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(54) **HIGH FIDELITY CURRENT DUMPING AUDIO AMPLIFIER WITH COMBINED FEEDBACK-CLEAN FEEDBACK**

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(57) **ABSTRACT**

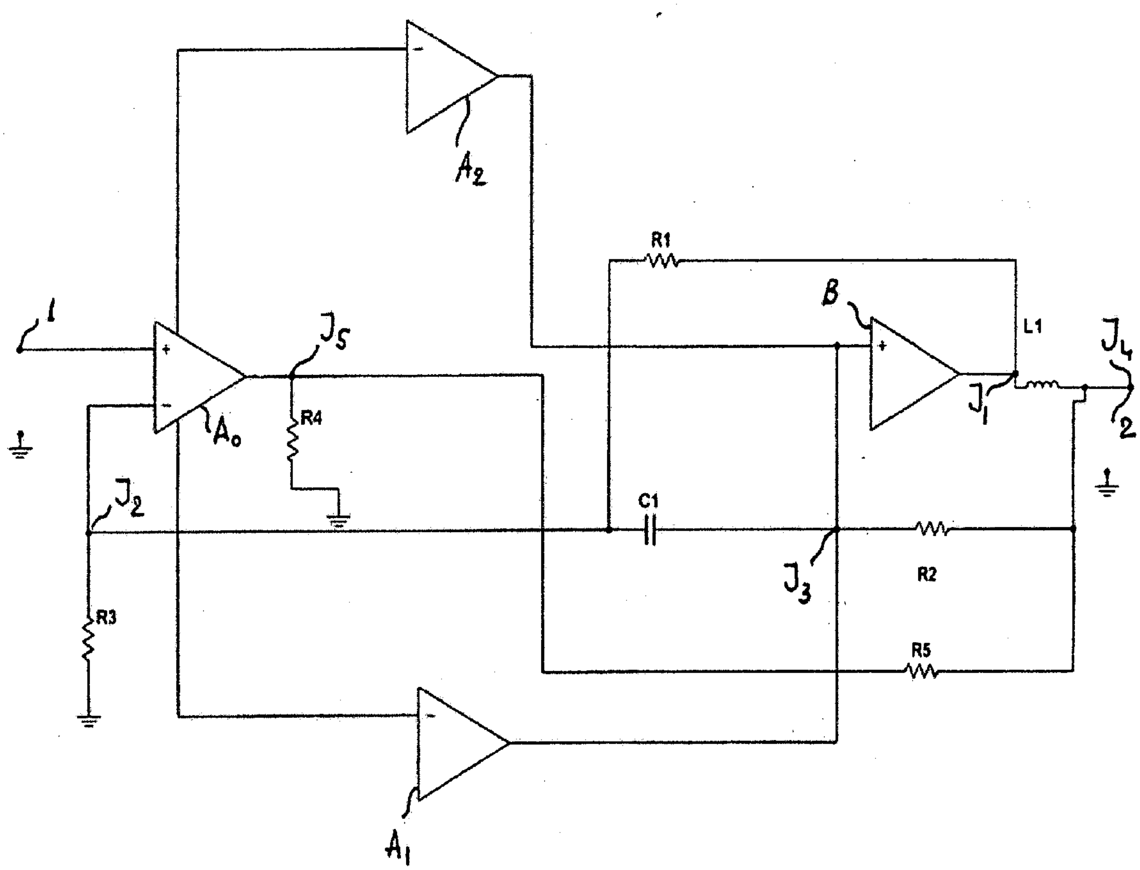
A high fidelity current dumping audio amplifier in which for achieving the best performance are combined the feedforward error correction and the negative feedback.

The principle of feedforward error correction in a balanced bridge in A.C. is used, including the whole audio frequency amplifier, combined with a classical negative feedback that includes the items of the amplification chain likely to introduce distortions.

The amplifier can be built in a symmetrical or in a asymmetrical structure.

The symmetrical structure of the amplifier contains an operational amplifier used as a voltage-current converter and signal de-phasing, two low power symmetrical amplifiers in “A” class with a current mirror structure with local feedback and a power stage in “B” class, with no quiescent current.

