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(71) Applicant (for all designated States except US): **TELEFONAKTIEBOLAGET LM ERICSSON (publ)**
[SE/SE]; S-126 25 Stockholm (SE).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **BRANDT, Per-Olof**
[SE/SE]; Rönngatan 4, S-234 31 Lomma (SE).

(74) Agent: **HOFMAN-BANG ZACCO A/S**; Hans
Bekkevolds Allé 7, DK-2900 Hellerup (DK).

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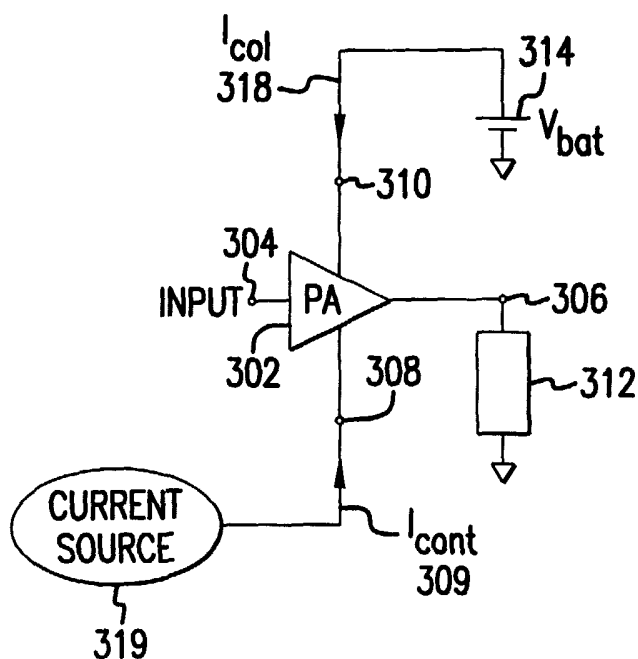
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(54) Title: CURRENT CONTROLLED POWER AMPLIFIER



(57) Abstract: A circuit for regulating the power provided to a load connected to an output of a power amplifier. The circuit using a control current, rather than a control voltage, to bias the power amplifier.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

CURRENT CONTROLLED POWER AMPLIFIER

BACKGROUND OF THE INVENTION

Field of the Invention

5 The present invention is generally related to power amplifiers, and, more specifically, to a system and method for regulating the power produced by a power amplifier.

Discussion of the Background

10 In certain communication systems, for example, the Global System for Mobile Communication (GSM), the output power of a transmitter within a communication device (e.g., a mobile phone) has to be well controlled due to the specifications of the communication system. In
15 transmitters used in GSM and GSM like systems, the output power of the transmitter is controlled by employing a control circuit that produces a 15 control voltage for biasing a power amplifier of the transmitter. For
20 example, a high control voltage produces higher output power and a low control voltage produces lower output power. In this way, a control voltage that biases the power amplifier can be used to control the output power.

 However, a problem with using a control voltage to bias the power amplifier is that there is not a pure
25 linear relationship between the control voltage and the output power. In other words, there is not a constant gain. FIG. 1 is a graph that illustrates the relationship between the control voltage and the current consumed by the power amplifier (also referred to as the "collector
30 current"). The collector current is proportional to the output power. Therefore, FIG. 1 illustrates indirectly

the relationship between the control voltage and the output power. As seen in FIG. 1, there is a low gain when the control voltage is below V_{low} , a high gain when the control voltage is between V_{low} and V_{high} , and a low gain when the control voltage is greater than V_{high} . Thus, a constant gain is not achieved. Specifically, when the control voltage is either low or high, the gain is essentially zero, and when the control voltage is in the middle region (i.e., between low and high), the gain can vary by a factor greater than 10.

It is desirable that there be a constant gain between the control signal and collector current.

SUMMARY OF THE INVENTION

The present invention overcomes the disadvantages described above by using a control current, rather than a control voltage, to bias the power amplifier. As shown in FIG. 2, the relationship between the control current and the collector current is much more linear than the relationship between the control voltage and the collector current. Thus, using a control current to bias the power amplifier a more constant gain is achieved.

