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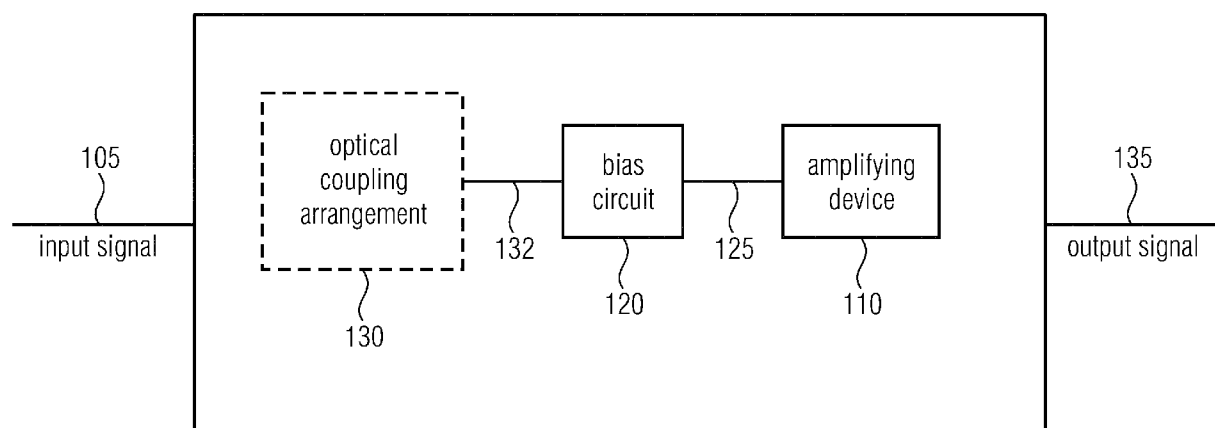


Fig. 1

(57) Abstract: An amplifier comprising an amplifying device (110) and a bias circuit (120) for providing a bias voltage for the amplifying device (110). The bias circuit (120) is configured to provide the bias voltage in dependence of an output signal of an optical coupling arrangement (130) which provides for an electrical isolation.



**Amplifier, Circuit for trimming a Bias Voltage, Method for amplifying an Input Signal
and Method for trimming a Bias Voltage**

Description

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Technical Field

Embodiments of the present invention relate to providing a bias voltage to an amplifying device.

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Background

It has been found that power amplifiers require a thorough control of the output stage to optimize signal fidelity versus a standby current consumption. It has been found that to ensure performance a cross current in output transistors may need to be adjusted well. It has been recognized that this adjustment requires exact process control or trimming (potentiometer) before the shipping of amplifier products. Some traditional designs use high voltage current mirrors to transfer a ground-related trim signal to a level of a power output stage.

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In US 2014/0300413 A1 a power transistor gate driver is disclosed.

In US 2011/0156819 A1 a low-noise high efficiency bias generation circuit and method are described.

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In light of the above mentioned conventional concepts, a desire exists for an improved concept for providing a bias voltage to an amplifying device.

Summary of the Invention

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Embodiments of the invention provide an amplifier comprising an amplifying device (e.g., a transistor) and a bias circuit for providing a bias voltage for the amplifying device. The bias circuit is configured to provide the bias voltage in dependence on an output signal (e.g., output current of an optocoupler or output current or output voltage of a solar cell) of an optical coupling arrangement (e.g., optocoupler or LED-solar cell arrangement) which

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provides for an electric isolation (e.g., such that the output signal of the optical coupling arrangement tunes or influences the bias voltage).

5 This embodiment is based on the idea the a provision of a bias voltage in dependence on an output signal of an optical coupling arrangement allows for a post-production tuning of a bias point while keeping a realization effort small and at the same time provides for an electrical decoupling between a trimming control and the amplifying device. The described embodiment eliminates a manual manufacturing trimming which may be necessary for conventional amplifiers and therefore allows a low-cost production of power stages. For
10 example, a cross current through the amplifying device (e.g., a transistor of a Class A amplifier) may be designed to be within a specified range for operation. For conventional amplifiers during manufacturing, it is necessary to make a final adjustment of the bias voltage. The described embodiment does not need a final adjustment as the bias voltage can still be adjusted based on the output signal of the optical coupling arrangement.
15 Thereby, an expensive manufacturing process step or quality check can be avoided. Moreover, considering the aging of components, characteristics of electric or electronic components may change, leading to a drift of the bias voltage compared to a state after manufacturing. The described embodiment can adjust for the ageing as, based on an appropriate output signal of the optical coupling arrangement, the bias voltage may be
20 readjusted.

In embodiments the bias circuit is configured to adjust the bias voltage based on the output signal of an optical coupling arrangement, when an operating point of the amplifying device deviates from a desired operating point. Adjusting the bias voltage
25 based on a deviation from a desired operating point is useful to avoid signal distortions in the output signal of the amplifier. Moreover, when ensuring operation of the amplifying device at an operating point, energy may be conserved compared to an unadjusted operating point, e.g. causing a too large cross current to be flowing through a transistor.

30 In embodiments, the bias circuit comprises a first resistor circuit in parallel to the optical coupling arrangement, wherein the first resistor is coupled to a control terminal of the amplifying device. Further, the optical coupling arrangement is configured to provide a contribution to a voltage drop over the first resistor, wherein the voltage drop over the first resistor is configured to adjust the bias voltage. Using a voltage drop over the first resistor
35 is a simple way of producing a desired voltage drop based on the knowledge of the resistor's resistance. For example, given the first resistor's resistance, the optical coupling

arrangement may provide a current through the first resistor and thereby produce a contribution to the voltage drop over the first resistor, which is proportional to the resistance of the first resistor and proportional to the current.

- 5 In embodiments, the bias circuit comprises a regulator circuited in parallel to the first resistor and a second resistor (e.g., in parallel to a series connection of the first resistor and the second resistor), wherein the second resistor is circuited in series to the first resistor. Moreover, the regulator is configured to limit the bias voltage based on a voltage drop over the second resistor, to thereby limit a voltage drop over the first resistor, leading
10 to an overall limited bias voltage. Using the described regulator, a too-large bias voltage can be avoided and, thereby, damaging the amplifying device may also be avoided.

- In embodiments the regulator is configured to limit (or regulate) the bias voltage (e.g., by diverting a current away) by offering a low impedance path in parallel to the first resistor
15 and the second resistor through the regulator when the voltage drop over the second resistor exceeds a limit. Thereby, a voltage drop over the series circuit of the first resistor and the second resistor is reduced. The described embodiment may be used to limit (or regulate) a voltage drop over the first and the second resistor by diverting a current such that it runs through the regulator and not through the first and the second resistor. By not
20 running through the first and the second resistor, a reduced voltage drop over the first and the second resistor is observed.

- In embodiments, the regulator is configured to limit (or regulate) the bias voltage based on a voltage of a middle node of a voltage divider, wherein the voltage divider comprises the
25 first resistor and the second resistor. The voltage drop over the voltage divider provides the bias voltage and the voltage drop over the voltage divider is influenced by the output signal of the optical coupling arrangement. Using the described voltage divider, a predefined voltage drop may be used over the second resistor to control the regulator, such that the regulator offers a low impedance path if a voltage drop over the second
30 resistor is increasing (i.e. exceeds a threshold). Thereby, as the first resistor and the second resistor are circuited in series, a current which would be running through the first resistor and the second resistor is diverted through the regulator, reducing a voltage drop over the first and the second resistor.

- 35 In embodiments the optical coupling arrangement is configured to receive a control signal to provide an optical signal on the basis of the control signal and to provide the output

signal of the optical coupling arrangement on the basis of the optical signal. Moreover, the output signal of the optical coupling arrangement is electrically isolated from the control signal. Using a control signal for the optical coupling arrangement enables flexible influence of the bias voltage based on the control signal. Further, through the electric isolation of the optical coupling arrangement, a circuit wherefrom the control signal may be originated from is electrically unaffected from the amplifier. Through the isolation, high voltages or high currents occurring in the amplifier damaging a circuit producing the control signal may be avoided.

- 10 In embodiments the optical coupling arrangement is configured to receive a pulse width modulated control signal. For example, using a pulse width modulated control signal may produce a pulsating light or optical signal which may be received, for example, by a solar cell or a photodiode of the optical coupling arrangement. Further, the optical signal may be converted to an electrical current and, in particular, through inertia to a substantially
15 constant bias. Using pulses with varying width allows for adjustment of an average amount of current to be injected into the bias circuit.