The asymmetrical structure of the amplifier contains an operational amplifier, a low power amplifier in “A” class, and a power stage in “B” class.



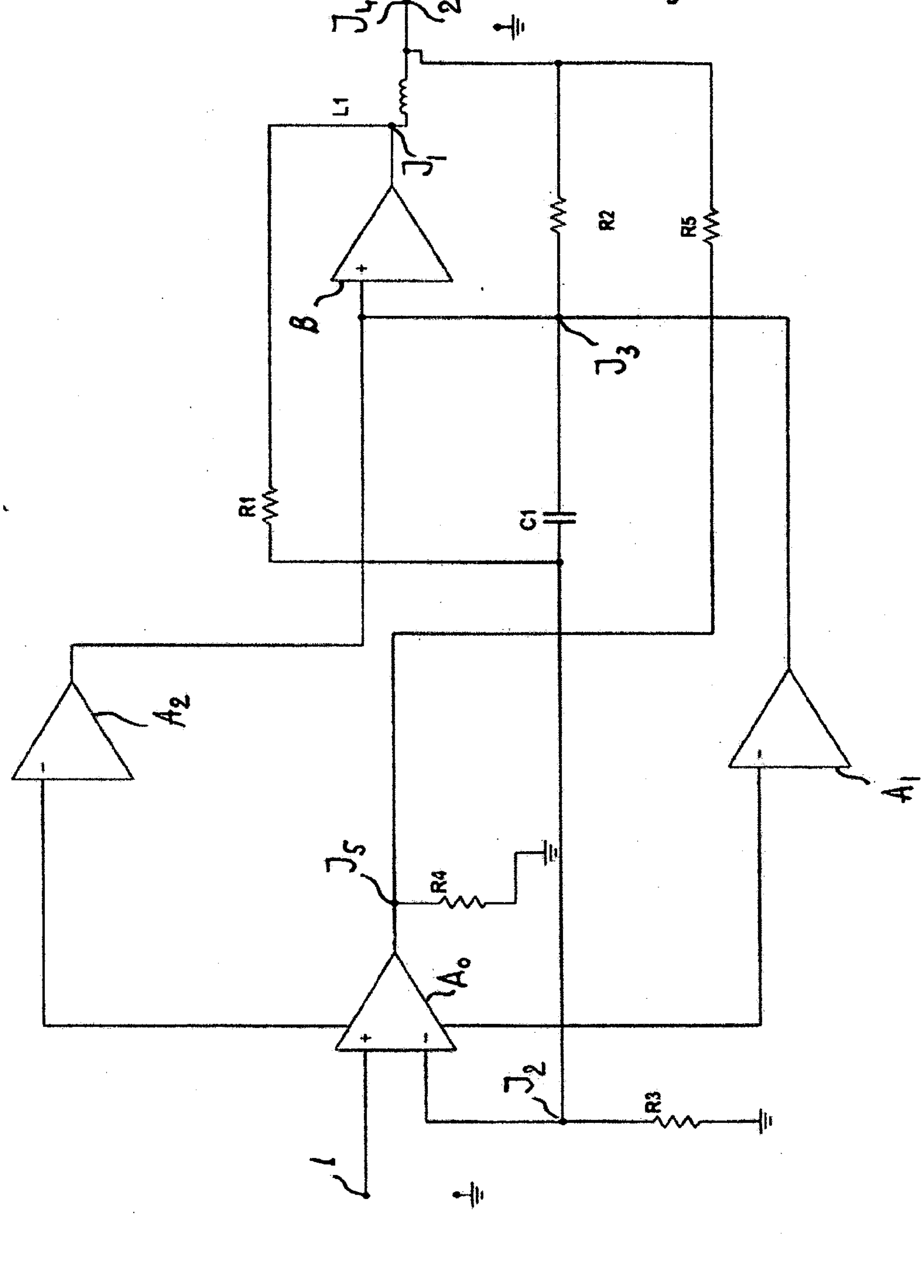