Advantageously, according to one embodiment, a feed forward technique is used in conjunction with the control current. The feed forward technique is most useful in the situations where it is desired to operate the power amplifier at high output power levels.

Further features and advantages of the present invention, as well as the structure and operation of various embodiments of the present invention, are

described in detail below with reference to the accompanying drawings.

It should be emphasized that the term "comprises/comprising" when used in this specification is
5 taken to specify the presence of stated features, integers, steps, or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

10 BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated herein and form part of the specification, illustrate various embodiments of the present invention and, together with the description, further serve to
15 explain the principles of the invention and to enable a person skilled in the pertinent art to make and use the invention. In the drawings, like reference numbers indicate identical or functionally similar elements. Additionally, the left-most digit(s) of a reference
20 number identifies the drawing in which the reference number first appears.

FIG. 1 is a graph that illustrates the relationship between the control voltage and the collector current.

25 FIG. 2 is a graph that illustrates the relationship between the control current and the collector current.

FIG. 3 is a functional block diagram of one embodiment of a circuit according to the present
30 invention.

FIG. 4 illustrates an example practical application of the present invention.

FIG. 5 is a block diagram that illustrates a feed forward circuit used in conjunction with the present invention.

FIG. 6 is a circuit diagram illustrating a circuit, according to one embodiment, for implementing the present invention as it shown in FIG. 4

FIG. 7 is a circuit diagram illustrating the circuit shown in FIG. 6 with a feed forward circuit, according to one embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

FIG. 3 is a functional block diagram of one embodiment of a circuit 300 according to the present invention. Circuit 300 includes a power amplifier 302 having an input 304 for receiving an input signal, an output 306 for connecting to a load 312, a control input 308 for receiving a control current (I_{cont}) 309, and a power input 310 for coupling power amplifier 302 to a power source (V_{bat}) 314.

Advantageously, circuit 300 also includes a controllable current source 319 that produces control current 309. Control current 309 is used to control the amount of power delivered to load 312 (also referred to as the "output power"). As shown in FIG 2, there is a linear (or nearly linear) relationship between control current 309 and a collector current 318, which is proportional to the output power. Therefore, by changing the amount of control current 309, one is able to change the collector current 318 by a proportional amount, and,

thereby, change the output power by a proportional amount. For example, if the output power should be increased, current source 319 is set to increase the amount of control current 309, which causes the output power to increase. Similarly, if the output power should be decreased, current source 319 is set to decrease the amount of control current 309, which causes the output power to decrease.

FIG. 4 illustrates an example practical application of the present invention. As shown in FIG. 4, a current sensor 402 is used to provide a reading of collector current 318. More specifically, current sensor 402 outputs a signal, such as a voltage (V_{sense}), that corresponds to the amount of current 318 flowing into power amplifier 302 (i.e., the "collector current"). This signal is provided as an input to a comparator 404, which is coupled to and controls current source 319. Comparator 404 compares the signal to a reference signal and adjusts the magnitude of control current 309 as a function of the difference between the signal and the reference signal by sending a control signal 405 to current source 319. In this way, comparator 404 and current source 319 can be used to regulate the output power as a function of the reference voltage.

For example, if it is desired to keep the output power at a constant level, the reference signal is kept constant and comparator 404 is configured to increase control current 309 if the signal from current sensor 402 is less than the reference signal and to decrease control current 309 if the signal from current sensor 402 is greater than the reference signal. In this way,

comparator 404 and current source 319 keep the collector current 318 constant, and, thereby regulates the output power.

FIG. 5 is a block diagram that illustrates a feed forward circuit 502 used in conjunction with the present invention. Feed forward circuit 502 functions to feed a portion of the control current 309 to an adder 504 that adds the output of feed forward circuit 502 to the output of current sensor 402. The output of adder is provided to an input of comparator 404. The reference signal is provided to the other input of comparator 404. Thus, comparator 404 will compare a signal equivalent to $I_{col} + I_{cont}/X$ to the reference signal. This embodiment of the invention is useful in the situation where a high output power is desired.

