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(54) **Title**: AUDIO CONNECTOR AND CIRCUITRY

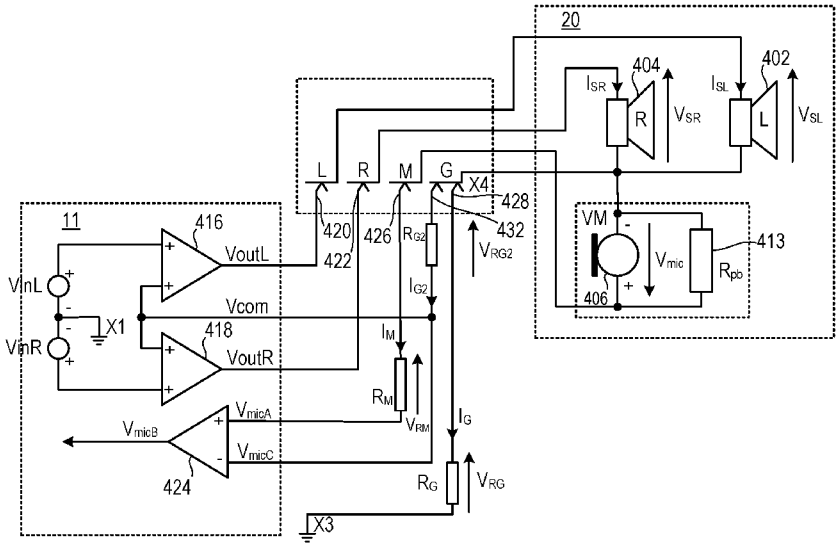

Figure 4a

(57) **Abstract**: A device (10) for connection to an audio accessory (20) comprising: a jack socket (14) for connection to a jack plug (25) of the audio accessory (20), a ground connection to a first socket contact (428) which is positioned to mate with a ground return pole of the plug (25). The jack socket (14) comprises a second contact (432) also positioned to mate with the ground return pole of the plug (25). Driver amplifiers (416, 418) comprise an input coupled to the second contact (432) and are configured to superimpose a signal present at the second contact (432) onto received speaker signal. It may achieve reducing the crosstalk which could distort or blur the stereo image.

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AUDIO CONNECTOR AND CIRCUITRY

This invention relates to a connector, e.g. a jack socket, for receiving a plug, and more specifically to a host device that includes such a connector, allowing an audio accessory device that has a suitable plug to be connected to the host device.

BACKGROUND

Many devices having audio outputs and/or inputs, such as mobile phones, tablets, computers and the like, are provided with a socket, allowing an audio accessory device with a suitable plug, such as a headset, to be connected to the device.

Figure 1 illustrates an audio system, in which an audio accessory 20, specifically a headset, is connected to a host device by means of a jack plug 25. The host device comprises circuitry 11, which connects to a number of contacts 26 in a jack socket. Figure 1 shows the situation in which the jack plug 25 is inserted into the jack socket, so that poles on the jack plug 25 make electrical contact with the contacts 26.

Figure 1 shows left and right driver amplifiers 102 and 104 driven from respective signal sources VinL and VinR. The signal sources VinL and VinR may for example comprise digital-to-analog converters (DACs) driven by received digital audio signals. These driver amplifiers 102, 104 are coupled to respective jack poles L and R by respective jack socket contacts. Signals from the driver amplifiers 102, 104 are then passed to left and right speakers respectively in the headset 20.

Figure 1 also shows an amplifier 106 serving as a microphone pre-amplifier coupled to a microphone pole, i.e. pole M, of the jack plug via a respective contact. The amplifier 106 thus receives a signal from a microphone in the headset 20.

The pole G of the jack plug 25 provides a common ground return path for the signal paths through the other three poles L, R & M.

In this example, the plug and socket arrangement is illustrated as being a 3.5mm 4-Pole TRRS (Tip/Ring/Ring/Sleeve) jack plug and jack socket arrangement. The small size of such a socket allows only a small area of physical, and hence electrical, contact between the jack contact within the socket and the cylindrical pole of the inserted plug.

Thus there may be an appreciable contact resistance between one or more respective jack contacts and respective poles, which may be further degraded due to corrosion or foreign matter.

Figure 1 also illustrates that there may be various parasitic resistances, including a jack contact resistance, in the ground path between the ground jack pole G, i.e. node X4, and a ground reference point X3 close to the circuitry 11. These various parasitic resistances are illustrated as lumped together into a single resistance element R_G. There may also be similar parasitic resistances between the microphone pole M of the jack plug and the microphone pre-amplifier 106 via the respective jack socket contact, and Figure 1 shows these parasitic resistances lumped similarly into a single resistance element R_M.

The input signals VinL and VinR of the driver amplifier circuitry 102, 104 and the resulting buffered outputs VoutL and VoutR may be referenced to some ground point X1 local to the driver amplifier circuitry 102, 104. The microphone pre-amplifier 106 may be explicitly or implicitly referenced to a ground point X2 local to the pre-amplifier 106. By careful design of local ground planes or ground tracks on PCBs and/or in integrated circuits, these grounds may be maintained close in voltage to a common ground reference point, say the ground pin of an integrated circuit implementation of the circuitry 11, which in turn may be closely coupled to some local ground reference point X3. However, the voltage signals VoutL and VoutR applied to the left and right speakers may give rise to corresponding ground return currents passing though the jack contact resistance and PCB trace resistance illustrated by R_G, so it is likely that the ground voltage on the pole of the jack, node X4, will be significantly different from that at X3 and will also be modulated by a.c. signal components of these ground return currents corresponding to the a.c. signal components of the applied voltages VoutL and VoutR.

Figure 2 is a more detailed electrical circuit diagram showing the system of Figure 1.

Thus, Figure 2 shows the left speaker 108, the right speaker 110, and the microphone 112 of the headset 20.

The current I_G through the ground pole G of the jack plug comprises both the currents I_{SL} and I_{SR} through the left and right speakers 108, 110. Thus, ignoring any ground

return current corresponding to current though the microphone pole, i.e. M pole, of the plug:

$I_G = I_{SL} + I_{SR}$.

Given that the resistance R_G is non-negligible, the ground voltage on the ground pole, i.e. G pole, of the jack, at node X4, will differ from that at X3 by a voltage V_{RG}, where:

$V_{RG} = I_G * R_G$.

The input voltage V_{micA} to the microphone amplifier 106 will not be identical to the voltage V_{mic} generated by the microphone 112, but will be modulated by the voltage V_{RG} as it varies with the variation of the total current I_G flowing through the left and right speakers 108, 110 into the ground return path. Thus there will be crosstalk of the electrical speaker signal into the sensitive microphone channel (which is especially relevant because a typical microphone signal might be only of the order of 10mV). That is:

$V_{micB} = V_{micA} = V_{mic} + V_{RG}$.

Also the respective voltages actually appearing across each respective speaker will be reduced by V_{RG}. That is:

V_{SL} = VoutL - V_{RG} and
V_{SR} = VoutR - V_{RG}

Since V_{RG} is dependent on both I_{SR} and I_{SL}, one effect is that the respective currents through each respective speaker influence the voltage that is generated across the other speaker, and so there is crosstalk from the right channel to the left channel, and from the left channel to the right channel, which can distort or blur the stereo image.

The ground return path via resistance R_G will also carry ground return current from any current taken though microphone pole M of the jack plug, and any modulation of this current may appear as audible crosstalk in the speaker outputs. The current through microphone pole M may comprise supply current for the microphone 112 which may

vary with the microphone signal and possibly also if the microphone 112 is turned on or off or passes though different microphone operating modes, possibly autonomously due to some internal voice activity detect or suchlike.

Also in some applications current on this microphone supply line is used to signal to the host device, for example via one or more pushbutton switches coupled between the microphone pole M and ground pole G either directly or via resistances, illustrated by resistance Rpb 113. Use of the one or more pushbutton switches may give rise to significant step changes in the current through poles M and G, which may in turn give audible artefacts through modulating V_{RG}.

SUMMARY

According to an aspect of the present invention, there is provided a device for connection to an audio accessory comprising:

(a) a jack socket for connection to a jack plug of the audio accessory, wherein the jack socket comprises:

(i) first and second contacts, positioned to mate with a first pole of the jack plug, wherein one of the first and second contacts is coupled to ground,

(ii) a third contact positioned to mate with a second pole of the jack plug, and

(iii) a fourth contact, positioned to mate with a third pole of the jack plug,

(b) a first audio driver amplifier, comprising:

(i) a first input coupled to receive a first driver signal,

(ii) a second input coupled to an other of the first and second contacts, and

(iii) an output coupled to said third contact, and

(c) a second audio driver amplifier, comprising:

(i) a first input coupled to receive a second driver signal,

(ii) a second input coupled to the other of the first and second contacts, and

(iii) an output coupled to said fourth contact.

According to another aspect of the present invention, there is provided a device for connection to an audio accessory comprising:

(a) a jack socket for connection to a jack plug of the audio accessory, wherein the jack socket comprises,

(i) first and second contacts, positioned to mate with a first pole of the jack plug, wherein one of the first and second contacts is coupled to ground,

(ii) a third contact positioned to mate with a second pole of the jack plug, and

(iii) a fourth contact, positioned to mate with a third pole of the jack plug,

(b) a first audio driver amplifier, comprising:

(i) a first input coupled to receive a first driver signal;

(ii) a second input coupled to an other of said first and second contacts, and

(iii) an output coupled to said third contact, and

(c) a microphone pre-amplifier comprising:

(i) a first input coupled to said fourth contact,

(ii) a second input coupled to the other of the first and second contacts, and

(iii) an output coupled to output an amplified signal to a terminal of the device.

According to another aspect of the present invention, there is provided a first device for connection to a second device, comprising:

(a) a first device connector for connection to a connector of the second device, wherein the first device connector comprises,

(i) a first contact, coupled to ground, positioned to mate with a first pole of the connector of the second device,

(ii) a second contact positioned to mate with the first pole of the connector of the second device,

(iii) a third contact positioned to mate with a second pole of the connector of the second device, and

(iv) a fourth contact, positioned to mate with a third pole of the connector of the second device,

(b) a first amplifier wherein,

(i) a first input of the first amplifier is coupled to the second contact of the first device connector,

(ii) a second input of the first amplifier is coupled to receive a driver signal, and

(iii) an output of the first amplifier is coupled to the third contact of the first device connector, and

(c) a second amplifier wherein,

(i) a first input of the second amplifier is coupled to the second contact,

(ii) a first port of the second amplifier is coupled to the fourth contact of first device connector, and

(iii) a second port of the second amplifier is coupled to a terminal of the device.

BRIEF DESCRIPTION OF FIGURES

Figure 1 is a circuit diagram of an audio system.

Figure 2 is a more detailed circuit diagram of the system of Figure 1.

Figure 3 illustrates an audio system.

Figure 4a is a circuit diagram of an audio system as shown in Figure 3.

Figure 4b illustrates a plug and socket in the audio system of Figure 4.

Figure 5a is a circuit diagram of an alternative audio system as shown in Figure 3.

Figure 5b illustrates a plug and socket in the audio system of Figure 5.

Figure 6a is a circuit diagram of a further alternative audio system as shown in Figure 3.

Figure 6b illustrates a plug and socket in the audio system of Figure 6a.

Figure 6c illustrates an alternative form of a plug and socket in the audio system of Figure 6a.

Figure 6d illustrates an alternative form of a plug and socket in the audio system of Figure 6a.

Figure 6e is a circuit diagram of a further alternative audio system as shown in Figure 3.

Figure 7a is a circuit diagram of a further alternative audio system as shown in Figure 3.

Figures 7b and 7b illustrate embodiments of a plug and socket in the audio system of Figure 7a.

Figure 8a is a circuit diagram of a further alternative audio system as shown in Figure 3.

Figures 8b and 8c illustrate embodiments of a plug and socket in the audio system of Figure 8a.

Figure 9a is a circuit diagram of a further alternative audio system as shown in Figure 3.

Figure 9b is a circuit diagram of a further alternative audio system as shown in Figure 3.

DETAILED DESCRIPTION

Figure 3 illustrates a host device 10, which may take the form of a mobile phone or tablet computer or suchlike, provided with a socket 14 into which a plug 25 may be attached. In this case, the plug 25 is provided on a cable 21 that forms part of an audio accessory 20. The audio accessory 20 is in the form of a headset, which comprises a pair of stereo speakers 22, 23, a voice microphone 24 and a push-button module 26. In this illustrated embodiment, plug 25 may be a jack plug, for instance a standard 3.5mm diameter multi-pole audio jack plug, and socket 14 may be a compatible jack socket, but other forms of multi-pole connector may alternatively be implemented.

The host device 10 comprises circuitry 11 which may communicate with an attached accessory 20 via multiple wires 17 (which may be printed circuit board (PCB) tracks, or cables with conductors soldered on to a PCB or connected via edge connectors or suchlike) and via the socket 14. The circuitry 11 may comprise driver amplifiers for driving the headset speakers 22, 23 and a microphone preamplifier for amplifying an analogue signal received from microphone 24. Circuitry 11 may also comprise other analog or digital functions and may be an integrated circuit in the form of an audio codec and may be coupled to other circuitry 18, 19a and 19b, for instance an applications processor or a Bluetooth modem or communications processor or suchlike. The location of circuitry 11 will be governed by many constraints, for example it may be preferable to situate circuitry 11 in close proximity to other circuitry 18 and 19a and 19b to reduce the length of the many connections between these circuits, possibly carrying high-speed digital signals, for instance three digital audio bus connections to or from an integrated circuit audio codec embodiment of circuitry 11 to or from an applications processor, an r.f. modem and a communications processor, in which case the circuitry 11 might not be located adjacent to the jack socket 14. A PCB is likely to be tightly packed, and thus wires 17 that are in the form of PCB tracks 17 may be minimum or

near minimum width. Thus there may be appreciable parasitic resistance of the metal tracks 17. In some cases this resistance may even be desirable, or may comprise the impedance of added components, to help protect the circuitry 11 from ESD (Electro-Static Discharge) events occurring at the external jack socket or to help filter high frequency EMI (Electromagnetic Interference).

The circuitry 11 may be provided with a star ground reference point 12.

Figure 4a is an electrical circuit diagram of a system of the general type shown in Figure 3 comprising an embodiment.

Thus, Figure 4a shows the left speaker 402, the right speaker 404, and the microphone 406 of the headset 20. The headset 20 is provided with a plug 25, which in this example is a TRRS jack plug. As shown in more detail in **Figure 4b**, the left speaker 402 is connected between the tip (T) 408 and the sleeve (S) 410 of the plug 25. The right speaker 404 is connected between the first ring (R1) 412 and the sleeve (S) 410 of the plug 25. The microphone 406 is connected between the second ring (R2) 414 and the sleeve (S) 410 of the plug 25. Thus, the sleeve (S) 410 acts as a common ground return.

The tip 408, first ring 412, second ring 414 and sleeve 410 of this plug may thus be regarded as the L, R, M and G poles respectively of the jack plug 25.

In the circuitry 11, as illustrated in Figure 4a, a left driver amplifier 416 is driven from a signal source VinL and produces a buffered output signal VoutL, and a right driver amplifier 418 is driven from a signal source VinR and produces a buffered output signal VoutR. The signal sources VinL and VinR may for example comprise digital-to-analog converters (DACs). Outputs of these driver amplifiers 416, 418 are coupled to respective jack socket contacts 420, 422.

