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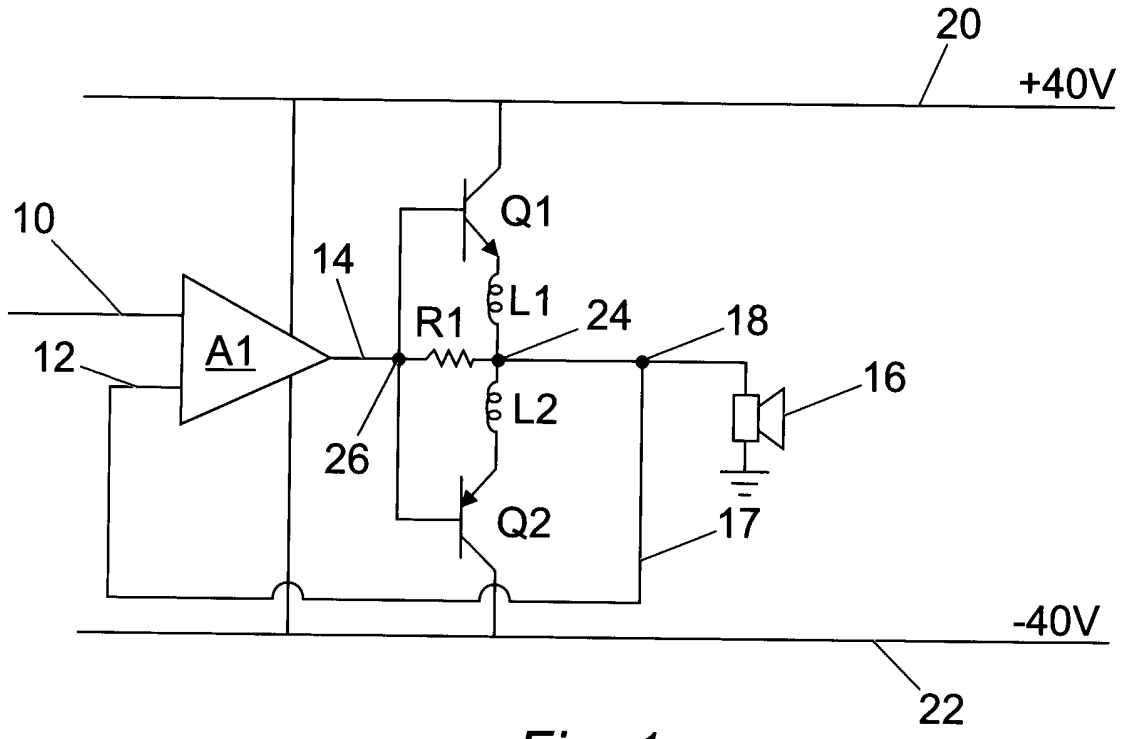
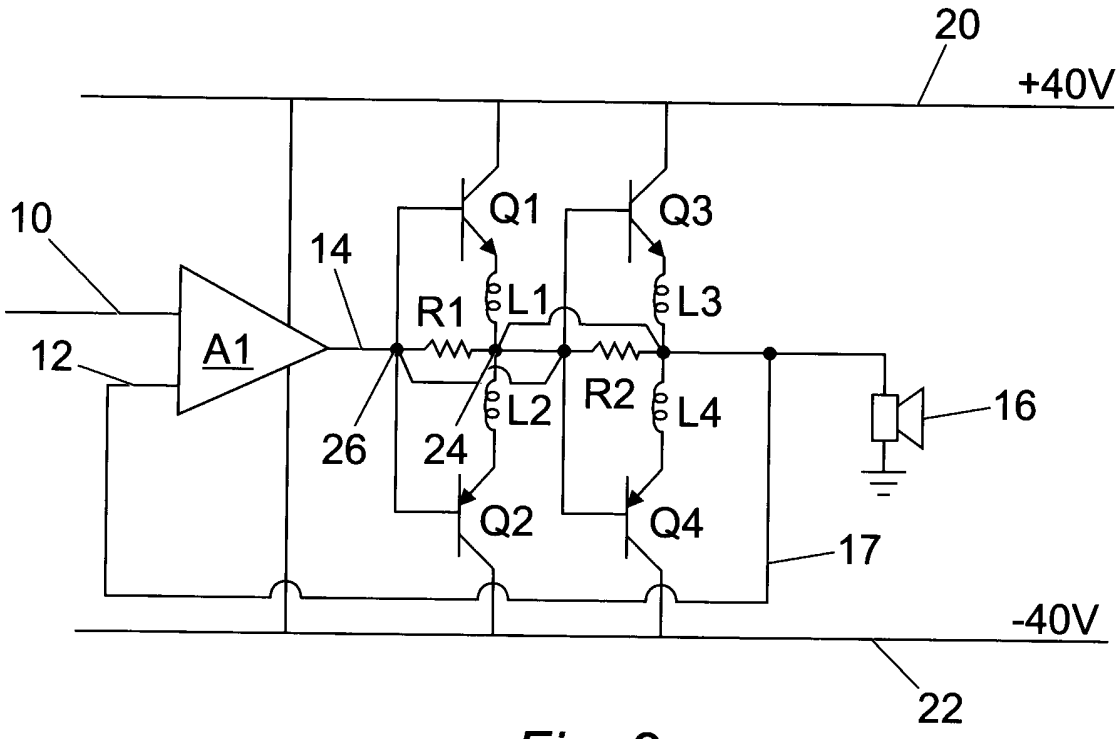