FIG. 6 is a circuit diagram illustrating a circuit 600, according to one embodiment, for implementing the present invention as it shown in FIG. 4. One skilled in the art understands that circuit 600 is not the only way to implement the high level circuit shown in FIG. 4 and that the invention is not limited to the specific circuit shown in FIG. 6 or any other specific circuit. As shown in FIG. 6, power amplifier 302 is implemented with two bi-polar junction transistors 601 and 602, current sensor 402 is implemented with a resistor 604, and comparator 404 and current source 319 are implemented using an operational amplifier (op-amp) 606. The power amplifier 302 shown in FIG. 6 functions to receive an input signal and produce an output signal that is an amplified version of the input signal. Op-amp

606 functions to output a current 309 that is used to control the output power of power amplifier 302.

FIG. 7 is a circuit diagram illustrating circuit 600 with a feed forward circuit 502 and an adder 504, according to one embodiment. One skilled in the art will appreciate that the specific feed forward circuit 502 that is shown in FIG. 7 is not the only way to implement a feed forward circuit and that the invention is not limited to the specific circuit shown in FIG. 7 or any other specific circuit. As shown in FIG. 7, feed forward circuit 502 includes a bi-polar junction transistor 710, a DC current source 712, and a first resistor 714, and adder 504 is implemented with a resistor. DC current source 712 is connected between ground and the base of transistor 710. First resistor 714 is connected between the base of transistor 710 and node N1. A first input 721 of adder 504 is connected to the collector of transistor 710 and a second input 722 of adder 504 is connected to node N2. The output 723 of adder 504 is connected to an input of op-amp 606. Lastly, the emitter of transistor 710 is connected to ground.

As described above, feed forward circuit 502 functions to feed a portion of the control current 309 to adder 504, which adds the output of feed forward circuit 502 to the output of current sensor 402 (in this case, resistor 604) to produce an output which is provided to an input of op-amp 606.

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example, and not limitation. It will be understood by

those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the following claims. Thus the breadth and scope of the

5 present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. A circuit, comprising:
a power amplifier that amplifies a
signal received at an input of the power amplifier, the
5 power amplifier having a control input for receiving a
control current for biasing the power amplifier, a power
input for coupling to a power source, and an output that
provides the amplified signal to a load; and
a controllable current source, coupled
10 to the control input, that generates the control current,
wherein
the control current is used to
regulate the power delivered to the load by the power
amplifier.
15
2. The circuit of claim 1, further
comprising:
a current sensor for outputting a
signal corresponding to the amount of current flowing
20 into the power amplifier from the power source; and
a comparator that is coupled to and
controls the controllable current source, wherein
the comparator compares the signal
outputted by the current sensor to a reference signal and
25 controls the controllable current source based on the
result of the comparison.
3. The circuit of claim 2, wherein the
current sensor comprises a resistor connected between the
30 power source and the power input.

4. The circuit of claim 2, wherein if the signal outputted by the current 5 sensor is greater than the reference signal the comparator controls the current source such that the control current is
5 decreased.

5. The circuit of claim 2, wherein if the signal outputted by the current sensor is less than the reference signal the comparator controls the current
10 source such that the control current is increased.

6. The circuit of claim 1, further comprising:
a feed forward circuit that functions
15 to output a portion of the control current; and
an adder that adds the output of the feed forward circuit to the output of the current sensor, wherein the output of adder is provided to an input of the comparator and the reference signal is provided to
20 another input of comparator, such that the comparator compares the output of the adder to the reference signal.

7. The circuit of claim 1, wherein the power amplifier is implemented with bi-polar junction
25 transistors.

8. A circuit, comprising:
amplification means for amplifying a signal received at an input of the amplification means,
30 the amplification means having a control input for receiving a control current for biasing the amplification

means, a power input for coupling to a power source, and
an output that provides the amplified signal to a load;
and current providing means for generating the control
current, the current providing means being coupled to the
5 control input, wherein

the control current is used to
regulate the power delivered to the load by the
amplification means.