- In embodiments the amplifier is configured to adjust the control signal in dependence of a cross current of the amplifying device. Using a control signal adjusted or regulated in
20 dependence of a cross current of the amplifying device can be helpful to bring a cross current of the amplifying device to an operation point of the amplifier.

- In embodiments the amplifier is configured to adjust the control signal based on a measurement of a characteristic of an output signal of the amplifier. Using a characteristic
25 of an output signal of the amplifier allows adjustment of the control signal such that an output signal of the amplifier is obtained with desired characteristics.

- In embodiments the amplifier is configured to measure a characteristic of an output signal of the amplifier by stepping through various bias voltage settings. Using various bias
30 voltage settings, an optimum characteristic of the output signal of the amplifier may be measured and, therefore, the control signal may be adjusted accordingly.

- In embodiments, the amplifier comprises a signal input line configured to receive an input signal to be amplified, a positive supply voltage terminal and a negative supply voltage
35 terminal. The positive supply voltage terminal and the negative supply voltage terminal are configured to provide supply voltages to the amplifier and the bias circuit is circuited

between the signal input line and a control terminal of the amplifying device, to allow for an optically isolated adjustment of a voltage shift between the signal input line and the control terminal. The described embodiment can advantageously use the adjusted bias voltage to keep a voltage shift between the signal input line and the control terminal at a specified level. Further, when a signal is input at the signal input line, the bias circuit acts to keep a voltage shift between the signal input line and the control terminal substantially constant.

In embodiments, the amplifier comprises a first current source, circuited between the positive supply voltage terminal and the bias circuit, wherein the first current source is configured to provide a predefined current to the bias circuit. Using the described first current source, a current may be provided to the first resistor leading to a voltage drop over the first resistor which may be close to an optimum bias voltage. Thus, the bias circuit may only need to make a fine adjustment of the voltage drop over the first resistor, using the output signal of the optical coupling arrangement.

In embodiments, the amplifier comprises a second current source and a second bias circuit, wherein the second current source is circuited between the negative supply voltage terminal and the second bias circuit. The second current source is configured to provide a predefined current to the second bias circuit based on the voltage provided at the negative supply voltage terminal. Using the second current source and the second bias circuit, a second amplifier may be used in the amplifier such that positive and negative signal components may be amplified.

In embodiments, the amplifying device is configured to provide a positive output signal of the amplifier when a positive input signal is applied. Moreover, the output signal has an equal or higher current than the input signal. The described amplifier can be used to take a positive input signal with a small current to produce a positive output signal with a high current.

In embodiments the amplifier comprises a second amplifying device, wherein the second amplifying device is configured to provide a negative output signal of the amplifier when a negative input signal is applied to the amplifier. Moreover, the output signal has an equal or higher current than the input signal. The described embodiment can beneficially produce an amplified negative output signal based on a negative input signal.

Embodiments of the invention provide a method for amplifying an input signal. The method comprises, providing a bias voltage for an amplifying device, wherein the bias voltage is provided in dependence of an output signal of an optical coupling arrangement which provides for an electric isolation.

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Embodiments according to the invention provide for a circuit for trimming a bias voltage. The circuit comprises a controlled source, wherein the controlled source is controlled via an optical signal. Further, the circuit comprises a first resistor, wherein the first resistor is circuited in parallel to the controlled source. Moreover, the controlled source is configured

10 to change a voltage drop across the first resistor, to thereby trim the bias voltage.

The described circuit is advantageous as it allows for a trimming of a bias voltage, e.g., after manufacturing of a device needing a bias voltage (e.g., an amplifier, a transistor, etc.) while keeping an effort reasonably small and providing for an electrical decoupling. In

15 devices where bias voltages are necessary, large scale production may lead to inaccurate bias voltages and, therefore, a trimming may be useful or even necessary for proper functionality. The described circuit can be used to adjust a voltage drop across the first resistor to influence the bias voltage. Further, an optical signal is used for controlling the controlled source and, thus, the change of a voltage drop across the first resistor. Based

20 on the optical signal an electric isolation is provided which may shield circuits from the bias voltage. For example, the optical signal may be produced by an auxiliary circuit and this circuit may be isolated from the circuit for trimming a bias voltage based on the optical signal.

In embodiments, the first resistor is coupled to a control terminal of an amplifying device, in order to provide the trimmed bias voltage to the amplifying device. Coupling the control terminal of an amplifying device to the first resistor allows to provide (e.g., immediately) the bias voltage based on a voltage drop over the first resistor, wherein the voltage drop may be manually or automatically adjusted or tuned by adjusting the optical signal. The

25 adjustment may be performed based on a deviation of an operating point of the amplifying device, e.g. a predefined cross current of the amplifying device.

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In embodiments, the circuit is configured to trim the bias voltage based on a cross current through the amplifying device. Trimming the bias voltage based on a cross current

35 enables keeping the power consumption of the amplifying device at a moderate level and avoiding distortions based on an incorrectly adjusted cross current of the amplifying

device. Thereby, a glitch in an amplified signal, e.g. the output signal of the amplifier, can be avoided, e.g., such that positive and negative half waves may be reproduced correctly in the output signal of the amplifier.

- 5 In embodiments, the circuit is configured to trim the bias voltage based on a measurement of the characteristic of an output signal of the amplifying device. Using a measurement of the characteristic of an output signal of the amplifying device enables adjusting the bias voltage such that the amplifying device may be operated in an operation point. The operation point may have optimal properties for a usage of the amplifying device. For
- 10 example: to provide an appropriate amplification of an input signal and a specified cross current, e.g., such that an appropriate amplification can be achieved and such that a power consumption is optimal while avoiding distortions in an output signal of the amplifier.
- 15 In embodiments, the circuit is configured to measure a characteristic of an output signal of the amplifying device by stepping through various bias trim settings (e.g., providing bias voltages with varying values to find an optimal value). By stepping through various bias trim settings an optimal characteristic of the output signal may be determined and based on this optimal characteristic of the output signal, a control signal is provided to the optical
- 20 coupling arrangement leading to a desired voltage drop across the first resistor, such that the desired characteristic of the output signal is obtained.

- In embodiments, the circuit for trimming the bias voltage is circuited between a signal input line for receiving an input signal to be amplified and a control terminal of an
- 25 amplifying device. Moreover, a voltage between the signal input line and the control terminal serves to bias the amplifying device. The described circuit can beneficially use a changed voltage drop across the first resistor to adjust the voltage between the signal input line and the control terminal such that a desired bias voltage is obtained and retained even in adverse condition (by compensating bias voltage variations based on the
- 30 output signal of the optical coupling arrangement).

- In embodiments, the circuit comprises a regulator circuited in parallel to the first resistor and a second resistor (e.g., in parallel to a series connection of the first resistor and the second resistor), wherein the second resistor and the first resistor are circuited in series.
- 35 Moreover, the regulator is configured to limit the bias voltage based on a voltage drop over the second resistor. As the first resistor and the second resistor are circuited in

series, a common current flows through the first and the second resistor, thereby, based on a knowledge of a voltage drop over the second resistor, an overall voltage drop over the first and the second resistor may be deduced. Thus, limiting a maximum voltage at the second resistor leads to an overall voltage over the first and the second resistor, e.g., the bias voltage, which is also limited.

In embodiments, the regulator is configured to limit the bias voltage by offering a low impedance path in parallel to the first resistor and the second resistor through the regulator, when the voltage drop over the second resistor exceeds a limit. Thereby, the circuit provides a limited voltage drop over the first resistor and the second resistor, leading to an overall limited bias voltage. For example, when a current flowing usually through the first and the second resistor is offered a path in parallel with a lower resistance due to Ohm's Law, the current will take the path with lower resistance. Thereby, a voltage drop over the first and the second resistor can be reduced.

In embodiments, the regulator is configured to limit the bias voltage based on a middle node of a voltage divider, wherein the voltage divider comprises a first resistor and a second resistor. Moreover, a voltage drop over the voltage divider provides the bias voltage and the voltage divider is influenced by an output signal of the controlled source. Using a voltage divider with known resistance values of the first and the second resistor, provides knowledge over a voltage drop across the entire voltage divider based on a voltage at a middle node of the voltage divider. Thereby, using the voltage at a middle node of the voltage divider, an effective voltage regulation can be implemented using the regulator. Moreover, the voltage may additionally or alternatively be influenced by the output signal of the controlled source by reducing or increasing a voltage drop over the first or the second resistor.

