

SPECIFICATION

Transformerless line terminating circuits

- 5 This invention relates to transformerless line terminating circuits and especially to loudspeaking telephones incorporating such circuits.

- Loudspeaking, or hands-free telephones, have achieved widespread acceptance in the commercial environment. Such telephones are convenient for conducting multi-party conversations when several people are gathered in one office. Another particularly convenient feature of the loudspeaking telephone is that the user may converse without actually being in contact with the telephone, except possibly to initially answer an incoming call.

- Typically, such loudspeaking, or as they are also called, speakerphone, telephones require a source of power to control the internal logic as well as to drive the loudspeaker. In addition, such telephones employ inductors and transformers in order to balance the impedance between the telephone line and the loudspeaker. This unbalance condition results because loudspeakers are inherently low impedance devices while the telephone line requires a much higher impedance for proper power transfer. It follows then that problems arise in situations where it is desired to utilize the convenience of a speakerphone at a low cost, without bulky inductors or transformers and without external power. These problems are compounded when it is remembered that as loop length changes the line impedance as well as the available power changes.

- According to the present invention there is provided a transformerless line terminating circuit having an input for connection to a communication line, said circuit comprising a power amplifier having an input stage including biasing means and an output stage, a transducer operable on signals received over said communication line, said transducer being connected to said power amplifier to form the loading impedance of the output stage thereof, and means for providing DC power to said amplifier, said DC power being received over said communication line, said means being arranged to reflect onto said input the loading impedance of said output stage, said reflection being scaled by said biasing means.

- In a preferred arrangement for carrying out the invention a loudspeaking telephone may be provided incorporating a transformerless line terminating circuit as aforesaid, the transducer taking the form of a loudspeaker. In such an arrangement the loudspeaker will be driven directly by the output stage of the power amplifier and it may be arranged that the power drain from the line is constant.

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

- 60 Figure 1, is a partially block schematic diagram of a transformerless line terminating circuit according to the present invention in the form of a loudspeaking telephone; and

- 65 Figures 2, 3 and 4 are more detailed circuit diagrams of various blocks shown in Figure 1.

As shown in Fig. 1, communication from a central office 10 is via a communication line 12 to a loudspeaking station set which has typically at its input line protection 20. The signal on the communication line 70 leads from the central office is provided to hybrid 30 and via receive variolossor 50 is provided to loudspeaker LS1. Audio from a talker is received via microphone MK1 and passed through preamp 70 and transmit variolossor 60 to hybrid 30 and back over 75 the communication leads 12 to the central office 10. Voice switch 40 monitors the signal levels from receive variolossor 50 and also from preamp 70, and based on these signals as well as signals from hybrid 30 serves to control the direction of communication 80 either to loudspeaker LS1 or from microphone MK1. The precise manner in which this is accomplished will be more fully detailed hereinafter.

Line protection circuit 20 is arranged with diode 24 which limits the voltage to 17.6 volts maximum and 85 is designed to limit high voltage surges. Polarity guard 21 utilizes four Schottky barrier diodes, 25, 26, 27 and 28, to insure proper voltage polarity to hybrid 30.

Turning now to FIG. 2, microphone MK1 is an electret transducer which provides an input to preamp 70, which amplifier contains voltage gain transistor 707 followed by emitter follower transistor 701. Capacitors 706, 709 and 704 provide radio frequency interference protection. Resistor 702 and capacitor 95 713 provide power supply voltage filtering. Preamp 70 is designed to provide a nominal 19.5 db of gain.

Transmit signals from preamp 70 are supplied via lead TTD, to voice switch 40 and to transmit variolossor 60. The operation of voice 100 switch 40 will be discussed hereinafter. Transmit signals at the input of transmit variolossor 60 are AC coupled, via capacitor 611 to JFET transistor 609, which is used as a voltage controlled variable resistor. Signals are provided through transistor 609 and 105 via capacitor 606 and amplifier transistor 603 over lead 63 to the base of transistor 307 in hybrid 30. Transmit variolossor 60 provides 11.5 db of voltage gain at 1000 Hz and capacitor 602 provides a pole at 3300 Hz for proper frequency response. Transmit 110 signals applied to the base of transistor 307 are supplied to the CO line over the T and R lead communication path.