10 9. The circuit of claim 8, further
comprising:

current sensing means for outputting a
signal corresponding to the amount of current flowing
into the amplification means from the power source; and

15 a comparator that is coupled to and
controls the current providing means, wherein

the comparator compares the signal
outputted by the current sensing means to a reference
signal and controls the current providing means based on
20 the result of the comparison.

10. The circuit of claim 9, wherein the
current sensing means comprises a resistor connected
between the power source and the power input.

25

11. The circuit of claim 9, wherein if the
signal outputted by the current sensing means is greater
than the reference signal the comparator controls the
current providing means such that the control current is
30 decreased.

12. The circuit of claim 9, wherein if the signal outputted by the current sensing means is less than the reference signal the comparator controls the current providing means such that the control current is
5 increased.

13. The circuit of claim 8, further comprising:
a feed forward circuit that functions
10 to output a portion of the control current; and
an adder that adds the output of the feed forward circuit to the output of the current sensing means, wherein the output of adder is provided to an input of the comparator and the reference signal is
15 provided to another input of comparator, such that the comparator compares the output of the adder to the reference signal.

14. The circuit of claim 8, wherein the
20 amplification means is implemented with bi-polar junction transistors.

15. In a circuit comprising a power amplifier comprising an input for receiving a signal, a
25 control input for receiving a control current for biasing the power amplifier, a power input for coupling to a power source, and an output for connecting the power amplifier to a load, a method, comprising the steps of:
amplifying the signal received at the
30 input of the power amplifier;

providing the amplified signal to the load, thereby providing power to the load; and

generating the control current; and

delivering the control current to the

5 control input, wherein

the control current is used to regulate the power delivered to the load by the power amplifier by biasing the power amplifier.

10 16. The method of claim 16, further comprising the step of measuring the current flowing into the power amplifier from the power source.

15 17. The method of claim 16, wherein the step of measuring the amount current flowing into the power amplifier from the power source comprises the step of generating a voltage corresponding to the amount of current flowing into the power amplifier from the power source.

20 18. The method of claim 17, further comprising the step of comparing the voltage to a reference voltage.

25 19. The method of claim 17, further comprising the step of increasing or decreasing the control current depending on the result of the comparison of the voltage to the reference voltage.

30 20. A method, comprising:

receiving a signal at an input of a
power amplifier;

amplifying the signal to produce an
amplified signal;

5 providing the amplified signal to a
load, thereby delivering power to the load; and

controlling the power delivered to the
load by using a control current to bias the power
amplifier.

10

21. The method of claim 20, further
comprising the step of producing a voltage corresponding
to an amount of current flowing into the power amplifier
from a power source.

15

22. The method of claim 21, further
comprising the step of comparing the voltage to a
reference voltage.

20

23. The method of claim 22, further
comprising the step of increasing or decreasing the
control current depending on the result of the comparison
of the voltage to the reference voltage.

