

SPECIFICATION

Electronic telephone circuit

- 5 This invention relates to a voltage regulation network, especially for an electronic circuit network in a telephone subscriber's instrument.

- 10 In telephone practice, the carbon microphone is established as the international standard to which other instruments are compared. With the introduction of the so-called electronic telephone, i.e. one in which the transducers are used in conjunction with electronic circuitry, the problem of parallel operation arises. Naturally if a good performance is to be expected from both telephones when functioning in this parallel mode, the terminal characteristics must be compatible. However, 20 the carbon microphone is a pressure-sensitive resistance which is unpredictable. Its resistance value varies not only with the speech signal, but also with the mean of the pressure wave, the position of the handset, and the 25 time of day.

- To further complicate matters the value of this resistance is so small that when supplied from a long line, in which case line current is low, the voltage developed across the telephone is small, i.e. 1.5 to 2.5 volts, and as the connections can be made either way round, polarity to the telephone may be reversed. The problem of making an electronic circuit work under these conditions has been 35 solved by the use of the bridge amplifier, as described and claimed in our Application No. 43602/78 (P. F. Blomley 2).

- The present invention seeks to provide an improved arrangement for use in a telephone circuit, possibly but not necessarily in association with the arrangements of the above-mentioned application.

- 40 According to the invention there is provided a shunt-voltage regulation circuit which includes a first amplifier to one input of which is applied a voltage from a voltage source and to another input of which is applied a first reference voltage so that the output of the amplifier is a voltage dependent on a comparison of said voltages, said output providing the regulated output of the circuit, a feed-back connection from the amplifier's output to the first input of the amplifier, a further output from the first amplifier from which a voltage 50 proportional to the output voltage of the first amplifier is applied to a first input of a second amplifier to a second input of which is applied a second reference voltage, and a connection from the output of the second amplifier to the source of the first reference voltage via which the said first reference voltage is adjustable in accordance with the value of the output voltage of the said amplifier, wherein as the current in the circuit to which the regulated 60 output is applied varies the voltage output of

the first amplifier is subject to very small variations above a threshold level, but to relatively large variation below the threshold, the voltage decreasing with current below said 70 threshold.

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

Figures 1, 2 and 3 are explanatory graphs.

- 75 *Figure 4* is a simplified circuit of an embodiment of the invention.

Figures 5 and 6 are further explanatory graphs,

- 80 *Figure 7* is a more detailed circuit of an embodiment of the invention.

- Figure 8* is a circuit of an electronic telephone circuit using the arrangement of the invention, and also the bridge amplifier of the above-mentioned Application No. 43602/78 85 (P. F. Blomley-2).

- To make the electronic network compatible with a carbon transducer instrument the new system of the above-mentioned application was used, which gave the "electronic" telephone a unique current-voltage static characteristic. However, such a telephone with its unusual characteristics, has to cope both with the low voltage imposed on the "electronic" telephone (which may have a "non-carbon" 90 microphone) by the carbon network, but also with large mean fluctuations at low line currents of this terminal voltage due to pressure waves during speech.

- Such dynamic voltage shift is illustrated in 100 Fig. 1, which in its upper portion diagrammatically represents a carbon transducer with incident sound waves. The graph shows the fluctuating voltage produced across the transducer for the words ONE and TWO, and for the handset being shaken. This indicates response to loud words.

- We now refer to Fig. 2 which is the voltage-current characteristic for an integrated circuit chip for use in an "electronic" telephone.

- 110 Note especially the "cut-off" region of the arrangement. Here a small voltage change across the subset causes large current changes in the electronic network, which is inconvenient for both the electronic network 115 and a carbon transducer in parallel therewith.

There are two curves, labelled NETWORK 1 and NETWORK 2, respectively for 3 volts and 2 volts across the set in the static state.