Figure 4a also shows an amplifier 424 serving as a microphone pre-amplifier with an input coupled to a jack socket contact 426.

A further jack socket contact 428 provides the common ground return path for the signal paths through the other three jack socket contacts.

Thus, when the jack plug is inserted into the jack socket, the tip contact 408 of the plug 25 contacts the jack socket contact 420; the first ring contact 412 of the plug 25 contacts the jack socket contact 422; the second ring contact 414 of the plug 25 contacts the jack socket contact 426; and the sleeve contact 410 of the plug 25 contacts the jack socket contact 428.

As shown in Figure 4a, the jack socket is provided with an additional jack socket contact 432. The additional jack socket contact 432 is positioned in the socket such that, when the plug 25 is inserted into the socket, the sleeve contact 410 of the plug 25 contacts the additional jack socket contact 432 as well as the jack socket contact 428.

The additional jack socket contact 432 is connected to a second input of the microphone amplifier 424. Preferably, amplifier 424 is designed to produce an output V_{micB} that depends on the difference between its two inputs V_{micA} and V_{micC}.

The additional jack socket contact 432 is also connected to respective second inputs of the left driver amplifier 416 and the right driver amplifier 418. The common voltage on these second inputs is denoted Vcom. Preferably, amplifier 416 is designed to produce an output VoutL which depends on the sum of VinL and Vcom, while amplifier 418 is similarly designed such that VoutR depends on the sum of VinR and Vcom. Preferably amplifiers 416 and 418 are identical in design or at least very similar, so as to provide well-matched signal paths from their respective inputs to their respective outputs. The respective second inputs of the amplifiers 416, 418 and 424 may be denoted the reference inputs for the amplifiers.

Figure 4a illustrates the various parasitic resistances in the ground path between the jack pole G, i.e. node X4, and a ground reference point, i.e. node, X3 close to the circuitry 11, lumped into a single resistance element R_G. These parasitic resistances may comprise the contact resistance of jack socket contact 428, solder resistance associated with the connection of pins of an associated jack socket terminals to a PCB on which the socket is mounted, trace resistance of any PCB track in the path, resistance of any cabling in the path, contact resistance associated with any edge connectors or suchlike between cables and PCBs or between PCBs, or many other possible parasitic or added series elements. In some embodiments there may also be one or more switches in this path, to allow reconfiguration of the socket contacts to

accommodate different types of accessory, and any such switches may have significant associated contact or active device on-resistance.

There may also be similar parasitic resistances, including a jack contact resistance component, between the jack pole M and the microphone pre-amplifier 424, and Figure 4a illustrates these as lumped into a single resistance element R_M. Similarly, any parasitic resistances associated with the path associated with the additional jack socket contact 432 are illustrated in Figure 4a lumped together as the resistance element R_{G2}.

To explain the operation of the circuit it may be assumed that the second or reference inputs of the left driver amplifier 416 and the right driver amplifier 418 that are connected to Vcom, and the inputs of the microphone amplifier 424 that are connected to V_{micA} and V_{micC} are all high impedance inputs. Hence, there will be negligible currents I_M and I_{G2} flowing through the respective parasitic resistances R_M and R_{G2} associated with the tracks to these inputs, and thus the voltage drops V_{RM} and V_{RG2} will also be negligible. Similarly if there are any parasitic resistances (not illustrated) associated with any separate (i.e. not shared) segments of paths between the illustrated shared impedance R_{G2} and the driver or microphone amplifier inputs any resulting voltage drops will also be negligible.

The current I_G through the ground pole G of the jack plug comprises both the currents I_{SL} and I_{SR} through the left and right speakers 402, 404. Thus, ignoring any current though the M pole of the plug that might return via pole G:

$$I_G = I_{SL} + I_{SR} .$$

Given that any current flowing though contact 432 may be negligible compared with that flowing though contact 428, the whole of I_G will flow through parasitic resistance R_G, and so the ground voltage on the G pole of the jack, at node X4, will differ from that at node X3 by a voltage V_{RG}, where:

$$V_{RG} = I_G * R_G .$$

The voltage actually appearing across each speaker 402, 404 will be the voltage generated by the respective drive amplifier 416, 418, reduced by V_{RG}. That is:
V_{SL} = VoutL - V_{RG} and

V_{SR} = VoutR - V_{RG} .

As mentioned above, amplifiers 416 and 418 are configured such that VoutL = VinL + Vcom, and VoutR = VinR + Vcom. Moreover, as V_{RG2} is negligible, Vcom = V_{RG}.

Thus:

V_{SL} = VoutL - V_{RG} = (VinL + Vcom) - V_{RG} = (VinL + V_{RG}) - V_{RG} = VinL, and

V_{SR} = VoutR - V_{RG} = (VinR + Vcom) - V_{RG} = (VinR + V_{RG}) - V_{RG} = VinR.

Thus, V_{SL} = VinL and V_{SR} = VinR, and there is no crosstalk signal at the speakers 402, 404.

As also mentioned above amplifier 424 is configured such that:

V_{micB} = V_{micA} - V_{mic} .

Considering the voltages shown in Figure 4a:

V_{micA} = V_{mic} + V_{RG} - V_{RM} and

V_{micC} = V_{RG} - V_{RG2} .

However, as mentioned above, V_{RM} and V_{RG2} are negligible, and so:

V_{micB} = V_{micA} - V_{mic} = (V_{mic} + V_{RG}) - V_{RG} = V_{mic}.

Thus the net voltage appearing at the output of the microphone preamplifier 424 is equal to V_{mic} (possibly with a voltage gain applied, depending on the configuration of the amplifier 424).

Any other interference appearing at the jack pole G, i.e. any other additional component of V_{RG} superimposed on I_G.R_G, due for instance to rectified EMI (electromagnetic interference) will also be removed from the net speaker drive and microphone sense signals.

The additional socket contact 432 may be implemented mechanically in various forms depending on the application. Figure 4a illustrates a construction where the additional contact 432 may be located on the same side of the jack plug as the contact 428. In other embodiments, where space and the mechanical construction technology allow, the additional contact 432 may be substantially on the opposite side of the jack plug

from the contact 428, as illustrated in Figure 4b, and displaced further along the plug in a direction parallel with the axis of the plug. Other mechanical configurations are of course possible.

Figure 5a is an electrical circuit diagram of a system similar to that shown in Figure 4a but without a microphone in the accessory.

Thus, Figure 5a shows the left speaker 502 and the right speaker 504 of the headset 20. The headset 20 is provided with a jack plug 25a, which in this example is a 3-pole TRS plug. As shown in **Figure 5b**, the left speaker 502 is connected between the tip (T) 506 and the sleeve (S) 508 of the plug 25. The right speaker 504 is connected between the ring (R) 510 and the sleeve (S) 508 of the plug 25. Thus, the sleeve 508 acts as a common ground return.

The tip 506, ring 510 and sleeve 508 of this plug may thus be regarded as the L, R and G poles respectively of the jack plug 25a.

In the circuitry 11, a left driver amplifier 512 is driven from a signal source VinL and produces a buffered output signal VoutL, and a right driver amplifier 514 is driven from a signal source VinR and produces a buffered output signal VoutR. The signal sources VinL and VinR may for example comprise digital-to-analog converters (DACs). The driver amplifiers 512, 514 are coupled to respective jack socket contacts 516, 518.

A third jack socket contact 520 provides the common ground return path for the signal paths through the other two jack socket contacts 516, 518.

Thus, when the jack plug 25a is inserted into the jack socket, the tip contact 506 of the plug 25a contacts the jack socket contact 516; the ring contact 510 of the plug 25a contacts the jack socket contact 518; and the sleeve contact 508 of the plug 25a contacts the jack socket contact 520.

As shown in Figure 5a, the jack socket is provided with an additional, i.e. a fourth, jack socket contact 522. The additional jack socket contact 522 is positioned in the socket such that, when the plug 25a is inserted into the socket, the sleeve contact 508 of the

plug 25a contacts the additional jack socket contact 522 as well as the jack socket contact 520.

The additional jack socket contact 522 is connected to respective second, i.e. reference, inputs of the left driver amplifier 512 and the right driver amplifier 514. The voltage on these second inputs is denoted Vcom. Preferably, amplifier 512 is designed to produce an output VoutL which depends on the sum of VinL and Vcom, and amplifier 514 is designed similarly to provide an output VoutR which depends on the sum of VinR and Vcom.

Figure 5a illustrates the various parasitic resistances in the ground path between the jack pole G and a ground reference point X3 close to the circuitry 11, lumped into a single resistance element R_G.

There may also be similar parasitic resistances between the jack plug pole G and the driver amplifiers via socket contact 522, and Figure 5a illustrates these as lumped into a single resistance element R_{G2}.

It can be assumed that the inputs of the left driver amplifier 512 and the right driver amplifier 514 connected to Vcom are high impedance. Hence, there will be a negligible current I_{G2} flowing in the parasitic resistance R_{G2} associated with the tracks to these inputs, and thus the voltage drop V_{RG2} will also be negligible.

The current I_G through the ground pole G of the jack plug 25a is the sum of the currents I_{SL} and I_{SR} through the left and right speakers 502, 504. That is:

$$I_G = I_{SL} + I_{SR} .$$

Given that any current flowing though contact 522 may be negligible compared with that flowing though contact 520 the whole of I_G will flow through parasitic resistance R_G, and so the ground voltage on the pole G of the jack, at node X4, will differ from that at node X3 by a voltage V_{RG}, where:

$$V_{RG} = I_G * R_G .$$

The voltage actually appearing across each speaker 502, 504 will be the voltage generated by the respective drive amplifier 512, 514, reduced by V_{RG}. That is:
V_{SL} = VoutL - V_{RG} and
V_{SR} = VoutR - V_{RG} .

As mentioned above, driver amplifiers 512 and 514 are configured such that VoutL = VinL + Vcom, and VoutR = VinR + Vcom. Moreover, as V_{RG2} is negligible, Vcom = V_{RG}.

Thus:
V_{SL} = VoutL - V_{RG} = (VinL + Vcom) - V_{RG} = (VinL + V_{RG}) - V_{RG} = VinL, and
V_{SR} = VoutR - V_{RG} = (VinR + Vcom) - V_{RG} = (VinR + V_{RG}) - V_{RG} = VinR.

Thus, V_{SL} = VinL and V_{SR} = VinR, and there is no crosstalk signal at the speakers 502, 504.

Any other interference appearing at the jack pole, i.e. any other additional component of V_{RG} superimposed on $I_G.R_G$, due for instance to rectified EMI (electromagnetic interference) or to ground return currents from other circuitry will also be removed from the net speaker drive signals.

The additional jack socket contact 522 may be implemented mechanically in various forms depending on the application. Figure 5b illustrates a construction where the additional contact 522 may be located on the same side of the jack plug as the contact 520. In other embodiments where space and the mechanical construction technology allow, the additional contact 522 may be substantially on the opposite side of the jack plug from the contact 520. Other mechanical configurations are of course possible.

Figure 6a is an electrical circuit diagram of an alternative system of the type shown in Figure 3, but again in which the accessory 20 currently attached does not have a microphone. The host device is however adapted so as to be able to operate in alternative configurations so as to co-operate with other accessories which may have microphones or other components coupled to poles of their respective plugs. These alternative configurations are enabled by means of a plurality of switches which may comprise switches illustrated as elements 626 and 624 and may also comprise other switches according to the configurations to be enabled.

Thus, Figure 6a shows the left speaker 602 and the right speaker 604. The headset 20 is provided with a jack plug 25b, which in this example is a 3-pole TRS plug. As illustrated in conjunction with **Figure 6b**, the left speaker 602 is connected between the tip (T) 606 and the sleeve (S) 608 of the plug 25b. The right speaker 604 is connected between the ring (R) 610 and the sleeve (S) 608 of the plug 25b. Thus, the sleeve 608 acts as a common ground return.

The tip 606, ring 610 and sleeve 608 of this plug may thus be regarded as the L, R and G poles respectively of the jack plug 25b.

In the circuitry 11, a left driver amplifier 612 is driven from a signal source VinL and produces a buffered output signal VoutL, and a right driver amplifier 614 is driven from a signal source VinR and produces a buffered output signal VoutR. The signal sources VinL, VinR may for example comprise digital-to-analog converters (DACs). These driver amplifiers 612, 614 are coupled to respective jack socket contacts 616, 618. Driver amplifiers 612 and 614 may be configured such that VoutL = VinL + Vcom, and VoutR = VinR + Vcom where Vcom is a voltage applied to a pair of respective second, i.e. reference, inputs of these driver amplifiers 612 and 614.

The jack socket is mechanically configured such that when the jack plug 25b is inserted into the jack socket, the tip contact 606 of the plug 25b contacts the jack socket contact 616; the ring contact 610 of the plug 25b contacts the jack socket contact 618; and the sleeve contact 608 of the plug 25b contacts the jack socket contact 620. As shown in Figures 6a and 6b, the jack socket is provided with an additional jack socket contact 622. The additional, i.e. fourth, jack socket contact 622 is positioned in the socket such that, when the plug 25b is inserted into the socket, the sleeve contact 608 of the plug 25b contacts the additional jack socket contact 622 as well as the jack socket contact 620.

Thus, similarly to the embodiment illustrated in Figures 5a and 5b, the jack socket comprises a plurality of jack contacts which are mechanically configured to mate with the common ground return pole G of a TRS plug when such a plug is inserted. However, in this particular embodiment, rather than one contact being permanently configured to provide a low impedance ground current return path to ground while the other is permanently dedicated to couple to driver amplifiers, in this embodiment each

is connected to respective poles of each switch 624 and 626. The other terminal of first switch 624 is coupled to ground at a ground reference point X3. The other terminal of second switch 626 may be coupled to driver amplifiers or other circuitry comprised in circuitry 11, which may comprise microphone amplifiers or other functions.

When the host device is configured to co-operate with the TRS plug of Figure 6b, the first switch 624 may be controlled to couple the jack plug pole G via one socket contact 620 to ground reference point X3 while the second switch 626 may be controlled to couple the jack plug pole G via the other socket contact 622 to the pair of respective second inputs of the left driver amplifier 612 and the right driver amplifier 614, i.e. to the signal line Vcom. Alternatively the roles of switches 624 and 626 may be interchanged such that jack plug pole G is coupled to ground X3 via switch 626 and to Vcom via switch 624.

Figure 6a illustrates the various parasitic resistances in the ground path from the jack pole G via socket contact 620 to the switches 624 and 626, lumped into a single resistance element R_G. Similarly Figure 6a illustrates the various parasitic resistances in the ground path from the jack pole G via socket contact 622 to the switches 624 and 626, lumped into a single resistance element R_M.

The parasitic resistances associated with the switch 624 are illustrated in Figure 6a lumped together as the resistance element R_{GS}, and the resistances associated with the switch 626 are shown in Figure 6a lumped together as the resistance element R_{CS}.

Assuming the case where ground pole G is coupled to ground reference point X3 via the contact 620 and the switch 624, and to Vcom via the contact 622 and the switch 626, and assuming that the inputs of the left driver amplifier 612 and the right driver amplifier 614 connected to Vcom are high impedance, there will be negligible currents flowing in the parasitic resistances R_M and R_{CS} associated with the path from pole G to Vcom, and thus any associated voltage drop will be negligible.