Fig. 1

Fig. 2

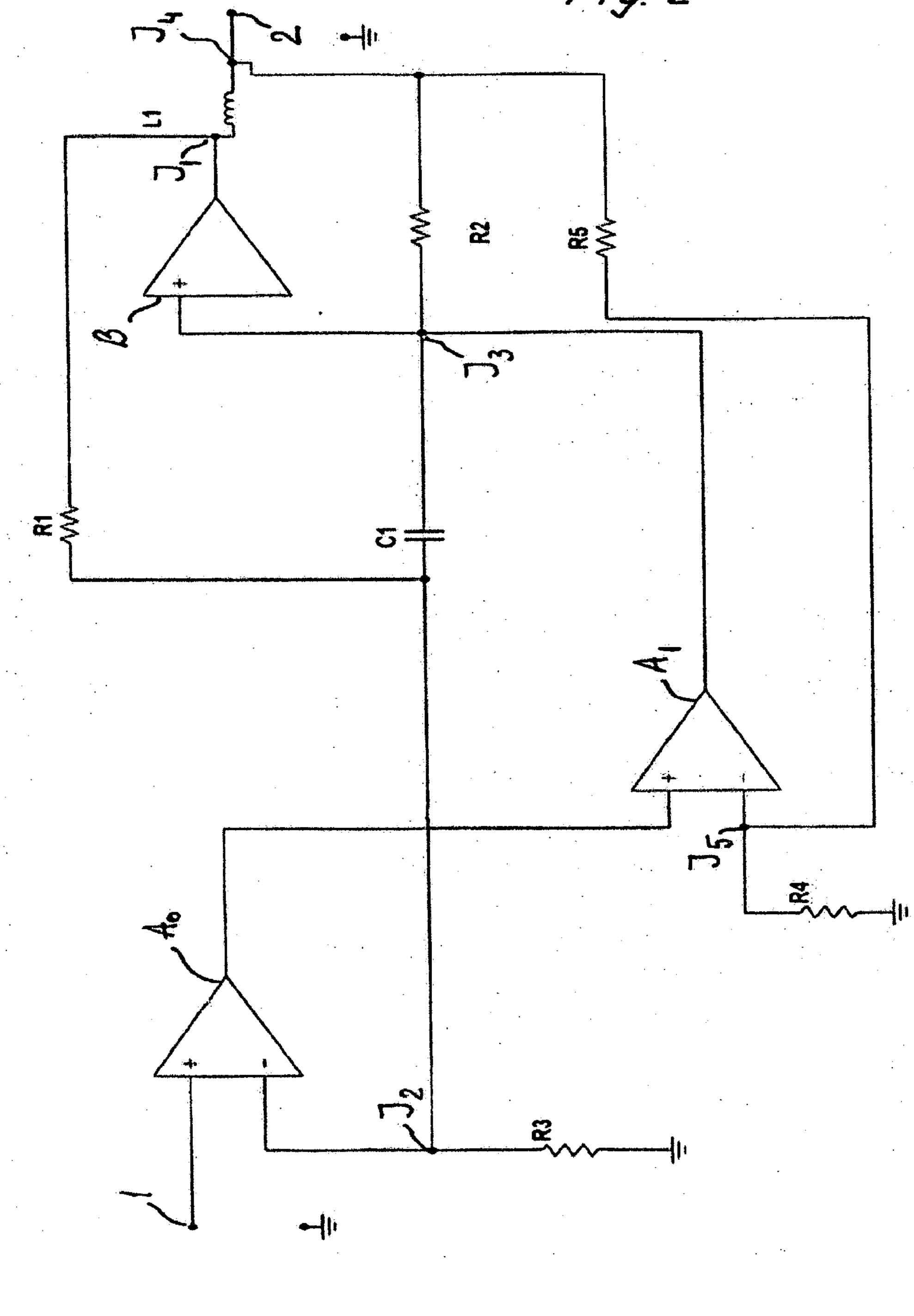
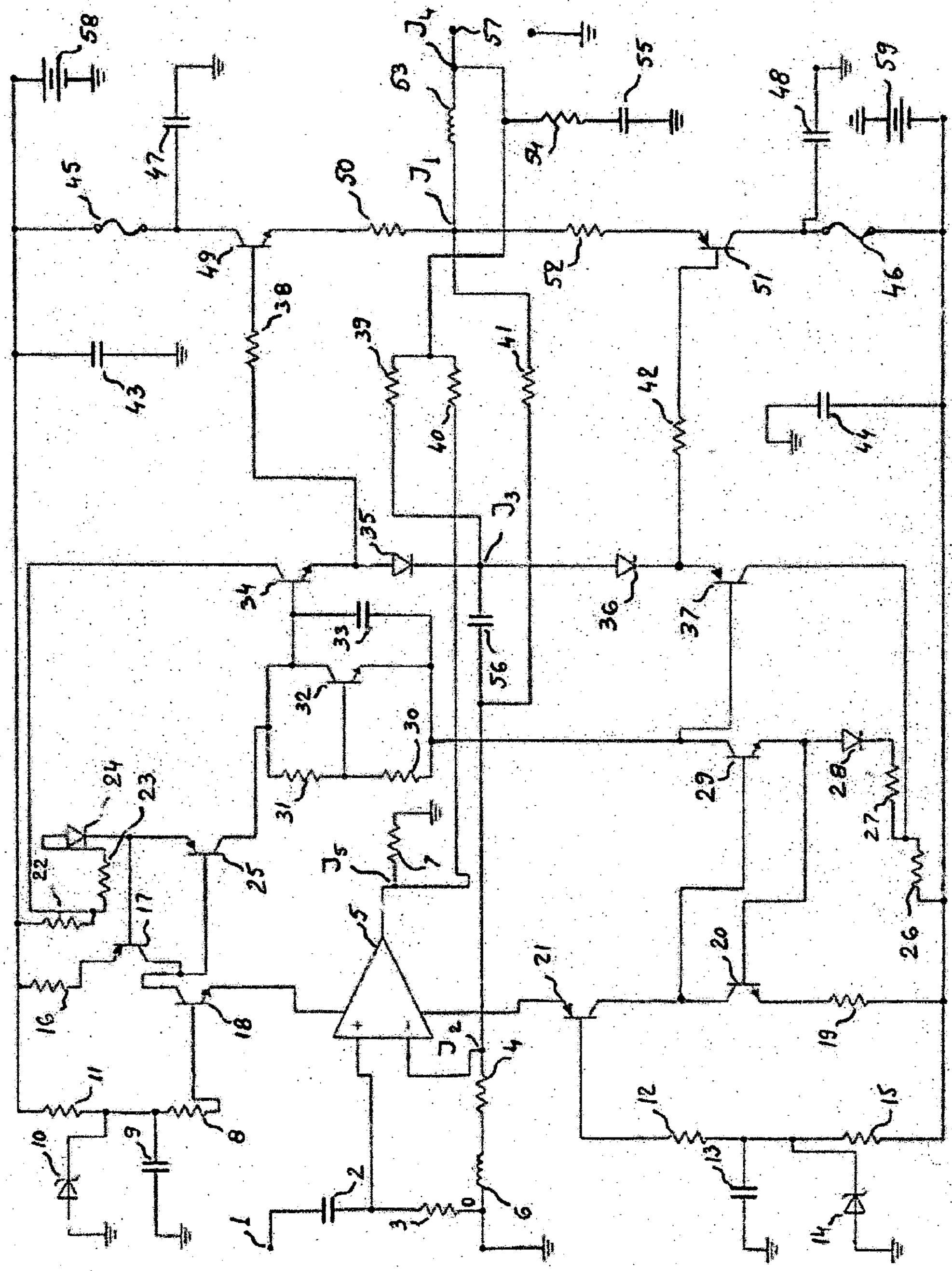