Hybrid 30 receives signals at the base of transistor 307 from transmit variolossor 60 and at the collectors of transistors 307 and 303 from the CO and receive variolossor 50. These signals are then provided to the base of transistor 302 through the voltage divider formed by resistors 301, 304 and 306. Transistor 302 is arranged as an emitter follower to 120 transmit signals to receive variolossor 50. Transistors 303 and 307 in hybrid 30 are connected in a Darlington configuration and act as an amplifier for transmit signals. The gain of the amplifier is determined by the ratio of collector to emitter impedance. 125 In this circuit the emitter impedance is resistor 306 in series with diode 308. The collector circuit impedance is determined by the receive circuit input impedance (as will be discussed hereinafter) in parallel with the telephone line impedance. Thus, as will 130 be discussed, the transmit gain through the hybrid is

dependent upon line termination.

The transhybrid loss from the base of transistor 307 to the base of transistor 302 is also dependent upon line termination. The signals at the emitter and collector of transistor 303 are transmitted to the base of transistor 302 with equal loss. In this arrangement the signals are 180 degrees out of phase and if the hybrid emitter impedance is matched to the collector circuit impedance, the signals cancel at the base of transistor 302. Thus, hybrid 30 effectively operates to prevent signals which originate at microphone MK1 (signals on lead 63) from being reproduced over loudspeaker LS1.

D.C. Line Termination

The d.c. line termination is provided by transistor 501 operating in a common base mode, which reflects back to the telephone line the d.c. resistance seen looking into the supply leads of the power amplifier. Base current for 501 is provided through resistors 507, 506, and diode 504. Diode 504 is used to regulate the voltage drop across 501, collector to emitter. This voltage drop is minimized to provide maximum available power to the power amplifier and to limit the power dissipation in 501, but must be large enough to ensure that 501 does not saturate for the maximum a.c. signals impressed upon its collector. Capacitor 503 provides RFI suppression and capacitor 512 acts as a filter capacitor for the power amplifier supply voltage.

The power amplifier supply current is drawn primarily by its output stage through transistor 532. The collector current of 532 is determined by its collector voltage which is applied across diode 531 and loudspeaker LS1. This voltage is determined by the power amplifier circuit, which is a feedback amplifier with a differential amplifier input stage consisting of transistors 521 and 523. D.C. feedback from the output stage to the input stage is provided by resistor 527. Therefore, the voltage at the collector of transistor 532 is equal to the voltage at the base of transistor 523 plus the small voltage drop across resistor 527 due to bias current, thus the feedback stabilizes the DC bias point, and the DC gain is unity. The voltage divider formed by resistors 518 and 519 determines the voltage at the base of transistor 521. Thus, the equivalent d.c. resistance seen at the power amplifier supply leads is given approximately by the total d.c. resistance of diode 531 and loudspeaker LS1 multiplied by $(1 + 518/519)$.

At high line currents, zener diode 513 limits the power amplifier supply voltage, thereby limiting the output power and the power dissipation in transistor 532. This circuit arrangement allows transistor 532 to be small, and low cost, and provides an acceptable output level for this application.

A.C. Line Termination

The a.c. impedance presented to the telephone line is determined primarily by the resistor 507 in series with capacitor 509. The a.c. impedance of the telephone line port of the hybrid circuit, which appears in parallel with resistor 507 and capacitor 509, is approximately 10.9K ohms. An additional parallel impedance presented by the collector of transistor 501 is a function of the unwanted a.c. signal returned through transistor 501 emitter from

the power amplifier supply leads. The attenuation of this returned signal is provided by the combined effect of resistors 502 and 506, and capacitor 505 on the a.c. gain of transistor 501 from emitter to collector. In the worst case (maximum volume control setting), the equivalent a.c. impedance of transistor 501 is approximately ten times the value of resistor 507. Thus, the overall a.c. impedance presented to the telephone line is approximately 700 Ω .