The current I_G through the ground pole G of the jack plug is the sum of the currents I_{SL} and I_{SR} through the left and right speakers 602, 604. That is:

$$I_G = I_{SL} + I_{SR} .$$

Considering the case where ground pole G is coupled to ground reference point X3 via the contact 620 and the switch 624, and given that any current flowing though contact 622 may be negligible compared with that flowing though contact 620 the whole of I_G will flow through parasitic resistance R_G, and so the ground voltage on the pole of the jack, at node X4, will differ from that at X3 by a voltage V_{RG}, where:

$V_{RG} = I_G * (R_G + R_{GS})$.

The voltage actually appearing across each speaker 602, 604 will be the voltage generated by the respective drive amplifier 614, 614, reduced by V_{RG}. That is:
V_{SL} = VoutL - V_{RG} and
V_{SR} = VoutR - V_{RG} .

As mentioned above, the driver amplifiers 612 and 614 may be configured such that VoutL = VinL + Vcom, and VoutR = VinR + Vcom. Moreover, as any voltage drop between plug pole G and Vcom is negligible, Vcom = V_{RG}.

Thus:
V_{SL} = VoutL - V_{RG} = (VinL + Vcom) - V_{RG} = (VinL + V_{RG}) - V_{RG} = VinL, and
V_{SR} = VoutR - V_{RG} = (VinR + Vcom) - V_{RG} = (VinR + V_{RG}) - V_{RG} = VinR.

Thus, V_{SL} = VinL and V_{SR} = VinR, and there is no crosstalk signal at the speakers 602, 604.

Any other interference appearing at the jack pole, i.e. any other additional component of V_{RG} superimposed on $I_G.R_G$, due for instance to rectified EMI or to ground return currents from other circuitry will also be removed from the net speaker drive signals.

The additional jack socket contact 622 may be implemented mechanically in various forms depending on the application. Figure 6a illustrates a construction where the additional contact 622 may be located on the same side of the jack plug as the contact 620. In other embodiments where space and the mechanical construction technology allow, the additional contact 622 may be substantially on the opposite side of the jack plug from the contact 620. Other mechanical configurations are of course possible.

Figures 6c and 6d illustrate examples of accessories with which a host device similar to that discussed with respect to Figures 6a and 6b might be configured to co-operate.

Figure 6c in conjunction with **Figure 6e** illustrates an accessory which comprises speakers 602, 604 connected to the tip 708 and first ring 712 of the jack. However in this accessory the common ground return of the speakers is connected to the second ring 714 of the jack rather than the sleeve. The sleeve 710 is connected to an array of one or more push-buttons in a module 26, which define a resistance Rpb between the sleeve and the common ground return. This resistance varies according to which buttons are pushed. In some cases one of the resistance values could essentially be zero, for example less than 1ohm or less than 100milohm or be essentially just the parasitic resistance of the cabling and switch contact resistance.

The tip 708, first ring 712, second ring 714 and sleeve 710 of this plug may thus be regarded as the L, R, G and M poles respectively of the jack plug 25e.

In use the ground pole G of the jack may be coupled to ground via socket contact 622 and switch 624. The sleeve of the jack plug, i.e. pole M, is coupled to circuitry 11 via socket contact 620 and switch 626. In order for circuitry 11 to be able to measure the resistance Rpb without audio artefacts, an a.c. signal current as illustrated by a.c. current source 690 of frequency outside the audio bandwidth or outside the passband of the speaker frequency response may be injected onto Rpb via switch 626, contact 620 and jack plug pole M and the resulting a.c. voltage monitored, for example by an ADC 691 as illustrated or by some analog amplitude detector. By means of circuitry 692 configured to compare the a.c. voltage or apparent impedance versus various predefined ranges consistent with the resistances corresponding to various push-button activations, the button or buttons activated may be detected, and control signals 693 generated to request corresponding action to be taken in the host device, for example to increase or decrease the playback volume or to start, pause or terminate playback.

By arguments similar to those above, when R_{pb} is set to a low value, of the same order as the parasitic resistances R_G, R_M etc., and the driver amplifiers present an adequately high input impedance at Vcom then there will be negligible current or voltage drop associated with resistances R_{pb}, R_G and R_{CS}, and so the ground sense voltage monitored by Vcom will be equal to the voltage drop V_{RG} between jack ground

node X4 and the ground reference node X3. Thus there will be no crosstalk between the speakers. Even for higher values of R_{pb}, say of the order of one kilohm, provided that the input impedance of the driver amplifiers and any other circuitry connected to Vcom is adequately high, say greater than 100kilohm or than 1Megohm, the current flowing from R_{pb} into Vcom will be low enough to still give greatly improved crosstalk over a circuit scheme without Vcom (i.e. a scheme equivalent to shorting Vcom to ground X3).

Figure 6d illustrates a similar accessory, but this accessory has poles G and M reversed (as illustrated by the dotted alternative connections 680 in Figure 6e). Thus the sleeve 710 is the common ground or pole G and the second ring is used as the signalling pole M.

This variant of accessory can be accommodated merely by switching both switches to the other position. That is, the ground pole G of the jack may be coupled to ground via socket contact 620 and switch 624. The second ring of the jack plug, i.e. pole M, is coupled to circuitry 11 via socket contact 622 and switch 624.

Again for an adequately high input impedance at Vcom, then there will be negligible current or voltage drop associated with resistances R_{pb}, R_G and R_{CS}, and so Vcom will follow V_{RG} and be superimposed on VinL and VinR and speaker crosstalk will be greatly improved.

In a further variant of accessories illustrated in Figures 6c, 6d and 6e, the pushbutton resistance Rpb may be replaced by a short circuit. Thus either of the G and M poles of the plug may both carry the ground return current from the speakers and the other may be used to sense the ground voltage at the speakers. The parasitic resistance of the wires between plug and cable may be lumped together with RG or RM, and again the voltage drop across the sense path will be negligible, and the driver amplifiers will deliver output voltages with the sensed speaker ground voltage superimposed.

Figure 7a is an electrical circuit diagram of a further alternative system of the general type shown in Figure 3 illustrating a further embodiment.

Thus, Figure 7a shows the left speaker 702, the right speaker 704, and the microphone 706 of the headset 20. The headset 20 is provided with a jack plug, which in this

example is a TRRS plug. The host device in this system comprises a socket, switches and circuitry 11 such that it can accommodate accessories that have plugs that are connected with different ground and microphone connections.

Figure 7b shows a jack plug 25e connected according to the OMTP standard, and **Figure 7c** shows a jack plug 25f connected according to the CTIA standard, and both figures show the connections between mating contacts in these plugs and the socket arrangement as also illustrated in Figure 7a.

More specifically, in the case of the OMTP jack plug 25e of **Figure 7b**, the common ground return connection is through the sleeve 710, and the microphone is connected to the second ring 714. The left speaker 702 is therefore connected between the tip (T) 708 and the sleeve (S) 710 of the plug 25e. The right speaker 704 is connected between the first ring (R1) 712 and the sleeve (S) 710 of the plug 25e. The microphone 706 is therefore connected between the second ring (R2) 714 and the sleeve (S) 710 of the plug 25. Thus, the second ring 714 acts as a common ground return.

The tip 708, first ring 712, second ring 714 and sleeve 701 of this plug may thus be regarded as the L, R, M and G poles respectively of the jack plug 25e.

In the case of the CTIA jack plug 25f of **Figure 7c**, the common ground return connection is through the second ring 714, and the microphone is connected to the sleeve 710.

The left speaker 702 is therefore connected between the tip (T) 708 and the second ring 714 of the plug 25f. The right speaker 704 is connected between the first ring (R1) 712 and the second ring 714 of the plug 25f. The microphone 706 is connected between the sleeve (S) 710 and the second ring (R2) 714 of the plug 25f. Thus, the second ring 714 acts as a common ground return.

The tip 708, first ring 712, second ring 714 and sleeve 701 of this plug may thus be regarded as the L, R, G and M poles respectively of the jack plug 25e.

In the circuitry 11, a left driver amplifier 716 is driven from a signal source VinL and produces a buffered output signal VoutL, and a right driver amplifier 718 is driven from a signal source VinR and produces a buffered output signal VoutR. The signal sources

VinL and VinR may for example comprise digital-to-analog converters (DACs). These driver amplifiers 716, 718 are coupled to respective jack socket contacts 720, 722. Driver amplifiers 716 and 718 may be configured such that VoutL = VinL + Vcom, and VoutR = VinR + Vcom where Vcom is a voltage applied to a pair of respective second inputs of these driver amplifiers 716 and 718. These second inputs are connectable via the switch 736 to the jack socket contact 728 or to the jack socket contact 726.

Figure 7a also shows an amplifier 724 serving as a microphone pre-amplifier coupled via two separate inputs to two jack socket contacts 726 and 728. Amplifier 724 is designed to produce an output V_{micB} that depends on the difference between its two inputs V_{micA} and V_{micC}.

The switch 734 is positioned to be able to connect the further jack socket contact 730 or further jack socket contact 732 to the ground point X3.

When a jack plug such as 25e or 25f is inserted into the jack socket, the tip contact 708 of the plug contacts the jack socket contact 720; the first ring contact 712 of the plug contacts the jack socket contact 722; the second ring contact 714 of the plug contacts the jack socket contacts 726 and 730; and the sleeve contact 710 of the plug contacts the jack socket contacts 728 and 732.

The circuitry 11 may be provided with circuitry 740 for determining the type of jack plug that has been inserted. That is, the circuitry 11 is able to determine the positions of the ground and microphone connections in the inserted jack plug, and hence whether it is a jack plug 25e connected according to the OMTP standard as shown in **Figure 7b** or a jack plug 25f connected according to the CTIA standard as shown in **Figure 7c**. There are many techniques known for this, generally involving injecting current into one or more contacts of the jack socket and measuring voltages at one or more other contacts or vice versa to determine the impedances between various contacts due to the components connected to the corresponding poles of the inserted jack plug. Thus circuitry 740 may be coupled to various ones of jack socket contacts 720, 722, 726, 728, 730 or 732 via switches 734 or 736 or other wired paths or switches to drive or sense voltage or current signals comprising signal levels or tones on these contacts.

If the ground pole G is determined to be in the sleeve of the jack plug as shown in the jack plug 25e, then switch 734 connects the contact 732 to the ground point X3 and the

switch 736 connects the contact 728 to the second inputs of the left and right driver amplifiers 716, 718.

If the ground pole G is determined to be in the second ring (R2) of the jack plug 25 as shown in the jack plug 25f, then the switch 734 connects the contact 730 to the ground point X3, and the switch 736 connects the contact 726 to the second inputs of the left and right driver amplifiers 716, 718.

The parasitic resistance associated with jack socket contact 732 is R_G. Equivalently the parasitic resistance associated with the jack socket contact 730 is R_M. However, the switch 734 also has a parasitic resistance R_{GS} associated with it. Therefore, the overall resistance of the ground path from the mating jack pole to the ground point X3 when the switch is connected to contact 730 Is $R_M + R_{GS}$. Equivalently, the overall resistance of the ground path from the mating jack pole to the ground point X3 when the switch is connected to the contact 732 is $R_G + R_{GS}$.

There may also be similar parasitic resistances between the microphone jack socket contacts 726 and 728, and the microphone pre-amplifier. Figure 7a shows these lumped into respective single resistance elements R_{M2} and R_{G2}.

There is also a parasitic resistance R_{CS} which is associated with the switch 736. However, as it can be assumed that the inputs of the left driver amplifier 716 and the right driver amplifier 718 connected to Vcom, and the inputs of the microphone amplifier 424 connected to V_{micA} and V_{micC} are high impedance inputs. Hence, there will be negligible currents I_{G2}, I_{CS} and I_{M2} flowing in the respective parasitic resistances R_{G2}, R_{Cs} and R_{M2} associated with the paths to these inputs, and thus the respective voltage drops V_{RG2}, V_{RCS} and V_{RM2} will also be negligible.

The current I_G through the ground pole G of the jack plug, whether this be positioned as shown in jack plug 25e or 25f, comprises both the currents I_{SL} and I_{SR} through the left and right speakers 702, 704. Thus, ignoring any current though the M pole of the plug:

$$I_G = I_{SL} + I_{SR} .$$

Given that substantially the whole of I_G will flow through R_G and R_{GS}, or though R_M or and R_{GS} depending on the switch configuration, the ground voltage on the pole of the

jack, at node X4 (or node X5 depending on the position of the ground connection in the jack plug), will differ from that at node X3 by a voltage V_{RG}, where:

$V_{RG} = I_G * (R_G + R_{GS})$or $I_G * (R_M + R_{GS})$.

The voltage actually appearing across each speaker 702, 704 will be the voltage generated by the respective drive amplifier 716, 718, reduced by V_{RG}. That is:
V_{SL} = VoutL - V_{RG} and
V_{SR} = VoutR - V_{RG} .

As mentioned above, VoutL = VinL + Vcom, and VoutR = VinR + Vcom. Moreover, as the voltage drops across parasitic resistances R_{G2}, R_{Cs} and R_{M2} will also be negligible, Vcom = V_{RG}.

Thus:
V_{SL} = VoutL - V_{RG} = (VinL + Vcom) - V_{RG} = (VinL + V_{RG}) - V_{RG} = VinL, and
V_{SR} = VoutR - V_{RG} = (VinR + Vcom) - V_{RG} = (VinR + V_{RG}) - V_{RG} = VinR.

Thus, V_{SL} = VinL and V_{SR} = VinR, and there is no crosstalk signal at the speakers 702, 704.

As also mentioned above:
$V_{micB} = V_{micA} - V_{mic}$.

Considering the voltages shown in Figure 7a:
$V_{micA} = V_{mic} + V_{RG} - V_{RM2}$ and
$V_{micC} = V_{RG} - V_{RG2}$.

However, as mentioned above, V_{RM2} and V_{RG2} are negligible, and so:
$V_{micB} = V_{micA} - V_{mic} = (V_{mic} + V_{RG}) - V_{RG}$.

Thus, the microphone preamplifier 724 is connected across the two contacts 726, 728 that are not used for the ground current return in either position of the switches 734, 736, and so it senses the microphone signal V_{mic} without any influence from the ground return current or any parasitic resistance in the socket contacts. The net voltage

appearing at the output of the preamplifier 724 is therefore equal to V_{mic} (probably with a voltage gain applied by the preamplifier 724).

Any other interference appearing at the jack pole, i.e. any other additional component of V_{RG} superimposed on $I_G.(R_G + R_{GS})$, due for instance to rectified EMI (Electromagnetic Interference) will also be removed from the net speaker drive and microphone sense signals.

The jack socket contacts 732 and 728 may be implemented mechanically in various forms depending on the application. Figure 7a illustrates a construction where the additional contacts 732 and 728 may be located on opposite sides of the jack plug. In other embodiments where space and the mechanical construction technology allow, the contacts 732 and 728 may be substantially on the same side of the jack plug, and displaced along the plug in a direction parallel with the axis of the plug.

The jack socket contacts 730 and 726 may be implemented mechanically in various forms depending on the application. Figure 7a illustrates a construction where the additional contacts 730 and 726 may be located on opposite sides of the jack plug. In other embodiments where space and the mechanical construction technology allow, the contacts 730 and 726 may be substantially on the same side of the jack plug, and displaced along the plug in a direction parallel with the axis of the plug.