Fig. 3



HIGH FIDELITY CURRENT DUMPING AUDIO AMPLIFIER WITH COMBINED FEEDBACK-CLEAN FEEDBACK

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U.S. Patent Documents

[0001] H. S. Black, U.S. Pat. No. 1,686,792

[0002] H. S. Black, U.S. Pat. No. 2,102,671

OTHER PUBLICATIONS

[0003] P. J. Walker, "Current Dumping Audio Amplifier," Wireless World, vol. 81, pp. 560-562, (1975 Dec.)

BACKGROUND OF THE INVENTION

[0004] 1. Field of the Invention

[0005] The invention relates to a high fidelity audio amplifier witch uses a new structure of combinated feedback composed by feedforward error correction and a negative feedback loop.

[0006] The invention develops a new structure of the feedback loops that can be used in an audio amplifier in order to improve performances using the advantages offered by feedforward error correction and negative feedback, both patented by H. S. Black, U.S. Pat. No. 2,102,671 and U.S. Pat. No. 1,686,792.

[0007] 2. Description of the Prior Art

[0008] There have made advances in the past years in the design of high fidelity audio frequency amplifiers but almost with new improvement new flaws are discovered.

[0009] The negative feedback largely used in audio frequency amplifiers, next to the indisputable advantages it offers (reduces distortions, increases the bandwidth, controls the amplifier response, etc.) has some disadvantages too (can-not minimize the distortions, can generate instability, decreases the overall gain, etc.

[0010] The feedforward error correction mainly allows cancelation of errors, i.e. distortion introduced by the amplifier in terms of stability and doesn't present a feedback loop that might leads to instability.

[0011] The invention try to solve another problems of a conventional amplifier i.e. poor linearity of the output power stage characteristics, poor thermal stability of the conventional output class AB stages, by using a class B output stage, without quiescent current, controlled by the combined feedback, the clean feedback.

[0012] Using combined feedback, the voltage distortion of the amplifier can be effectively improved by the negative feedback loop in the high frequency regions.

[0013] The object of this invention is to provide a new structure of the feedback loops witch allow to obtain a simple, but high performance audio amplifier in terms of stability, low harmonic and intermodulation distortion, excellent dynamic performance and above all outstanding sonic performance.

BRIEF SUMMARY OF THE INVENTION

[0014] The present invention has been developed with a view to solve the disadvantages of the conventional amplifiers and to provide an improved amplifier circuit in which the problems caused by nonlinearity of the output power stages are solved, the voltage distortion rate in the high frequency regions of the audio spectrum is improved, which reduces the group delay in time domain, and the thermal stability of the output stage is improved using a class B stage.

[0015] The presented invention relates to an audio amplifier that uses a feedforward error correction based on the principle of the balanced bridge in order to minimize distortion of the output stage, followed by application of classical negative feedback loop in order to obtain a very low level of harmonic and intermodulation distortion.

[0016] In conventional audio amplifiers the output signal taken from the output in the negative feedback loop is distorted; in the amplifier circuit of the present invention the output feedback signal in the negative feedback loop have a very low level of distortion because it was previously cleaned up by the feedforward error correction loop, and the feedback is a clean feedback.

[0017] The effect of combined feedback increases at high frequencies and permit to reduce the level of high order harmonics and intermodulation products generated by the output stage.

[0018] In order to improve performances both loops, feedforward error correction and negative feedback are current feedback loops.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. **1** is a circuit block diagram of a symmetrical current dumping audio amplifier using combined feedback.

[0020] FIG. **2** is a circuit block diagram of a asymmetrical current dumping audio amplifier using combined feedback.

[0021] FIG. **3** is an electrical schematic diagram of a symmetrical current dumping audio amplifier using combined feedback.

DETAILED DESCRIPTION OF THE INVENTION

[0022] The presented invention "HIGH FIDELITY CURRENT DUMPING AUDIO AMPLIFIER WITH COMBINED FEEDBACK-CLEAN FEEDBACK" relates to a high-fidelity audio frequency amplifier that uses the feedforward error correction and the negative feedback in order to improve performance. The negative feedback largely used in audio frequency amplifiers next to the indisputable advantages it offers, (reduces distortions, increases the bandwidth, controls the amplifier's response, etc.) has some disadvantages too (can not minimize the distortions, can generate instability, decreases the overall gain, etc.)

