lead of capacitor C2 is connected to an input lead of the second coil P2. The opposite input lead of coil P2 is connected to line DSLR 13. The two leads of the second coil of transformer T1 are connected to Hybrid 107.

[0038] The high pass filter 106 illustrated in FIG. 4 is of a standard type, any circuit which separates the high frequency data input from the DC and POTS signals can be used. After this separation is accomplished, the Hybrid 107 need only operate at low voltage.

[0039] The low voltage filter 104 can be any continuous time filter, which provides the desired filtering. Several of these filters are well known in the art. Among the well known integrated circuit continuous time filters are Gm-C filters and MOSFET-C filters. Each of these filter types can be implemented with multiple stages providing for filters of several orders. A standard ladder filter (which employs inductors and capacitors for a multistage filtering circuit similar to the high voltage filter shown in FIG. 2) will accomplish the low voltage filtering, however it is difficult to accurately construct an inductor on an IC chip and implementation with individual components will take a great deal of space on the circuit board and defeat the purpose of the invention.

[0040] A second embodiment of the invention is shown in FIG. 5. The embodiment shown in FIG. 5 differs from the
preferred embodiment shown in FIG. 4 in that part of the filtering is shifted to the digital side of CODEC 105. In this embodiment, the filtering is split between a Low Voltage Filter 110 and a Digital Filtering Circuit 111 located on line 23.

[0041] The examples illustrated here are representative examples and in no way limit the scope of this application. Other obvious embodiments of the invention will be apparent to one skilled in the art and are included within the scope of this application. One obvious embodiment is to not have a data path so that only POTS signals are processed.

What is claimed is:

1. A signal coupler comprises:
   high-voltage low pass filter operably coupled to low pass filter an analog signal to produce a partially filtered Plain Old Telephone System (POTS) signal;
   subscriber loop interface circuit operably coupled to provide a two-wire to four-wire interface conversion between a PTIP line and PRING line carrying the filtered POTS signal, a transmit line pair, and a receive line pair,
   wherein an incoming portion of the partially filtered POTS signal is provided on the transmit line pair and
   low-voltage low pass filter operably coupled to low pass filter the incoming portion of the partially filtered POTS signal to produce a filtered incoming POTS signal.

2. The signal coupler of claim 1, wherein the high-voltage low pass filter further comprises:
   a pair of resistors;
   a pair of inductors; and
   a capacitor operably coupled to the pair of resistors and to the pair of inductors to provide a single stage-second order low pass filter.

3. The signal coupler of claim 2, wherein the low-voltage low pass filter further comprises:
   continuous time low pass filter stage operably coupled to provide second order filtering of the incoming portion of the partially filtered POTS signal to produce the filtered incoming POTS signal.

4. The signal coupler of claim 2, wherein the low-voltage low pass filter further comprises:
   first continuous time low pass filter stage operably coupled to provide second order filtering of the incoming portion of the partially filtered POTS signal to produce a first filtered incoming POTS signal;
   second continuous time low pass filter stage operably coupled to provide second order filtering of the first filtered incoming POTS signal to produce a second filtered incoming POTS signal; and
   third continuous time low pass filter stage operably coupled to provide second order filtering of the second filtered incoming POTS signal to produce the filtered incoming POTS signal.

5. The signal coupler of claim 1 further comprises:
   coding/decoding circuit operably coupled to the filtered incoming POTS signal into a digital POTS signal; and
   digital low pass filter operably coupled to digitally low pass filter the digital POTS signal to produce a filtered POTS signal.

6. The signal coupler of claim 1 further comprises:
   high pass filter operably coupled to high pass filter the analog signal to produce data signals; and
   hybrid operably coupled to provide a two-wire to four-wire interface between a line carrying the data signals and a transmit line and a receive line.