Figure 8a is an electrical circuit diagram of a further alternative system of the general type shown in Figure 3. Specifically, Figure 8a shows the headset 20 as being a mono headset, having a left speaker 802 and a right speaker 804 connected in parallel, and also having a microphone 806.

As shown in **Figure 8b** in conjunction with Figure 8a the headset 20 is provided with a jack plug 25g, which in this example is a TRS plug. The left speaker 802 is connected between the tip (T) 808 and the sleeve (S) 810 of the plug 25g. The right speaker 804 is similarly connected between the tip (R) 808 and the sleeve (S) 810 of the plug 25g, so that the two speakers receive the same driving signal. The microphone 806 is connected between the ring (R) 812 and the sleeve (S) 810 of the plug 25g. Thus, the sleeve 810 acts as a common ground return.

The tip 808, ring 812, and sleeve 810 of this plug may thus be regarded as the LR, M and G poles respectively of the jack plug 25g.

In the circuitry 11, a single driver amplifier 814 is driven from a signal source VinLR which may comprise a DAC and produces a buffered output signal VoutLR. An output of driver amplifier 814 is coupled to the jack socket contact 816.

Figure 8a also shows an amplifier 818 serving as a microphone pre-amplifier with an input coupled to a jack socket contact 820.

A further, i.e. a fourth, jack socket contact 822 provides the common ground return path for the signal paths through the jack socket contacts 816 and 820.

Thus, when the jack plug is inserted into the jack socket, the tip contact 808 of the plug 25g contacts the jack socket contact 816; the ring contact 812 of the plug 25g contacts the jack socket contact 820; and the sleeve contact 810 of the plug 25g contacts the jack socket contact 822.

As shown in Figure 8a, the jack socket is provided with an additional jack socket contact 824. The additional jack socket contact 824 is positioned in the socket such that, when the plug 25g is inserted into the socket, the sleeve contact 810 of the plug 25 contacts the additional jack socket contact 824 as well as the jack socket contact 822.

The additional jack socket contact 824 is connected to a second input of the microphone amplifier 818. Thus, the amplifier 818 is designed to produce an output V_{micB} that depends on the difference between its two inputs V_{micA} and V_{micC}.

The additional jack socket contact 824 is also connected to a second input of the driver amplifier 814. The voltage on this second input is Vcom. Preferably, amplifier 814 is designed to produce an output VoutLR which depends on the sum of VinLR and Vcom.

Figure 8a illustrates the various parasitic resistances in the ground path between the jack pole G and a ground reference point X3 close to the circuitry 11, lumped into a single resistance element R_G.

There may also be similar parasitic resistances between the jack plug pole M and the microphone pre-amplifier 818, and Figure 8a shows these lumped into a single resistance element R_M.

The parasitic resistances associated with the additional jack socket contact 824 are shown in Figure 8a as the resistance element R_{G2}.

It can be assumed that the second, i.e. reference, input of the driver amplifier 814 connected to Vcom, and the inputs of the microphone amplifier 818 connected to V_{micA} and V_{micC} are high impedance inputs. Hence, there will be negligible currents I_M and I_{G2} flowing in the respective parasitic resistances R_M and R_{G2} associated with the tracks to these inputs, and thus the voltage drops V_{RM} and V_{RG2} will also be negligible.

The current I_G through the ground pole G of the jack plug comprises both the currents I_{SL} and I_{SR} through the left and right speakers 802, 804 and also any current I_M though the M pole of the plug that might return via pole G:

$$I_G = I_{SL} + I_{SR} + I_M.$$

Given that any current flowing though contact 824 may be negligible compared with that flowing though contact 822, the whole of I_G will flow through parasitic resistance R_G, and so the ground voltage on the pole of the jack, at node X4, will differ from that at X3 by a voltage V_{RG}, where:

$$V_{RG} = I_G * R_G .$$

The voltage actually appearing across each speaker 802, 804 will be the voltage generated by the driver amplifier 814, reduced by V_{RG}. That is:

$$V_{SL} = V_{SR} = \text{VoutLR} - V_{RG}.$$

As mentioned above, amplifier 814 is configured such that VoutLR = VinLR + Vcom.

Moreover, as V_{RG2} is negligible, Vcom = V_{RG}.

Thus:

$V_{SL} = V_{SR} = VoutLR - V_{RG} = (VinLR + Vcom) - V_{RG} = (VinLR + V_{RG}) - V_{RG} = VinLR$

Thus, $V_{SL} = VinLR$ and $V_{SR} = VinLR$, and any microphone signal cannot cause crosstalk at the speakers 802, 804.

As also mentioned above:
$V_{micB} = V_{micA} - V_{mic}$.

Considering the voltages shown in Figure 8a:
$V_{micA} = V_{mic} + V_{RG} - V_{RM}$ and
$V_{micC} = V_{RG} - V_{RG2}$.

However, as mentioned above, V_{RM} and V_{RG2} are negligible, and so:
$V_{micB} = V_{micA} - V_{mic} = (V_{mic} + V_{RG}) - V_{RG} = V_{mic}$.

Thus the net voltage appearing at the output of the preamplifier 818 is equal to V_{mic} (probably with a voltage gain applied by the preamplifier).

Any other interference appearing at the jack pole, i.e. any other additional component of V_{RG} superimposed on $I_G.R_G$, due for instance to rectified EMI (electromagnetic interference) will also be removed from the net speaker drive and microphone sense signals.

The additional jack socket contact 824 may be implemented mechanically in various forms depending on the application. **Figure 8c** illustrates a construction where the additional contact 824 is located on the opposite side of the jack plug from the contact 822, and Figure 8b illustrates a construction where the additional contact 824 is substantially on the same side of the jack plug as the contact 822, and displaced further along the plug in a direction parallel with the axis of the plug.

Figure 8a illustrates an example where the speakers 802, 804 are connected in parallel. However, exactly the same circuitry 11 can be provided in the case where the speakers 802, 804 are connected in series, or in the case where there is only one speaker.

It will also be noted that, while Figure 8a shows the second input of the driver amplifier 814 being connected to the additional contact 824, in examples where the speaker

drive gain accuracy or microphone-to-speaker crosstalk is not considered important, the second input of the driver amplifier 814 need not be connected to the additional contact 824 and may instead be connected to a ground closely coupled to ground reference point X3.

Embodiments described so far relate to a device having a socket that is configured to receive a cylindrical plug. However, other connectors may be used. Thus, in further embodiments, the mechanical configuration of the plug may be different from the cylindrical plug with poles distributed along a common axis described hitherto. Various mechanical configurations are possible for a socket to still provide a plurality of contacts to mate with a signal pole of an inserted plug. For instance a receptacle for a USB Type C plug may comprise two separate contacts in the area normally occupied by a single contact, or in an area facing a contact of an inserted USB Type C plug. The USB Type C plug may be wired to an adapter or captive accessory according to the USB Type C Audio Adapter Accessory Mode. Preferably the multi-pole contact is on one or both terminals assigned to MIC/GND (M/G) or GND/MIC (G/M) in this mode.

In embodiments above, the accessory has been illustrated as comprising a plug or male connector, inserted into a socket or female connector on the device. In further embodiments, the device may comprise a male connector and the accessory a female connector. In some embodiments the connectors may be sex-less, for example each being a coplanar array of contact pads or suchlike, mechanically held together by means such as magnetic elements.

The terms host device and accessory device have been used to denote respectively a first device containing circuitry 11 connected to a second device containing some acoustic load or transducer connected together by some detachable connector means. In some cases the first device containing the circuitry 11 may be more naturally be considered an accessory and the second device containing some acoustic load or transducer may be considered a host device.

Switches coupled to the M and G poles have been illustrated as single-pole double-throw switches, where the pole of the switch may be connected to one of two other terminals. These may be implemented as a pair of elements, for example MOS transistor switches, connected between the common switch pole to respective other terminals, with one of the two switches being in a conductive state and the other in a

non-conductive state at any one time. However in some embodiments the switches may be controlled so that at some times both switches may be on at the same time or neither of the two switches is on at the same time.

Figure 9a and **Figure 9b** illustrate further embodiments. These illustrate embodiments similar to Figures 6a and 6e respectively, with like numbered elements denoting equivalent components, but in this case the device may incorporate a different receptacle and plug arrangement, such as a USB Type C arrangement, interposed between the switches and amplifiers and the socket contacts. The accessory plug may be inserted into a 3.5mm audio jack-to-USB adapter comprising a four pole jack socket and a 24-pin USB-C plug wired according to the USB Type C Audio Adapter Accessory Mode annex, which is incorporated herein by reference, of which the six most relevant contacts are shown. This plug may be attached in either rotational polarity to a 24-pin USB Type C receptacle, wired to couple to circuitry 11 as shown. In this case the combination of the host device and the adapter may be considered as a device coupled to the accessory. It will be appreciated by those skilled in the art that while a 24-pin USB Type C arrangement has many more contacts than a traditional 3 or 4 pole audio socket and plug arrangement that are allocated to other non-audio functionality, and therefore more capability and/or flexibility, the USB-C contacts other than those associated with audio accessory functionality have been ignored for reasons of clarity.

In each case the operation associated with Figures 9a and 9b is similar to that described with respect to Figures 6a and 6e respectively. For analysis, any relevant parasitic resistances associated with the USB socket connections or any cabling between the sockets and the circuitry 11 may be lumped together with R_G or R_M and crosstalk due to all components of these resistances may be shown to be reduced by similar analysis to that of Figures 6a and 6e.

Note that as used herein the term module shall be used to refer to a functional unit or block which may be implemented at least partly by dedicated hardware components such as custom defined circuitry and/or at least partly be implemented by one or more software processors or appropriate code running on a suitable general purpose processor or the like. A module may itself comprise other modules or functional units. A module may be provided by multiple components or sub-modules which need not be co-located and could be provided on different integrated circuits and/or running on different processors.

Embodiments may be implemented in a host device, especially a portable and/or battery powered host device such as a mobile telephone, an audio player, a video player, a PDA, a mobile computing platform such as a laptop computer or tablet and/or a games device for example. Embodiments of the invention may also be implemented wholly or partially in accessories attachable to a host device, for example in active speakers or headsets or the like. Especially in more complex devices, there may be more than one connector and associated signal paths per aspects of the invention.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. The word "comprising" does not exclude the presence of elements or steps other than those listed in a claim, "a" or "an" does not exclude a plurality, and a single feature or other unit may fulfil the functions of several units recited in the claims. Any reference numerals or labels in the claims shall not be construed so as to limit their scope. Terms such as amplify or gain include possibly applying a scaling factor of less than unity to a signal.

CLAIMS

1. A device for connection to an audio accessory comprising:
   (a) a jack socket for connection to a jack plug of the audio accessory, wherein the jack socket comprises:
      (i) first and second contacts, positioned to mate with a first pole of the jack plug, wherein one of the first and second contacts is coupled to ground,
      (ii) a third contact positioned to mate with a second pole of the jack plug, and
      (iii) a fourth contact, positioned to mate with a third pole of the jack plug,
   (b) a first audio driver amplifier, comprising:
      (i) a first input coupled to receive a first driver signal,
      (ii) a second input coupled to an other of the first and second contacts, and
      (iii) an output coupled to said third contact, and
   (c) a second audio driver amplifier, comprising:
      (i) a first input coupled to receive a second driver signal,
      (ii) a second input coupled to said other of the first and second contacts, and
      (iii) an output coupled to said fourth contact.

2. A device as claimed in claim 1, wherein
the first audio driver amplifier is configured to superimpose a signal received at the second input thereof onto the first driver signal, and to output the result to the third contact of the jack socket.

3. A device as claimed in claim 1 or 2, wherein
the second audio driver amplifier is configured to superimpose a signal received at the second input thereof onto the second driver signal, and to output the result to the fourth contact of the jack socket.

4. A device as claimed in any of claims 1 to 3, further comprising:
   (d) a third amplifier, comprising:

(i) a first input coupled to the other of the first and second contacts of the jack socket, and

(ii) a second input coupled to a fifth contact of the jack socket which is positioned to mate with a fourth pole of the jack plug, wherein the third amplifier is configured to output a signal based on the difference between a signal received at the first input thereof and a signal received at the second input thereof.

5. A device as claimed in any of claims 1 to 4, wherein the first contact and the second contact are positioned to contact the first pole of the jack plug on opposite sides of the jack socket.

6. A device as claimed in any of claims 1 to 4, wherein the first contact and the second contact are positioned to contact the first pole of the jack plug on the same side of the jack socket, laterally displaced from one another.

7. A device as claimed in any of claims 1 to 6, further comprising:

a first switch, for switchably determining which of the first contact and the second contacts is the one coupled to ground; and

a second switch, for switchably connecting the other of the first and second contacts to the respective second inputs of the first and second audio driver amplifiers.

8. A device as claimed in any of claims 1 to 6, further comprising:

a sixth contact positioned to mate with the second pole of the jack plug, wherein the ground is switchably connected to the one of the first and second contacts or to the sixth contact.

9. A device as claimed in any preceding claim, wherein the device is a computing device and/or a portable communications device.

10. A device as claimed in claim 9, wherein the device is a tablet computer.

11. A device as claimed in claim 9, wherein the device is a smartphone.

12. A device for connection to an audio accessory comprising:

(a) a jack socket for connection to a jack plug of the audio accessory, wherein the jack socket comprises,

(i) first and second contacts, positioned to mate with a first pole of the jack plug, wherein one of the first and second contacts is coupled to ground,

(ii) a third contact positioned to mate with a second pole of the jack plug, and

(iii) a fourth contact, positioned to mate with a third pole of the jack plug,

(b) a first audio driver amplifier, comprising:

(i) a first input coupled to receive a first driver signal;

(ii) a second input coupled to an other of said first and second contacts, and

(iii) an output coupled to said third contact, and

(c) a microphone pre-amplifier comprising:

(i) a first input coupled to said fourth contact,

(ii) a second input coupled to said other of the first and second contacts, and

(iii) an output coupled to output an amplified signal.

13. A device as claimed in claim 12, wherein

the first audio driver amplifier is configured to superimpose a signal received at the second input thereof onto the first driver signal, and to output the result to the third contact of the jack socket.

14. A device as claimed in claim 12 or 13, wherein

the microphone pre-amplifier is configured to generate the amplified signal based on a difference between signals received at the first and second inputs thereof.

15. A device as claimed in any of claims 12 to 14, wherein the first contact and the second contact are positioned to contact the first pole of the jack plug on opposite sides of the jack socket.

16. A device as claimed in any of claims 12 to 14, wherein the first contact and the second contact are positioned to contact the first pole of the jack plug on the same side of the jack socket, laterally displaced from one another.

17. A device as claimed in any of claims 12 to 16, wherein the device is a computing device and/or a portable communications device.

18. A device as claimed in claim 17, wherein the device is a tablet computer.

19. A device as claimed in claim 17, wherein the device is a smartphone.

20. A first device for connection to a second device, comprising:

(a) a first device connector for connection to a connector of the second device, wherein the first device connector comprises,

(i) a first contact, coupled to ground, positioned to mate with a first pole of the connector of the second device,

(ii) a second contact positioned to mate with the first pole of the connector of the second device,

(iii) a third contact positioned to mate with a second pole of the connector of the second device, and

(iv) a fourth contact, positioned to mate with a third pole of the connector of the second device,

(b) a first amplifier wherein,

(i) a first input of the first amplifier is coupled to the second contact of the first device connector,

(ii) a second input of the first amplifier is coupled to receive a driver signal, and

(iii) an output of the first amplifier is coupled to the third contact of the first device connector, and

(c) a second amplifier wherein,

(i) a first input of the second amplifier is coupled to the second contact,

(ii) a first port of the second amplifier is coupled to the fourth contact of first device connector, and

(iii) a second port of the second amplifier is coupled to a terminal of the device.