[0023] The feedforward error correction mainly allows cancelation of errors, i.e. distortion introduced by the amplifier in terms of stability and doesn't present a feedback loop that might lead to instability.

[0024] The feedforward error correction was used in the Quad 405-909 audio amplifiers, using the principle of balanced bridge in A.C.

[0025] The presented invention relates to an audio frequency amplifier that uses a feedforward error correction based on the principle of balanced bridge in A.C. in order to minimize distortions, followed by application of classical negative feedback loop, in this case the output feedback signal is "clean", obtaining a very low level of harmonic and intermodulation distortion.

[0026] The block diagram of a symmetrical current dumping audio frequency amplifier using combined feedback, clean feedback, is presented in FIG. **1** where:

[0027] **A0**=low level operational amplifier.

[0028] **A1**, **A2**=inverting low power amplifiers in "A" class.

[0029] B=current amplifier, with unity voltage gain, without quiescent current, in "B" class.

[0030] The audio frequency signal applied to A**0** at the input terminal **1** is amplified by this; due to the R**4** low value load resistance, in the power supply circuit of A**0** will appear variations of the supply current used to control amplifiers A**1** and A**2**, appropriate to the two half signal alternation.

[0031] At low level, the output signal is ensured by the low power amplifiers in "A" class, A**1** and A**2**; when the level increases, the voltage drop across the R**2** resistor increases, the current amplifier B begins to dump current to the output load terminal **2** thru the L**1** coil.

[0032] Reducing crossover distortions that occur when passing from "A" class to "B" class is ensured by including the amplifier in a balanced bridge in A.C., with the equilibrium condition: L**1**=R**1**C**1**R**2**, connected at the junction points J**1**,J**2**,J**3**,J**4**.

[0033] Part of the audio signal taken after the L**1** coil at junction point J**4**, "cleaned" by distortions, is applied through the divisor made out of R**4** and R**5** resistors to the amplifier A**0**, at the junction point J**5**; negative feedback loop includes the output stage of the A**0** amplifier, the A**1**,A**2**, amplifiers and the current amplifier B.

[0034] Due to the fact that the audio signal applied in the negative feedback loop is previously "cleaned" of distortions by the feedforward error correction, a low level of harmonic and intermodulation distortion is obtained.

[0035] In FIG. **2** is presented the block diagram of an asymmetric current dumping audio frequency amplifier with combined feedback, clean feedback.

[0036] In the block diagram in FIG. **2**:

[0037] A**0**=low level operational amplifier.

[0038] A**1**=low power amplifier in "A" class.

[0039] B=current amplifier, with unity voltage gain, without quiescent current, in "B" class.

[0040] Low level amplifier A**0** amplifies the audio frequency signal applied to the input terminal **1**, which is then amplified by the low power amplifier in "A" class, A**1**.

[0041] At low level, the output current is supplied by the low-power amplifier in "A" class, A**1**.

[0042] When the level increases, the voltage drop across the R**2** resistance increases, the output current amplifier B begins to dump current to the output terminal **2** thru the L**1** coil.

[0043] Reducing crossover distortions from "A" class to "B" class is ensured by including the current amplifier B in a balanced bridge in A.C., L**1**,C**1**,R**1**,R**2**, with equilibrium condition: L**1**=R**1**R**2**C**1**, connected at the junction points J**1**,J**2**, J**3**,J**4**.

[0044] Part of the output audio signal, taken at the junction point J**4**, "cleaned" by distortions, is applied with the resistive divisor R**5**/R**4** to the inverting port of the A**1** amplifier, at the junction point J**5**, further reducing distortions, using a negative feedback loop.

[0045] In FIG. **3** is an electrical schematic diagram of a symmetrical current dumping audio frequency amplifier with combined feedback, using the circuit block diagram from FIG. **1**.

