

IMPROVEMENTS IN OR RELATING TO AMPLIFIER CIRCUITS FOR
HIGH IMPEDANCE SIGNAL SOURCE

5 This invention relates to amplifier circuits for operation
with high impedance signal sources.

Electret microphones have for some time been available which
use plastic dielectric materials that permanently retain an
electrostatic charge and which exhibit sufficiently low output
impedance to operate with discrete component transistor amplifiers.

10 Miniaturisation of the electret microphone and amplifier
package by replacing the discrete component transistor amplifier
with an LSI amplifier has not heretofore been possible because as
the electret microphone is made smaller its capacitance is decreased
and, therefore, small electret microphones exhibit an impedance
15 which is too great to drive a conventional amplifier. For example,
to achieve a low-frequency cut off of 100 hertz, a microphone with a
capacitance of at least two hundred picofarads must be used but
small electret microphones may exhibit a capacitance of only one to
ten picofarads. In order to provide equivalent low frequency
20 rolloff from the electret microphone, the input resistance of an
appropriate amplifier must vary inversely with the microphone
capacitance.

According to this invention an amplifier circuit for operation
with a signal source of predetermined high impedance includes an
25 amplifier, an input coupling circuit for coupling the source to the
amplifier and providing a high-to-low

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impedance conversion between the source and the amplifier, and a like coupling circuit for providing to the amplifier substantially solely a signal equal to an unwanted signal provided to the amplifier by the input coupling circuit, whereby the amplifier output is substantially solely an amplified version of the signal from the source.

Each coupling circuit may provide two stages of impedance transformation and may include a bipolar transistor arranged in an emitter-follower configuration following a unipolar transistor arranged as a source follower. Where the input coupling circuit serves to connect a capacitive signal source, such as an electret microphone, to the amplifier, the other coupling circuit may be a duplicate of the input coupling circuit whilst including a fixed capacitor which approximates the capacitance of the signal source and which, in appropriate cases, is small enough to be integrated with other elements of the amplifying and coupling circuits. The duplicate coupling circuit provides a DC reference voltage that closely matches that of the input coupling stage so that the difference in outputs between the input stage and the duplicate coupling circuit is essentially the AC voltage of the signal source.

The amplifier circuit may include a precision current repeater circuit capable of operation at very low voltages having first and second unipolar transistors which provide a precisely controlled current transfer ratio that is insensitive to variation in bipolar transistor gain. Where the coupling circuits include unipolar transistors such a repeater serves to drive the unipolar transistors.

The invention will now be described by way of example with reference to the accompanying drawings in which like references denote like parts, and in which:

- FIG. 1 is a block diagram of an embodiment of the invention;
- FIG. 2 is a simplified schematic drawing of an

embodiment of the invention;

FIG. 3 is a detailed schematic drawing which particularly shows the input biasing circuit of the coupling circuits;

5 FIG. 4 shows the small signal resistance provided by elements of the input biasing circuit of FIG. 3 as a function of instantaneous signal voltage level provided by a microphone of the capacitance type; and

10 FIG. 5 is a detailed schematic drawing of an integrated circuit amplifier embodying the invention.

Referring now to FIG. 1, a block diagram of an integrated circuit amplifier for a high impedance microphone 100 of the capacitance type is shown. The expression high impedance microphone of the capacitance
15 type is intended to refer to what are generally known in the art as electret microphones and capacitance microphones, the latter differing from the former in that its dielectric is not permanently charged. The present integrated circuit amplifier comprises a coupling means
20 comprising duplicate coupling circuits 101a and 101b for coupling to a high impedance such as microphone 100 of the capacitance type. Microphone 100 is most likely a miniature electret microphone housed in the same package as the amplifier. The amplifier also comprises a gain
25 providing amplifier circuit 102 connected to the outputs of the coupling circuit. A reference source 103 of direct current voltage biases diode circuits of the duplicate coupling circuits 101a and 101b and provides a reference DC voltage to the gain providing amplifier circuit 102.

30 Input coupling circuit 101a primarily serves an impedance conversion function. More particularly described in the discussion of FIG. 2, the coupling circuit 101a is capable of proximately simulating a resistor of the order of hundreds of megohms. Because the impedance of a
35 capacitive microphone 100 varies with frequency, it is well known in the art that a coupling circuit for optimum performance should provide an impedance greater
38 than the largest impedance provided by the capacitive

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microphone in the frequency band of interest.

With existent materials, there is a practical lower limit on the gap that can be constructed between charged elements of an electret. Thus, it is well known in the manufacture of electret microphones that as the area of the electret cell decreases, so does the capacitance presented. Accordingly, an electret significantly smaller than electrets presently available must exhibit a much smaller capacitance. Consequently, the optimal input impedance for an amplifier matching such an electret will be much greater. The present coupling circuit 101a provides an input resistance of the order of hundreds of megohms and an output resistance of the order of one to ten kilohms while providing a nearly unity signal voltage gain.

Coupling circuit 101a is entirely duplicated by coupling circuit 101b. In order to perfectly balance the electret cell 100, coupling circuit 101b comprises a capacitance value equivalent to the equivalent capacitance C_{eq} of the electret cell and the stray capacitance C_s of the connection. The perfectly balanced circuit alleviates power supply noise and other noise.