21. A device as claimed in claim 20, wherein the first port of the second amplifier is an input of the second amplifier and the second port of the second amplifier is an output of the second amplifier.

22. A device as claimed in claim 20, wherein the first port of the second amplifier is an output of the second amplifier and the second port of the second amplifier is an input of the second amplifier.

23. A device for connection to an audio accessory comprising:

(a) a jack socket for connection to a jack plug of the audio accessory, wherein the jack socket comprises:

(i) a first contact, coupled to ground, positioned to mate with a first pole of the jack plug,

(ii) a third contact positioned to mate with a second pole of the jack plug, and

(iii) a fourth contact, positioned to mate with a third pole of the jack plug,

(b) a first audio driver amplifier, having:

(i) a first input coupled to receive a first driver signal, and

(ii) an output coupled to said third contact, and

(c) a second audio driver amplifier, having:

(i) a first input coupled to receive a second driver signal, and

(ii) an output coupled to said fourth contact.

wherein

said jack socket comprises a second contact positioned to mate with the first pole of the plug

said second contact is coupled to a respective second input of each of the first and second driver amplifiers and

each of said first and second amplifiers are configured to superimpose the signal received at the respective second input onto an output signal at said respective driver amplifier output.

24. A device for connection to an audio accessory comprising:

(a) a jack socket for connection to a jack plug of the audio accessory,

(b) a ground connection to a first socket contact which is positioned to mate with a ground return pole of the plug when inserted and

(c) a pair of driver amplifiers each for driving a respective speaker signal onto a respective other pair of contacts of the socket

wherein

said jack socket comprises a second contact also positioned to mate with the ground return pole of the plug and

each of said driver amplifiers comprises an input coupled to said second contact and is configured to superimpose a signal present at the second contact onto said respective speaker signal.

25. A device as claimed in claim 24 wherein said first and second contacts are positioned to both mate with the same pole of a 3-pole jack plug.

26. A device as claimed in claim 25 wherein said first and second contacts are positioned to both mate with the sleeve of a 3-pole jack plug.

27. A device as claimed in claim 24 wherein said first and second contacts are positioned to both mate with the same pole of a 4-pole jack plug.

28. A device for connection to an audio accessory comprising:

a) a jack socket for connection to a jack plug of the audio accessory,

b) a ground connection to a first socket contact which is positioned to mate with a ground return pole of the plug when inserted, and

c) a driver amplifier for driving a speaker signal onto a further contact of the socket,

wherein:

said jack socket comprises a second contact also positioned to mate with the ground return pole of the plug,

said driver amplifier comprises an input coupled to said second contact and is configured to superimpose a signal present at the second contact onto said speaker signal.

29. A device for connection to an audio accessory comprising:

a) a jack socket for connection to a jack plug of the audio accessory,

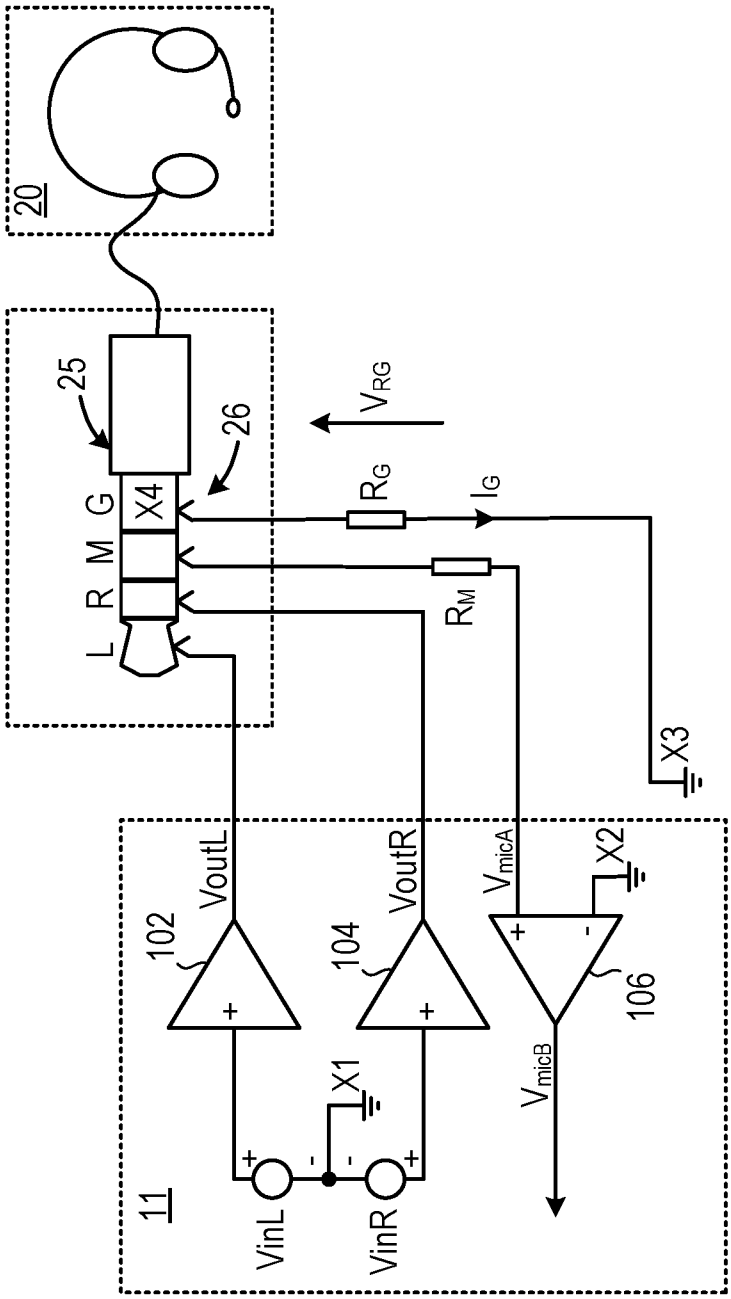
b) a ground connection to a first socket contact which is positioned to mate with a ground return pole of the plug when inserted,

c) a microphone pre-amplifier with an input coupled to a third contact of the socket

wherein:

a) said jack socket comprises a second contact also positioned to mate with the ground return pole of the plug

b) said microphone pre-amplifier is configured to output a signal based on the difference between the voltages on said second and third contacts.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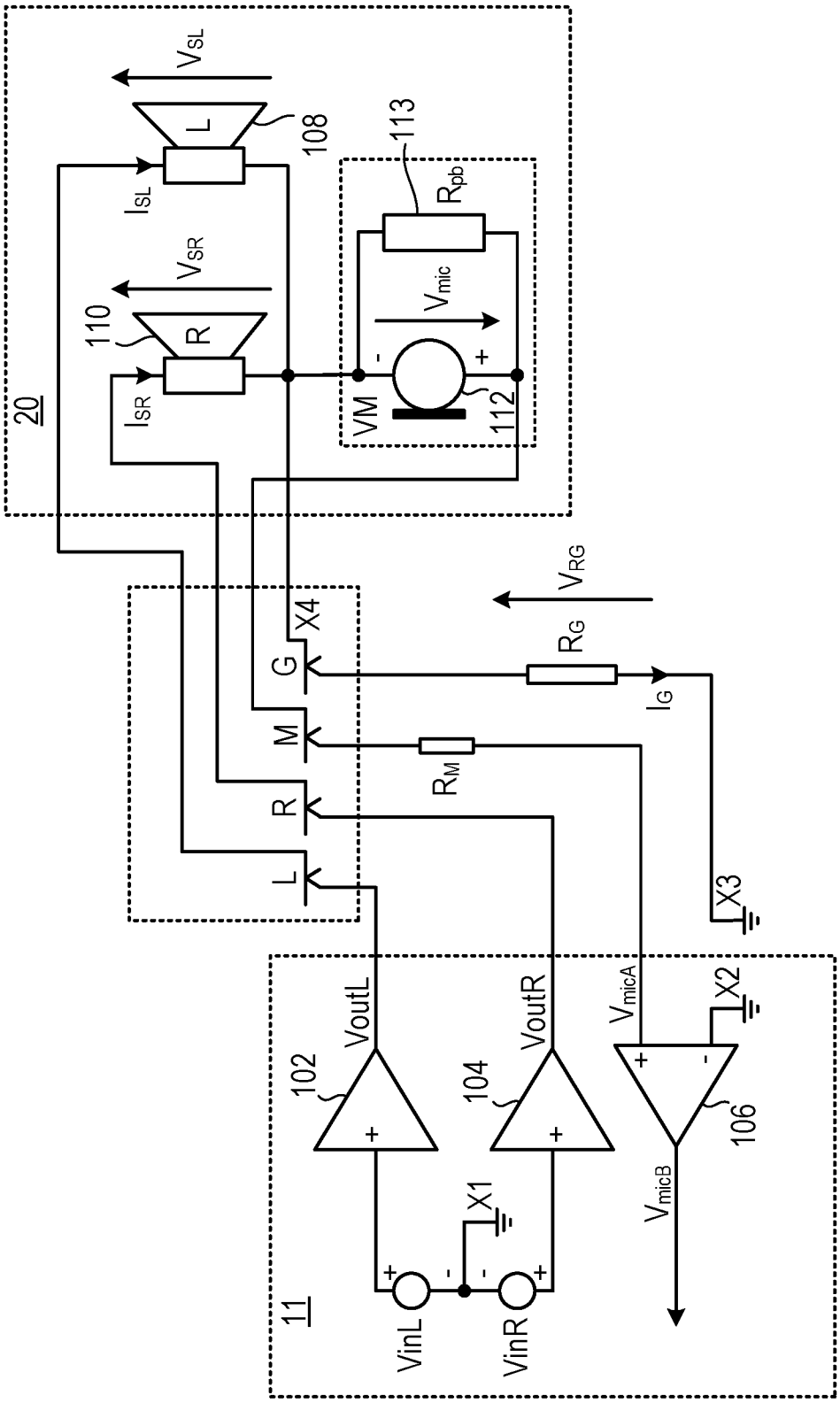
106
X1
VinL
VinR
V_{micB}

Figure 1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VinR

Figure 2

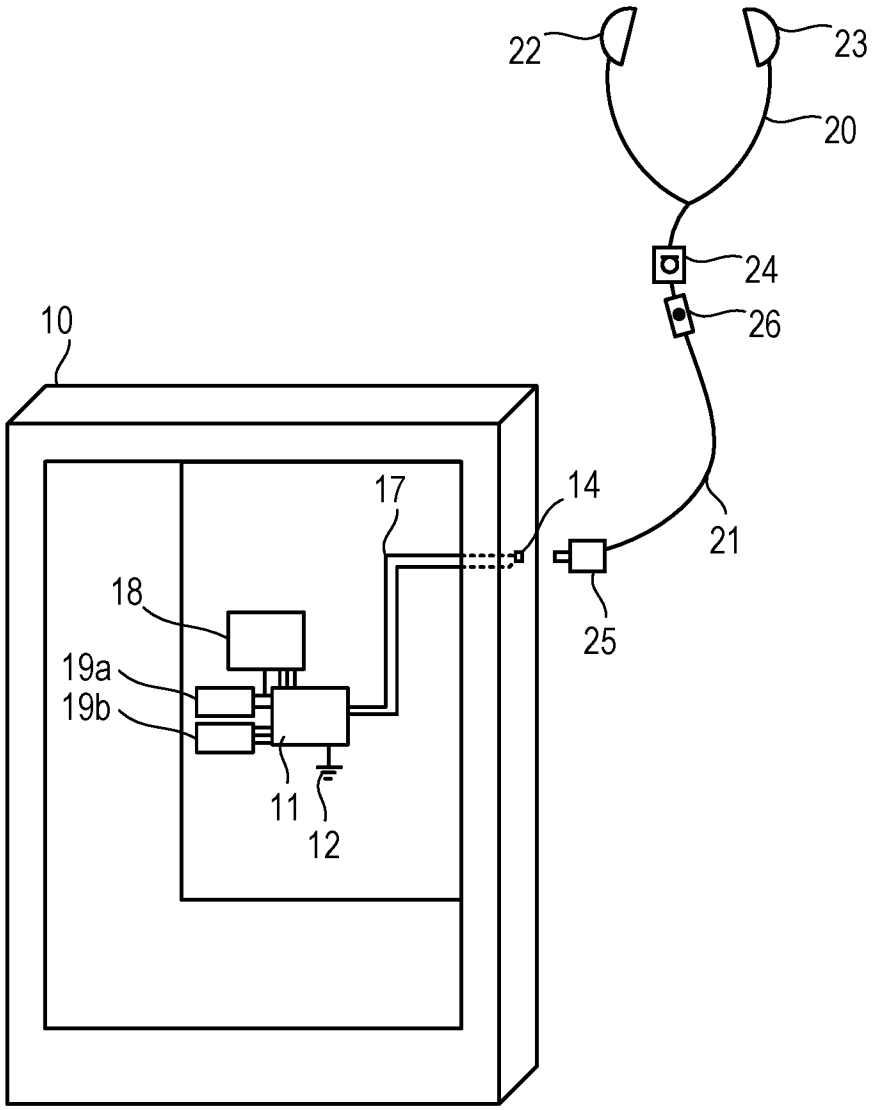
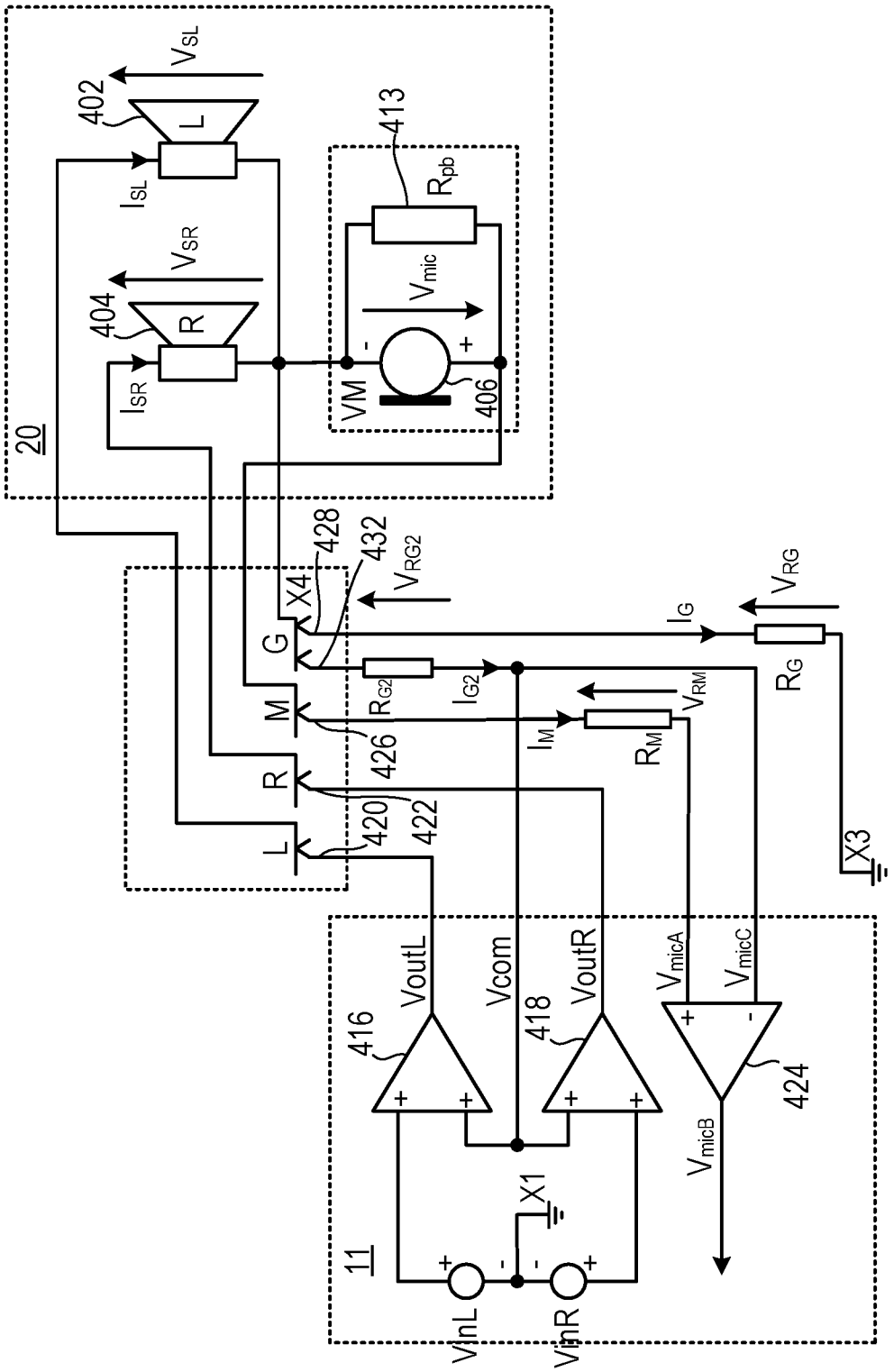


