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(54) **CIRCUIT ASSEMBLY FOR PROCESSING AN ELECTRICAL SIGNAL OF A MICROPHONE**

SCHALTUNGSANORDNUNG ZUR VERARBEITUNG EINES ELEKTRISCHEN SIGNALS EINES MIKROFONS

AGENCEMENT DE CIRCUIT POUR TRAITEMENT D'UN SIGNAL ÉLECTRIQUE DE MICROPHONE

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(56) References cited:
WO-A1-99/38355
GB-A- 2 377 848
US-A1- 2009 296 952
US-A1- 2010 177 924

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a combination of a microphone and a circuit assembly for processing an electrical signal of the microphone, a device comprising such a combination of a microphone and a circuit assembly for processing an electrical signal of the microphone, and a method for processing an electrical signal of a microphone. The invention relates especially to a reduction of disturbances on an electrical signal of a microphone when the microphone is connected to a device via a multi-port plug-and-socket connection. The disturbances may comprise for example a resonance, an echo, a crosstalk, or a so called bumblebee noise.

BACKGROUND OF THE INVENTION

[0002] Mobile devices, for example mobile phones or smart phones, are frequently used in connection with portable hands free sets (PHF). These portable hands free sets comprise for example a stereo earphone, a microphone and an antenna. The portable hands free set is usually connected to the mobile device via a phone jack. The phone jack may comprise a multi-port plug-and-socket connection comprising for example four electrical contacts providing signal paths for a left and a right earphone signal, a microphone signal, and ground. An antenna signal may additionally be transferred by one of these signal paths, for example via a signal path of the left or the right earphone signal.

[0003] However, currently there are at least two different audio connector standards used for these phone jacks, the OMTP (open mobile terminal platform) used in Europe and the CTIA (cellular telecommunications industry association) used in North America. The two connector types differ at least in an interchanged position of the ground and microphone contacts. Therefore, a circuit design is need which allows to change the signals associated to the contacts to support both standards. However, due to the demand to use a common ground for the earphone audio signals and the microphone signals in combination with the demand of transferring the antenna signal, disturbances may occur especially on the microphone signal.

[0004] Therefore, there is a need to reduce disturbance on a microphone signal.

[0005] A combination of a microphone and a circuit assembly for processing an electrical signal of the microphone according to the preamble of claim 1 is known from GB 2 377 848 A. In addition WO 99/38355 A1 proposes to use switches to exchange a bias voltage and a microphone signal in order to be able to use two different connection types of microphones.

SUMMARY OF THE INVENTION

[0006] According to the present invention, this object is achieved by a combination of a microphone and a circuit assembly for processing an electrical signal of the microphone as defined in claim 1, and a method for processing an electrical signal of a microphone as defined in claim 12. The dependent claims define preferred and advantageous embodiments of the invention.

[0007] According to an aspect of the present invention a combination of a microphone and a circuit assembly for processing an electrical signal of the microphone is provided. The microphone has an inherent impedance and comprises a first electrical output and a second electrical output. A voltage between the first electrical output and the second output corresponds to an acoustic input signal received by the microphone. The circuit assembly comprises an impedance circuit, a signal processing unit comprising a first input and a second input, a first electrical signal path, and a second electrical signal path. The first electrical signal path is coupleable to the first electrical output of the microphone, that means that the first electrical signal path can be coupled to the first electrical output of the microphone via e.g. a phone jack. Furthermore, the first electrical signal path is coupled to the first input of the signal processing unit. The second electrical signal path is coupleable to the second electrical output of the microphone and is further coupled to the second input of the signal processing unit via the impedance circuit. An impedance value of the impedance circuit is selected based on an impedance value of the inherent impedance of the microphone.

[0008] The microphone can be assumed to comprise a current source and an impedance in parallel. Therefore, an equivalent circuit of the microphone may comprise an ideal current source and the inherent impedance in parallel to the ideal current source. When coupling the above-described circuit assembly to the microphone, the first electrical output of the microphone is coupled directly to the signal processing unit and the second electrical output of the microphone is coupled via the second signal path and the impedance circuit to the signal processing unit. When a disturbing signal is added to the second electrical signal path, for example due to a common usage of the second electrical signal path by the microphone and an earphone as a common ground path, the disturbing signal influences a signal on the first electrical output of the microphone via the inherent impedance of the microphone, and the disturbing signal influences the signal of the microphone at the second electrical output of the microphone running through the impedance circuit. Therefore, the signal processing unit sees the disturbing signal at the first input through the inherent impedance of the microphone and at the second input through the impedance circuit. This allows the signal processing unit, for example by using a differential amplifier, to detect and compensate the disturbing signal.

[0009] The circuit assembly comprises a further impedance circuit which couples the second electrical signal path to ground. The second electrical signal path may be used as a common ground return path for the microphone and one or more earphone loudspeakers of a portable hands free set. By coupling the second electrical signal path via an impedance to ground, for example via an inductive impedance like a bead, a ground signal path can be provided and at the same time an antenna signal may be received from a wiring of the portable hands free set without being effected by the ground connection of the portable hands free set.

[0010] According to an embodiment, the first electrical signal path and the second electrical signal path are comprised in a multiport plug and socket connection for detachably connecting the microphone to the first and second electrical signal paths. Thus, a detachable connection between the portable hands free set and a mobile device, for example a mobile phone, can be realized. The multiport plug and socket connection may comprise furthermore a third electrical signal path which is coupled to an electrical signal source feeding a further electrical signal with respect to ground into the third electrical signal path. The further electrical signal may comprise for example an audio output signal to be output by an earphone speaker of the portable hands free set. Furthermore, the multiport plug and socket connection may comprise a fourth electrical signal path which is coupled to an electrical signal source feeding another electrical signal with respect to ground into the fourth electrical signal path. The other electrical signal may comprise for example a further audio output signal for a further earphone speaker. Thus, a portable hands free set with stereo earphone speakers and a microphone can be realized. The first, second, third or the fourth electrical signal path may be furthermore coupled to a radio frequency receiver adapted to receive an antenna signal via the first, second, third or fourth electrical signal path, respectively. Thus, a portable hands free set providing audio input and output as well as a radio frequency antenna can be coupled to a mobile device via a multiport plug and socket connection with a minimum of electrical contacts in the multiport plug and socket connection. For example, a multiport plug and socket connection with four contacts may be sufficient to realize a stereo portable hands free set including a microphone and a radio frequency antenna.

[0011] However, as already described above in the background of the invention, currently there are at least two different standards for connecting a portable hands free set to a mobile device, the OMTP used in Europe and the CTIA used in North America. The two connector types differ at least in an interchanged position of the ground and microphone contacts. Therefore, the circuit assembly may comprisethree switches. A first switch is coupled to the first electrical signal path, the second electrical signal path and the first input of the signal processing unit. The first switch is configured to selectively couple the first electrical signal path or the second electrical signal path to the first input of the signal processing unit. A second switch is coupled to the first electrical signal path, the second electrical signal path and ground. The second switch is configured to selectively couple the first electrical signal path or the second electrical signal path to ground via a further impedance circuit. Thus, the first switch and the second switch allow to couple portable hands free sets in which a ground and a microphone signal may be interchanged at the first electrical signal path and the second electrical signal path. By appropriately controlling the first and the second switch, depending on the portable hands free set, the required ground and microphone signal connections can be provided. By coupling the second electrical signal path to ground via the further impedance circuit, an antenna signal can be received via the portable hands free set as described above. Furthermore, the circuit assembly comprises a third switch coupled to the first electrical signal path, the second electrical signal path and the second input of the signal processing unit. The third switch is configured to selectively couple the first electrical signal path or the second electrical signal path to the second input of the signal processing unit via the impedance circuit. An impedance value of the impedance circuit is selected based on an impedance value of the inherent impedance of the microphone. As described above, by using the first electrical signal path or the second electrical signal path as a common ground return path for the portable hands free set, a disturbance on the common ground return path may influence the electrical signals from the microphone. By additionally coupling the common ground return path via the impedance circuit to the signal processing unit via the third switch, the signal processing unit is facilitated to detect and reduce such a disturbance. As the switches themselves may have a resistance or an impedance, a disturbing signal e.g. due to an earphone signal on the common ground path may generate a disturbance due to the switch resistance or switch impedance. The switch resistance or switch impedance of the third switch is considerably smaller than the impedance of the impedance circuit and can be neglected. However, a disturbance generated due to the switch resistance or switch impedance of a switch coupled to ground may be considerable. Therefore, by providing the microphone signal at the first input of the processing unit and via the impedance circuit at the second input, the disturbance is thus detectable by the signal processing unit and can be removed or compensated.

[0012] According to an embodiment, the impedance value of the impedance circuit corresponds substantially to the impedance value of the inherent impedance of the microphone. The impedance circuit may comprise a series connection of a resistive element and a capacitive element. This combination of elements allows to approximate the inherent impedance of the microphone appropriately. E.g., the value of the impedance circuit may be in the same order of magnitude as the value of the inherent impedance.