- In the NETWORK 1 case, the compromise 120 is one of trying to optimise a good signal swing, which increases directly as a function of voltage drop, against minimising power dissipation at high line currents, also increased directly as a function of voltage drop. 125 Unfortunately this compromise is good for both signal swing and power dissipation, but as soon as a carbon network is placed in parallel with its microphone, the operating point is forced into the cut-off region.

- 130 NETWORK 2 sacrifices the long line swing

form improved parallel performance, but even this has difficulties with a shaken hand set which can take the instrument into its cut-off region as shown by the arrow. It also has difficulties due to low resistance carbon networks.

The technique on which the voltage regulator of the present invention is based is to split the operating characteristic into two regions, as will be seen from Fig. 3. The first of these is a constant voltage region at the right-hand side, in which variation in subset current produce very small variations in the voltage across the subset, and which is chosen for considerations such as short line dissipation and good signal swing. The other region, between the constant voltage region and the cut-off region is a so-called current region, which enables the voltage across the terminals to vary by up to 1.5 volts with very little difference in the operational conditions of the electronic network.

When a telephone subset circuit includes a shunt voltage regulator with a characteristic of the type shown in Fig. 3, it receives the incoming line current and its output controls the operating conditions of the main amplifier for the subset's microphone, which is assumed not to be a carbon microphone, e.g. it could be a moving coil microphone or an electret microphone. However, the arrangement is also usable in conjunction with a carbon microphone. The manner in which the regulator is used in a subset circuit will become clear when we describe Fig. 8.

With such a circuit used in a telephone circuit, when parallel operation occurs, with a carbon network, the electronic network is never forced into the cut-off region by the large fluctuations in terminal voltage which may occur during speech.

To produce the current-voltage characteristic of Fig. 3, the electronic network includes two circuit blocks, the first of which is basically a shunt voltage regulator using the band-gap reference voltage available in a bipolar integrated circuit. A simple realisation of such a circuit is shown in Fig. 4, in which A is a high-gain transconductance amplifier with a high output impedance, of about 20 Kohms, its gain g_m is of the order of 50 amps/volt.

The amplifier A compares the voltage applied to its inverting input from the voltage supply for a tone generator with the band-gap reference voltage of 3.4 volts, applied from B G to the non-inverting input of the amplifier. The output of this amplifier is applied to one side of the line, so that the amplifier exerts an influence on the line current I_L and line voltage V_L , as indicated on Fig. 4.

The amplifier has a high transconductance (g_m), which, assuming that $I_c = 0$, means that the voltage error ΔV , (equal to I_L/g_m) would approach zero (5mV), so that the terminal voltage in such case would be zero. If as is

the case in practice, I_c is not zero, the voltage across the line is given by

$$V_L = V_R + I_c R_1$$

where V_R is the reference voltage from BG, and R_1 is the feedback resistor of the amplifier A. This it is which explains the small slope in the I_L-V_L characteristics.

One of the requirements of the electronic network is that it should supply up to 1mA for the line generation supply referred to above. Using such a system the voltage across capacitor C5 is equal to V_R , plus the small error voltage ΔV , even though current is drawn from the node B. Thus the system simply increases the line voltage by an amount $I_T \times R_1$, when the tone generator integrated circuit draws its current I_T .

Further to the above indicated requirements of a simple shunt voltage regulation, the circuit has to be able to drive signal onto the line, and the output impedance in the audio frequency band (300-3.4 KHz) should be 600 ohms. In order to induce signal onto the line an error signal is introduced inside the feed-back loop, which is then amplified and fed directly onto the line.

To produce the high current-voltage slope below 20 mA, see Fig. 3, an additional block called a "fire-down" circuit is added. The basic idea is to change the voltage reference as a function of line current, i.e. the lower the current the lower the reference voltage below a specified line current. The two curves of Figs. 5 and 6 show the required characteristics, which makes it possible for the full V_R to be available in normal, i.e. non-parallel, operation, i.e. above 20mA line current.

The fire down block, plus the voltage regulation, is shown in Fig. 7, with some explanatory graphs shown as insets.