Figure 3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L
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R_{G2}
I_{G2}
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V_{RG}
R_G
I_M
R_M
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VinL
VinR

Figure 4a

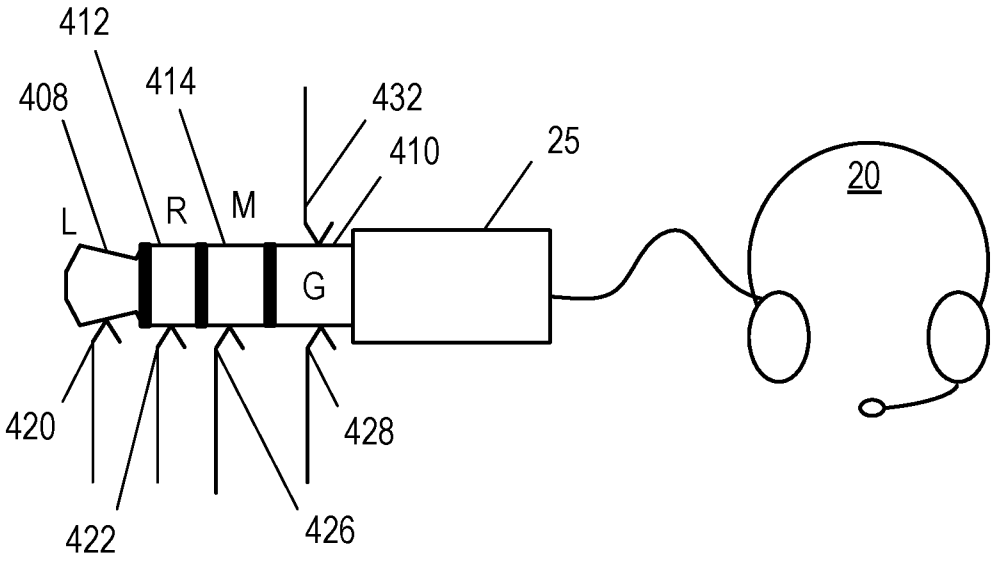

Figure 4b

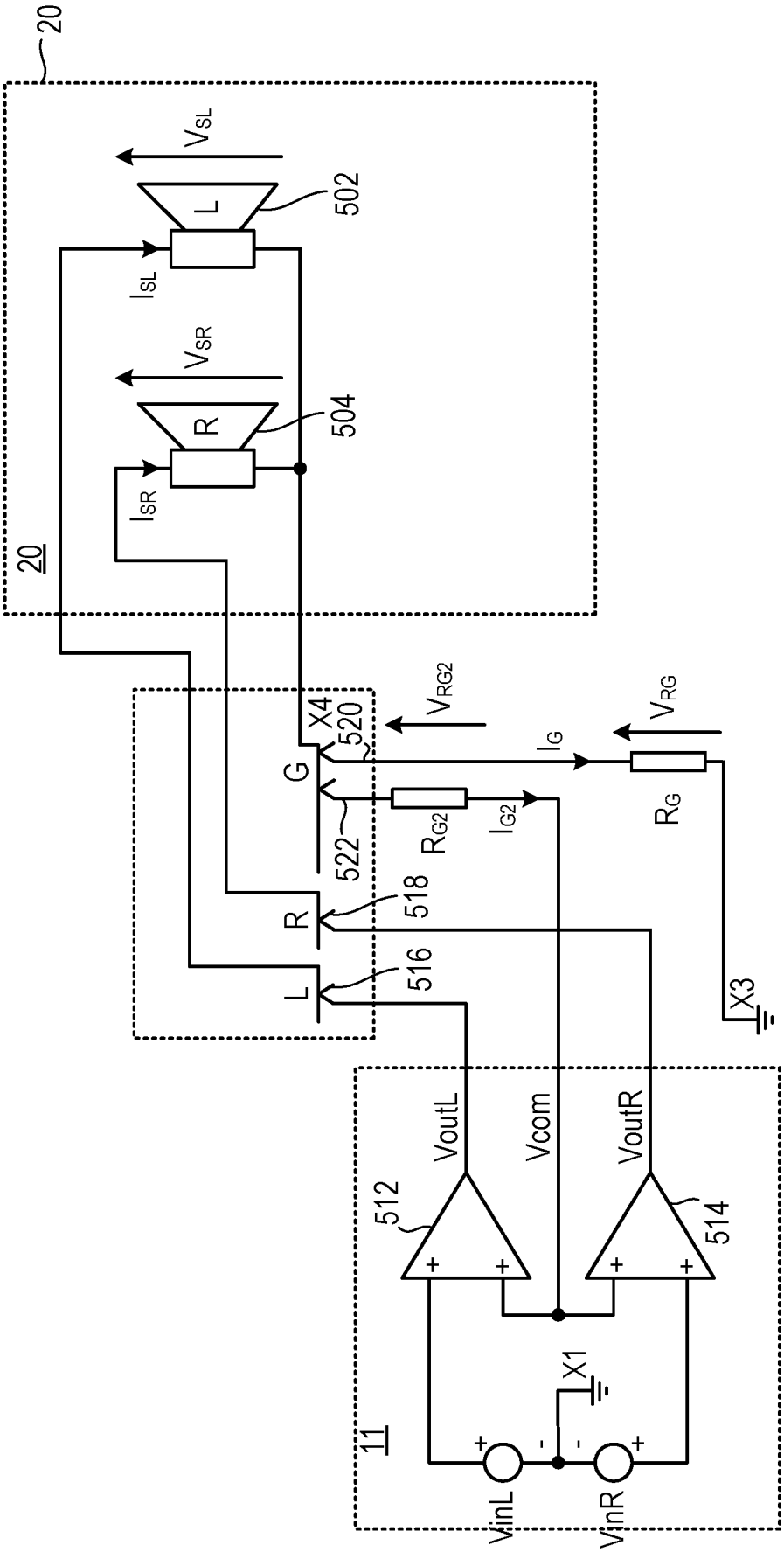
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Figure 5a

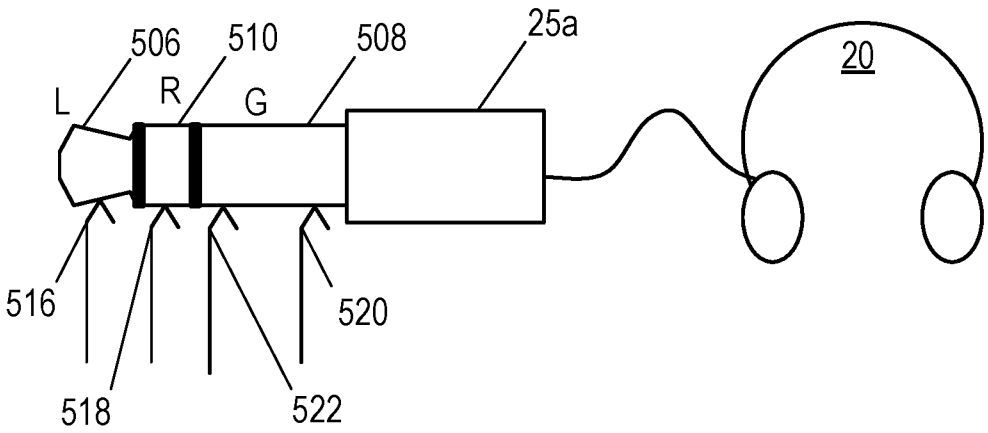
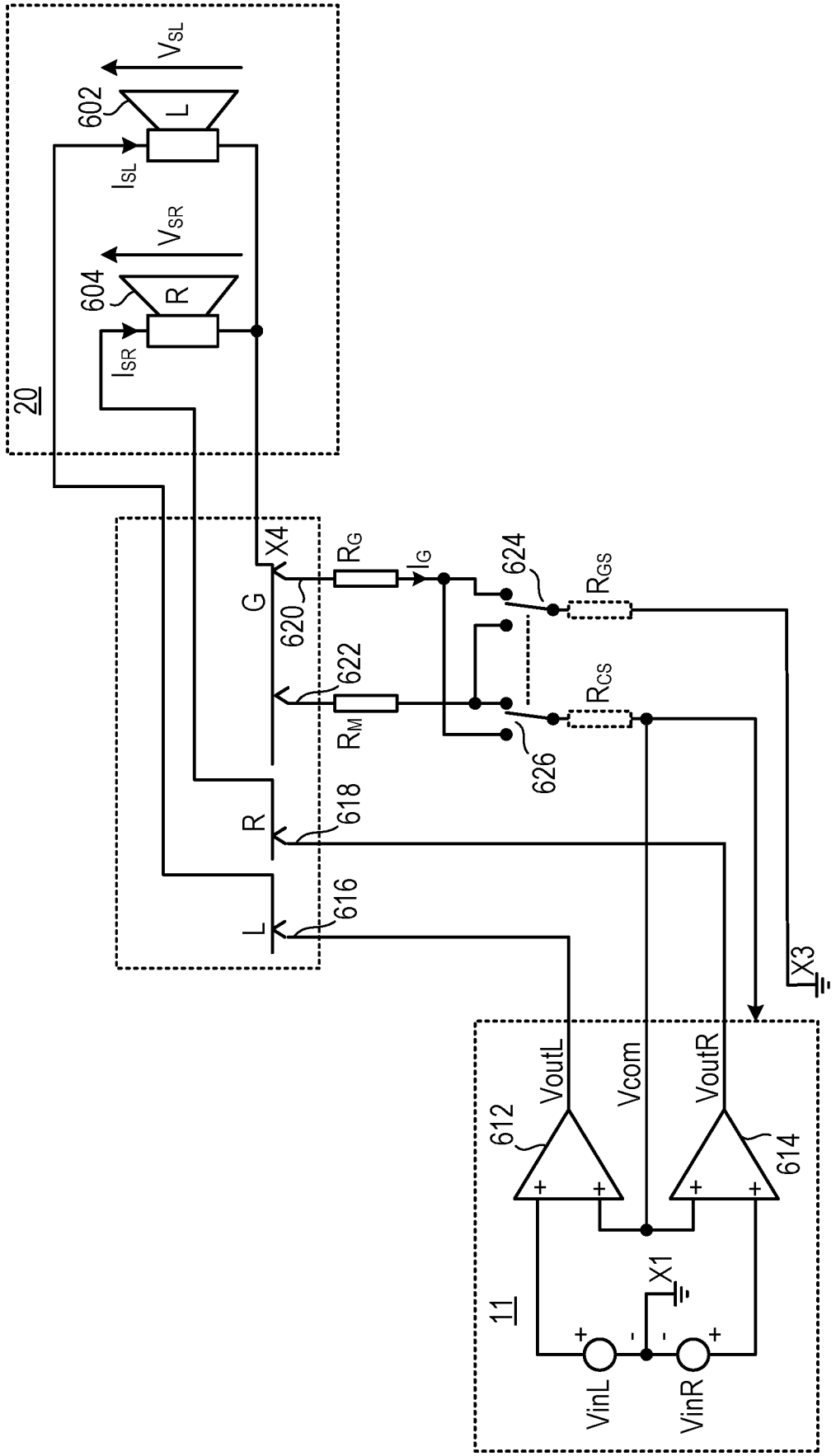


Figure 5b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VoutR
614
X1
VinL
VinR