[0013] According to an embodiment, the circuit assembly comprises furthermore a first low pass filter being coupled to the first input of the signal processing unit, and a second high pass filter being coupled to the second input of the signal processing unit. When the circuit assembly is used for coupling a portable hands free set to a mobile device, and the wiring of the portable hands free set is used as a radio frequency antenna, all signal paths may typically comprise inductive elements in a series connection, for example beads, to avoid a shortcut of the antenna signal. Furthermore, these inductive elements may also act as a part of a low pass filter for frequencies lower than for example 1-10MHz, which may help to reject frequencies introduced from the outside. Furthermore, during an electrostatic discharge (ESD) the inductive elements may add an impedance during the first 100-1000ns after a discharge that forces more current to flow through corresponding ESD protection diodes and less current through the circuits more sensitive protection diodes during this time. However, these inductive elements may generate resonance disturbances on the microphone signals provided to the signal processing unit. The low pass filters at the inputs of the signal processing unit may reduce such resonances, which may especially occur due to the inductive elements during electrostatic discharge (ESD) or current clamp tests.

[0014] According to another aspect of the present invention, a device is provided which comprises a multiport plug and socket connection for coupling the device to a microphone and a circuit assembly as described above. The device may comprise a mobile phone, a personal digital assistant, a mobile music player or a navigation system. The microphone may be comprised in a portable hands free set which may comprise additionally mono or stereo earspeakers and a radio frequency antenna for receiving for example broadcast radio frequency signals, especially radio broadcast signals in an FM frequency range.

[0015] Although specific features described in the above summary and the following detailed description are described in connection with specific embodiments, it is to be understood that the features of the embodiments may be combined with each other unless specifically noted otherwise.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The invention will now be described in more detail with reference to the accompanying drawings.

Fig. 1 shows a circuit diagram of a mobile device according to an embodiment of the present invention.

Fig. 2 shows a circuit diagram comprising a circuit assembly according to an embodiment of the present invention.

Fig. 3 shows a circuit diagram comprising a circuit assembly according to an embodiment of the present invention, which may be used for simulating the effect of the circuit assembly.

Fig. 4 shows simulation results of the circuit diagram of Fig. 3.

Fig. 5 shows a circuit diagram comprising a circuit assembly according to an embodiment of the present invention, which may be used for simulating an influence of switches.

Fig. 6 shows simulation results of the circuit diagram of Fig. 5.

Fig. 7 shows a circuit diagram comprising a further circuit assembly according to an embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0017] In the following, exemplary embodiments of the present invention will be described in more detail. It has to be understood that the following description is given only for the purpose of illustrating the principles of the invention and is not to be taken in a limiting sense. Rather, the scope of the invention is defined only by the appended claims and is not intended to be limited by the exemplary embodiments hereinafter.

[0018] It is to be understood that the features of the various exemplary embodiments described herein may be combined with each other unless specifically noted otherwise. Furthermore, any direct coupling of functional units or components in the embodiments shown in the Figures or described in the following detailed description may also be realized as an indirect coupling. Finally, same reference signs in the various instances of the drawings refer to similar or identical components.

[0019] Fig. 1 shows a circuit diagram of a mobile device 100 adapted to adapt to a portable hands free set (PHF) according to either an OMTP or a CTIA standard. On the left hand side of Fig. 1 the two possible portable hands free sets 101 and 102 which can be connected to the mobile device 100 via an audio connector 110 are shown. Portable hands free set 101 is wired according to the CTIA standard and portable hands free set 102 is wired according to the OMTP standard. Each of the portable hands free sets 101, 102 comprises a microphone 103, a right earspeaker 104, and a left earspeaker 105. Furthermore, the wire to the right earspeaker 104 may be used as an FM antenna, as will be explained below. The portable hands free set 101, 102 may be connected to the audio connector 110 of the mobile device 100 via an audio jack. For example, the portable hands free set 101, 102 may comprise an audio jack plug with four terminals 106-109 which may be received by a corresponding audio jack socket of the audio connector 110 comprising four terminals 111-114 for establishing a connection to the corresponding terminals 106-109 of the portable hands free set. The audio jack plug and the audio jack socket constitute a so called multiport plug and socket connection. The audio connector 110 may comprise an additional electrical pin 115 which breaks the connection to terminal 114 when the audio jack plug of the portable hands free set is inserted into the audio connector 110. Pin 115 may be connected to a corresponding detect line 116 to detect when the portable hands free set is coupled to the mobile device 100. The terminals 111 and 112 of the audio connector 110 each comprise two terminals 117, 118 and 119, 120, respectively. Terminals 118 and 119 are used as so called "sense" terminals to couple the microphone 103 via an impedance comprising a resistor 125, 126 and a capacitance 130 to a microphone signal processing unit 140 to enable a disturbance reduction on the microphone signal, for example an echo cancellation, in the microphone signal processing unit 140 as will be described below. Terminal 118 is used as sense terminal when the CTIA portable hands free set 101 is connected to the mobile device 100, and terminal 119 is used as the sense terminal when the OMTP portable hands free set 102 is connected to the mobile device 100. By using these sense terminals 118, 119 it is possible to sense the lower side of the microphone 103 without any influence from the high currents generated to drive the earspeakers 104, 105.

[0020] As can be seen from the wirings of the CTIA portable hands free set (PHF) 101 and the OMTP portable hands free set (PHF) 102, the main difference between the two portable hands free sets is that the signal from the microphone 103 and the common ground are exchanged on terminals 106 and 107. In CTIA PHF 101 terminal 106 is the common ground for the microphone 103 and the earspeakers 104, 105, and terminal 107 is used for passing the signal from the microphone 103. In the OMTP PHF 102 the common ground is located at terminal 107 and the signal of the microphone 103 is passed via terminal 106. In both portable hands free sets 101, 102 a signal for the right earspeaker 104 is passed via terminal 108 and a signal for the left earspeaker 105 is passed via terminal 109. When one of the portable hands free sets 101, 102 is connected to the mobile device 100, terminal 109 is connected to terminal 114, terminal 108 is connected to terminal 113, terminal 107 is connected to terminal 112 (and thus to terminals 119, 120), and terminal 106 is connected to terminal 111 (and thus to terminals 117 and 118).

[0021] The wiring of the portable hands free set 101, 102 is additionally used as an FM antenna. Therefore, each of the terminals 113, 114, 117 and 120 of the audio connector 110 is first connected to corresponding ferrite beads 121-124 to provide high impedance for the FM antenna signal. For the sense terminals 118, 119 the resistors 125, 126 provide the high impedance for the FM antenna signal. The FM antenna signal is decoupled from terminal 113 via a capacitor 127 and provided for further use at terminal 128. Audio signals for the earspeakers 104 and 105 are provided at corresponding terminals 138 and 139.

[0022] To accomplish interworking with the different wiring of the CTIA PHF 101 and the OMTP PHF 102 three switches 131-133 are provided. The switches 131-133 may be simultaneously toggled from a first switching position to a second switching position and vice versa under control of a control signal on line 134. The switches 131-133 may be comprised in an integrated semiconductor circuit or a relay or a manual switch. The terminals 111 and 112 are coupled via the beads 121, 122 and the resistors 125, 126 to one side of the switches 131-133, and a first microphone input terminal 135 and a second microphone input terminal 136 of the microphone signal processing unit, and ground 137 are connected to another side of the switches 131-133. Additionally, for electrostatic discharge (ESD) protection at each coupling between the audio connector 110 and the microphone signal processing unit 140 a corresponding ESD diode 141, 142 is provided and connected to ground. Corresponding ESD diodes 143 and 144 are provided for ESD protection on signal paths coupled to terminals 113 and 114.

[0023] In the first switching position of the switches 131-133 the first microphone input terminal 135 is connected to terminal 117, the second microphone input terminal 136 is connected to terminal 119, and ground 137 is connected to terminal 120. Thus, in the first switching position the OMTP PHF 102 may be correctly driven by the mobile device 100. In the second switching position of the switches 131-133 the first microphone input terminal 135 is connected via switch 131 to terminal 120, the second microphone input terminal 136 is connected via the switch 132 to terminal 118, and ground 137 is connected via the switch 133 to terminal 117. Thus, in the second switching position the CTIA PHF 101 may be driven correctly by the mobile device 100. To sum up, the three switches 131-133 can select between OMTP and CTIA operation by cross connecting the microphone input signal of the microphone input terminals 135, 136 and the common ground 137. It should be noted that the ESD diodes 141-144 and additional components for EMC (electromagnetic compatibility) protection may be comprised in an integrated circuit 129 as shown in Fig. 1. Furthermore, the circuit 129 may also comprise components of an audio and current clamp input filtering system together with some capacitors and the current clamp rejecting system together with additional ferrite beads 145, 146.

[0024] At terminal 147 a bias voltage for driving the microphone 103 is provided via a resistor 148 and resistors 149, 150 to the microphone 103. Furthermore, at each microphone input terminal 135, 136 of the microphone signal processing unit 140 a filter comprising a capacitor 151, 152 and a resistor 153, 154 is provided for reducing resonance on the microphone signals during an ESD protection test or a current clamp test which may occur due to the beads 121-124.

[0025] Functioning of the circuit shown in Fig. 1, especially the principle of operation of the impedance circuit 125, 126, 130 of the sense terminals 118, 119 for reducing disturbances on the microphone signal, and especially the advantages arising from the use of the switch 132, will be described in more detail in connection with the circuit diagrams of Figs. 2, 3 and 5.