[0046] The audio signal taken from the input terminal **1** is applied by capacitor **2** on the input of the operational amplifier **5** and it is amplified by it. Due to the low value of the load resistance **7**, in the supply circuit of the operational amplifier **5**, achieved with diode **10**, capacitor **9**, resistor **11**, resistor **8**, transistor **18** for the positive supply port and diode **14**, capacitor **13**, resistor **15**, resistor **12**, transistor **21** for the negative supply port will appear current variations, with opposite phase, appropriate for the two half alternating of the audio signal, operational amplifier **5** acting as a voltage-current converter.

[0047] The load for the level shifter stages achieved with transistors **8** and **21** are Wilson current mirrors achieved with transistor **17**, resistors **16**, **22** and **23**, diode **24**, transistor **25** and transistor **20**, resistors **19**, **26** and **27**, diode **28**, transistor **29**. The audio frequency signal is current amplified in "A" class stage, achieved with transistor **34** for a half alternation and with transistor **37** for the other half alternation of the signal.

[0048] In order to improve performance, the current mirrors are provided with a local feedback loop, achieved by connecting the transistor **34** collector, respectively **37** in the emitter circuit of transistors **25** and **29**, through resistive divisor formed of resistors **22**, **23**, and **26**, **27**.

[0049] These values are chosen so that in idle the operating conditions of the current mirror do not change.

[0050] Transistor **32**, resistor **31**, resistor **30**, capacitor **33** form on one hand a super diode circuit, with important role in establishing a correct mode of operation for the current mirrors and for amplifier thermal stability, and on the other hand acts as a current-voltage converter.

[0051] The audio signal in the emitter of transistor **34** is applied by the diode **35** and resistor **39** to the load terminal **57** for positive half alternation, respectively in the emitter of transistor **37** by diode **36** and resistor **39** for the negative half alternation.

[0052] In the absence or low signal, final power transistors **49** and **51** do not conduct, the signal is taken from the emitter circuit of transistors **34** and **37** with resistor **39** and applied to load at the output terminal **57**.

[0053] When the signal level increases, the voltage drop on resistor **39** increases and summed with the one on diodes **35** and **36** determine the opening of power transistors **49** and **51** which at low level do not conduct.

[0054] Reducing crossover distortions which appear when passing from "A" class of signal operation at low level to "B" class at high level of signal is made using the principle of balanced bridge in A.C. formed by coil **53**, resistor **41**, resistor **39** and capacitor **56**.

[0055] The balanced bridge acts effectively on the entire amplifier, significantly reducing distortions.

[0056] If it weren't for the additional negative feedback loop made of resistors **40** and **7**, this could be the structure of an audio frequency amplifier with good performances.

[0057] By introducing this additional negative feedback loop, a fraction of the output signal, a signal "cleaned" by distortions through the balanced bridge in A.C., is applied by the divisor formed from resistance **40** and **7** to the output of the operational amplifier **5**.

[0058] In the negative feedback loop are included output transistors of the operational amplifier, the level shifter stage made with transistor **18**, the Wilson current mirrors made with transistors **17**, **25**, **34** and the output stage made with power transistor **49** for a half alternation, as well as the level shifter stage made with transistor **21**, the

[0059] Wilson current mirror made with transistors **20**, **29**, **37**, the output stage made with the power transistor **51** for the other half alternation of the audio signal, further reducing distortions.

[0060] The series circuit made of resistor **55** and capacitor **54** has the role to prevent high frequency oscillations.

[0061] Coil **6** has the role to provide roll off of response at high frequency.

[0062] Resistors **50** and **52** produce a slight local negative feedback and improve the thermal stability of the power transistors at high level.

[0063] Fuses **45** and **46** have the role to protect the power transistors.

[0064] Capacitors **43**, **47** and **44**, **48** have the role to cut the supply route and to prevent oscillations which can appear because of the supply circuit.

[0065] Power supply is made from two voltage sources, **58** and **59**, symmetrical, unregulated, properly sized.

[0066] Using the combined feedback, a symmetrical structure with the current mirrors with local feedback, allows obtaining high performances under a scheme with a relatively simple structure.