In embodiments, the controlled source is configured to receive an optical signal on the basis of an electrical control signal and to provide an output signal of the controlled source on the basis of the optical control signal. Moreover, the output signal of the controlled source is electrically isolated from the electrical control signal. Using the described circuit a beneficial isolation of the electrical control signal from, e.g., the bias voltage can be achieved. Moreover, the electrical control signal may be produced in a low voltage circuit while the circuit for trimming the bias voltage may, for example, be integrated in a high voltage environment (e.g., an amplifier). Therefore, electrical isolation may be an important factor in the described application. The electrical control signal may, for

example, excite a light emitting diode (LED) and the controlled source may be a photodiode or a solar cell which receives the optical control signal.

5 In embodiments, the controlled source is configured to receive an optical control signal which is based on a pulse width a modulated electric control signal. Using a pulse width modulation enables simple adjustment of a current of the controlled source based on the width of the pulses of the pulse-width-modulated electrical control signal.

10 Embodiments provide for a method for trimming a bias voltage. A method comprises controlling a control source via an optical signal. Further, changing a voltage drop across a first resistor, circuited in parallel to the controlled source. Moreover, the method comprises trimming the bias voltage based on the voltage drop across the first resistor.

15 The methods can be supplemented by all features and functionalities which are herein-described with respect to apparatuses, either individually or in combination.

Brief Description of the Figures

20 In the following, embodiments of the present invention will be explained with reference to the accompanying drawings, in which:

Fig. 1 shows a block diagram of an amplifier according to embodiments of the invention;

25 Fig. 2 shows a block diagram of an amplifier according to embodiments of the invention;

Fig. 3 shows a schematic of a circuit for trimming a bias voltage according to embodiments of the invention;

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Fig. 4 shows a schematic of a circuit for trimming a bias voltage according to embodiments of the invention;

Fig. 5 shows a detailed schematic of an amplifier according to embodiments of the invention;

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Fig. 6 shows a flow chart of a method for amplifying an input signal according to embodiments of the invention;

Fig. 7 shows a flow chart of a method for trimming a bias voltage according to embodiments of the invention.

Detailed Description of the Embodiments

Fig. 1 shows a block diagram of an amplifier 100 according to embodiments of the invention. The amplifier 100 comprises an amplifying device 110, a bias circuit 120 and an optical coupling arrangement 130 (which may be a part of the bias circuit 120 or which may be an external component). Moreover, the amplifier 100 takes as input an input signal 105 and provides an amplified input signal as the output signal 135.

The bias circuit 120 is configured to provide a bias voltage for the amplifying device 110, wherein the bias circuit 120 is configured to provide the bias voltage 125 in dependence on an output signal 132 of the optical coupling arrangement 130 which provides for an electrical isolation. Further, the amplifying device 110 may be configured to work at an operation point. Therefore, a bias voltage 125 is provided to the amplifying device 110 by the bias circuit 120. As the bias voltage 125 may deviate from a desired voltage, e.g., necessary for keeping the amplifying device 110 at the operation point, the bias circuit 120 is provided by the optical coupling arrangement with an appropriate output signal 132 of the optical coupling arrangement 130. Moreover, the output signal 132 of the optical coupling arrangement is configured to provide or contribute to the bias voltage 125, e.g. such that a deviation of the bias voltage 125 (from a desired bias voltage) is reduced or compensated.

The described amplifier 100 can beneficially provide a bias voltage 125 based on the output signal 132 of the optical coupling arrangement such that the bias voltage 125 may, for example, be adjusted. For example, in large scale production of amplifiers, a bias voltage of an amplifier after production may not correspond to a desired bias voltage and, therefore, tedious quality control may be necessary for conventional amplifiers to obtain high quality amplifiers. The described amplifier 100, however, prevents the need for this tedious quality control as the bias voltage 125 may be changed based on the output signal 132 of the optical coupling arrangement after manufacturing of the amplifier 100. Moreover, a signal used to control the optical coupling arrangement 130 is decoupled

from the output signal 132 of the optical coupling arrangement, i.e., electrically isolated. Thereby, a control signal to the optical coupling arrangement may be provided from a circuit which is unaffected from voltages occurring in the amplifier 100.

- 5 In the following aspects of embodiments of the invention are described which can be used by themselves or in combination with any of the embodiments described herein. In other words, the embodiments described herein can be supplemented by any of the features and functionalities described in the following, either individually or in combination.
- 10 Fig. 2 shows a block diagram of an amplifier 200 according to embodiments of the invention. Amplifier 200 comprises an (first) amplifying device 210, a second amplifying device 260, a (first) bias circuit 220, a second bias circuit 270, a first current source 240, and a second current source 290. Moreover, the amplifier 200 comprises a signal input line 205, a signal output line 235, a positive supply voltage terminal 242 and negative supply voltage terminal, 292. The positive supply voltage terminal 242 and the negative supply voltage terminal 292 are configured to provide a positive supply voltage and a negative supply voltage to the amplifier 200, respectively.

The bias circuit 220 comprises a first resistor 221, a second resistor 222, an optical coupling arrangement 223, and a regulator 224. Moreover, the bias circuit 220 is circuited between the signal input line 205 and a control terminal of the amplifying device 210 (e.g. a gate or base electrode of a transistor). Furthermore, the second bias circuit 270 is circuited between the signal input line 205 and a control terminal of the second amplifying device 260. The bias circuit 220 provides a (first) bias voltage on a control line 225 to the amplifying device 210, and the second bias circuit 270 provides a second bias voltage on a second control line 275 to the second amplifying device 260.

Dependent on a current provided by the first current source 240 to the bias circuit 220, a voltage drop over the first resistor 221 and the second resistor 222, which are circuited in series, may provide a basis for the bias voltage on the control line 225, provided to the amplifying device 210. However, as the first current source 240 may provide an inexact current or non-accurate current to the bias circuit 220, the voltage drop over the first resistor 221 and the second resistor 222 may deviate from a desired bias voltage. Therefore, the optical coupling arrangement 223 may change the voltage drop over the first resistor 221 such that the bias voltage on the control line 225 may be brought closer to a desired voltage. The optical coupling arrangement 223 takes as input a control signal

223a, which may be electric, and is converted to an optical signal in the optical coupling arrangement. Based on the optical signal, the optical coupling arrangement 223 provides an output current which provides a (positive or negative) contribution to the voltage drop over the first resistor 221, thereby, influencing the bias voltage on the control line 225. In the described manner, the optical coupling arrangement 223 allows for a control of the bias voltage through the control signal 223a. Moreover, the control signal 223a is electrically isolated from the bias voltage 225 based on an optical transmission in the optical coupling arrangement 223.

The second bias circuit 270 may act according to the bias circuit 220, based on a second control signal 273a and a current provided by the second current source 290. Moreover, the first current source 240 and the second current source 290 provide defined currents to the amplifier 200 based on voltages of the positive supply voltage terminal 242 and the negative supply voltage terminal 292. Furthermore, an input signal fed into the amplifier through the signal input line 205 will be output amplified as the output signal of the amplifier 235. For example, the signal input line 205 may have (comparatively) high impedance, and therefore a current of a signal input may be (comparatively) small. An output signal of the amplifier 200, provided via the output signal line 235 may, therefore, provide an output signal with a higher current than an input signal.

Fig. 3 shows a schematic of a circuit 300 for trimming a bias voltage according to embodiments of the invention. The circuit 300 comprises a controlled source 310 and a first resistor 320. The controlled source 310 is controlled via an optical signal 305 and the first resistor 320 is circuited in parallel to the controlled source 310. Moreover, the controlled source 310 is configured to change a voltage drop 325 across the first resistor 320, to thereby trim the bias voltage.

The controlled source 310 takes as input an optical signal 305 to provide a current through the first resistor 320. The current provided to the first resistor 320 causes a changed voltage drop 325 over the first resistor 320. Based on the voltage drop 325 over the first resistor 320, a (positive or negative) contribution to the bias voltage is provided, for example, a bias voltage for an amplifying device (e.g., a transistor). Moreover, based on the optical signal 305, the voltage drop 325 can be trimmed, i.e., adjusted, such that a contribution to a bias voltage is provided which may serve to bring an amplifying device, using the bias voltage, closer to a desired operating point of the amplifying device. Moreover, through the optical signal 305, an isolation of the circuit 300 from a circuit

producing the optical signal 305 is provided, which may be beneficial to avoid damaging a circuit producing the optical signal 305 from high voltages or currents in a circuit in which the circuit 300 may be integrated.

5 Fig. 4 shows a schematic of a circuit 400 for trimming a bias voltage according to embodiments of the invention. The circuit 400 comprises a controlled source 410, a first resistor 420, a second resistor 430 and regulator 440. The first resistor 410 and the second resistor 420 can be grouped into a voltage divider 435 (i.e., may be circuited in series).