[0026] Fig. 2 shows a circuit diagram representing only the essential parts of the circuit diagram of Fig. 1, wherein some components of Fig. 1 are replaced by equivalent components for simulating the circuit diagram with an analogue circuit simulation tool. Same reference signs in Fig. 2 and Fig. 1 refer to same components or to equivalent components as will be described in the following. Fig. 2 shows the case in which the OMTP PHF 102 is coupled to the mobile device 100 and therefore the switches 131-133 are in the first switching position as shown in Fig. 1. The common ground return path of the microphone 103 and the earspeakers 104, 105 is therefore located at terminal 112, 107, 119, and 120. The common ground return path is connected via bead 122 and switch 133 to ground 137.

[0027] In Fig. 2 the microphone 103 is shown as an equivalent circuit comprising a current source 201 and in parallel an inherent impedance comprising a series connection of a capacitor 202 and a resistor 203. The earspeakers 104 and 105 are represented in Fig. 2 as resistors 104 and 105, respectively. A resistance of a signal path from the earspeaker signal sources 138, 139 to the earspeakers 104, 105 is represented in Fig. 2 by resistors 205, 206. The signal sources of the audio signals for the earspeakers 104, 105 are represented in Fig. 2 as oscillating voltage sources 138, 139. For a simulation (the simulation results will be discussed later), signal source 138 represents the audio source for the right channel and may have a frequency of for example 827 Hz, and signal source 139 may represent the left audio channel and may have a frequency of 1000 Hz. The bias voltage 147 is represented by a direct current voltage source 147 in Fig. 2. In series with this voltage source 147 an oscillating voltage source 207 is shown in Fig. 2 which represents a variation of the bias voltage when in practice of a mobile device the battery voltage drops for example during a GSM transmission burst. The disturbance generated by the transmission burst of a mobile phone working according to the GSM standard would typically generate a disturbing sound signal which is also called "bumblebee" noise due to its frequency profile. Furthermore, during such a transmission burst a ground potential may be raised and therefore an oscillating voltage source 208 is shown in Fig. 2 representing a corresponding disturbance on the ground signal. For the simulation, a frequency of the oscillating voltage sources 207, 208 may be selected at 1230 Hz. The microphone signal processing unit 140 of Fig. 1 is replaced in Fig. 2 by an operational amplifier 140 which receives at a first input 135 the signal from one end of the microphone 103 and at a second input 136 the signal from the other end of the microphone 103 guided through the impedance circuit comprising the resistor 126 and the capacity 130. At the output of the operational amplifier 140 a microphone signal 209 is provided.

[0028] Instead of simply processing the microphone signal from terminal 106 with respect to ground, the ground signal 107 of the common ground path of the portable hands free set is additionally guided through the impedance circuit comprising resistor 126 and capacitor 130 to the operational amplifier 140. The resistor 126 and the capacitor 130 are selected such that the resulting impedance corresponds substantially the inherent impedance of the microphone 103 represented by resistor 203 and capacitor 202. A value of the impedance circuit 126, 130 may be selected in the same order of magnitude as the impedance value of the inherent impedance 202, 203 of the microphone 103. For example, a typical microphone of a portable hands free set may have an inherent impedance with the capacitance 202 being about 4.7 μF and the resistance 203 being about 6 kΩ. Therefore, the capacitance 130 may be selected in a range of 1-10 μF and the resistor 126 may be selected in the range of 1-10 kΩ.

[0029] As can be seen from Fig. 2, when a disturbance on the common ground path occurs, for example due to a transmission burst of a GSM mobile device, this disturbance may be simulated by the oscillating voltage 208 which influences a voltage on the signal at 107. However, due to the impedance circuit 126, 130 which mirrors the inherent impedance 202, 203 of the microphone 103, this disturbance acts in the same way on both signals which are received at the inputs 135 and 136 of the operational amplifier 140. Therefore, the disturbance generated by the oscillating voltage 208 acts in a common mode on the operational amplifier 140 which performs a common mode rejection which reduces the disturbance on the microphone output signal 209.

[0030] In Fig. 1 the mirror impedance circuit is switched by a separate switch 132 instead of being switched together with switch 133. The reasons for this will be explained in the following in connection with Figs. 3 and 5.

[0031] Fig. 3 shows a circuit diagram which may be used for simulating the circuit of Fig. 1 when only one switch instead of the two switches 133 and 132 is used. The circuit diagram of Fig. 3 is very similar to the circuit diagram of Fig. 2 and the only difference is an additional resistor 210 in the common ground return path. This additional resistor 210 represents a resistance of the audio connector 110, the bead 121 and the common switch which replaces the two switches 133 and 132. An assumed value of this resistor 210 may be 2 Ω. When audio signals are output to the earspeakers 104, 105, these audio signals use the common return path and are therefore guided through resistor 210. This results in a voltage drop due to the audio signal for the earspeakers over resistor 210 which disturbs the output signal of the microphone 103 at the output 106 and the ground level of the microphone at the common ground 107. Therefore, an echo signal of the audio signal of the earspeakers is present at the microphone output 106.

[0032] Simulation results for the circuit shown in Fig. 3 are depicted in Fig. 4. Fig. 4 shows a frequency spectrum 401 of the audio signal for the right earspeaker, a frequency spectrum 402 of the audio signal for the left earspeaker, a frequency spectrum 403 of the common ground return path (for example at 107), a frequency spectrum 404 at the output 209 of the operational amplifier 140, and a frequency spectrum 405 at the output of the oscillating voltage generator 208. As can be seen from Fig. 4, the signal 403 on the common ground return path (for example at 107) is about 30 dB below the audio signals 401, 402 for the right and the left earspeakers. At the output 209 the echo signals 404 from the right and left earspeakers are about 40 dB below the audio signals 401, 402 of the earspeakers. Furthermore, as shown in Fig. 4, the above-described bumblebee disturbance 405, which has in the frequency range around 1230 Hz the same spectrum as the spectrum 403 of the common ground return path, is reduced by the common mode rejection by around 30 dB (the peak of spectrum 403 is about -40 dB and the peak of the spectrum 404 is about -70 dB at 1230 Hz). As can be seen from Fig. 4, the common mode rejection works very efficiently (30 dB) on the bumblebee noise, but rather poor (10 dB between spectrum 403 and spectrum 404 at 827 Hz and 1000 Hz) for the echo reduction. The reason for this is that the voltage drop over resistor 210 is mainly influenced by the relatively high currents of the audio signals for the earphones on the common ground return path. This voltage drop cannot be compensated by the common mode rejection of the circuit of Fig. 3.

[0033] Therefore, in Fig. 1 two separate switches 132 and 133 are provided for coupling the common return path 107 separately to the mirror impedance circuit 126, 130 and to ground, respectively. A corresponding circuit diagram for simulating both switches 132 and 133 is shown in Fig. 5. Resistor 210 represents switch 133 connecting the common ground path to ground 137. Resistor 211 represents switch 132 connecting the common return path to the mirror impedance circuit 126, 130. A voltage drop over the resistor 210 due to the currents of the audio signals for the left and right earspeakers still occurs. However, this voltage drop will not occur over resistor 211 as resistor 211 is in series connection with the mirror impedance 126, 130 which is much higher than the resistance of the switch 132 (which may be assumed to 2 Ω).

[0034] Simulation results of the circuit of Fig. 5 are depicted in Fig. 6. As can be seen from Fig. 6, the common mode rejection is now working on the echo from the audio signals from the earspeakers as well as on the bumblebee disturbance. The spectrum 404 of the microphone output signal 209 is now around 30 dB below the spectrum 403 of the echo disturbance on the common ground path.

[0035] Fig. 7 shows a further circuit diagram for coupling a portable hands free set (PHF) according to either an OMTP or a CTIA standard. Switches 703 and 704 provide the same cross connect switching logic as switches 131 and 133 of Fig. 1. Beads 121 a and 122a are used for decoupling the radio frequency signal received by the PHF. Protection diodes 701 and 702 are used for ESD protection of the switches 703 and 704, respectively. Beads 121b and 122b serve for a current clamp protection. Furthermore, beads 121b and 122b contribute to an ESD protection together with diodes 701 and 702. DC resistance affects return echo, therefore, preferably beads with a low DC resistance may be used. An on-resistance of the switches 703 and 704 may also be low as the resistance adds to the return echo.

[0036] Capacitor 130, switch 132, and resistors 125a, 125b, 126a, 126b form a feedback net which may cancel unwanted signals on the ground connection of the audio connector 110. Furthermore, these components may improve current clamp and bumble-bee performance. Protection diodes 705, 706 and resistors 125b, 126b may serve for ESD protection of switch 132.

Claims

1. A combination of a microphone (103) and a circuit assembly for processing an electrical signal of the microphone (103),
the microphone (103) having an inherent impedance (202, 203) and comprising a first electrical output (106) and a second electrical output (107), wherein a voltage between the first electrical output (106) and the second electrical output (107) corresponds to an acoustic input signal received by the microphone (103), and
the circuit assembly comprising:

- an impedance circuit (125, 126, 130) having an impedance value to be selected based on an impedance value of the inherent impedance (202, 203) of the microphone (103),
- a signal processing unit (140) comprising a first input (135) and a second input (136),
- a first electrical signal path (111) coupleable to the first electrical output (106) of the microphone (103) and coupled to the first input (135) of the signal processing unit (140), and
- a second electrical signal path (112) coupleable to the second electrical output (107) of the microphone (103) and coupled to the second input (136) of the signal processing unit (140) via the impedance circuit (125, 126, 130),

characterized in that the second electrical signal path (112) is additionally coupled to ground (137) via a further inductive impedance circuit (122).