Figure 6a

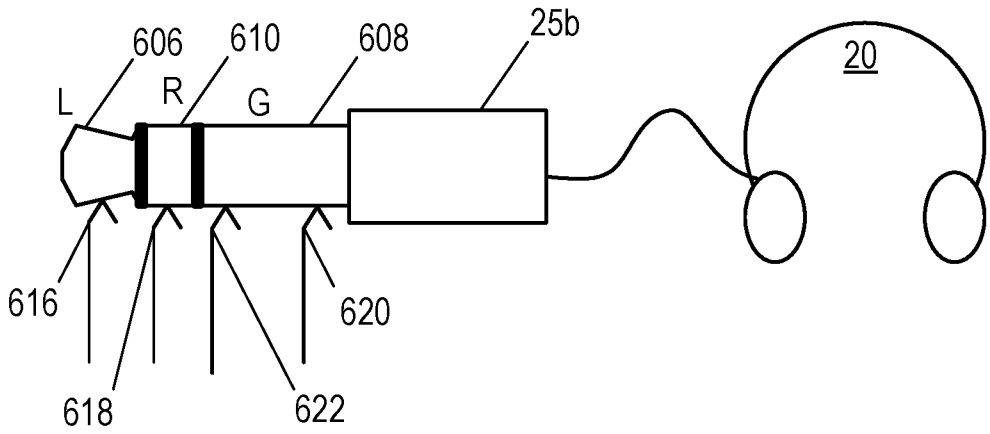

Figure 6b

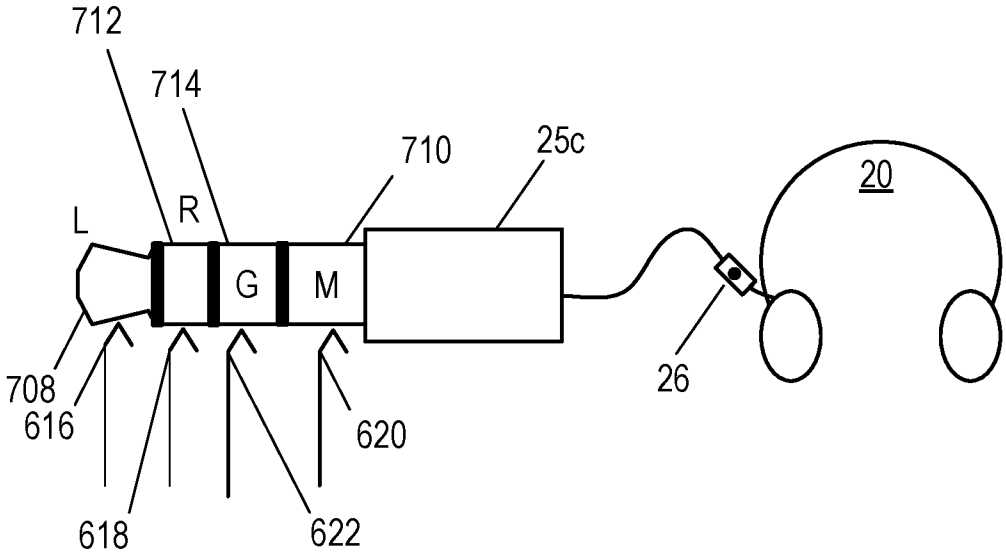

Figure 6c

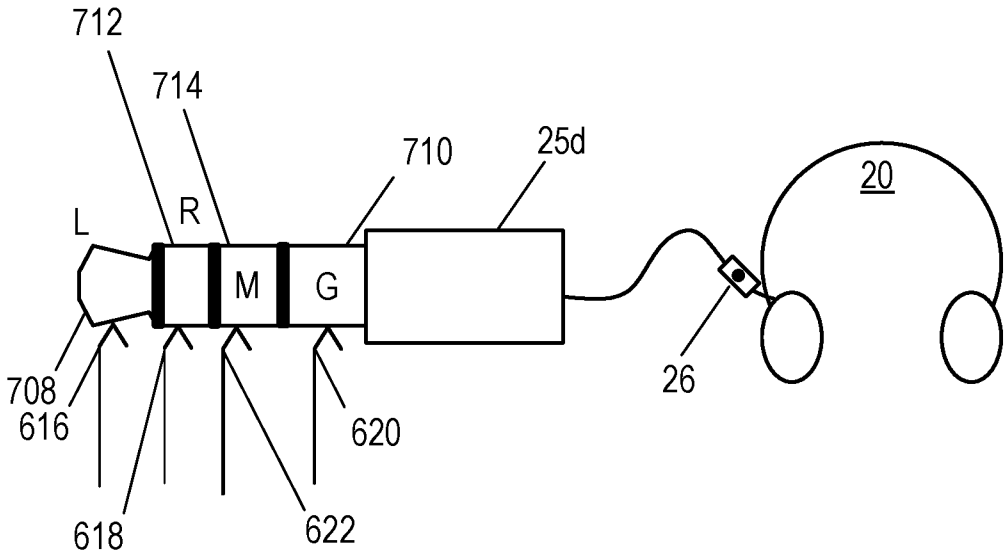

Figure 6d

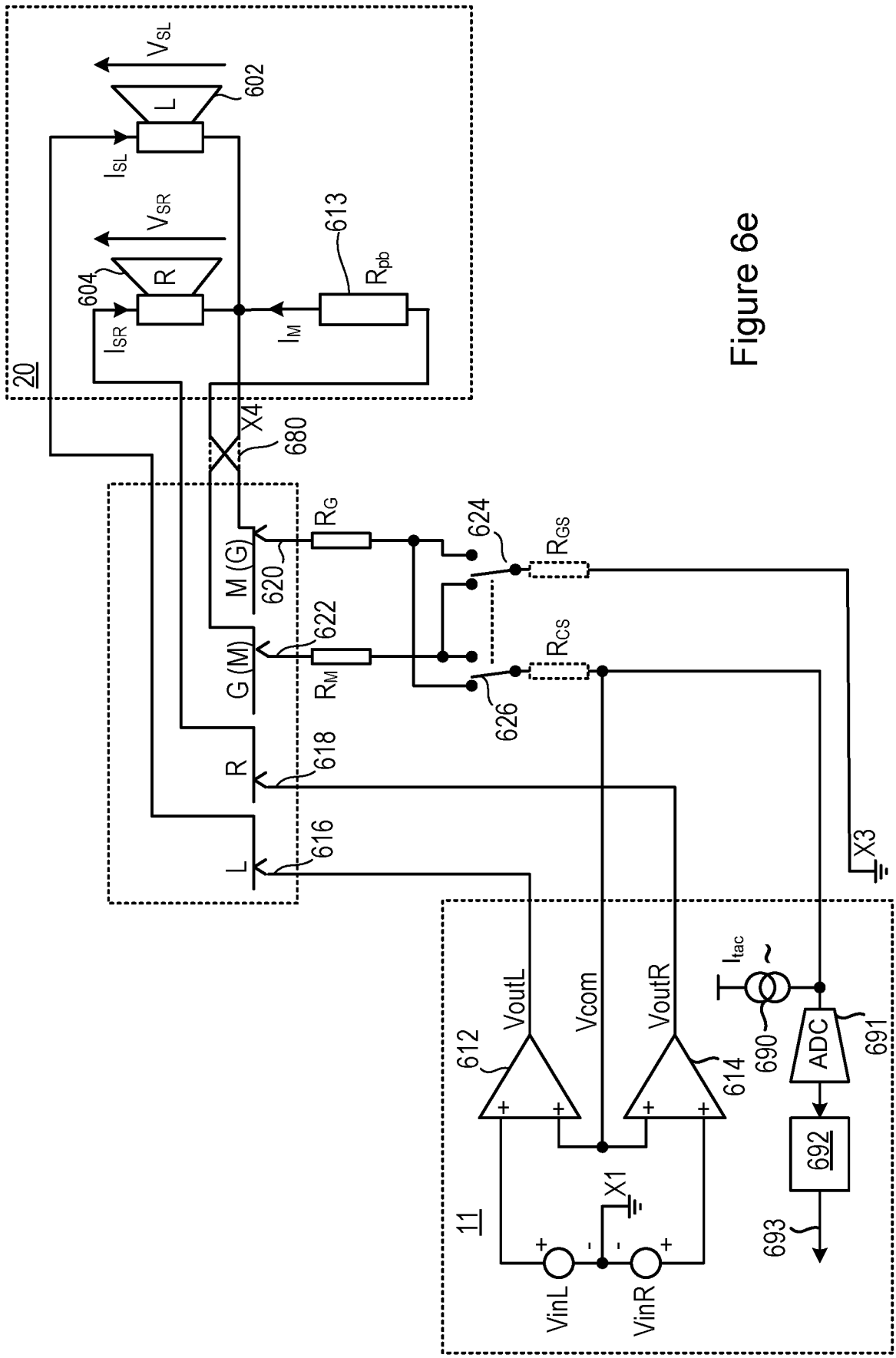
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Figure 6e

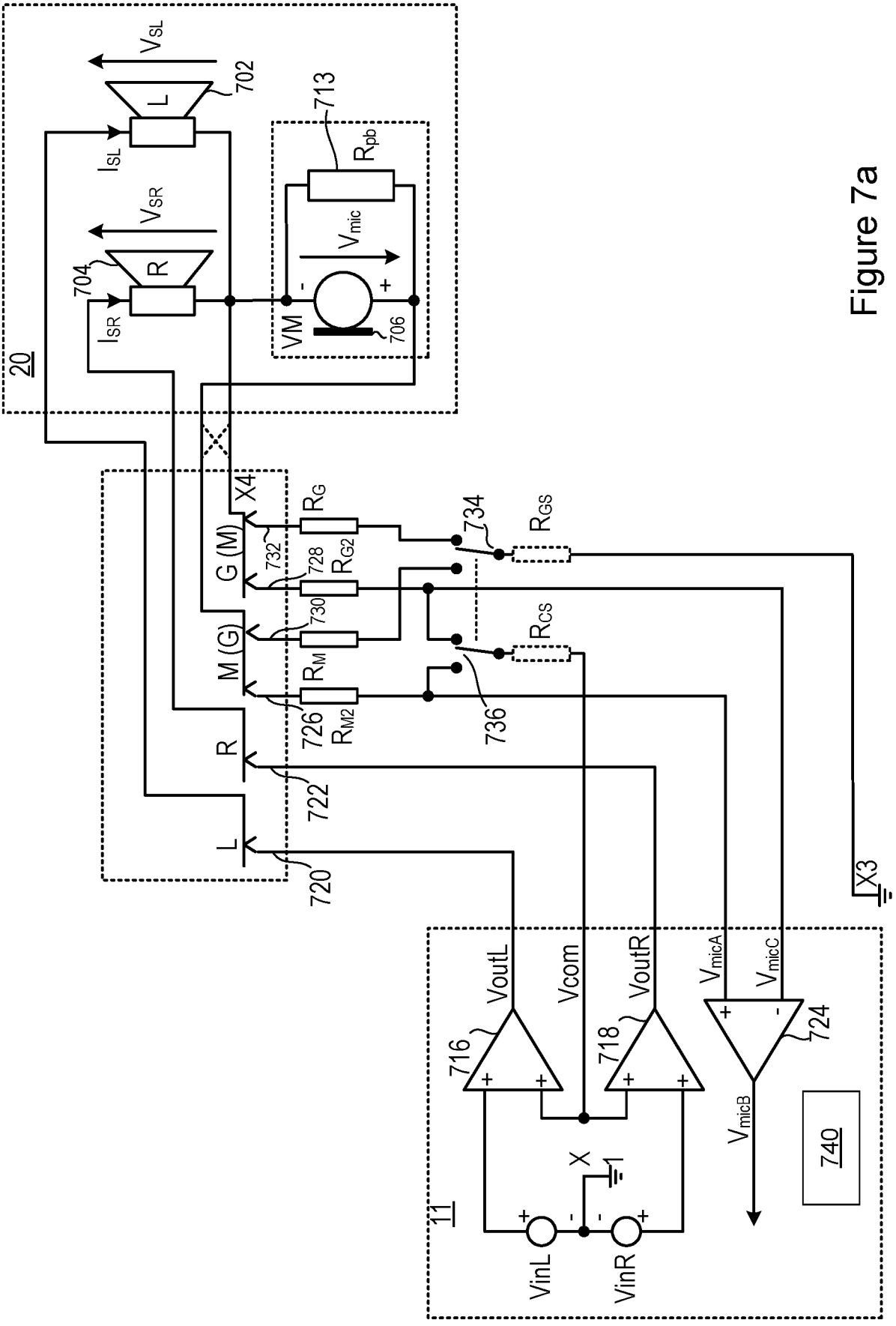
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Figure 7a