The coupling circuits 101a and 101b are connected to the gain providing amplifier circuit 102. In combination with the coupling circuits, amplifier 102 provides an overall gain to the output of capacitive microphone 100, while reducing the source impedance to a considerably lesser value.

Referring now to FIG. 2, a simplified schematic drawing of coupling circuits 101a and 101b of FIG. 1 is shown. Power supply and element polarities may be reversed in this and subsequent figures, i.e. NPN for PNP transistors, N-channel field effect transistors are shown; MOS field effect transistors may be likewise employed.

Coupling circuit 101a comprises input terminals IN1 and IN2 for connecting to capacitive microphone 100. At terminals IN1 and IN2, an extremely high input resistance is presented to the capacitive microphone

circuit 100. In particular, a low value constant current source 221 is shown which comprises one element of an input biasing circuit more particularly described in the discussion of FIG. 3. The current source 221 is provided for driving diodes Q1 and Q2, symmetrically placed about input terminal IN1. Reference voltage source 103 (FIG. 1) provides a DC reference voltage V_r at node 206 for biasing diodes Q1 and Q2. The arrangement of the diodes Q1 and Q2, the current source 221, and the reference voltage at node 206 proximately simulate a resistor having a value of the order of hundreds of megohms.

Input terminal IN1 is also connected to the gate of a unipolar transistor J1. The unipolar transistor J1 is driven by a current source 201. Transistor J1 provides a first stage of impedance reduction and has its source connected to the base of a bipolar transistor Q4. The bipolar transistor Q4 is connected as an emitter follower for providing a second stage of impedance reduction, if required. It is biased by current source 204. Between transistor Q4 and current source 204 is node 208 which connects the coupling circuit to gain providing amplifier circuit 102.

The quiescent voltage at node 208 is controlled by direct current reference voltage source 103 (FIG. 1). The reference voltage V_r at node 206 is raised to a higher voltage by the anode to cathode drop over diode Q2. That higher voltage likewise appears at node 212 and is dropped in value by the emitter to base voltage of transistor Q4. As a result, the quiescent DC voltage V_i at node 208 directly tracks the reference voltage provided at node 206 by source 103.

As a result of the extremely high impedance at terminal IN1, the electrical signal output of microphone 100 is highly susceptible to noise and, in particular, to power supply noise at 213. To alleviate the noise and to reject its effects, duplicate coupling circuit 101b is provided. In particular, in order to duplicate the microphone 100, a capacitor C2 connects to

symmetrical diodes Q17 and Q18 in a similar manner as microphone 100 is connected to diodes Q1 and Q2. The value of capacitor C2 should be chosen so as to simulate the equivalent capacitance C_{eq} and stray capacitance C_s of microphone 100. In effect, the duplicated combination of diodes Q17 and Q18, unipolar transistor J3 and bipolar transistor Q14 perfectly balance the impedance conversion circuit comprising diodes Q1 and Q2, unipolar transistor J1, and bipolar transistor Q4.

Reference voltage source circuit 103 (FIG. 1) provides reference voltage V_r at node 206 of coupling circuit 101b, the same node as is shown in coupling circuit 101a (FIG. 2). As a result of voltage V_r appearing at node 206, node 209 of duplicate coupling circuit 101b provides an approximately identical DC bias voltage V_2 to gain providing amplifier circuit 102 as does node 208 of coupling circuit 101a. The voltage difference between nodes 208 and 209 is essentially the output AC signal voltage of the microphone 100. Thus noise entering at node 213, or DC voltage drifts appearing in both coupling circuit 101a or 101b, appear equally on nodes 208 and 209 as common mode input signals to amplifier 102. Such signals are thus not amplified by the operation of gain providing circuit 102.

Gain providing circuit 102 in simplified form comprises a Complementary Bipolar Integrated Circuit (CBIC) operational amplifier 210. It is connected to node 208 by resistor R22 and to node 209 by resistor R23. The ratio of resistor R24 to resistor R23 controls the closed loop gain of the gain providing amplifier circuit 102. The amplified output signal of microphone 100 is provided at terminal OT1 with reference to ground terminal OT2. While a CBIC operational amplifier is suggested, other integrated circuit amplifiers known in the art may be substituted therefor, provided any necessary design changes are made to coupling circuit 101a and 101b.

Referring to FIG. 3, an input biasing circuit for coupling circuits 101a and 101b comprises a constant

current source 302 and a diode circuit 301. Current source 302 and diode circuit 301 in combination are represented in FIG. 2 by current source 221 and 222.

The diode circuit 301 comprises series-connected

- 5 diodes Q20 and Q21 whose emitter junction areas are a multiple M_x of the emitter junction areas of diodes Q1, Q2, Q17, or Q18.