1/4

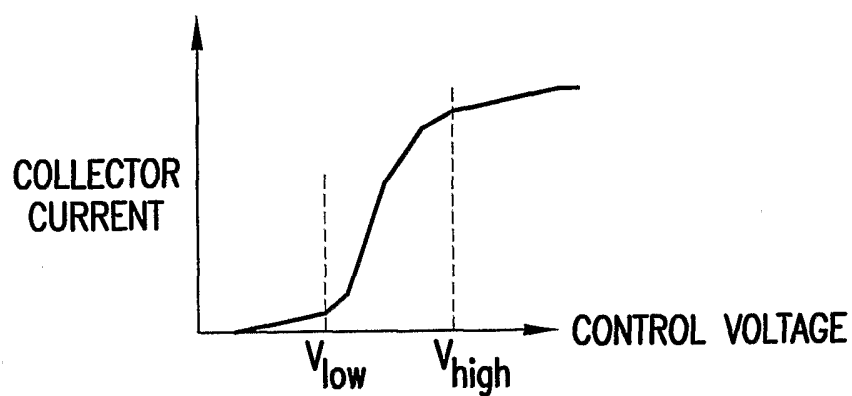


FIG.1

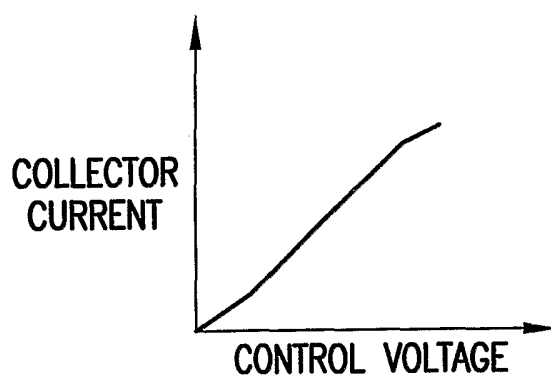