What is claimed is:

1. A symmetric current dumping audio amplifier circuit comprising:

an operational amplifier having a non-inverting input and a inverting input, a positive bias port, a negative bias port and an output connected to the ground thru a resistor.

a first low power amplifier in class "A" having an inverting input connected to the negative bias port of the said operational amplifier.

a second low power amplifier in "A" class having an inverting input connected to the positive bias port of the said operational amplifier.

a power stage in "B" class having a non-inverting input connected to the output of the said first and second low power amplifiers in "A" class and an output connected to the load thru a an impedance element.

a load connected between said output terminal and the ground.

a feedforward error correction bridge connected to the inverting input of the said operational amplifier at junction point J**2**, to the non-inverting input of the said power stage in "B" class at the junction point J**3** at the output of the said power stage in "B" class at junction point J**1** and the load in junction point J**4**.

a negative feedback circuit connected between said load at the junction point J**4** and the output terminal of the said operational amplifier at the junction point J**5**.

2. A symmetric amplifier circuit as claimed in claim **1** where the combination of the feedforward error correction bridge followed by a negative feedback loop is used to create a clean feedback loop for achieving the best performance.

3. A symmetric amplifier circuit as claimed in claim **1** which use current amplification and current feedback loops for achieving the best performance.

4. A symmetric amplifier circuit as claimed in claim **1** where the balance of the bridge is obtained in a specific frequency region.

5. A symmetrical amplifier circuit diagram as claimed in claim **1** comprising:

an operational amplifier having a non-inverting input being a signal input, an inverting input, a negative bias port, a positive bias port and an output connected to the ground thru a resistor, used as a tension-current converter.

a first low power amplifier in "A" class having an input connected to the negative bias port of the said operational amplifier comprising a level shifter loaded on a improved Wilson current mirror circuit with local feedback, and a low impedance output terminal using an emitter follower.

a second low power amplifier in "A" class having an input connected to the positive bias port of the said operational amplifier comprising a level shifter loaded on a improved Wilson current mirror circuit with local feedback, and a low impedance output terminal using an emitter follower.

a temperature compensating current control and a current to voltage converter comprising a transistor connected in a Vbe multiplier structure.

a power stage having an input connected between the low impedance output of the said first low power amplifier in "A" class and the second said second low power amplifier in class "A", and the output connected to the load thru a impedance circuit, comprising a pair of transistors of opposite polarity.

a feedforward error correction bridge circuit connected at the output terminal of the said power stage at the junction point J**1**, at the inverting input of the said operational amplifier at the junction point J**2**, at the output of the said first and second power stage and at the input of the said first and second power stage at the junction point J**3** and at the load terminal at the junction point J**4**.

a negative feedback loop connected between the load terminal of the amplifier at the junction point J**4** and at the output terminal of the said operational amplifier at the junction point J**5**, used as an input terminal for the feedback loop circuit.

6. An asymmetric current dumping audio amplifier circuit comprising:

an operational amplifier having a non inverting input and a inverting input.

a low power amplifier in "A" class having a non inverting input connected to the output of the said operational amplifier and a inverting input.

a low power class "A" amplifier having a non inverting input connected to the output of the said operational amplifier, an inverting input and an output terminal.

a power output stage in "B" class of operation having a non-inverting input and an output connected to the load thru an impedance element.

a load connected between the output terminal of the said power output stage and the ground.

a feedforward error correction bridge circuit connected at the output terminal of the said power stage at the junction point J**1**, at the inverting input of the said operational amplifier at the junction point J**2**, at the output of the said low power amplifier in class "A" at the junction point J**3**, and at the load terminal at the junction point J**4**.

a negative feedback loop connected at said load terminal at the junction point J**4** and at the inverting input terminal of the said low power amplifier in class "A", at the junction point J**5**.

7. An asymmetric amplifier circuit as in claim **6** where the combination of the feedforward error correction bridge followed by a negative feedback loop is used to create a clean feedback loop for achieving the best performance.

8. An asymmetric amplifier circuit as in claim **6** where the balance of the bridge is obtained in a specific frequency region.

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