2. The combination of claim 1, the circuit assembly further comprising:

- a first switch (131) coupled to the first electrical signal path (111), the second electrical signal path (112), and the first input (135) of the signal processing unit (140), and configured to selectively couple the first electrical signal path (111) or the second electrical signal path (112) to the first input (135) of the signal processing unit (140),
- a second switch (133) coupled to the first electrical signal path (111), the second electrical signal path (112), and ground (137), and configured to selectively couple the first electrical signal path (111) or the second electrical signal path (112) to ground (137) via a further inductive impedance circuit (121, 122), and
- a third switch (132) coupled to the first electrical signal path (111), the second electrical signal path (112), and the second input (136) of the signal processing unit (140), and configured to selectively couple the first electrical signal path (111) or the second electrical signal path (112) to the second input (136) of the signal processing unit (140) via the impedance circuit (125, 126, 130).

3. The combination according to any one of the preceding claims, wherein the first electrical signal path (111) and the second electrical signal path (112) are comprised in a multi-port plug-and-socket connection (110) for detachably connecting the microphone (103) to the first and second electrical signal paths (111, 112).

4. The combination according to claim 3, wherein the multi-port plug-and-socket connection (110) comprises furthermore a third electrical signal path (113), wherein the third electrical signal path (113) is coupled to an electrical signal source (138) feeding a further electrical signal with respect to ground (137) into the third electrical signal path (113).

5. The combination according to claim 4, wherein the first, second or third electrical signal path (111-113) is furthermore coupled to a radio frequency receiver (128) adapted to receive an antenna signal via the first, second or third electrical signal path (111-113).

6. The combination according to any one of the preceding claims, wherein the impedance value of the impedance circuit (125, 126, 130) corresponds substantially to the impedance value of the inherent impedance (202, 203) of the microphone (103).

7. The combination according to any one of the preceding claims, wherein the impedance circuit (125, 126, 130) comprises a series connection of a resistive element (125, 126) and a capacitive element (130).

8. The combination according to any one of the preceding claims, wherein the signal processing unit (140) comprises a differential amplifier configured to generate an electrical microphone output signal (209) based on a voltage difference at the first input (135) and the second input (136).

9. The combination according to any one of the preceding claims, the circuit assembly further comprising:

- a first low-pass filter (151, 153) being coupled to the first input (135) of the signal processing unit (140), and
- a second low-pass filter (152, 154) being coupled to the second input (136) of the signal processing unit (140).

10. A device comprising:

- the combination of a microphone (103) and a circuit assembly according to any one of the preceding claims, and
- a multi-port plug-and-socket connection (110) for coupling the device (100) to the microphone (103).

11. The device according to claim 10, wherein the device (100) comprises at least one device of a group consisting of a mobile phone, a personal digital assistant, a mobile music player, and a navigation system.

12. A method for processing an electrical signal of a microphone, the microphone (103) having an inherent impedance (202, 203) and providing a first electrical output signal and a second electrical output signal, wherein a voltage between the first electrical output signal and the second electrical output signal corresponds to an acoustic input signal received by the microphone (103), the method comprising:

- guiding the second electrical output signal of the microphone (103) through an impedance circuit (125, 126, 130) having an impedance value selected based on an impedance value of the inherent impedance (202, 203) of the microphone (103), and
- generating an electrical microphone output signal (209) based on a signal difference between the first electrical output signal and the second electrical output signal guided through the impedance circuit (125, 126, 130),

characterized in that the second electrical output signal of the microphone (103) is additionally guided via a further inductive impedance circuit (122) to ground (137).

13. The method of claim 12, the method further comprising:

- providing a signal processing unit (140) configured to generate the electrical microphone output signal (209) based on electrical microphone signals at a first input (135) and a second input (136) of the signal processing unit (140),
- coupling a first electrical output (106) of the microphone (103) to the first input (135) of the signal processing unit (140),
- coupling a second electrical output (107) of the microphone (103) and the second input (136) of the signal processing unit (140) via the impedance circuit (125, 126, 130).

Patentansprüche

1. Kombination eines Mikrofons (103) und einer Schaltungsanordnung zum Verarbeiten eines elektrischen Signals des Mikrofons (103),
wobei das Mikrofon (103) eine inhärente Impedanz (202, 203) aufweist und einen ersten elektrischen Ausgang (106) und einen zweiten elektrischen Ausgang (107) umfasst, wobei eine Spannung zwischen dem ersten elektrischen Ausgang (106) und dem zweiten elektrischen Ausgang (107) einem von dem Mikrofon (103) empfangenen akustischen Eingangssignal entspricht, und wobei die Schaltungsanordnung umfasst:

- eine Impedanzschaltung (125, 126, 130) mit einem Impedanzwert, welcher basierend auf einem Impedanzwert der inhärenten Impedanz (202, 203) des Mikrofons (103) auszuwählen ist,
- eine Signalverarbeitungseinheit (140), umfassend einen ersten Eingang (135) und einen zweiten Eingang (136),
- einen ersten elektrischen Signalpfad (111), welcher an den ersten elektrischen Ausgang (106) des Mikrofons (103) koppelbar ist und an den ersten Eingang (135) der Signalverarbeitungseinheit (140) gekoppelt ist, und
- einen zweiten elektrischen Signalpfad (112), welcher an den zweiten elektrischen Ausgang (107) des Mikrofons (103) koppelbar ist und über die Impedanzschaltung (125, 126, 130) an den zweiten Eingang (136) der Signalverarbeitungseinheit (140) gekoppelt ist,

dadurch gekennzeichnet, dass der zweite elektrische Signalpfad (112) zusätzlich über eine weitere induktive Impedanzschaltung (122) an Masse (137) gekoppelt ist.

2. Kombination gemäß Anspruch 1, wobei die Schaltungsanordnung ferner umfasst:

- einen ersten Schalter (131), welcher an den ersten elektrischen Signalpfad (111), den zweiten elektrischen Signalpfad (112) und den ersten Eingang (135) der Signalverarbeitungseinheit (140) gekoppelt ist, und dazu eingerichtet ist, den ersten elektrischen Signalpfad (111) oder den zweiten elektrischen Signalpfad (112) selektiv an den ersten Eingang (135) der Signalverarbeitungseinheit (140) zu koppeln,
- einen zweiten Schalter (133), welcher an den ersten elektrischen Signalpfad (111), den zweiten elektrischen Signalpfad (112) und an Masse (137) gekoppelt ist, und dazu eingerichtet ist, den ersten elektrischen Signalpfad (111) oder den zweiten elektrischen Signalpfad (112) selektiv über eine weitere induktive Impedanzschaltung (121, 122) an Masse (137) zu koppeln, und
- einen dritten Schalter (132), welcher an den ersten elektrischen Signalpfad (111), den zweiten elektrischen Signalpfad (112), und den zweiten Eingang (136) der Signalverarbeitungseinheit (140) gekoppelt ist, und dazu eingerichtet ist, den ersten elektrischen Signalpfad (111) oder den zweiten elektrischen Signalpfad (112) über die Impedanzschaltung (125, 126, 130) selektiv an den zweiten Eingang (136) der Signalverarbeitungseinheit (140) zu koppeln.

3. Kombination gemäß einem jeden der vorhergehenden Ansprüche, wobei der erste elektrische Signalpfad (111) und der zweite elektrische Signalpfad (112) zum lösbaren Verbinden des Mikrofons (103) mit den ersten und zweiten elektrischen Signalpfaden (111, 112) in einer Multiport-Steckverbindung (110) umfasst sind.

4. Kombination gemäß Anspruch 3, wobei die Multiport-Steckverbindung (110) ferner einen dritten elektrischen Signalpfad (113) umfasst, wobei der dritte elektrische Signalpfad (113) an eine elektrische Signalquelle (138) gekoppelt ist, welche dem dritten elektrischen Signalpfad (113) ein weiteres, auf Masse (137) bezogenes elektrisches Signal zuführt.

5. Kombination gemäß Anspruch 4, wobei der erste, zweite oder dritte elektrische Signalpfad (111-113) ferner an einen Hochfrequenzempfänger (128) gekoppelt ist, welcher dazu eingerichtet ist, ein Antennensignal über den ersten, zweiten oder dritten elektrischen Signalpfad (111-113) zu empfangen.

6. Kombination gemäß einem jeden der vorhergehenden Ansprüche, wobei der Impedanzwert der Impedanzschaltung (125, 126, 130) im wesentlichen dem Impedanzwert der inhärenten Impedanz (202, 203) des Mikrofons (103) entspricht.

7. Kombination gemäß einem jeden der vorhergehenden Ansprüche, wobei die Impedanzschaltung (125, 126, 130) eine Reihenschaltung eines resistiven Elements (125, 126) und eines kapazitiven Elements (130) umfasst.

8. Kombination gemäß einem jeden der vorhergehenden Ansprüche, wobei die Signalverarbeitungseinheit (140) einen Differenzverstärker umfasst, welcher dazu eingerichtet ist, basierend auf einer Spannungsdifferenz an dem ersten Eingang (135) und dem zweiten Eingang (136) ein elektrisches Mikrofonausgangssignal (209) zu erzeugen.