FIG.2

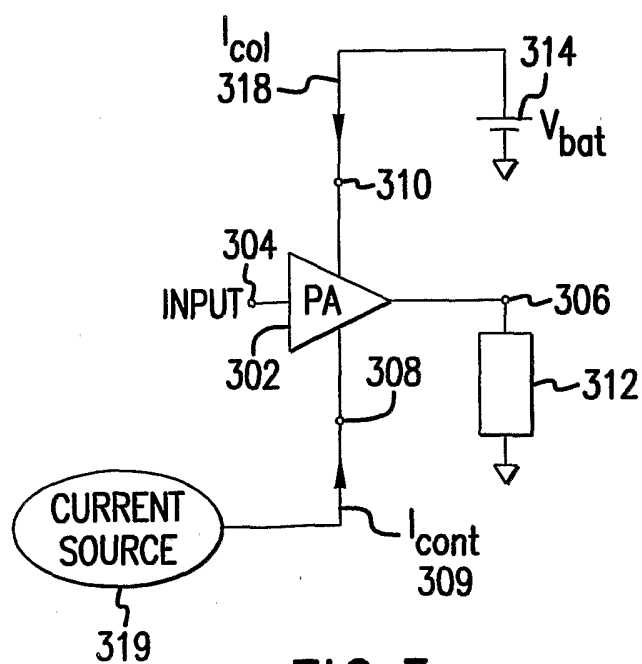


FIG.3

2/4

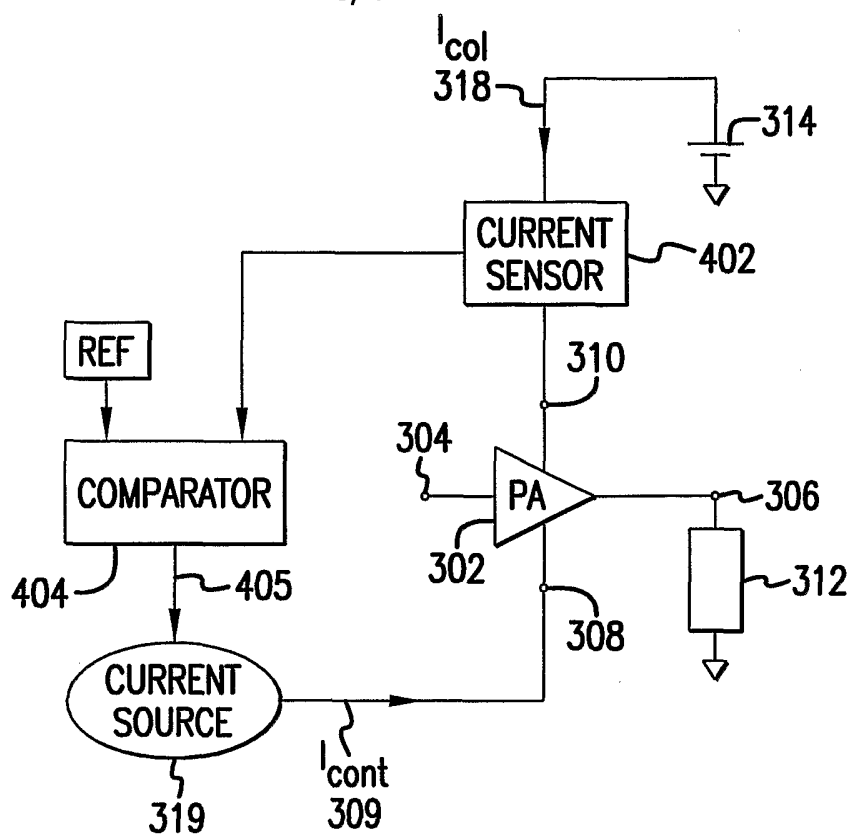