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Furthermore, the circuit 400 is circuited between a signal input line 455 and an amplifying device 450. In particular, the circuit 400 provides a bias voltage 425b to a control terminal of the amplifying device 450. In other words, the circuit 400 serves to bias the amplifying device 450 from a voltage of the signal input line 455. Therefore, a substantially constant
15 voltage shift between the signal input line 455 and the amplifying device 450 (or a control terminal thereof) is obtained. Moreover, in the circuit 400 the bias voltage 425b is influenced by a voltage drop 425a over the first resistor 420 (e.g., the voltage drop 425a is part of the voltage drop 425b). The voltage drop 425a is thus influenced by a current 411 provided by the controlled source 410 through the first resistor 420. Further, the
20 controlled source 410 takes for control of the current 411 provided to the first resistor 420, an optical control signal 405 as input. The optical control signal 405 defines the amount of the current 411 provided to the first resistor 420. Thereby, the voltage drop 425a over the first resistor 410 of the circuit 400 can be controlled. Moreover, the bias voltage 425b may comprise the voltage drop 425a and a voltage drop over the second resistor 430. Thereby
25 the voltage drop 425a may directly influence the bias voltage 425b.

Furthermore, the regulator 440 of the circuit 400 is configured to limit the bias voltage 425b based on a voltage drop over the second resistor 430. In other words, the regulator 440 avoids excessive bias voltages 425b which may be harmful, e.g., to the amplifying
30 device 450 or the circuit 400. The regulator 440 may operate by rerouting or diverting a current, which would usually flow through the voltage divider 435 (e.g., comprising the first resistor 420 and the second resistor 430), through the regulator 440. As the current is diverted from the voltage divider 435, a changed voltage drop over the voltage divider 435 is obtained reducing or limiting the bias voltage 425b. In embodiments, a voltage over the
35 voltage divider 435 may directly serve as the bias voltage 425b. For example, a voltage drop over the second resistor 430 may be regulated to take a predetermined value by the

regulator. Thus, the bias voltage may, for example, be the sum of an approximately fixed voltage drop over the second resistor 430 and an available voltage drop, adjusted by the optical coupling element, over the first resistor.

5 Fig. 5 shows a detailed schematic of an amplifier 500 according to embodiments of the invention. The amplifier 500 comprises an (first) amplifying device 510, a second amplifying device 560, a (first) bias circuit 520, a second bias circuit 570, a first current source 540 and a second current source 590.

10 The (first) bias circuit 520 is circuited between a control terminal of the first amplifying device 510 and a signal input line 505 and the (first) bias circuit 520 and the first current source 540 are coupled to a first control node 543, which is coupled to a control terminal (e.g. gate terminal) of the first amplifying device 510 via an (optional) resistor and the first control line 545. The second bias circuit 570 is circuited between the signal input line 505
15 and a control terminal of the second amplifying device 560 and the second bias circuit 570 and the second current source 590 are coupled to a second control node 593, which is coupled to a control terminal (e.g. gate terminal) of the second amplifying device 560 via an (optional) resistor 594 and the second control line 595. Furthermore, the first current source 540 is circuited between a positive supply voltage terminal 542 and the first control
20 node 543. The second current source 590 is circuited between a negative supply voltage terminal 592 and the second control node 593. Moreover, a first capacitor 546 is circuited between the signal input line 505 and the first control node 543 and a second capacitor 596 is circuited between the signal input line 505 and the second control node 593. Further, the first capacitor 546 is circuited in parallel to the first bias circuit 520 and the
25 second capacitor 596 is circuited in parallel to the second bias circuit 570.

The first current source 540 and the second current source 590 each comprise a transistor, i.e., bipolar junction transistor (BJT) 541 (PNP type) and bipolar junction transistor 591 (NPN type), wherein the transistors 541 and 591 are adjusted to provide
30 predefined currents to the first control node 543 and the second control node 593. In a steady state the current provided by the first current source 540 flows through the first bias circuit 520 and the current provided by the second current source 590 flows through the second bias circuit 570. The adjustment of the transistors is performed on the basis of two diodes and a resistor, circuited between a control terminal (e.g. a base terminal) of the
35 transistors 541 and 591 and a source terminal of the transistors 541 and 591. In other words, the two diodes provide each a voltage drop of about 0.7V which is equal to a sum

of a voltage drop over the control terminal and the source terminal and a voltage drop over the resistor, thereby, adjusting a current through the resistors 541 and 591. The first current source 540 and the second current source 590 each provide substantially identical currents with inverted polarity, such that a current flowing through the first bias circuit 520 is identical to a current flowing through the second bias circuit 570.

The (first) amplifying device 510 is an n-channel field effect transistor (e.g. an n-channel MOSFET (Metal-Oxide-Semiconductor Field Effect transistor)) and the second amplifying device 560 is a p-channel field effect transistor (e.g. a p-channel MOSFET). Furthermore, the (first) bias circuit 520 comprises an optocoupler (optical coupling arrangement) 523 which provides for an opto isolation, a first resistor 521, a second resistor 522, and a regulator 524. The regulator 524 may also be referred to as an adjustable Zener diode or an adjustable Zener shunt regulator. The optocoupler 523 comprises an optional control circuit to actively control a current provided to the first resistor 521. The first resistor 521 and the second resistor 522 are circuited in series and form the voltage divider 525, which is circuited between the signal input line 505 and the first control line 545. A first terminal of the first resistor 521 is coupled to the first control node 543, a second terminal of the first resistor 521 is coupled to a first terminal of the second resistor 522 and a second terminal of the second resistor 522 is coupled to the signal input line 505. Further, the optocoupler is circuited in parallel to the first resistor 521, wherein a positive terminal of the optocoupler 523 is coupled to the first terminal of the first resistor 521 and a negative terminal of the optocoupler 523 is coupled to the second terminal of the first resistor 521. The regulator 524 comprises a cathode, an anode and a reference node. The reference node is coupled to the middle node of the voltage divider 525, the anode is coupled to the signal input line 505 and the cathode is coupled to the first control node 543.

Moreover, the bias circuit 520 is configured to provide a bias voltage between the signal input line 505 and the first control line 525. Furthermore, the bias circuit 520 is configured to adjust or tune the bias voltage based on an input control signal 523a of the optical coupling arrangement 523. Based on an output signal of the optical coupling arrangement 523 a current is provided to the first resistor 521 to provide a (positive or negative) contribution to a voltage drop over the first resistor 521. The optocoupler 523 is a photovoltaic MOSFET driver, which may, for example, act as an active element and is capable to provide a short circuit output current and an open circuit output voltage in the presence of an optical excitation. For example, the optocoupler 523 and the first resistor 521 may be designed such that an output current of the optocoupler 523, which is

provided in the presence of an optical excitation, causes a voltage (or voltage variation) over the first resistor 521 of at least 5mV, to thereby allow for a variation of an operating point. When the reference voltage obtained by the regulator 524 is exceeding a limit, the regulator 524 offers a low impedance path in parallel to the voltage divider and therefore
5 may reduce a voltage drop over the voltage divider 525, through regulation of the voltage drop over the second resistor 522. Thereby, excessive bias voltages can be avoided which could potentially harm the amplifying devices 510 and 560. Thus the voltage drop across the second resistor 522 is kept substantially constant, and a change of the voltage across the first resistor 521, which is caused by the optocoupler 523, results in a change
10 of the operating point.

Generally, the first capacitor 546 is circuited between the signal input line 505 and the first control line 545 such that a substantially constant voltage difference (which can nevertheless be adjusted by the optocoupler 523) is retained between the signal input line
15 505 and the first control line 545. Moreover, the substantial constant voltage serves to bias the first amplifying device 510. Further, the second capacitor 596 is circuited between the signal input line 505 and the second control line 595 such that a substantially constant voltage difference is retained between the signal input line 505 and the second control line 595. Moreover, the substantial constant voltage serves to bias the second amplifying
20 device 560. Furthermore, the first capacitor 546 may serve to smooth a change of the voltage drop caused by the bias circuit 520. Further, the substantially constant voltage differences are retained, when an input signal on the signal input line 505 varies the voltage on the signal input line 505.

25 The second bias circuit 570 comprises elements which are similar to elements of the (first) bias circuit 520 but is not necessarily equipped with an optocoupler such as the optical coupling arrangement 523. In embodiments, however, the second bias circuit 570 may also comprise an optical coupling arrangement (e.g. optocoupler 523).

30 Fig. 6 shows a flow chart of a method 600 for amplifying an input signal according to embodiments of the invention. A method 600 comprises providing 610 a bias voltage for an amplifying device, wherein the bias voltage is provided in dependence of an output signal of an optical coupling arrangement which provides for an electrical isolation.