9. Kombination gemäß einem jeden der vorhergehenden Ansprüche, wobei die Schaltungsanordnung ferner umfasst:

- ein erstes Tiefpassfilter (151, 153), welches an den ersten Eingang (135) der Signalverarbeitungseinheit (140) gekoppelt ist, und
- ein zweites Tiefpassfilter (152, 154), welches an den zweiten Eingang (136) der Signalverarbeitungseinheit (140) gekoppelt ist.

10. Vorrichtung, umfassend:

- die Kombination eines Mikrofons (103) und einer Schaltungsanordnung gemäß einem jeden der vorhergehenden Ansprüche, und
- eine Multiport-Steckverbindung (110) zum Koppeln der Vorrichtung (100) mit dem Mikrofon (103).

11. Vorrichtung gemäß Anspruch 10, wobei die Vorrichtung (100) zumindest eine Vorrichtung aus einer Gruppe bestehend aus einem Mobiltelefon, einem persönlichen digitalen Assistenten, einem mobilen Musikwiedergabegerät, und einem Navigationssystem umfasst.

12. Verfahren zum Verarbeiten eines elektrischen Signals eines Mikrofons, wobei das Mikrofon (103) eine inhärente Impedanz (202, 203) aufweist und ein erstes elektrisches Ausgangssignal und ein zweites elektrisches Ausgangssignal bereitstellt, wobei eine Spannung zwischen dem ersten elektrischen Ausgangssignal und dem zweiten elektrischen Ausgangssignal einem durch das Mikrofon (103) empfangenen akustischen Eingangssignal entspricht, wobei das Verfahren umfasst:

- Führen des zweiten elektrischen Ausgangssignals des Mikrofons (103) durch eine Impedanzschaltung (125, 126,130) mit einem Impedanzwert, welcher ausgewählt ist basierend auf einem Impedanzwert der inhärenten Impedanz (202, 203) des Mikrofons (103), und
- Erzeugen eines elektrischen Mikrofonausgangssignals (209) basierend auf einer Signaldifferenz zwischen dem ersten elektrischen Ausgangssignal und dem durch die Impedanzschaltung (125,126,130) geführten zweiten elektrischen Ausgangssignal,

dadurch gekennzeichnet, dass das zweite elektrische Ausgangssignal des Mikrofons (103) zusätzlich über eine weitere induktive Impedanzschaltung (122) auf Masse (137) geführt ist.

13. Verfahren gemäß Anspruch 12, wobei das Verfahren ferner umfasst:

- Bereitstellen einer Signalverarbeitungseinheit (140), welche dazu eingerichtet ist, das elektrische Mikrofonausgangssignal (209) basierend auf elektrischen Mikrofonsignalen an einem ersten Eingang (135) und einem zweiten Eingang (136) der Signalverarbeitungseinheit (140) zu erzeugen,
- Koppeln eines ersten elektrischen Ausgangs (106) des Mikrofons (103) an den ersten Eingang (135) der Signalverarbeitungseinheit (140),
- Koppeln eines zweiten elektrischen Ausgangs (107) des Mikrofons (103) und des zweiten Eingangs (136) der Signalverarbeitungseinheit (140) über die Impedanzschaltung (125, 126, 130).

Revendications

1. Combinaison d'un microphone (103) et d'un ensemble de circuits pour traiter un signal électrique du microphone (103),
le microphone (103) ayant une impédance inhérente (202, 203) et comprenant une première sortie électrique (106) et une deuxième sortie électrique (107), où une tension entre la première sortie électrique (106) et la deuxième sortie électrique (107) correspond à un signal d'entrée acoustique reçu par le microphone (103), et l'ensemble de circuits comprenant :

- un circuit d'impédance (125, 126, 130) ayant une valeur d'impédance devant être sélectionnée sur la base d'une valeur d'impédance de l'impédance inhérente (202, 203) du microphone (103),
- une unité de traitement de signal (140) com-

prenant une première entrée (135) et une deuxième entrée (136),

- un premier chemin de signal électrique (111) pouvant être couplé à la première sortie électrique (106) du microphone (103) et couplé à la première entrée (135) de l'unité de traitement de signal (140), et
- un deuxième chemin de signal électrique (112) pouvant être couplé à la deuxième sortie électrique (107) du microphone (103) et à la deuxième entrée (136) de l'unité de traitement de signal (140) par l'intermédiaire du circuit d'impédance (125, 126, 130),

caractérisé en ce que le deuxième chemin de signal électrique (112) est en outre couplé à la masse (137) par l'intermédiaire d'un circuit d'impédance inductive supplémentaire (122).

2. Combinaison de la revendication 1, dans laquelle l'ensemble de circuits comprend en outre :

- un premier commutateur (131) couplé au premier chemin de signal électrique (111), au deuxième chemin de signal électrique (112) et à la première entrée (135) de l'unité de traitement de signal (140), et configuré pour coupler sélectivement le premier chemin de signal électrique (111) ou le deuxième chemin de signal électrique (112) à la première entrée (135) de l'unité de traitement de signal (140),
- un deuxième commutateur (133) couplé au premier chemin de signal électrique (111), au deuxième chemin de signal électrique (112) et à la masse (137), et configuré pour coupler sélectivement le premier chemin de signal électrique (111) ou le deuxième chemin de signal électrique (112) à la masse (137) par l'intermédiaire d'un circuit d'impédance inductive supplémentaire (121, 122), et
- un troisième commutateur (132) couplé au premier chemin de signal électrique (111), au deuxième chemin de signal électrique (112) et à la deuxième entrée (136) de l'unité de traitement de signal (140), et configuré pour coupler sélectivement le premier chemin de signal électrique (111) ou le deuxième chemin de signal électrique (112) à la deuxième entrée (136) de l'unité de traitement de signal (140) par l'intermédiaire du circuit d'impédance (125, 126, 130).

3. Combinaison selon l'une quelconque des revendications précédentes, dans laquelle le premier chemin de signal électrique (111) et le deuxième chemin de signal électrique (112) sont compris dans une connexion mâle-femelle à ports multiples (110) pour connecter de manière amovible le microphone (103) aux premier et deuxième chemins de signal électrique (111, 112).

4. Combinaison selon la revendication 3, dans laquelle la connexion mâle-femelle à ports multiples (110) comprend en outre un troisième chemin de signal électrique (113), où le troisième chemin de signal électrique (113) est couplé à une source de signal électrique (138) alimentant un signal électrique supplémentaire par rapport à la masse (137) dans le troisième chemin de signal électrique (113).

5. Combinaison selon la revendication 4, dans laquelle le premier, le deuxième ou le troisième chemin de signal électrique (111-113) est en outre couplé à un récepteur de radiofréquence (128) adapté pour recevoir un signal d'antenne via le premier, le deuxième ou le troisième chemin de signal électrique (111-113).

6. Combinaison selon l'une quelconque des revendications précédentes, dans laquelle la valeur d'impédance du circuit d'impédance (125, 126, 130) correspond sensiblement à la valeur d'impédance de l'impédance inhérente (202, 203) du microphone (103).

7. Combinaison selon l'une quelconque des revendications précédentes, dans laquelle le circuit d'impédance (125, 126, 130) comprend une connexion en série d'un élément résistif (125, 126) et d'un élément capacitif (130).

8. Combinaison selon l'une quelconque des revendications précédentes, dans laquelle l'unité de traitement de signal (140) comprend un amplificateur différentiel configuré pour générer un signal de sortie électrique de microphone (209) basé sur une différence de tension au niveau de la première entrée (135) et de la deuxième entrée (136).

9. Combinaison selon l'une quelconque des revendications précédentes, dans laquelle l'ensemble de circuits comprend en outre :

- un premier filtre passe-bas (151, 153) étant couplé à la première entrée (135) de l'unité de traitement de signal (140), et
- un deuxième filtre passe-bas (152, 154) étant couplé à la deuxième entrée (136) de l'unité de traitement de signal (140).

10. Dispositif comprenant :

- la combinaison d'un microphone (103) et d'un ensemble de circuits selon l'une quelconque des revendications précédentes, et
- une connexion mâle-femelle à ports multiples (110) pour coupler le dispositif (100) au micro-

phone (103).

11. Dispositif selon la revendication 10, dans lequel le dispositif (100) comprend au moins un dispositif d'un groupe constitué par un téléphone mobile, un assistant numérique personnel, un lecteur audio portable et un système de navigation.