FIG. 4

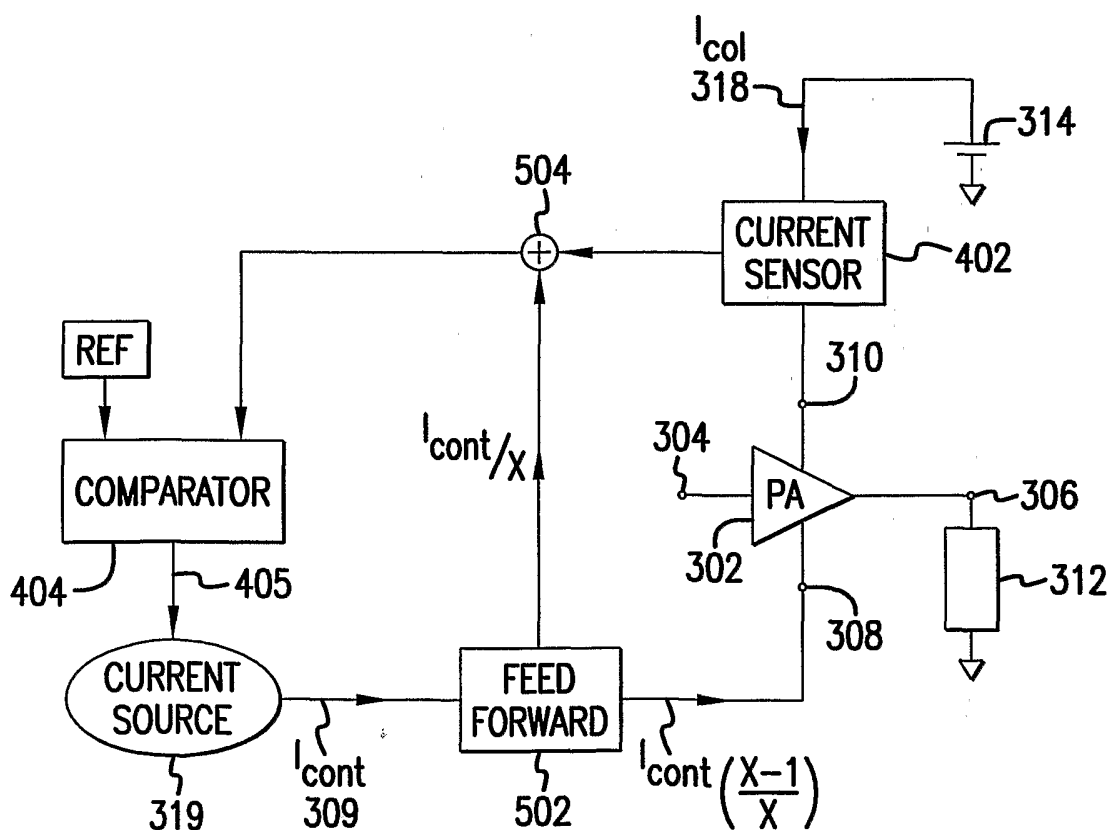
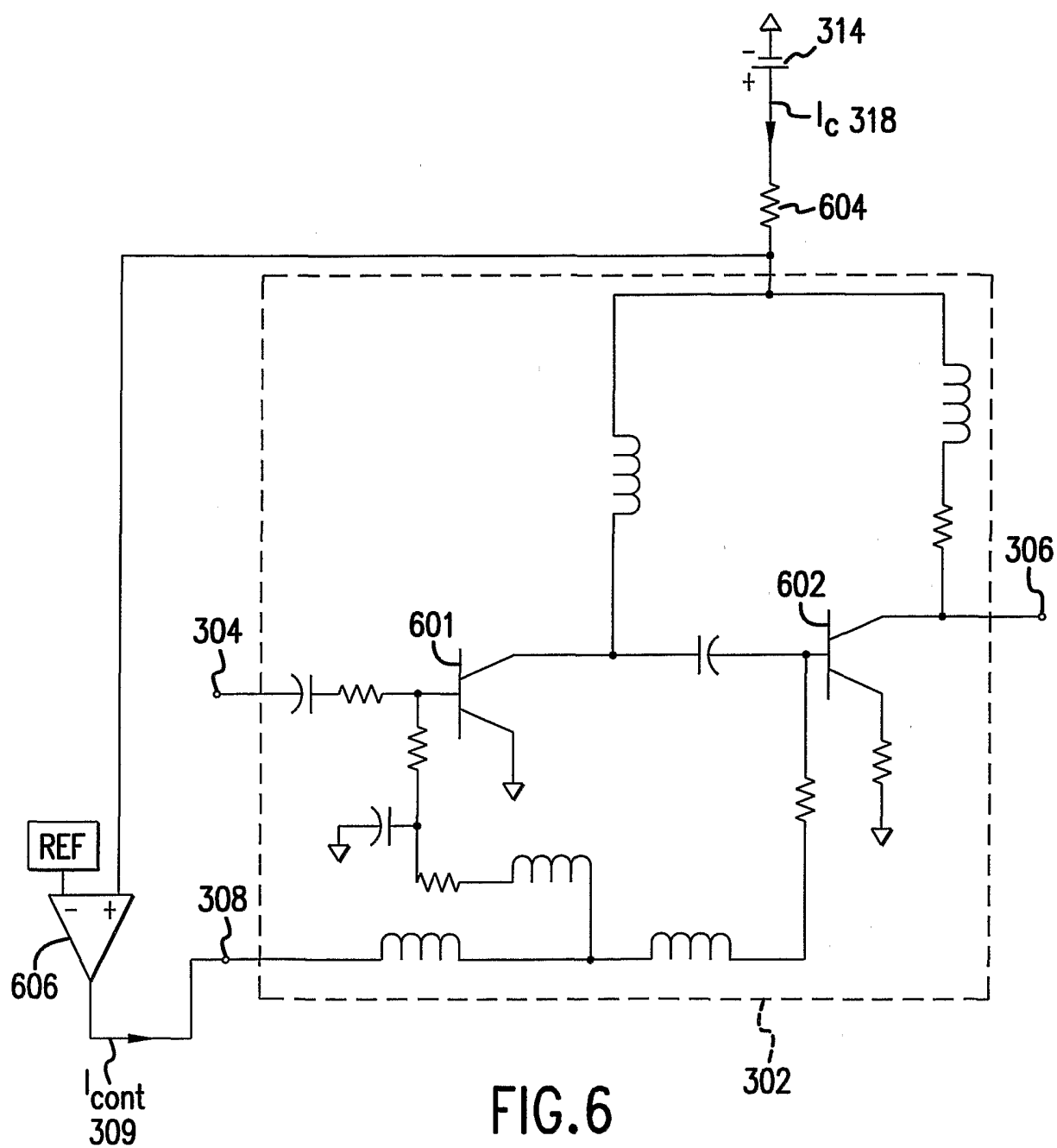