Transmission Control

Transistor 514 and its associated components act as a variable loss circuit. Transistor 514 is a junction field-effect transistor (JFET) whose drain-to-source resistance is controlled by the d.c. voltage applied to its gate over lead RVL. Capacitors 508 and 515 couple the receive signal in and out of the receive varioloss circuit, respectively. Resistor 510 provides a d.c. path to ground from the drain of transistor 514 and resistors 516 and 517 provide a d.c. path to ground from the source of transistor 514. Resistor 516 is a potentiometer which also provides the volume control function. It has an audio taper in order to provide a fairly linear loss versus rotation characteristic. Resistor 517 limits the maximum loss end of the volume control range. Capacitor 511 provides RFI suppression.

Power Amplifier—Operation

Since the power amplifier of receive varioloss 50 derives its power from the telephone line, it performs the dual function of amplifying receive signals and determining the d.c. line termination, as previously discussed. The power amplifier is basically a three-stage feedback amplifier with a differential input stage, an emitter-follower intermediate stage, and a single-ended, common-emitter output stage.

Transistors 521 and 523 form the differential input stage with resistors 520 and 524. The bias for the base of transistor 521 is provided by the voltage divider formed by resistors 518 and 519. The bias for the base of transistor 523 is provided through feedback resistor 527. The gain of this stage is a function of bias current which determines the transconductance of transistors 521 and 523. In order to achieve sufficient open loop gain, the supply voltage for the first stage is taken from the junction of resistors 506 and 507. This supply voltage is higher than the supply voltage for the output stage allowing use of a high bias current (more gain) for the input stage. In addition, the signal appearing on the output supply voltage is well-filtered from this supply eliminating an undesired feedback path. Capacitor 522 provides RFI suppression.

Transistor 525 acts as an emitter-follower in order to present a high load impedance to the first stage. Transistor 525 emitter voltage is connected directly to the base of transistor 532 which provides the common emitter output stage. Loudspeaker LS1, which can be arranged in the well-known manner with a coil impedance 533, to convert electrical signals to audio signals presents the dominant loading impedance on the output stage. This impedance includes both resistive and reactive components.

Resistors 528 and 527, and capacitors 529 and 530 form the feedback network for the power amplifier and thereby determine both the AC and DC closed-

loop gain at maximum line current. At lower line currents, the closed-loop gain will be reduced slightly due to the resulting reduction in open-loop gain. The AC gain must be sufficient to drive the loudspeaker. This gain has a nominal value of 34 db at audio frequencies.

Voice Switch — Function

As shown in FIG. 2, three inputs to the voice switch are taken from different points in the transmission paths: one (TTD) from the transmit preamplifier output, one (RTD) from the hybrid receive port, and one (RSC) from the power amplifier output. Two of these inputs (TTD and RTD) are used to determine which transmission path has the highest level signal and to switch loss into the appropriate path. The other input (RSG) is used to hold the circuit in the receive mode after a receive signal has been detected and loss has been switched out of the receive path. This input, as will be seen, prevents signals which are acoustically coupled from the receive path to the transmit path from switching the circuit to the transmit mode.

The switched loss is provided by transistor 514 in receive variolosses 50 and by transistor 609 in the transmit variolosses under control of outputs from the voice switch. The voice switch provides suitable thresholds and timing for the switching function.

The circuit is designed to be transmit idle, i.e., the quiescent mode (no transmission signals present for a long time) is the transmit mode (no loss in transmit path, high loss in receive path).

Voice Switch — Operation

As shown in FIG. 3, signals over lead RSG (Receive Switch Guard) and lead RTD (Receive Talk-Down) are provided to op amp 416 to provide a control signal of negative polarity.

The RTD input is taken from the emitter of transistor 302 (FIG. 2) at the receive port of the hybrid circuit via transistor 305 and resistor 310 which provide an emitter-follower stage to buffer the input, thus providing a high impedance load to the receive path and isolating the RTD input from the RSG input.