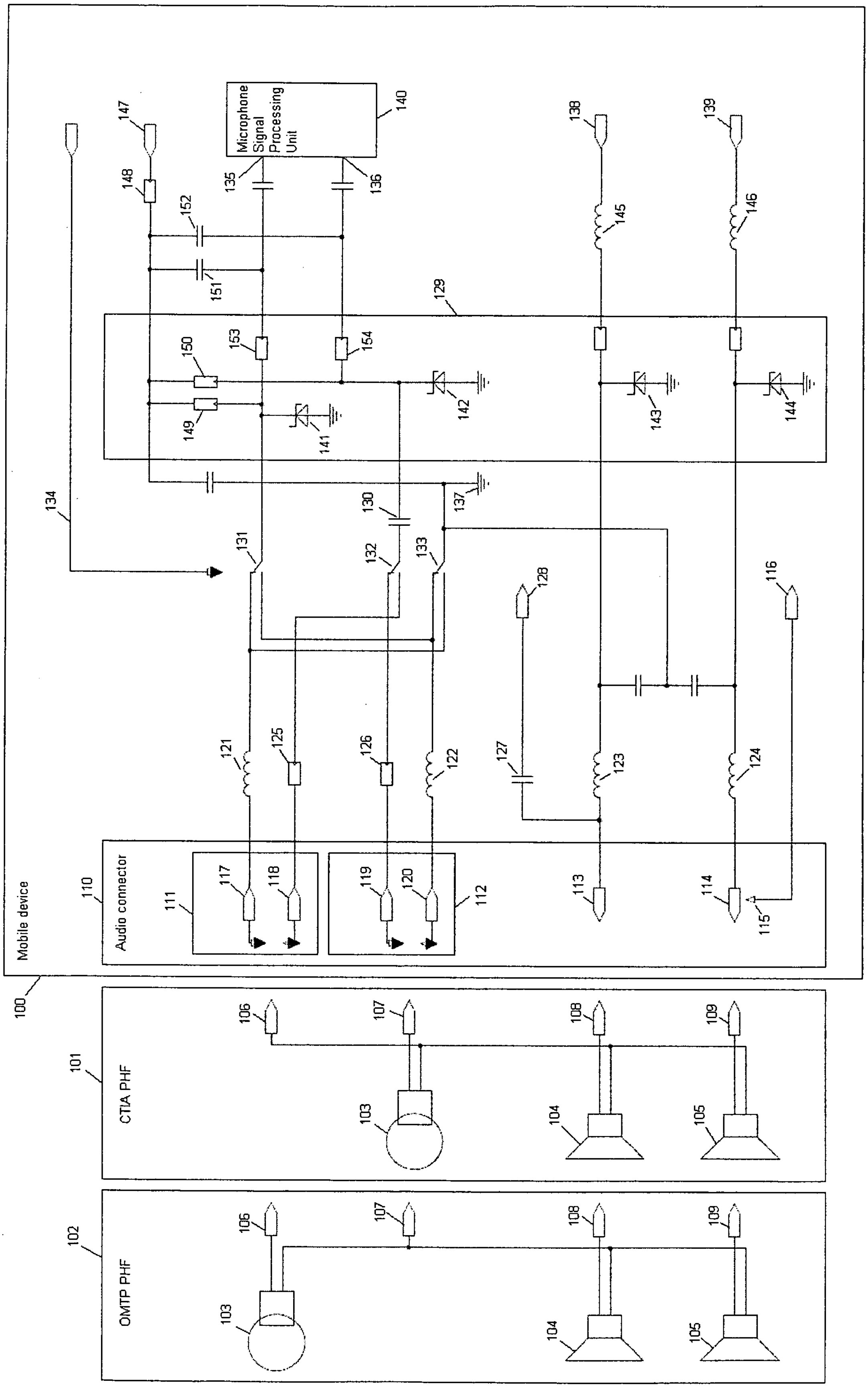
12. Procédé de traitement d'un signal électrique d'un microphone, le microphone (103) ayant une impédance inhérente (202, 203) et fournissant un premier signal de sortie électrique et un deuxième signal de sortie électrique, dans lequel une tension entre le premier signal de sortie électrique et le deuxième signal de sortie électrique correspond à un signal d'entrée acoustique reçu par le microphone (103), le procédé comprenant le fait :

- de guider le deuxième signal de sortie électrique du microphone (103) à travers un circuit d'impédance (125, 126, 130) ayant une valeur d'impédance choisie sur la base d'une valeur d'impédance de l'impédance inhérente (202, 203) du microphone (103), et
- de générer un signal de sortie électrique de microphone (209) sur la base d'une différence de signal entre le premier signal de sortie électrique et le deuxième signal de sortie électrique guidé à travers le circuit d'impédance (125, 126, 130),

caractérisé en ce que le deuxième signal de sortie électrique du microphone (103) est en outre guidé par l'intermédiaire d'un circuit d'impédance inductif supplémentaire (122) vers la masse (137).

13. Procédé de la revendication 12, le procédé comprenant en outre le fait de :

- fournir une unité de traitement de signal (140) configurée pour générer le signal de sortie électrique de microphone (209) sur la base de signaux électriques de microphone au niveau d'une première entrée (135) et d'une deuxième entrée (136) de l'unité de traitement de signal (140),
- coupler une première sortie électrique (106) du microphone (103) à la première entrée (135) de l'unité de traitement de signal (140),
- coupler une deuxième sortie électrique (107) du microphone (103) et la deuxième entrée (136) de l'unité de traitement de signal (140) par l'intermédiaire du circuit d'impédance (125, 126, 130).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Microphone Signal Processing Unit
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Fig. 1

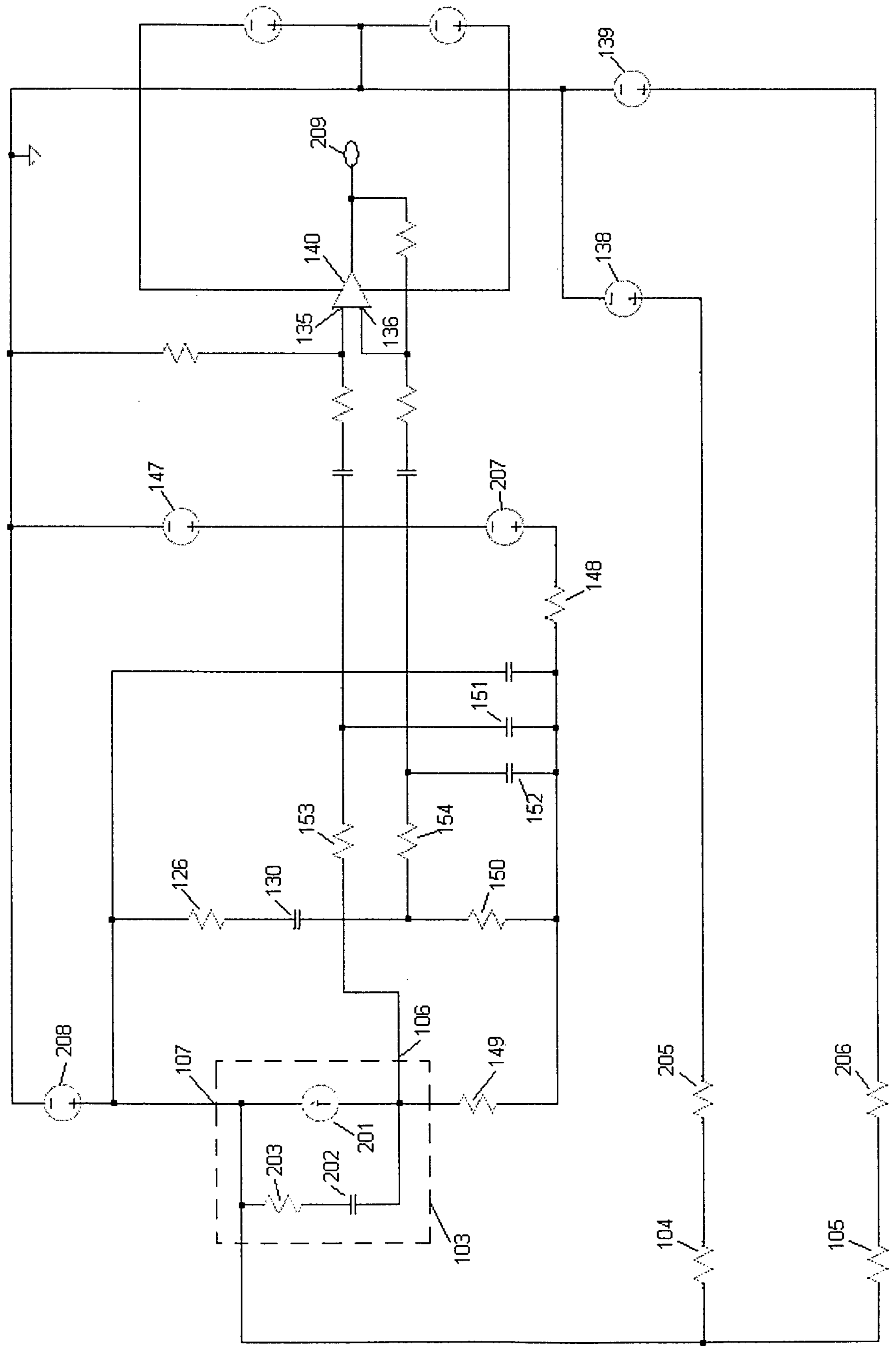
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Fig. 2