Here the voltage across R_1 is the product of the line current and the value of R_1 : now when the voltage decreases to equal V_{R1} , the reference voltage for a second amplifier A_1 , the amplifier A which was previously saturated begins to amplify the small decreases in V_{R1} causing the output from this amplifier A to decrease the voltage reference for the regulator block.

Thus it will be seen that when the line current I_L decreases the voltage across R_1 also decreases, which changes the value of V_x at the input to A_1 . The amplified version of this voltage V_x is used, via A_1 , to change the basic voltage V_L which decreases pro rata as the line current decreases.

The threshold for this "fire-down" sequence is set by the voltage reference V_{R1} and the value of the feedback resistor R_1 . The components R_f and C_s are not directly involved but they are necessary when the two blocks are used for the transmission of signals to the line.

In the block diagram of Fig. 8 the block labelled POS BRIDGE contains the bridge amplifier described and claimed in my application 43602/78 (P.F. Blomley—2), and it

5 produces the positive supply voltage for the circuit from terminal 14 across the resistor R1 (Fig. 7). The speech voltages incoming to the telephone set via the terminals designated LINE TERMINATIONS shown reach the ear-
10 piece via terminal 14, capacitor C6, terminal 9, resistor Z1 of the SIDETONE NETWORK, terminal 10, receiver amplifier RX AMP and the receiver output circuit RX O/P. This latter block includes such additional amplification as
15 may be needed.

Note that due to the characteristics of the bridge amplifier in the block POS BRIDGE, as explained in the above mentioned application, the direct voltage is made available by POS
20 BRIDGE with very small voltage drop from the incoming line voltage. This, as explained in the above mentioned application, is especially important when the set is connected to a long line, or when the set is parallel with a low
25 voltage (e.g. carbon microphone type) telephone set.

The positive supply voltage from terminal 3 is also applied to a reference amplifier REF AMP, where it is compared with an internally
30 generated reference voltage V_R . An error signal which results from the difference between the signals at the two inputs to the REF AMP is generated by this comparison at the output or REF AMP to adjust the amplification for
35 outgoing speech and voice frequency signal, via the connection shown from REF AMP to the main amplifier MAIN AMP and LINE DRIVE block. The combination in the Fig. 8 of the REF AMP, MAIN AMP and LINE DRIVE
40 form the equivalent of the amplifier A of Figs. 4 and 7. The circuit which generates the reference voltage V_R is controlled by A' (fire down) circuit designated in Fig. 8 as FIRE DOWN which corresponds to the amplifier A1
45 of Fig. 7.

In correlating Fig. 7 with Fig. 8 there can be seen in Fig. 8, a path from positive supply terminal to the upper input lead of RED AMP. The second input of the REF AMP receives
50 the reference voltage from the output of the fire down amplifier. One output of the regulator circuit (amplifier A of Fig. 7) is coupled from the main output of the LINE DRIVE block through resistance R_v to the upper input of
55 the FIRE DOWN amplifier. A further output of the LINE DRIVE to the positive bridge input 1, comprises the feedback path to the upper lead of the REF AMP including a path through terminal 1, the POS BRIDGE, terminal 14,
60 resistor R1 and terminal 3 at the positive supply. The LINE DRIVE main output may also be traced through terminal 16 and resistor R6 to ground at terminal 2. The upper input to the FIRE DOWN may also be traced
65 to terminal 7 coupled to ground through cap-

itor C8. The reference input to the FIRE DOWN amplifier of Fig. 8 is in fact generated inside the FIRE DOWN amplifier and referenced to ground at terminal 2.

70 The voltage between terminals 7 and 2 (in Fig. 8) is a voltage which corresponds to the mean value of current in resistor R6 and thus controls when the regulator of the present circuit starts to decrease the control voltage of
75 the source which in effect appears at terminal 3.