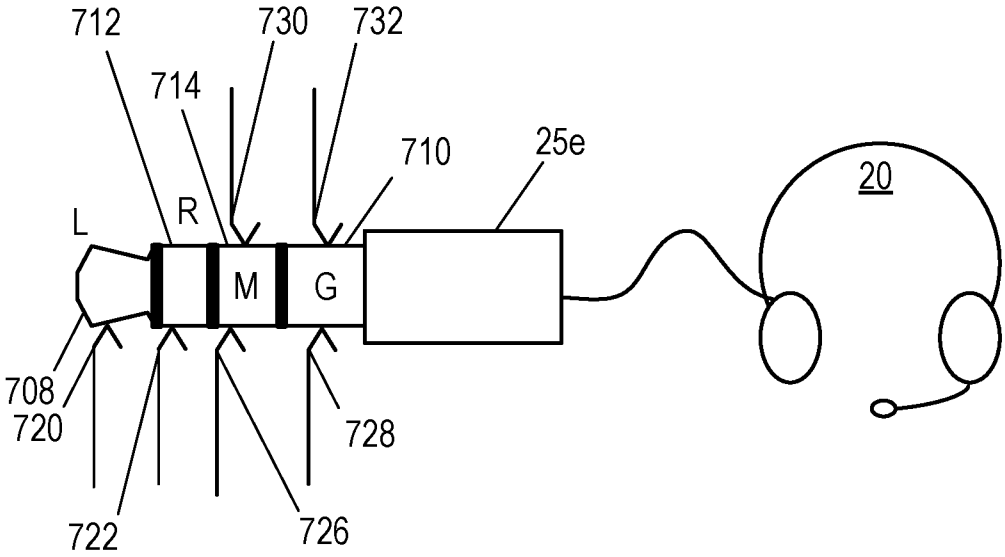

Figure 7b

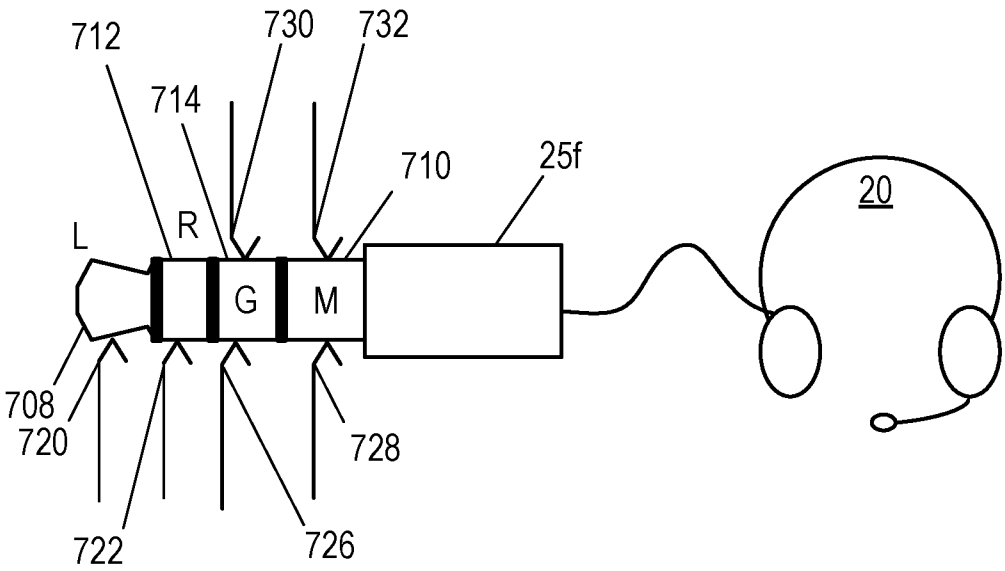

Figure 7c

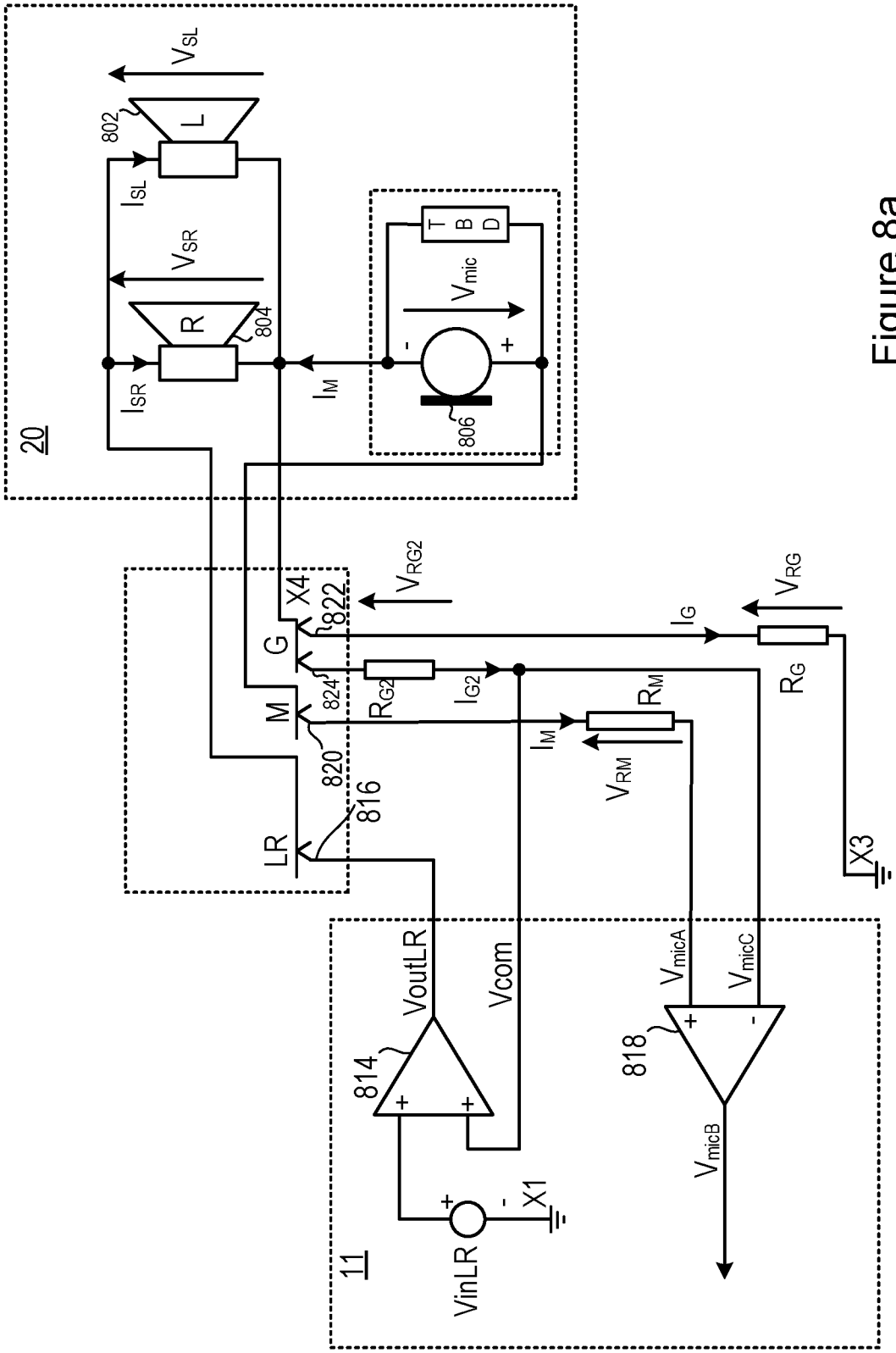
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Figure 8a

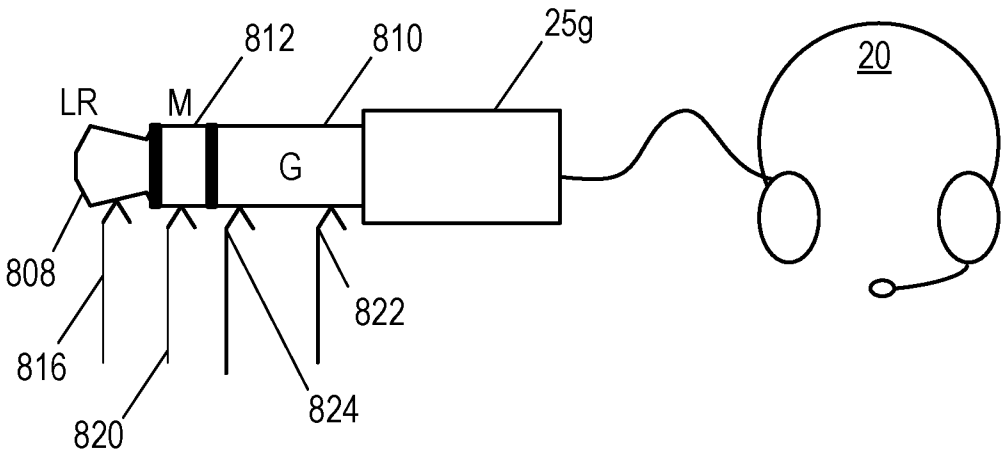

Figure 8b

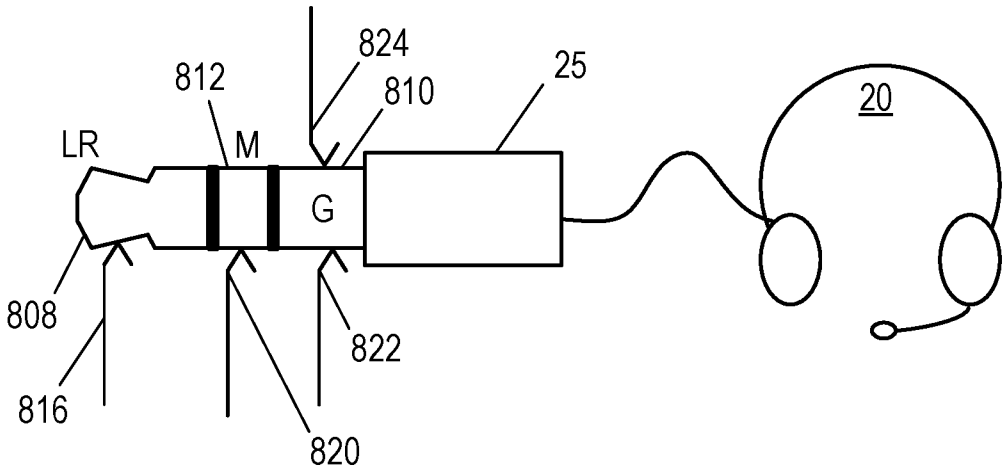

Figure 8c

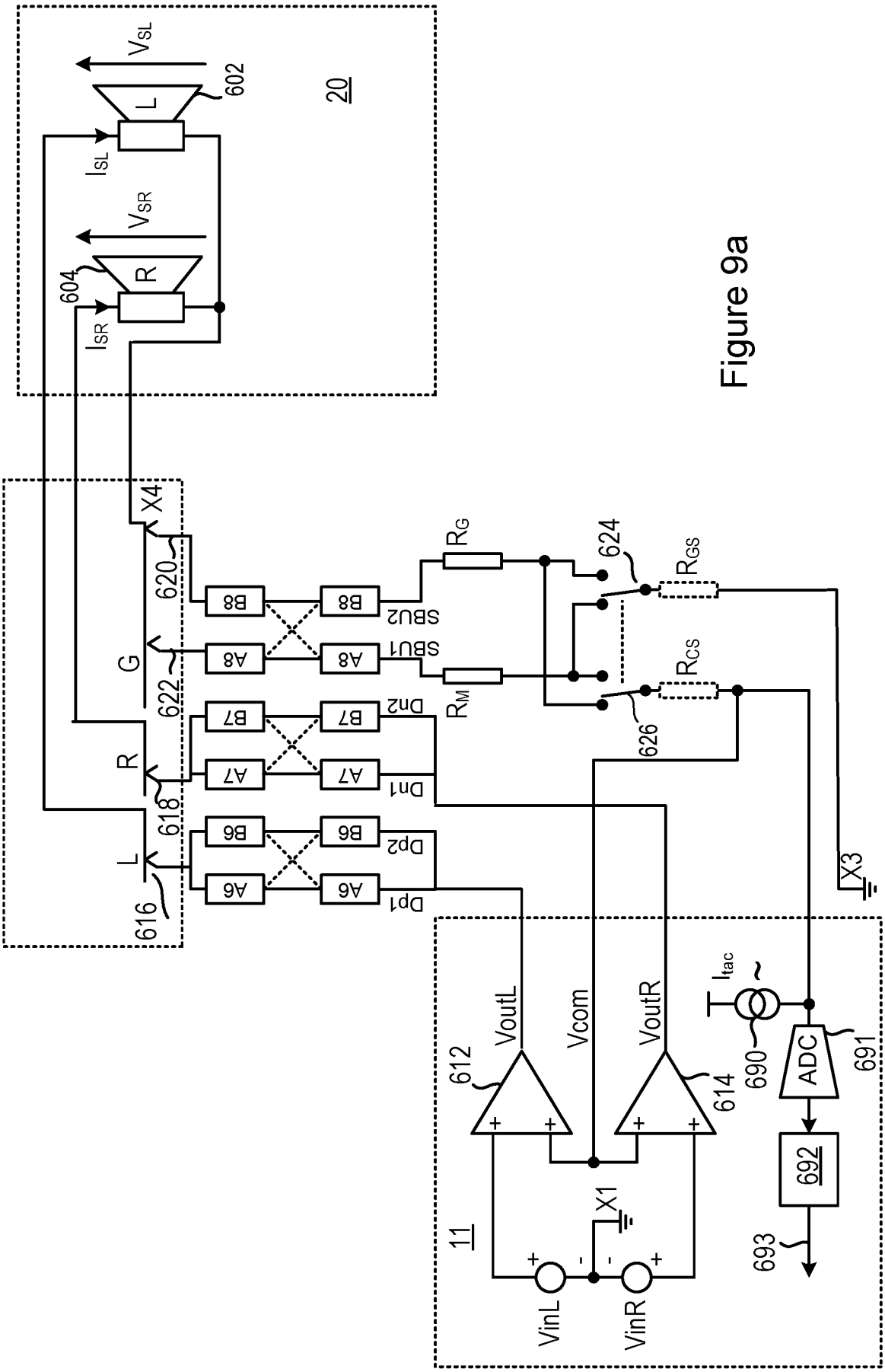
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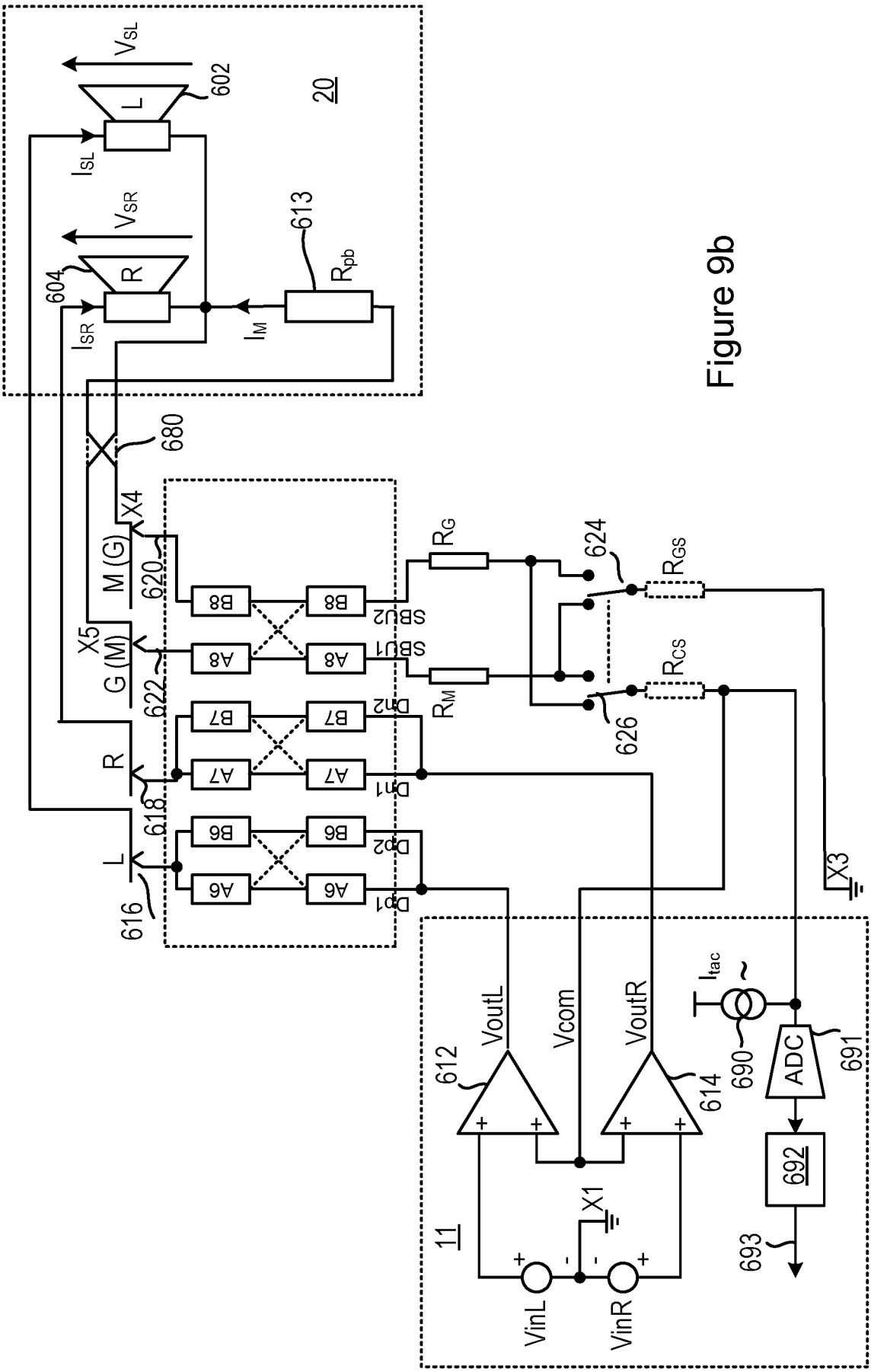
Figure 9a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VoutR
ADC

Figure 9b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2015/080823

A. CLASSIFICATION OF SUBJECT MATTER

H04R 3/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04R; H04S; H01R; H04M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC, CNKI, CNPAT, IEEE, GOOGLE: connect+, gound, plug, audio+, tip, sleeve, stereo, ring, trrs, crosstalk, socket, headphone, headset, 3.5, amplifier, speaker, contact, earphone, compare

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 104519444 A (NUVOTON TECHNOLOGY CORP.) 15 April 2015 (2015-04-15) description, paragraphs 80-85 and figure 3	1-29
A	CN 103686531 A (SAMSUNG ELECTRONICS CO., LTD.) 26 March 2014 (2014-03-26) the whole document	1-29
A	JP 2009278564 A (ONKYO K.K.) 26 November 2009 (2009-11-26) the whole document	1-29
A	CN 103096216 A (QINGDAO GE'ER ACOUSTICS TECHNOLOGY CO.) 08 May 2013 (2013-05-08) the whole document	1-29
A	GB 2513629 A (INCUS LABORATORIES LIMITED) 05 November 2014 (2014-11-05) the whole document	1-29

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
01 February 2016	**24 February 2016**

Name and mailing address of the ISA/CN	Authorized officer
STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China**	**WANG,Xiaoxi**
Facsimile No. **(86-10)62019451**	Telephone No. **(86-10)010-61648134**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2015/080823

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	104519444	A	15 April 2015	US	2015098579	A1	09 April 2015
				KR	20150040738	A	15 April 2015
CN	103686531	A	26 March 2014	WO	2014035109	A1	06 March 2014
				KR	20140030425	A	12 March 2014
				EP	2704450	A1	05 March 2014
				AU	2013221915	A1	20 March 2014
				JP	2014050108	A	17 March 2014
				US	2014064512	A1	06 March 2014
				CA	2825434	A1	28 February 2014
				TW	201414114	A	01 April 2014
JP	2009278564	A	26 November 2009	None			
CN	103096216	A	08 May 2013	None			
GB	2513629	A	05 November 2014	None			