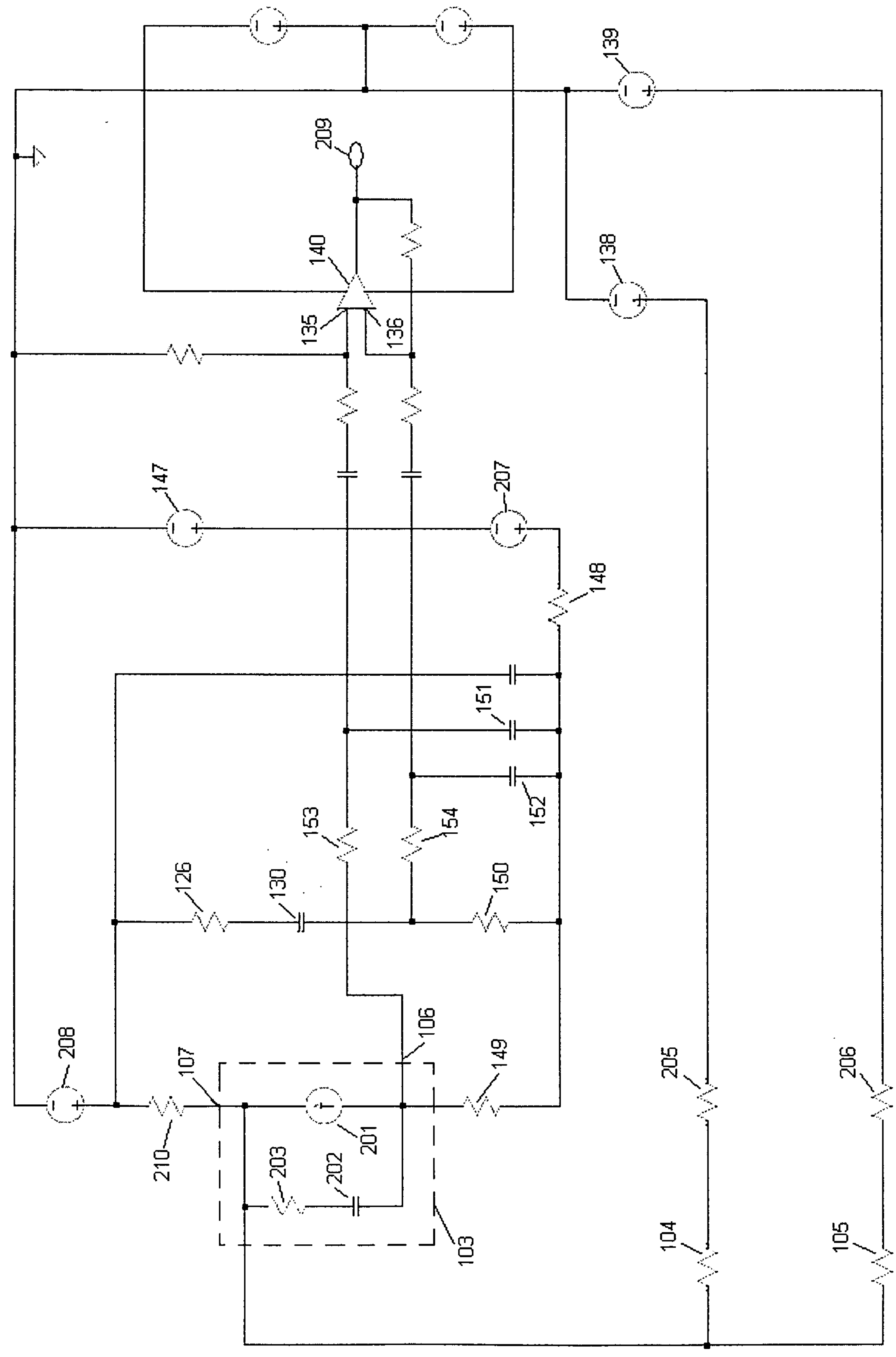
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Fig. 3

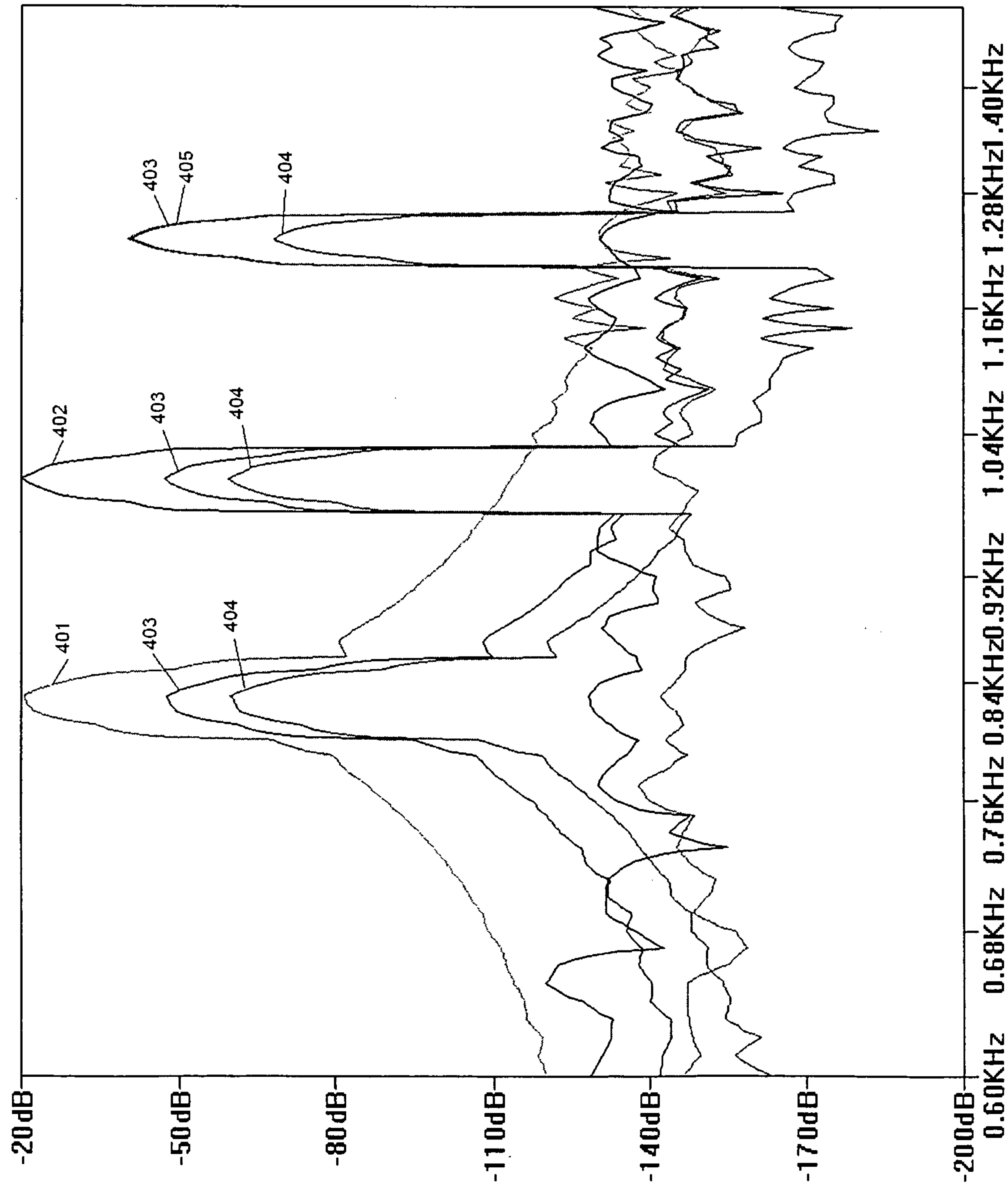
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Fig. 4

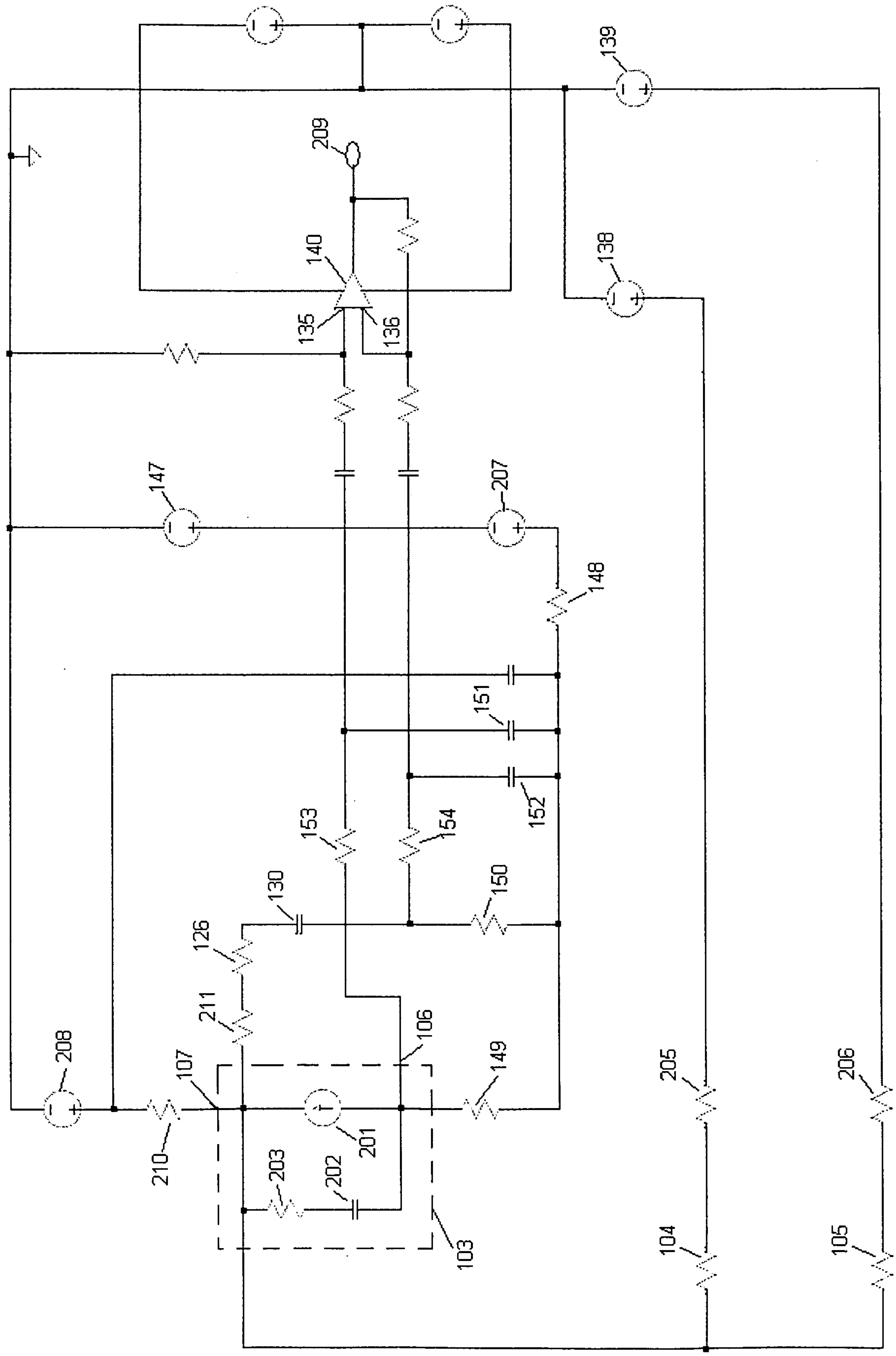
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Fig. 5