- The current source 302 comprises first and second bipolar transistors Q23 and Q19, the emitter junction area of transistor Q23 being a multiple of that of transistor Q19. The collector of transistor Q19 drives the aforementioned diodes. Transistor Q23 is connected to resistances R10 and R11, which are in turn connected to unipolar transistor J7. The source and gate of transistor J7 are connected forming a two terminal current source. Resistor R10, the emitter area ratio of transistors Q23 and Q19, and the nominal drain saturation current I_{dss} of transistor J7 provide a highly controlled collector current in transistor Q19, whose value is constant and insensitive to small variations in the current through transistor J7.

- The present input biasing circuit provides protection from microphone overload. Diodes Q20 and Q21, like diodes Q1 and Q2, are connected between the reference voltage V_r at node 206 and constant current source 302, which forward biases all diodes.

The current I in an integrated circuit diode is given by

$$I = J_0 A_j \left(e^{\frac{qV}{kT}} - 1 \right).$$

- where J_0 is a process dependent constant; A_j is the junction area; q is the electronic charge; V is the diode voltage; k is Boltzman's constant; and T is absolute temperature. (Note that $\frac{kT}{q}$ at room temperature is approximately 25 millivolts.) Then the small-signal

resistance of the diode under forward bias is given by

$$R = \frac{dV}{dI} = \frac{kT}{qI}$$

5 Thus, diodes fabricated with the same process, with the same applied voltage, and having different junction areas exhibit small-signal resistances which vary inversely with their junction areas.

10 If the FET gate currents are negligible, Q20 has an emitter junction area fifty times that of similarly fabricated diode Q1, and diodes Q21 and Q2 are similarly fabricated and area-ratioed, it follows that Q1 and Q2 will each exhibit a small-signal resistance fifty times that of Q20 and Q21.

15 One particular purpose of diodes Q1 and Q2 is to minimise the input capacitance presented to microphone 100 at terminal IN1. However, the symmetrical placement of first and second diodes Q1 and Q2 about input IN1, together with biasing diodes Q20 and Q21 provides a further
20 advantage. Such a symmetrical diode arrangement provides progressive signal compression and limiting to voltage swings from the microphone of either polarity which are in excess of normal signal levels. This might occur, for example, when one taps the microphone, blows into it, or
25 otherwise overloads it.

 Using the above equations for current flow in a diode, it is possible to calculate the small-signal input resistance between input IN1 and ground as a function of the instantaneous AC signal input voltage from
30 microphone 100. A plot of this relationship is shown in FIG. 4. For small AC signal voltages ($< \pm kT/q$), the small-signal input resistance is relatively constant. However, if the instantaneous signal voltage becomes large ($> \pm 2 kT/q$), the small-signal resistance decreases
35 exponentially with instantaneous signal voltage magnitude. Thus any unwanted charge on the input node IN1 (FIGS. 1, 2 and 3) due to large-amplitude transient signals from
38 microphone 100 is quickly dispersed, rapidly restoring

quiescent bias conditions. Thus this circuit provides a large input resistance (and hence good low-frequency response) for small signals, while providing a small input resistance, progressive signal limiting, and fast overload recovery for large signals.

Referring now to FIG. 5, a detailed schematic drawing of an embodiment of an integrated circuit amplifier for a high impedance microphone of the capacitance type includes a plurality of current repeaters 901, 902, and 903 which are employed throughout for driving various elements of the circuit. Transistors Q3, Q7, Q12 and Q24 provide additional current taps from circuits 901, 902 and 903. Also, the previously described gain providing amplifier circuit 102 is shown in detail and comprises transistors Q7, Q8, Q9, Q10, Q11, Q12, Q13, resistors R7, R8, R22, R23, R24 and capacitor C1.

Reference voltage circuit 103 comprises bipolar transistor Q32 and voltage dividing resistors R12, R13 and R21. Transistor Q22 of current source 902, with its collector-base junction reverse-biased, provides a constant collector current which flows through resistor R21 and provides a reference voltage at node 206 that is independent of supply voltages at node 213. At low supply voltages, however, transistor Q22 saturates, and transistor Q32, along with resistors R12, R13, and R21, provides a DC reference voltage that is sufficiently below the supply voltage V_s to maintain bias current flow in diodes Q1 and Q2 (preventing the saturation of transistor Q19). Thus reference voltage circuit 103 will function at a lower supply voltage V_s at node 213 than is possible with a fixed reference bias.

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1. An amplifier circuit for operation with a signal source of predetermined high impedance, the circuit including an amplifier, an input coupling circuit for coupling the source to the amplifier and providing a high-to-low impedance conversion between the source and the amplifier, and a like coupling circuit for providing to the amplifier substantially solely a signal equal to an unwanted signal provided to the amplifier by the input coupling circuit, whereby the amplifier output is substantially solely an amplified version of the signal from the source.

2. A circuit as claimed in claim 1 including an input bias circuit, and a circuit for providing a reference source of direct current voltage.

3. A circuit as claimed in claim 1 including an input bias circuit for limiting the signal from the source.

4. A circuit as claimed in claim 3 wherein the input coupling circuit includes one or more diodes, and the input bias circuit includes at least one diode connected in parallel with, and having a junction area much greater than the junction area of, the one or more diodes of the coupling circuit.

5. An amplifier circuit substantially as herein described with reference to Fig. 1, 2, 3 or 5 of the accompanying drawings.

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