20
+40V
10
14
Q1
L1
R1
24
18
12
A1
16
L2
26
Q2
17
-40V
22

Fig. 1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Q1
Q3
14
R1
L1
L3
12
A1
R2
16
L2
L4
26
24
Q2
Q4
17
-40V
22

Fig. 2

Amplifiers

The present invention relates to amplifiers, particularly but not exclusively linear audio power amplifiers.

Most 'high end' audio power amplifiers are built using many discrete components: transistors, diodes, resistors, capacitors etc. An alternative approach, used generally in lower performance, lower power applications, uses single silicon chip 'monolithic' power amplifiers where essentially the entire amplifier circuit is integrated on to one or a few chips and packaged in one device. A minimal number of external parts are required to complete the application. Some high performance monolithic amplifier solutions can be adapted for 'high-end' use.

The advantage of monolithic amplifier solutions is that it is possible to integrate much more complex circuitry than could be practically built with

discrete components, giving the potential for very high performance. Their disadvantage is that their power handling is limited. This invention concerns a method of combining the advantages of monolithic chips and discrete transistors to create compact, reliable high performance audio amplifiers, very simply.

It is known to add a number of discrete 'booster' transistors on to the output of a monolithic amplifier. The monolithic generates all the output power up to a very safe and defined limit, then the booster transistors switch on to provide virtually unlimited further power. The potential problem with this type of arrangement is the discontinuity at the instant when the boosters switch on and off. The present invention provides a simple and effective solution to this problem, requiring only the addition of small inductors.

In accordance with a first aspect of the present invention, there is provided an amplifier comprising:

a primary power amplifier comprising at least one integrated circuit and having a signal input and an output, the output being connected to a first output node; and

a secondary amplifier formed from discrete components and connected between the output of the primary amplifier and said first output node, said secondary amplifier being operable to boost the output from the primary amplifier in response to the

output current from the primary amplifier reaching a predetermined threshold value; wherein

said secondary amplifier includes at least one inductance for extending a switching off period of said secondary amplifier.

Preferably, said secondary amplifier comprises at least a first amplifier stage including:

first and second complementary transistors, first and second inductances and a resistance;

said first transistor having a power supply terminal connected to a positive power supply, an output terminal connected via said first inductance to a second output node located between said primary amplifier output and said first output node, and a control terminal connected to a third output node located between said primary amplifier output and said second output node;

said second transistor having a power supply terminal connected to a negative power supply, an output terminal connected via said second inductance to said second output node, and a control terminal connected to said third output node; and

said resistance being connected between said second and third output nodes for setting said threshold value for switching said first and second transistors.

Preferably, a feedback loop connects said first output node to a feedback input of the primary power amplifier.

In alternative embodiments, the secondary amplifier may include a plurality of similar amplifier stages cascaded within said feedback loop.

Preferably, said primary power amplifier is a monolithic amplifier solution comprising at least one integrated circuit.

Preferably, transistors of said secondary amplifier comprise bipolar transistors.

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:
Fig. 1 is a circuit diagram illustrating a preferred embodiment of the present invention; and
Fig. 2 is a circuit diagram exemplifying alternative embodiments of the present invention.

Referring now to the drawings, amplifier A1 represents a monolithic linear audio amplifier solution, which may comprise one or more integrated circuits. Solutions of this type are well known in the art and will not be described further herein. Amplifier A1 has a first signal input 10 for receiving an input signal, a second feedback input 12 and an output 14 connected, in use, to a loudspeaker 16 or other output transducer or the like. A feedback path 17 connects the feedback input 12 to a first node 18 between the output 14 and the loudspeaker 16. Positive and negative DC

power supply rails 20 and 22 are also connected to the amplifier A1 in a conventional manner.