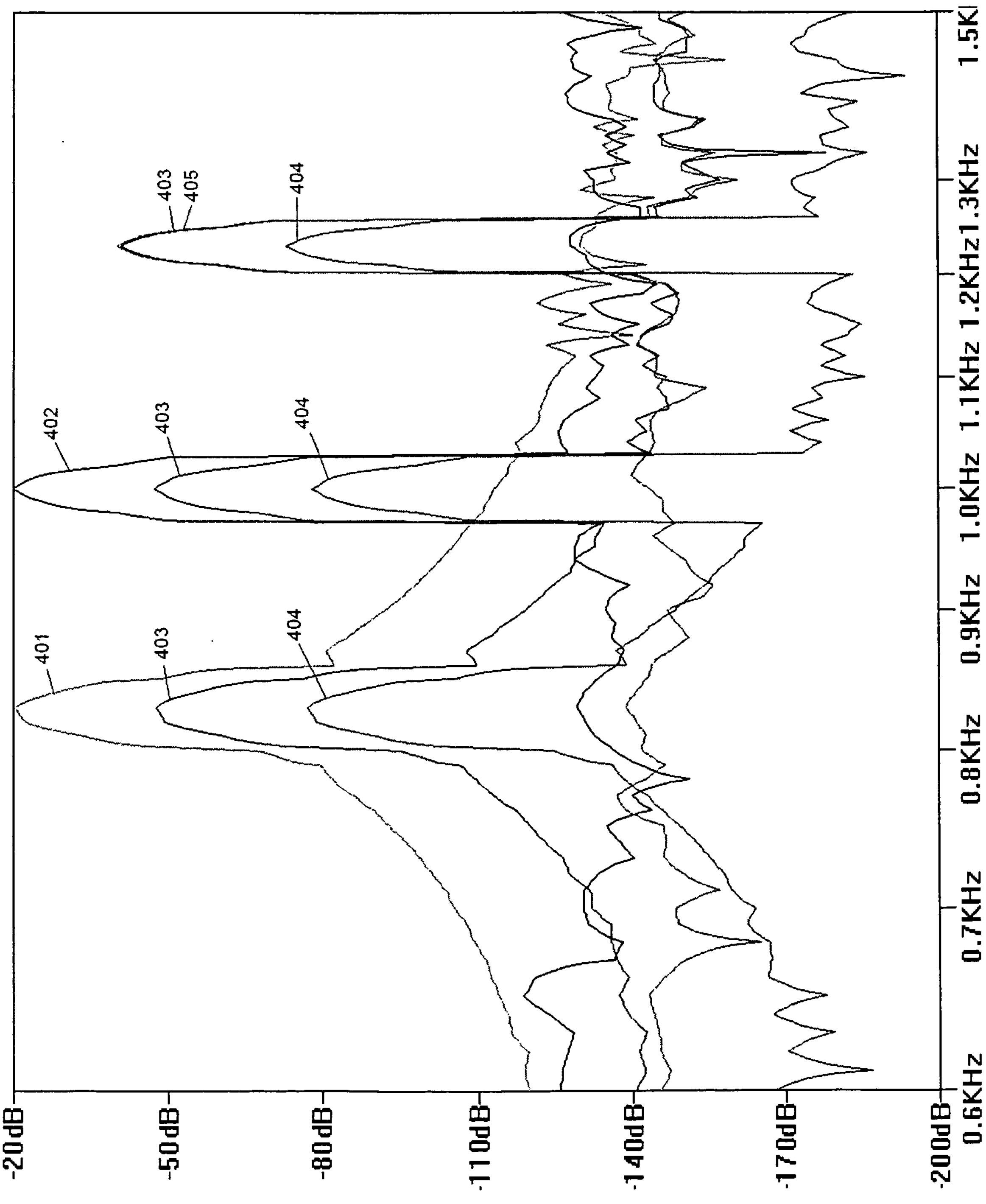
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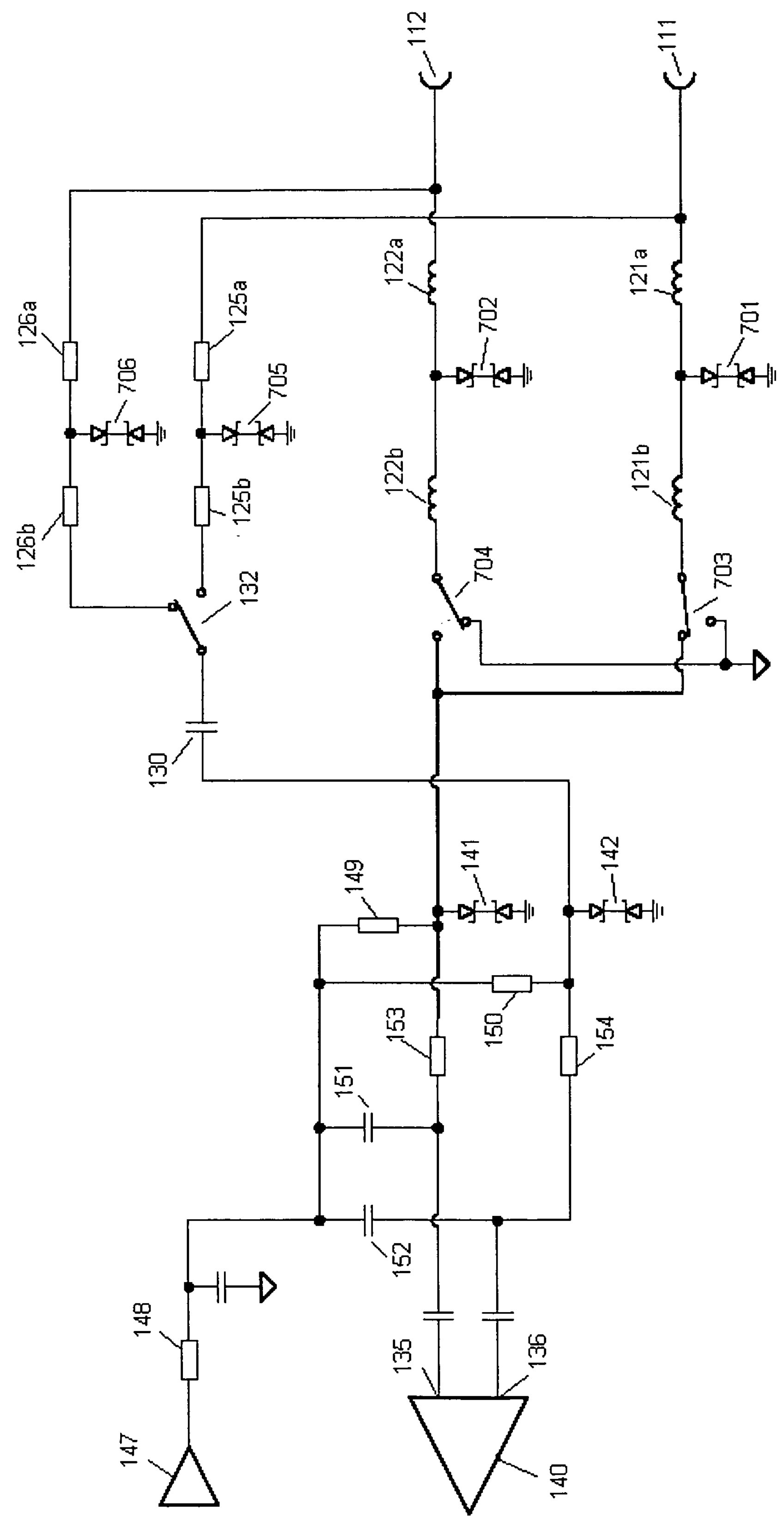
Fig. 6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141
142
153
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151
152
148
135
136
147
140

Fig. 7

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- GB 2377848 A **[0005]**
- WO 9938355 A1 **[0005]**