Capacitor 401 (FIG. 3) couples the RTD receive signal into the op amp stage where the gain is determined by the ratio of resistor 402 to resistor 412. Capacitor 411 provides high frequency roll-off to improve the transmit lock-out margin. Diodes 413 and 414 in the feedback network of op amp 416 provide precision half-wave rectification of the signal. Capacitor 415 provides RFI suppression.

The RSG signal from the power amplifier output (FIG. 2) is coupled to the op amp 416 by capacitor 403. The gain for this input is determined by the ratio of resistors 404 and 412. Signals are provided over lead TTD to op amp 425 via capacitor 417 to provide a signal of positive polarity. The gain for this signal is determined by the ratio of resistors 418 and 421.

The RSG input is coupled from the power amplifier output (FIG. 2) through capacitor 405 and resistor 407 to the base of transistor 408. Transistor 408 provides rectification and amplification of signals which exceed the base-emitter voltage. Resistor 406 ensures that transistor 408 is off when no receive signal is present. Resistor 409 and capacitor 410 in the collector circuit provide a low pass filter with a fast attack time. The d.c. voltage developed across

capacitor 410 while a signal is present will then decay slowly through resistor 419 when the signal is removed. The positive polarity of the signal across capacitor 410 will reduce the effective signal from the TTD input by a factor determined by the ratio of resistors 419 and 418. Diodes 422 and 423 in the feedback network of op amp 425 provide precision half-wave rectification of the input signal. Capacitor 424 provides RFI suppression.

Op amp 431 and its associated components provide a comparison (linear addition) of the rectifier outputs and inverts, amplifies, and filters the sum of these signals. Note that the rectifier outputs via diodes 414 and 423 are of opposite polarity; thus the sum of these signals is equal to the difference in amplitudes. The comparator output will have a positive polarity if a receive signal is present and a negative polarity if a transmit signal is present. The rectifier signals are d.c. coupled through resistors 450 and 426 and the gain of the comparator circuit is determined by the ratio of these resistors to resistor 430. Varistor 428 limits the comparator output and capacitor 429 provides filtering so that the comparator output follows the envelope of a speech signal. Resistor 432 provides d.c. bias for the positive input terminal of the op amp.

Op amp 439 and its associated components provide detection of an input signal above a threshold determined by varistor 433. Resistors 438 and 434 determine the gain for the signal above this threshold. Capacitor 437 determines the attack and decay times of this circuit. Resistor 435 provides a d.c. path for the op amp bias current. Varistor 436 limits the output so that the op amp is not over-driven. The output of this circuit will have a negative polarity for a receive signal and a positive polarity for a transmit signal.

The detector output is applied through resistor 440 to the base of transistor 441 which provides a level shifting function. A receive signal produces a negative polarity detector output which turns transistor 441 on. The collector of transistor 441 is connected to the base of transistor 444 through resistor 442; therefore a receive signal will cause transistor 444 to turn on. Resistor 443 ensures that transistor 444 is off when there is no receive signal above threshold. The RVL lead control voltage, which is applied to the gate of transistor 514 (FIG. 2) is taken from the collector of transistor 444. Therefore, when a receive signal is detected by the voice switch circuit, transistor 514 (FIG. 2) is turned on and no loss is produced in the receive variolosses. The collector of transistor 444 is also connected through resistor 446 to the base of transistor 448 which inverts the RVL control signal. Resistor 447 ensures that transistor 448 is off when there is no receive signal. Resistor 449 provides a path from the collector of transistor 448 to ground. The TVL lead control voltage which is applied to the gate of transistor 609 (FIG. 2), is taken from the collector of transistor 448. Therefore, the variolosses control voltages RVL and TVL will be of opposite polarity so that the TVL lead will be high (transmit mode) when the RVL lead is low and vice versa.

Quiet switch 445 is normally open and performs

the quieting function when closed by locking the variolossers in the receive mode; i.e., transistor 514 (FIG. 2) on, transistor 609 (FIG. 2) off. This places high loss in the transmit variolosses 60 and allows transmission through the receive variolosses 50.