A booster circuit, formed from discrete components for boosting the output current from amplifier A1 includes a complementary pair of first and second transistors Q1 and Q2 and resistance R1. In preferred embodiments the transistors Q1 and Q2 are bipolar transistors (one n-p-n type and one p-n-p type). The collectors (power supply terminals) of the transistors Q1 and Q2 are connected to the positive and negative power rails 20 and 22 respectively. The emitters (output terminals) of the transistors Q1 and Q2 are connected to a second node 24 between the amplifier output 14 and the first node 18 (i.e. inside the feedback path 17). The bases (control terminals) of the transistors Q1 and Q2 are connected to a third node 26 between the amplifier output 14 and the second node 24. The resistance R1 is connected in series between the second and third nodes 24 and 26.

In operation of the circuit as described thus far, transistors Q1 and Q2 are both switched off as long as the output current from the amplifier A1 is below a threshold determined by the value of resistance R1. When the threshold current is reached, the complementary transistors Q1 and Q2 are switched on alternately on positive and negative parts respectively of the current cycle, thereby providing additional amplification of the output signal from the amplifier A1.

A problem with the arrangement as described above arises because the transistors Q1 and Q2 do not switch on and off instantaneously, causing discontinuities in the current/time characteristic of the final output to the loudspeaker 16. This is easily remedied for switching on, by setting the threshold so that the transistors switch on "early". However, there remains a problem with discontinuity of the power output at switch off.

Biasing the transistors Q1 and Q2, so as to reduce their switching period, would mitigate this problem, but the complexity of suitable biasing circuitry would defeat the purpose of using a monolithic amplifier solution.

In accordance with the present invention, the problem is solved by the use of inductances L1 and L2, one of which is connected between the emitter of each of the respective transistors Q1 and Q2 and the second node 24.

The inductances L1 and L2 have the effect of slowing down the switching off of the transistors Q1 and Q2, thereby smoothing any discontinuity that might occur at the switching of the transistors. At switch off, as the output current of Q1 or Q2 falls below the threshold, the emitter voltage briefly (i.e. for a period on the order of microseconds) drops below the base voltage so that the decaying inductor current circulates from the emitter to the base of the

transistor, keeping the transistor turned on for a period (again on the order of microseconds, determined by the time constant of the inductive circuit), sufficient to smooth any switching discontinuity.

In a typical application, the transistors Q1 and Q2 will be switched off until the output from the monolithic amplifier A1 reaches a threshold of about 5A, and will then switch on to boost the output as required. The value of resistor R1, which determines the switching threshold, might typically be about 100 mΩ and the inductance of L1 and L2 of the order of several μH, in order to provide a time constant of the order of microseconds. The values of L1 and L2 are not critical, being determined by the required switching speed. If they are too large, transistor switch-on will be too slow; if too small, the switch-off delay effect will be insufficient.

Bipolar transistors are preferred, but MOSFETs could be used instead.

Fig. 1 shows the amplifier having a single booster stage, but it will be understood that multiple booster stages can be provided by cascading multiple booster circuits similar to that of Fig. 1 within the feedback loop 17. Fig. 2 shows a circuit with two cascaded booster stages.

The invention enables the advantages of monolithic amplifier solutions to be exploited while allowing the output of the monolithic amplifier to be boosted to any required level without distortion in a simple and cost-effective manner.

Improvements and modifications may be incorporated without departing from the scope of the invention.

Claims

1. An amplifier comprising:

a primary power amplifier comprising at least one integrated circuit and having a signal input and an output, the output being connected to a first output node; and

a secondary amplifier formed from discrete components and connected between the output of the primary amplifier and said first output node, said secondary amplifier being operable to boost the output from the primary amplifier in response to the output current from the primary amplifier reaching a predetermined threshold value; wherein

said secondary amplifier includes at least one inductance for extending a switching off period of said secondary amplifier.

2. An amplifier according to claim 1, wherein said secondary amplifier comprises at least a first amplifier stage including:

first and second complementary transistors, first and second inductances and a resistance;

said first transistor having a power supply terminal connected to a positive power supply, an output terminal connected via said first inductance to a second output node located between said primary amplifier output and said first output node, and a control terminal connected to a third output node located between said primary amplifier output and said second output node;

said second transistor having a power supply terminal connected to a negative power supply, an output terminal connected via said second inductance to said second output node, and a control terminal connected to said third output node; and

said resistance being connected between said second and third output nodes for setting said threshold value for switching said first and second transistors.

3. An amplifier according to claim 1 or claim 2, wherein a feedback loop connects said first output node to a feedback input of the primary power amplifier.

4. An amplifier according to claim 3, wherein the secondary amplifier includes a plurality of similar amplifier stages cascaded within said feedback loop.

5. An amplifier according to any preceding claim, wherein said primary power amplifier is a monolithic amplifier solution comprising at least one integrated circuit.

6. An amplifier according to any preceding claim, wherein transistors of said secondary amplifier comprise bipolar transistors.

7. An amplifier substantially as hereinbefore described with reference to the accompanying drawings.