35 Fig. 7 shows a flow chart of a method 700 for trimming a bias voltage according to embodiments of the invention. The method 700 comprises controlling 710 a controlled

source via an optical signal. Further, the method 700 comprise changing 720 a voltage drop across a first resistor, circuited in parallel to the controlled source, to thereby trim the bias voltage.

5 Further Aspects

In the following, some further aspects of the invention will be described which can be used individually or in combination with any of the other embodiments described herein.

- 10 It has been found that, power amplifiers require a thorough control of the output stage to optimize signal fidelity versus standby current consumption. To ensure performance the cross current in the output transistors needs to be well adjusted. This requires exact process control or trimming (potentiometer) before shipment of amplifier product. Some traditional designs use high voltage current mirrors to transfer the ground related trim
15 signal to the level of the power output stage.

Apparatuses and methods according to embodiments of the invention allow trimming a performance of a power stage in application and may not require trim steps during product manufacturing or sophisticated process control. For high voltage amplifiers also the circuit
20 size is reduced.

Advantages of embodiments compared to conventional concepts are:

- Eliminating a manual manufacturing trimming of power stages.
- 25 - Enables low cost production of power stages.
- Allows for isolated design which enables a reduced component size for high voltage amplifiers.

In embodiments, a cross current of a power amplifier output stage is controlled by a
30 voltage difference of the transistor control voltage (Class A output stage): bias voltage.

In embodiments, the output current of a solar cell is used to tune the bias voltage of output FETs. Also an isolating opto-coupler in linear operation may be used to influence the bias voltage.

In embodiments, an opto-isolated input control voltage or current is used to modify the bias voltage independence of the amplifier output voltage. The bias voltage controls the cross current through output transistors.

- 5 In embodiments, a control signal can be created by a DAC (digital to analog converter) or filtered PWM (pulse width modulated) signal from low voltage based circuitry.

In embodiments, by running AC performance tests at different bias settings, an optimum power stage performance can be determined at any time (also after product shipment).

Claims

1. An amplifier (100; 200; 500), comprising:

5 an amplifying device (110; 210; 510); and

a bias circuit (120; 220; 520) for providing a bias voltage for the amplifying device;

wherein the bias circuit is configured to provide the bias voltage in dependence on
10 an output signal of an optical coupling arrangement (130; 223; 523) which provides
for an electrical isolation.
2. Amplifier according to claim 1, wherein the bias circuit is configured to adjust the
bias voltage based on the output signal of an optical coupling arrangement, when
15 an operating point of the amplifying device deviates from a desired operating point.
3. Amplifier according to claim 1 or claim 2, wherein the bias circuit comprises a first
resistor (221; 521) circuited in parallel to the optical coupling arrangement, wherein
the first resistor is coupled to a control terminal of the amplifying device, and
20 wherein the optical coupling arrangement is configured to provide a contribution to
a voltage drop over the first resistor, wherein the voltage drop over the first resistor
is configured to adjust the bias voltage.
- 25 4. Amplifier according to claim 3 wherein the bias circuit comprises a regulator (224;
524) circuited in parallel to the first resistor and a second resistor (222; 522),
wherein the second resistor is circuited in series to the first resistor, and

wherein the regulator is configured to limit the bias voltage based on a voltage
30 drop over the second resistor.
5. Amplifier according to claim 4, wherein the regulator is configured to limit the bias
voltage by offering a low impedance path in parallel to the first resistor and the
second resistor through the regulator when the voltage drop over the second
35 resistor exceeds a limit.

6. Amplifier according to claim 4 or claim 5, wherein the regulator is configured to limit the bias voltage based on a voltage at a middle node of a voltage divider (525), wherein the voltage divider comprises the first resistor and the second resistor, wherein a voltage drop over the voltage divider provides the bias voltage, and wherein the voltage drop over the voltage divider is influenced by the output signal of the optical coupling arrangement.
7. Amplifier according to one of the claims 1 to 6, wherein the optical coupling arrangement is configured to receive a control signal (223a) to provide an optical signal on the basis of the control signal and to provide the output signal of the optical coupling arrangement on the basis of the optical signal, wherein the output signal of the optical coupling arrangement is electrically isolated from the control signal.
8. Amplifier according to claim 7, wherein the optical coupling arrangement is configured to receive a pulse width-modulated control signal.
9. Amplifier according to according to claim 7 or claim 8, wherein the amplifier is configured to adjust the control signal in dependence of a cross current of the amplifying device.
10. Amplifier according to one of the claims 7 to 9, wherein the amplifier is configured to adjust the control signal based on a measurement of a characteristic of an output signal of the amplifier.
11. Amplifier according to claim 10, wherein the amplifier is configured to measure a characteristic of an output signal of the amplifier by stepping through various bias voltage settings.
12. Amplifier according to one of the claims 1 to 11, wherein the amplifier comprises:
- a signal input line (205; 505) configured to receive an input signal to be amplified,
- a positive supply voltage terminal (242; 542), and
- a negative supply voltage terminal (292; 592),

wherein the positive supply voltage terminal and the negative supply voltage terminal are configured to provide supply voltages to the amplifier,

5 wherein the bias circuit is circuited between the signal input line and a control terminal of the amplifying device, to allow for an optically isolated adjustment of a voltage shift between the signal input line and the control terminal.

13. Amplifier according to claim 12, wherein the amplifier comprises a first current
10 source (240; 540) circuited between the positive supply voltage terminal and the bias circuit, wherein the first current source is configured to provide a predefined current to the bias circuit.

14. Amplifier according to claim 12 or claim 13, wherein the amplifier comprises a
15 second current source (290; 590), and a second bias circuit (270; 570), wherein the second current source is circuited between the negative supply voltage terminal and the second bias circuit, wherein the second current source is configured to provide a predefined current to the second bias circuit based on a voltage provided by the negative supply voltage terminal.

20 15. Amplifier according to one of the claims 1 to 14, wherein the amplifying device is configured to provide a positive output signal of the amplifier when a positive input signal is applied, wherein the output signal has an equal or higher current than the input signal.

25 16. Amplifier according to one of the claims 1 to 15, wherein the amplifier comprises a second amplifying device (260; 560), wherein the second amplifying device is configured to provide a negative output signal of the amplifier when a negative input signal is applied to the amplifier, wherein the output signal has an equal or
30 higher current than the input signal.

17. Method (600) for amplifying an input signal comprising:

providing (610) a bias voltage for an amplifying device,

wherein the bias voltage is provided in dependence of an output signal of an optical coupling arrangement which provides for an electric isolation.

18. Circuit for trimming (300; 400; 520) a bias voltage, comprising:

a controlled source (310; 410; 523), wherein the controlled source is controlled via an optical signal; and

a first resistor (320; 420; 521);

wherein the first resistor is circuited in parallel to the controlled source; and

wherein the controlled source is configured to change a voltage drop across the first resistor, to thereby trim the bias voltage.

19. Circuit according to claim 18, wherein the first resistor is coupled to a control terminal of an amplifying device (450; 510), in order to provide the trimmed bias voltage to the amplifying device.

20. Circuit according to claim 19, wherein the circuit is configured to trim the bias voltage based on a measurement of a characteristic of an output signal of the amplifying device.

21. Circuit according to claim 20, wherein the circuit is configured to measure the characteristic of the output signal of the amplifying device by stepping through various bias trim settings.

22. Circuit according to one of the claims 19 to 21, wherein the circuit is configured to trim the bias voltage based on a cross current through the amplifying device.

23. Circuit according to one of the claims 18 to 22, wherein the circuit for trimming the bias voltage is circuited between a signal input line (455; 505) for receiving an input signal to be amplified and a control terminal of the amplifying device, wherein a voltage between the signal input line and the control terminal serves to bias the amplifying device

24. Circuit according to one of the claims 18 to 23, wherein the circuit comprises a regulator (440; 524) circuited in parallel to the first resistor and a second resistor, wherein the second resistor and the first resistor are circuited in series, and

5 wherein the regulator is configured to limit the bias voltage based on a voltage drop over the second resistor.

25. Circuit according to claim 24, wherein the regulator is configured to limit the bias voltage by offering a low impedance path in parallel to the first and the second resistor through the regulator when the voltage drop over the second resistor exceeds a limit.

26. Circuit according to claim 24 or claim 25, wherein the regulator is configured to limit the bias voltage based on a voltage at a middle node of a voltage divider (435; 525), wherein the voltage divider comprises the first resistor and the second resistor, wherein a voltage drop over the voltage divider provides the bias voltage, and wherein the voltage drop over the voltage divider is influenced by an output signal of the controlled source.