FIG. 5



4/4

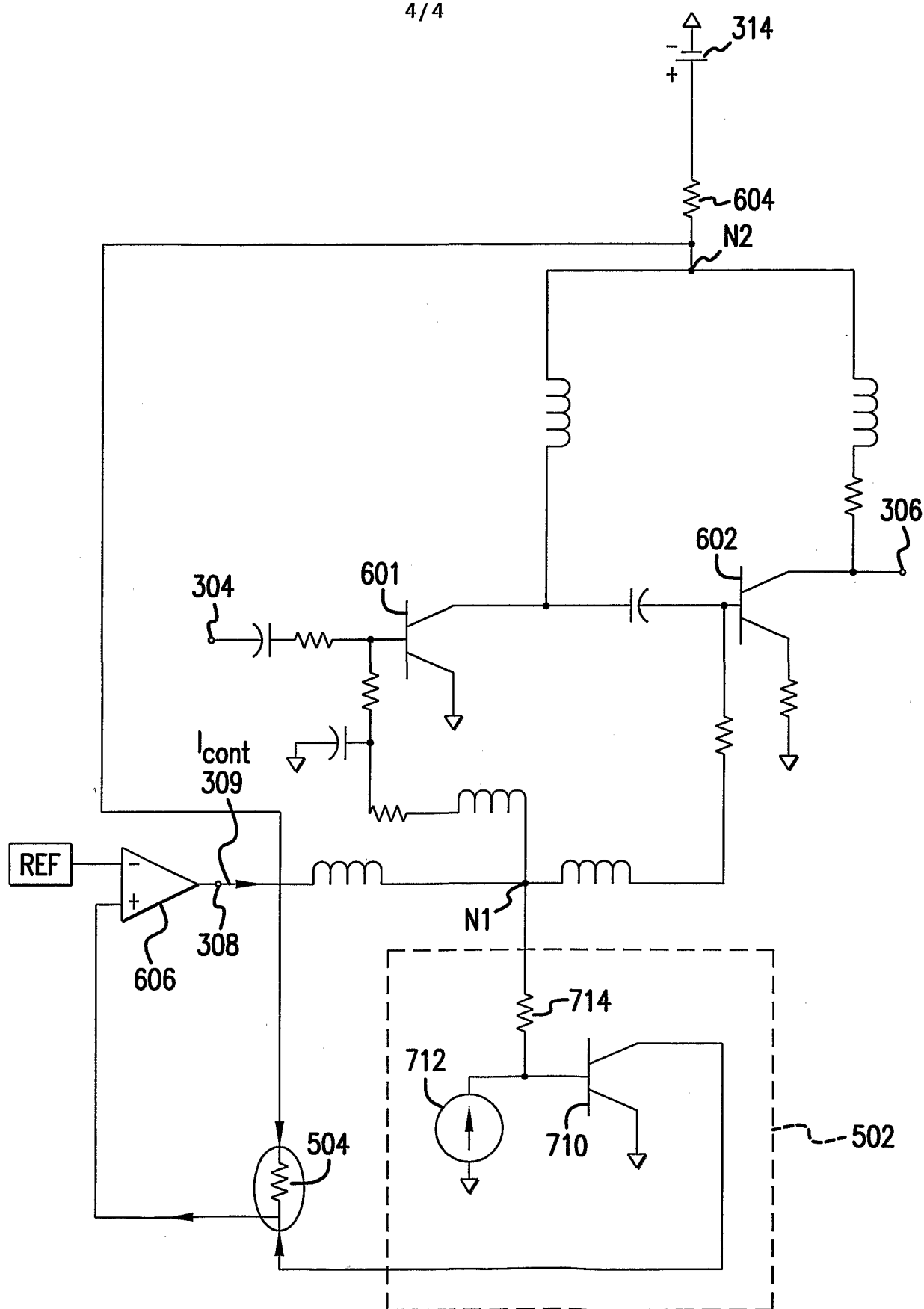


FIG.7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 02/05986

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H03G3/30

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)

IPC 7 H03G

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 practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 497 125 A (ROYDS IAN D) 5 March 1996 (1996-03-05) column 3, line 51 -column 5, line 50; figures 2-4	1,2,4-9, 11,12, 14-23
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	-/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

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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

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G document member of the same patent family

Date of the actual completion of the international search

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Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Segaert, P

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 02/05986

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

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