Battery Feed Circuit Control

As shown in FIG. 4, transistor 803 acts as a switch to disconnect the 9V battery load when the speakerphone circuit is inactive. Base current to turn transistor 803 on is provided through resistor 804 by transistor 805 which is controlled through resistor 806 by the voltage (V_L) across capacitor 509 (Fig. 2) of receive variolosses 50 due to line termination.

Resistors 802 and 807 ensure that transistors 803 and 805, respectively, are off when there is no connection to the telephone line, thereby disconnecting the battery feed circuit line $+V_B$ from the battery 801.

Capacitor 808 provides filtering for the battery voltage applied to the circuits. A voltage divider formed by resistors 809 and 810 determines the circuit ground V_A for the voice switch circuits. Transistor 811 and resistor 812 form an emitter-follower which together with capacitor 813 maintains a constant voltage difference between the voice switch circuit ground V_A and the negative battery terminal.

Battery 801 is used to provide power for the voice switch 40, transmit variolosses 60 and preamp 70. If this battery were also to be used for powering the loudspeaker, then the current drain would be of such a magnitude that battery life would be reduced by a factor of approximately 10, thereby making it necessary to constantly change batteries in the unit. It is theoretically possible to eliminate the 9V battery 801 and to power the complete unit from the line voltage. However, since the line voltage is low and is constantly changing, the circuitry required to achieve the necessary linearity over the full voltage range would be expensive. The provision of the battery 801 to power the low current drain circuits is thus an advantageous cost expedient.

While the inventive concept has been discussed in terms of communication to and from a central office, it is of course understood that such communication may be over any communication line where power, in the form of talking battery, is provided. An example of such a situation could be an intercom line. The loudspeaker shown is of the electro-mechanical type which operates to convert electrical signals to audio signals. However, the concept discussed herein contemplates other types of terminating transducers for speech, video, or data, and in digital as well as analog form.

CLAIMS

1. A transformerless line terminating circuit having an input for connection to a communication line, said circuit comprising a power amplifier having an input stage including biasing means and an output stage, a transducer operable on signals received over said communication line, said transducer being connected to said power amplifier to form the loading impedance of the output stage thereof, and means for providing DC power to said amplifier, said DC power being received over said communication line, said means being arranged to reflect onto said input the loading impedance of said output stage,

said reflection being scaled by said biasing means.

2. A circuit as claimed in claim 1, comprising means connected between said amplifier output and input stages for establishing a DC gain of unit and for providing AC gain sufficient to drive said transducer.

3. A circuit as claimed in any preceding claim, in which said amplifier input stage is a transistor differential stage, and said amplifier output stage includes a transistor arranged in common emitter configuration.

4. A circuit as claimed in any preceding claim, in which said transducer is a loudspeaker having an inductive coil, and in which said amplifier loading impedance includes the impedance of said inductive coil.

5. A loudspeaking telephone comprising a transformerless line terminating circuit as claimed in any preceding claim, said transducer taking the form of a loudspeaker.

6. A loudspeaking telephone as claimed in claim 5, in which the power amplifier comprises a differential input stage including said biasing means, an emitter follower intermediate stage, and a single-ended output stage, said output stage including a transistor arranged in common emitter configuration.

7. A loudspeaking telephone as claimed in claim 6, in which the loudspeaker is coupled to the collector electrode of said transistor via diode means.

8. A transformerless line terminating circuit substantially as hereinbefore described with reference to the accompanying drawings.

9. A loudspeaking telephone substantially as hereinbefore described with reference to the accompanying drawings.

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said reflection being scaled by said biasing means.

2. A circuit as claimed in claim 1, comprising means connected between said amplifier output and input stages for establishing a DC gain of unit and for providing AC gain sufficient to drive said transducer.

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5. A loudspeaking telephone comprising a transformerless line terminating circuit as claimed in any preceding claim, said transducer taking the form of a loudspeaker.

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