20 27. Circuit according to one of the claims 18 to 26, wherein the controlled source is configured to receive an optical control signal (405) on the basis of an electrical control signal and to provide an output signal (411) of the controlled source on the basis of the optical control signal, wherein the output signal of the controlled source is electrically isolated from the electrical control signal.

25 28. Circuit according to claims 18 to 27, wherein the controlled source is configured to receive an optical control signal which is based on a pulse width-modulated electrical control signal.

30 29. Method (700) for trimming a bias voltage comprising:

controlling (710) a controlled source via an optical signal,

35 changing (720) a voltage drop across a first resistor, circuited in parallel to the controlled source, to thereby trim the bias voltage.

100

1/7

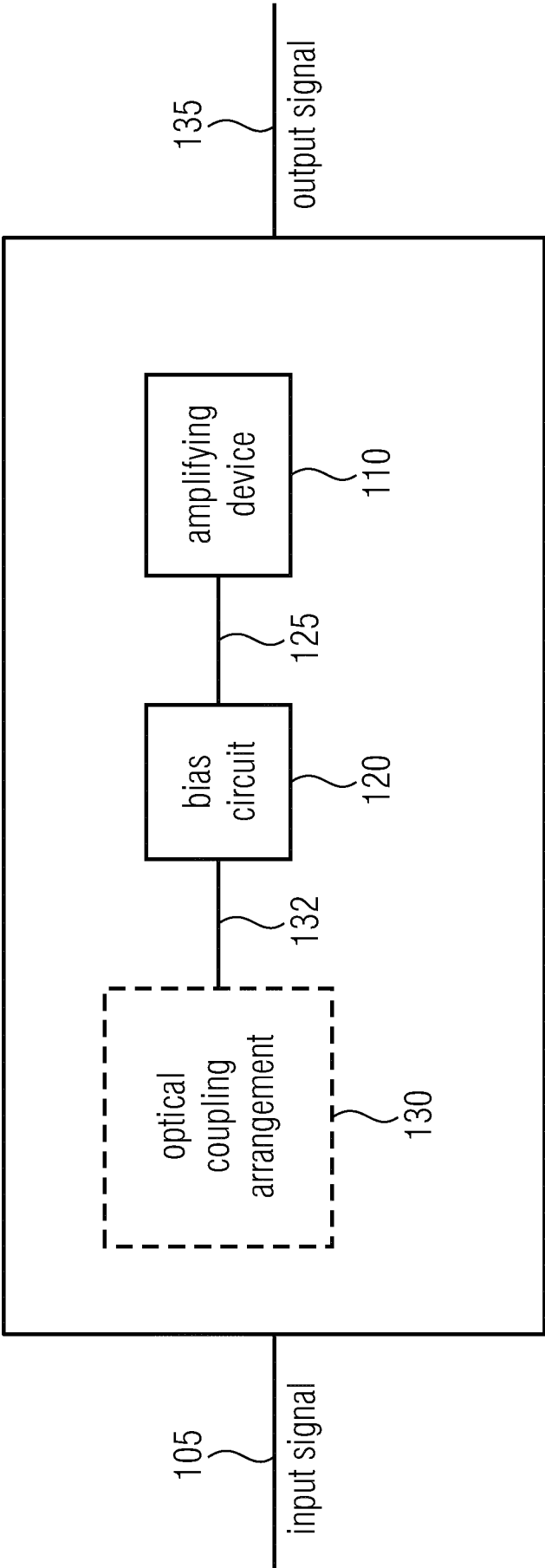


Fig. 1

200

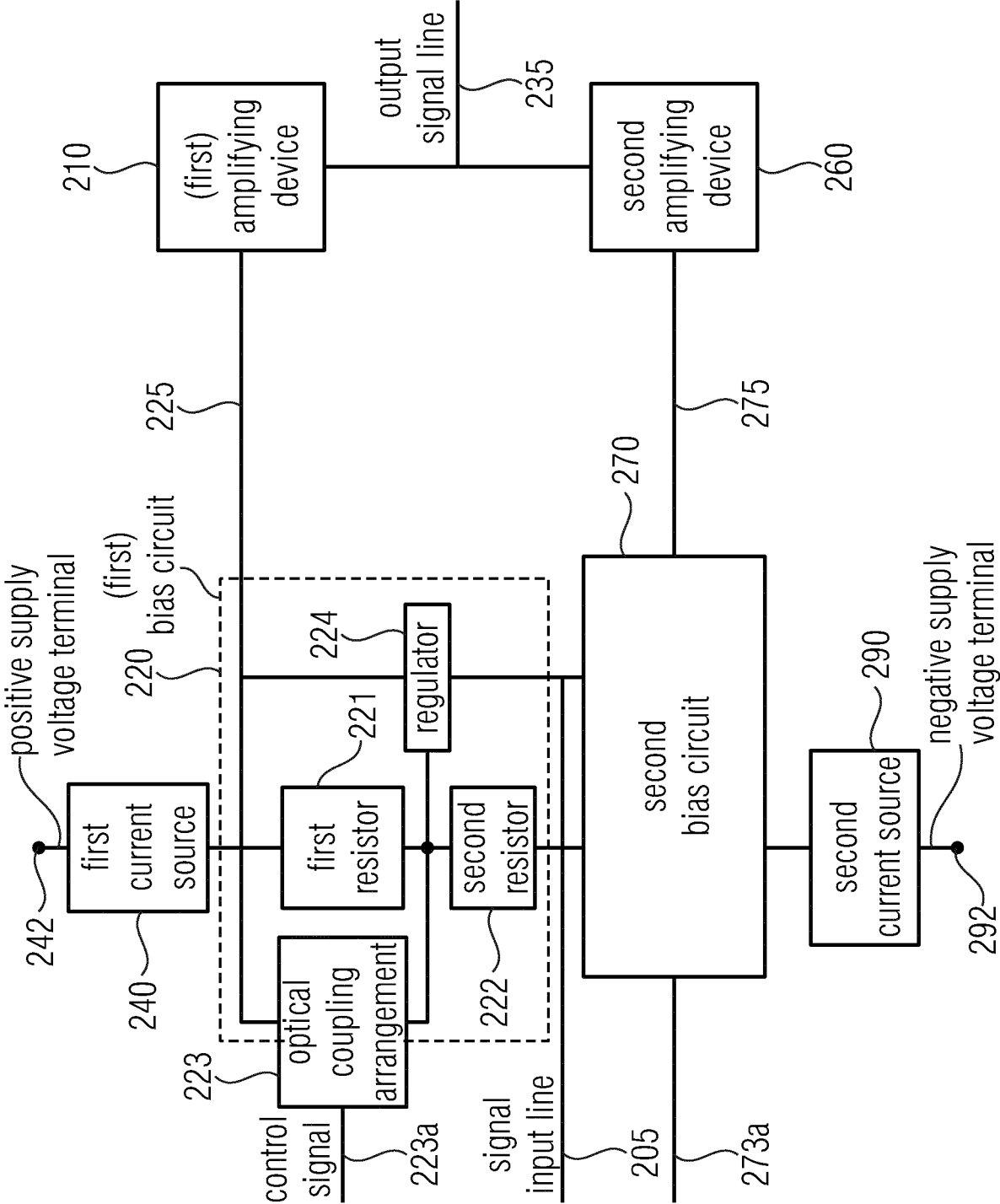


Fig. 2

300

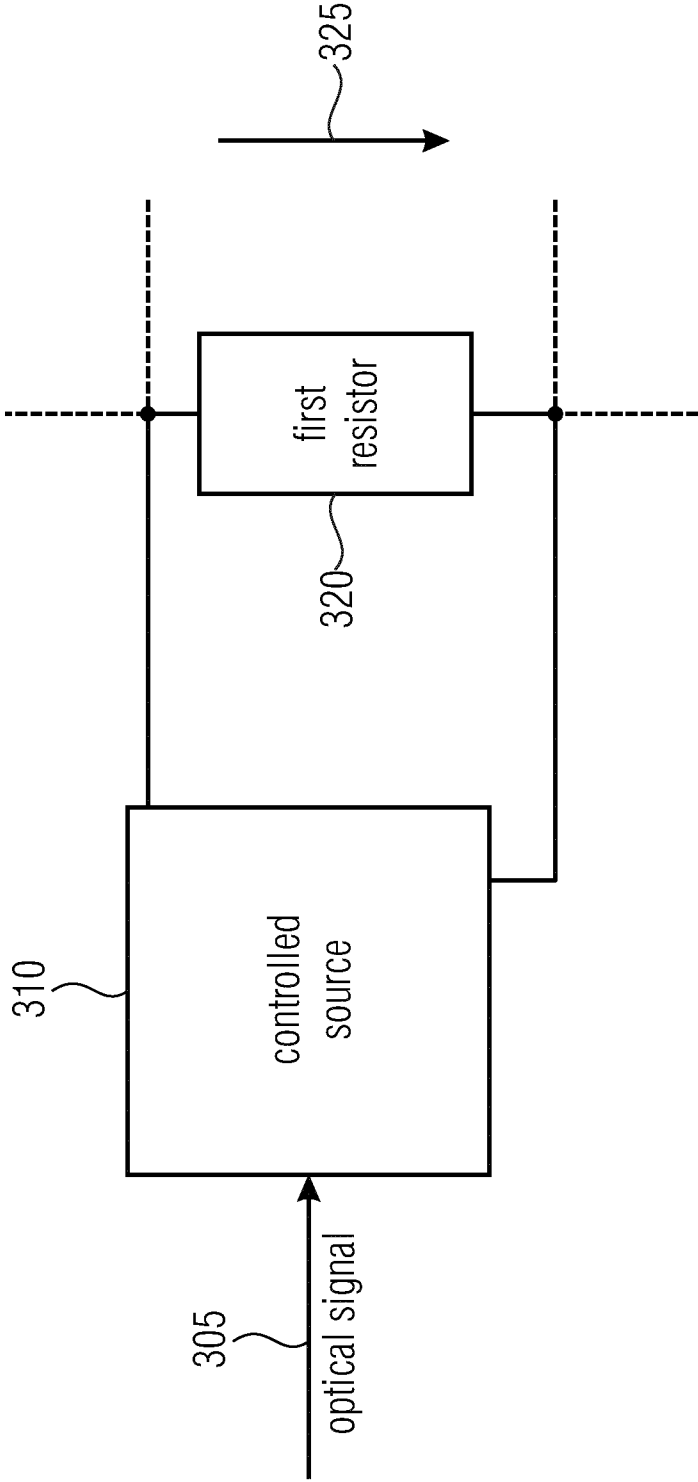


Fig. 3

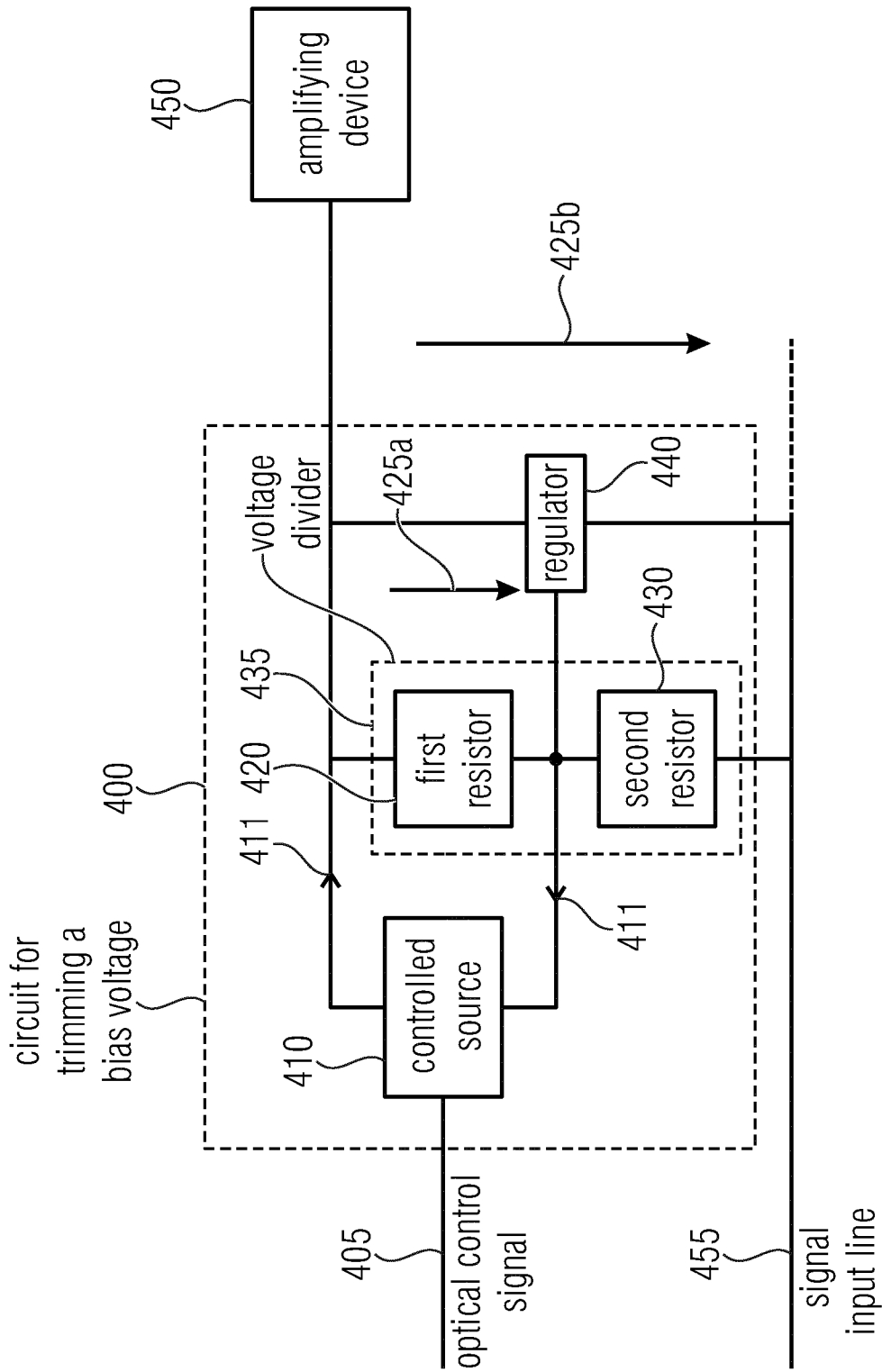


Fig. 4

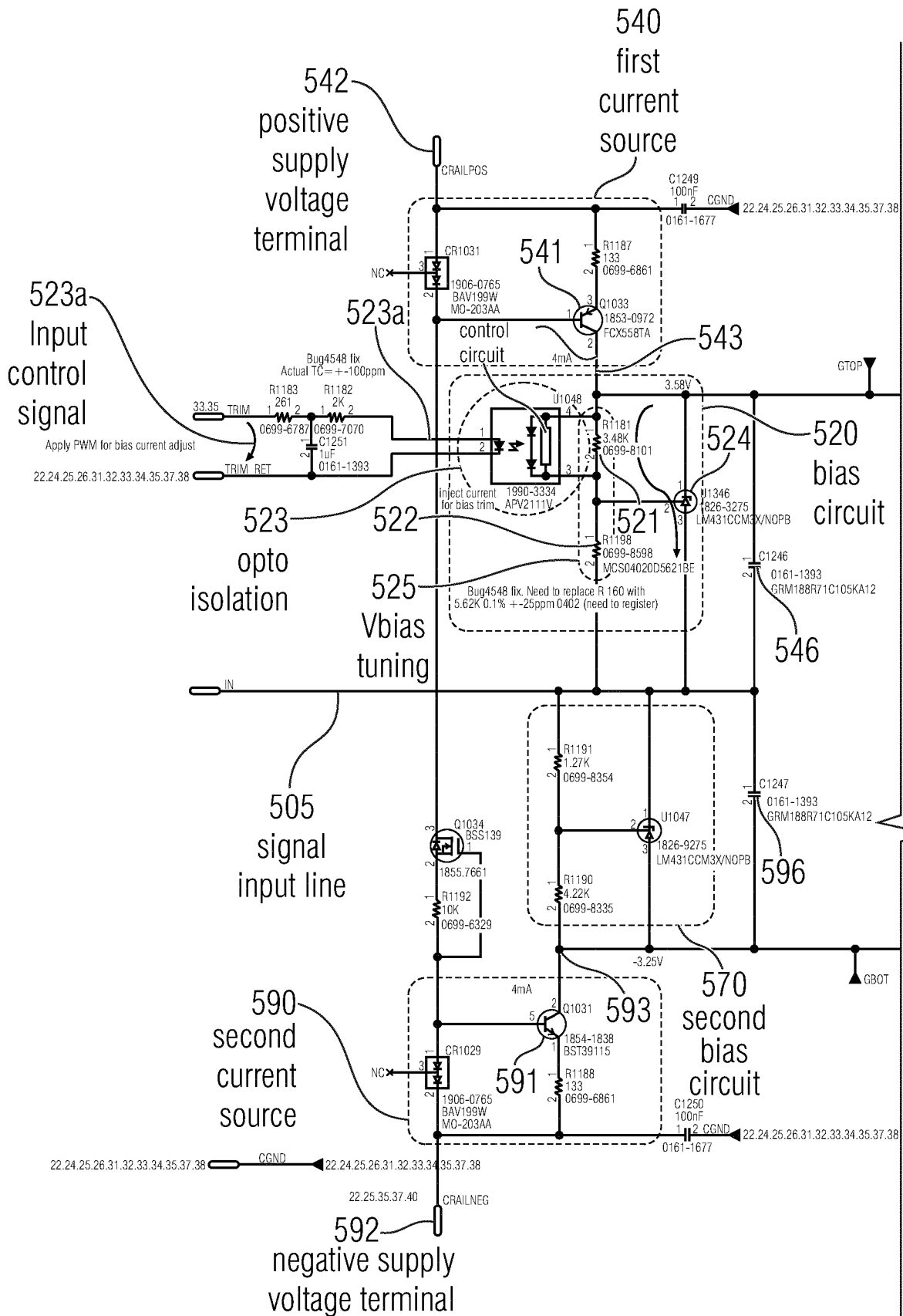


Fig. 5	
Fig. 5A	Fig. 5B

Fig. 5A

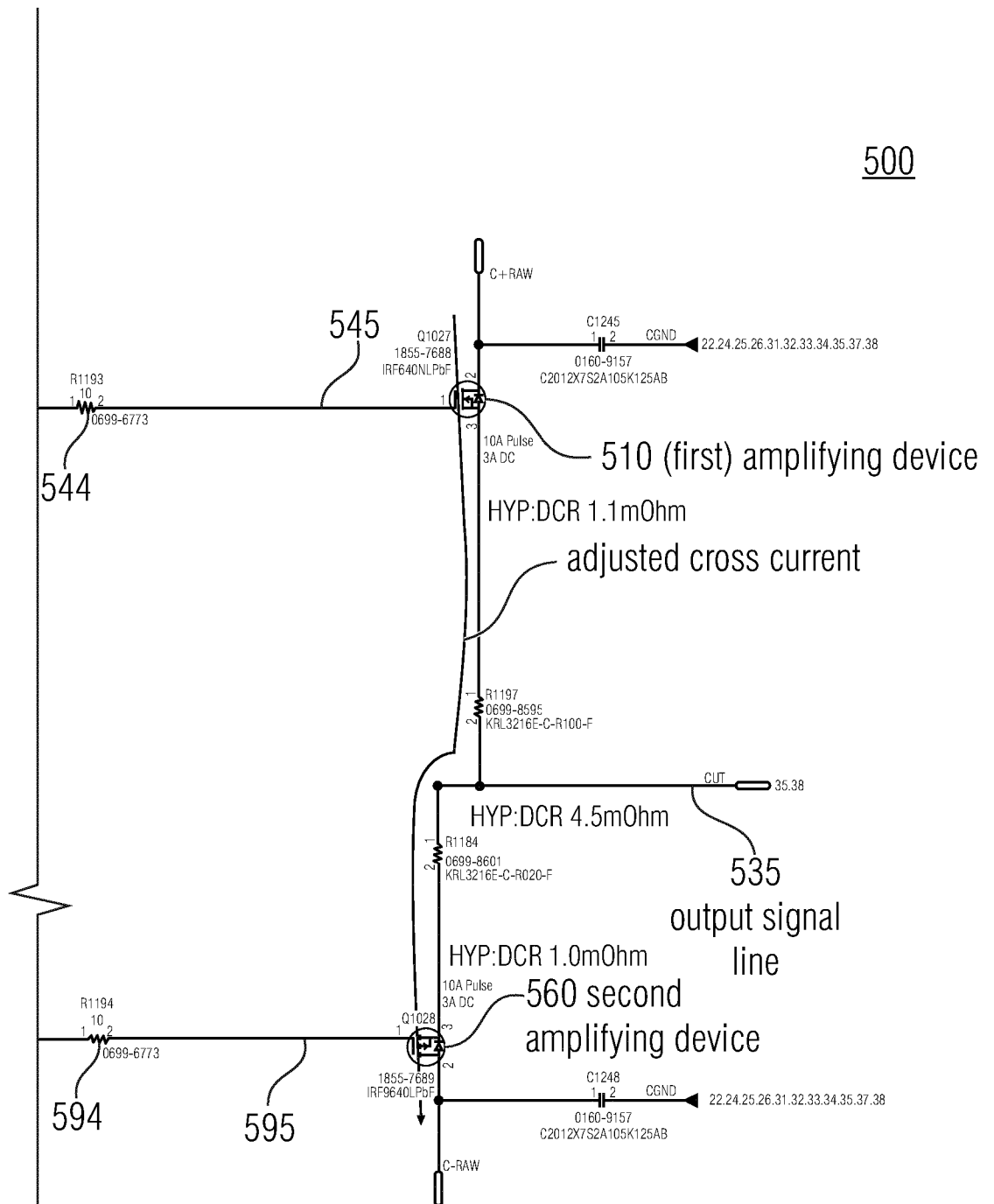
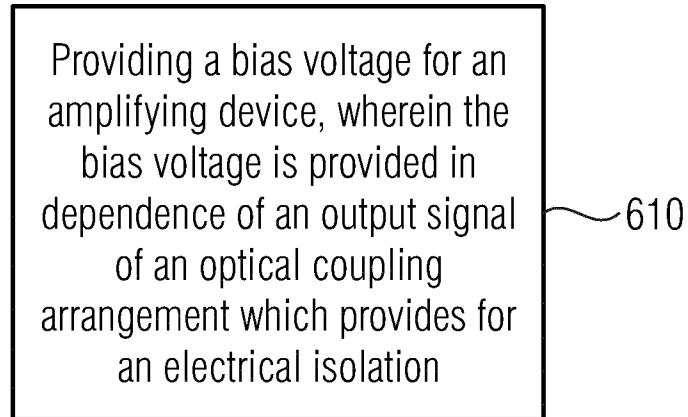
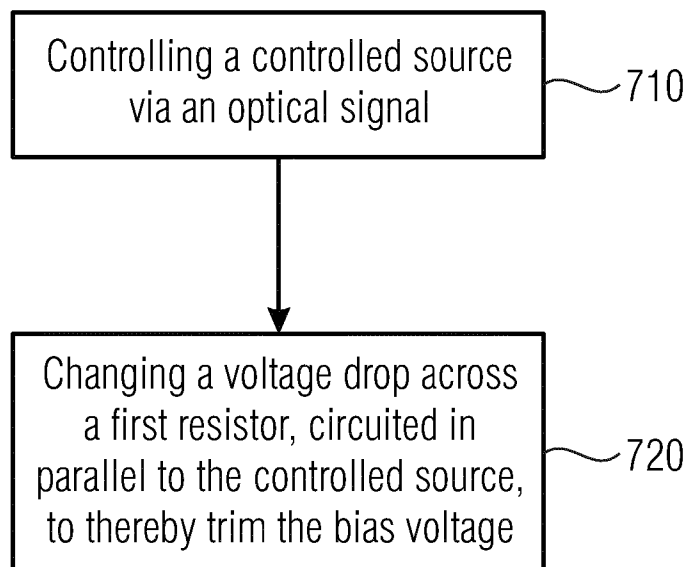
500

Fig. 5B

Fig. 5	
Fig. 5A	Fig. 5B

600**Fig. 6**700**Fig. 7**

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/060254

A. CLASSIFICATION OF SUBJECT MATTER INV. H03F1/30 H03F3/30 H03F3/08 H03F1/02 H03F3/21 ADD.		
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) H03F		
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) 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 4 638 260 A (HAMLEY JAMES P [US]) 20 January 1987 (1987-01-20) column 2, line 13 - column 19, line 16; figures 1,2,3,4a,4b,5a,5b,5c,6,7 -----	1-29
X	US 5 216 379 A (HAMLEY JAMES P [US]) 1 June 1993 (1993-06-01) column 2, line 31 - column 12, line 21; figures 1,2,6A,6B,7 -----	1-29
A	GB 1 234 983 A (PHILIPS ELECTRONIC ASSOCIATED [GB]) 9 June 1971 (1971-06-09) page 1, left-hand column, line 10 - page 3, left-hand column, line 15; figure 1 -----	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 20 December 2017		Date of mailing of the international search report 08/01/2018
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Fedi, Giulio

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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