The speech from the microphone passes via an input amplifier 1/P, the main amplifier MAIN AMP and line drive circuitry LINE
80 DRIVE to the terminal 16, from which it passes via the SIDE TONE NETWORK (Z1-Z2). Capacitor C6, terminal 14 and POS BRIDGE to the line. The terminal 9 of the SIDE TONE NETWORK is connected via SYM
85 Clip to the input amplifier 1/P to control the latter in accordance with the amplitude at 9, i.e. to give a measure of automatic volume control. When voice frequency signals usually from a push-button key set have to be sent,
90 these signals reach MAIN AMP via a voice frequency amplifier VF. This signal is muted via the connection shown, in the presence of speech, the means to control the mute input not being shown. Control of the operations of
95 the various circuit elements is also affected, in accordance with line conditions via another amplifier REG AMP.

Finally the blocks labelled RX BRIDGE and NEG BRIDGE perform similar functions to
100 those performed by the blocks RXB and RLB of the circuit shown in Fig. 4 of the above mentioned application. It should be noted that when a relatively small circuit assembly such as that of Fig. 7 is configured as a portion
105 of a complex integrated circuit such as that of Fig. 8, rigid terminal to terminal correspondence is not feasible. In addition, the function of the single amplifier A of Fig. 7 may be performed by a plurality of amplifiers in the
110 integrated circuit of Fig. 8, however, the combined amplifier of REF AMP, MAIN AMP and LINE DRIVE performs its combined function in the manner of amplifier A of Fig. 7.

115 CLAIMS

1. A shunt-voltage regulation circuit which includes a first amplifier to one input of which is applied a voltage from a voltage source and to another input of which is applied a first
120 reference voltage so that the output of the amplifier is a voltage dependent on a comparison of said voltages, said output providing the regulated output of the circuit, a feed-back connection from the amplifier's output to the
125 first input of the amplifier, a further output from the first amplifier from which a voltage proportional to the output voltage of the first amplifier is applied to a first input of a second amplifier to a second input of which is applied
130 a second reference voltage, and a connection



In the block diagram of Fig. 8 the block labelled POS BRIDGE contains the bridge amplifier described and claimed in my application 43602/78 (P.F. Blomley—2), and it

5 produces the positive supply voltage for the circuit from terminal 14 across the resistor R1 (Fig. 7). The speech voltages incoming to the telephone set via the terminals designated LINE TERMINATIONS shown reach the ear-
10 piece via terminal 14, capacitor C6, terminal 9, resistor Z1 of the SIDETONE NETWORK, terminal 10, receiver amplifier RX AMP and the receiver output circuit RX O/P. This latter block includes such additional amplification as
15 may be needed.

Note that due to the characteristics of the bridge amplifier in the block POS BRIDGE, as explained in the above mentioned application, the direct voltage is made available by POS
20 BRIDGE with very small voltage drop from the incoming line voltage. This, as explained in the above mentioned application, is especially important when the set is connected to a long line, or when the set is parallel with a low
25 voltage (e.g. carbon microphone type) telephone set.

The positive supply voltage from terminal 3 is also applied to a reference amplifier REF AMP, where it is compared with an internally
30 generated reference voltage V_R . An error signal which results from the difference between the signals at the two inputs to the REF AMP is generated by this comparison at the output or REF AMP to adjust the amplification for
35 outgoing speech and voice frequency signal, via the connection shown from REF AMP to the main amplifier MAIN AMP and LINE DRIVE block. The combination in the Fig. 8 of the REF AMP, MAIN AMP and LINE DRIVE
40 form the equivalent of the amplifier A of Figs. 4 and 7. The circuit which generates the reference voltage V_R is controlled by A' (fire down) circuit designated in Fig. 8 as FIRE DOWN which corresponds to the amplifier A1
45 of Fig. 7.

In correlating Fig. 7 with Fig. 8 there can be seen in Fig. 8, a path from positive supply terminal to the upper input lead of RED AMP. The second input of the REF AMP receives
50 the reference voltage from the output of the fire down amplifier. One output of the regulator circuit (amplifier A of Fig. 7) is coupled from the main output of the LINE DRIVE block through resistance R_v to the upper input of
55 the FIRE DOWN amplifier. A further output of the LINE DRIVE to the positive bridge input 1, comprises the feedback path to the upper lead of the REF AMP including a path through terminal 1, the POS BRIDGE, terminal 14,
60 resistor R1 and terminal 3 at the positive supply. The LINE DRIVE main output may also be traced through terminal 16 and resistor R6 to ground at terminal 2. The upper input to the FIRE DOWN may also be traced
65 to terminal 7 coupled to ground through cap-

acitor C8. The reference input to the FIRE DOWN amplifier of Fig. 8 is in fact generated inside the FIRE DOWN amplifier and referenced to ground at terminal 2.

70 The voltage between terminals 7 and 2 (in Fig. 8) is a voltage which corresponds to the mean value of current in resistor R6 and thus controls when the regulator of the present circuit starts to decrease the control voltage of the source which in effect appears at terminal
75 3.

The speech from the microphone passes via an input amplifier 1/P, the main amplifier MAIN AMP and line drive circuitry LINE
80 DRIVE to the terminal 16, from which it passes via the SIDE TONE NETWORK (Z1-Z2). Capacitor C6, terminal 14 and POS BRIDGE to the line. The terminal 9 of the SIDE TONE NETWORK is connected via SYM
85 Clip to the input amplifier 1/P to control the latter in accordance with the amplitude at 9, i.e. to give a measure of automatic volume control. When voice frequency signals usually from a push-button key set have to be sent,
90 these signals reach MAIN AMP via a voice frequency amplifier VF. This signal is muted via the connection shown, in the presence of speech, the means to control the mute input not being shown. Control of the operations of
95 the various circuit elements is also affected, in accordance with line conditions via another amplifier REG AMP.

Finally the blocks labelled RX BRIDGE and NEG BRIDGE perform similar functions to
100 those performed by the blocks RXB and RLB of the circuit shown in Fig. 4 of the above mentioned application. It should be noted that when a relatively small circuit assembly such as that of Fig. 7 is configured as a portion
105 of a complex integrated circuit such as that of Fig. 8, rigid terminal to terminal correspondence is not feasible. In addition, the function of the single amplifier A of Fig. 7 may be performed by a plurality of amplifiers in the
110 integrated circuit of Fig. 8, however, the combined amplifier of REF AMP, MAIN AMP and LINE DRIVE performs its combined function in the manner of amplifier A of Fig. 7.

115 CLAIMS

1. A shunt-voltage regulation circuit which includes a first amplifier to one input of which is applied a voltage from a voltage source and to another input of which is applied a first
120 reference voltage so that the output of the amplifier is a voltage dependent on a comparison of said voltages, said output providing the regulated output of the circuit, a feed-back connection from the amplifier's output to the
125 first input of the amplifier, a further output from the first amplifier from which a voltage proportional to the output voltage of the first amplifier is applied to a first input of a second amplifier to a second input of which is applied
130 a second reference voltage, and a connection



from the output of the second amplifier to the source of the first reference voltage via which the said first reference voltage is adjustable in accordance with the value of the output voltage of the said amplifier, wherein as the

- 5 current in the circuit to which the regulated output is applied varies the voltage output of the first amplifier is subjected to very small variations above a threshold level, but to
- 10 relatively large variation below the threshold, the voltage decreasing with current below said threshold.

2. A circuit as claimed in claim 1, in which the connection from the output of the
- 15 first amplifier to the first input of the second amplifier includes a resistive impedance with a capacitor connected from that first input to a reference so that audio frequency signals may be passed via the first amplifier.

- 20 3. An electric circuit for use in a telephone subscriber's instrument in which line voltage is regulated by a circuit such as that of claim 1 or 2.

4. A shunt voltage regulation circuit substantially as described with reference to Figs.
- 25 3, 4, 5, 6 and 7 of the accompanying drawings.

5. An electronic circuit for use in a telephone subscribers instrument, substantially as
- 30 described with reference to Fig. 8 of the accompanying drawings.