



(51) International Patent Classification:

H03F 3/45 (2006.01) *H03K 5/1532* (2006.01)
G01R 19/04 (2006.01)

(21) International Application Number:

PCT/US2019/037864

(22) International Filing Date:

19 June 2019 (19.06.2019)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/744,276 11 October 2018 (11.10.2018) US
16/411,449 14 May 2019 (14.05.2019) US

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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,

(54) Title: OPERATIONAL AMPLIFIER WITH CONTROLLABLE OUTPUT MODES

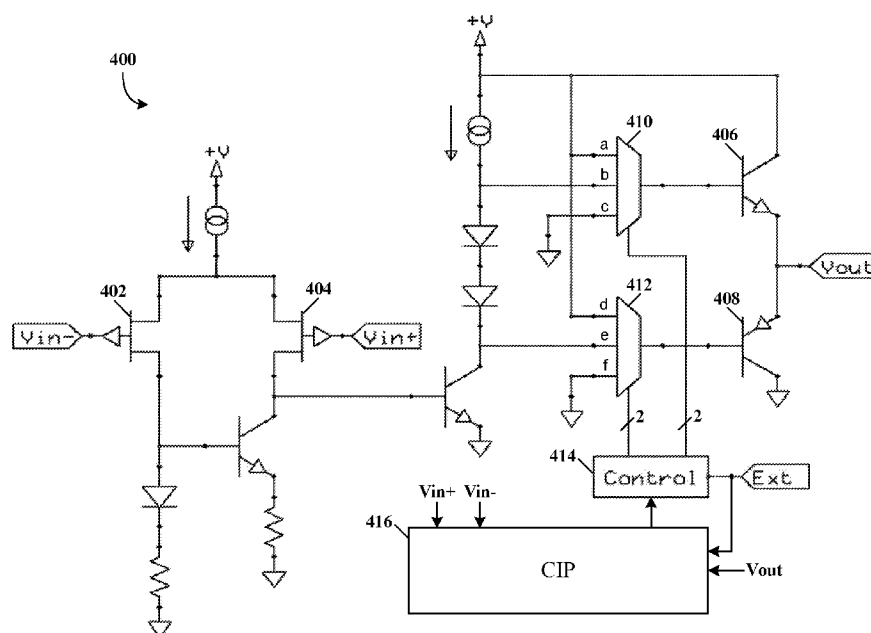


FIGURE 8

(57) **Abstract:** An operational amplifier with totem pole connected output transistors having inputs coupled to multiplexers for selectable coupling of signals and voltage levels thereto. The high and low output transistors may be forced hard on or hard off in addition to normal coupling of signals thereto. The operation of the output transistors may be dynamically changed to pass only positive going signals, negative going signals, placed in a tristate high impedance state, hard connected to a supply voltage and/or hard connected to supply common return. A core independent peripheral (CIP) may also be coupled to the operational amplifier for dynamically changing the multiplexer inputs in real time, as can external control signals to a control circuit coupled to the multiplexers.



CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
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TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

OPERATIONAL AMPLIFIER WITH CONTROLLABLE OUTPUT MODES

RELATED PATENT APPLICATION

This application claims priority to commonly owned United States Provisional Patent Application Serial Number 62/744,276; filed October 11, 2018; entitled “Operational
5 Amplifier with Peak Track and Hold Output Modes,” and is hereby incorporated by reference herein for all purposes.

TECHNICAL FIELD

The present disclosure relates to operational amplifiers and, more particularly, to an operational amplifier with controllable output modes.

BACKGROUND

10 AC coupled waveforms often require DC level restoration for processing. To accomplish this detection of minimum and maximum voltages of a signal waveform are needed to generate an offset. A circuit may be used to track a minimum or maximum voltage amplitude value of the signal waveform in real time and provides this voltage level to a DC level
15 restoration circuit. Typically, this tracking is accomplished with an operational amplifier and an external diode/transistor as shown in Figures 1a and 1b.

Known designs use an external diode/transistor to convert the totem pole output of an operational amplifier into a high side / low side only driver. This has two problems, the forward bias voltage of the diode/transistor reduces common mode range, and the inability to
20 dynamically control the output configuration limits the design to the circuit layout option selected. Furthermore, external switches are required to reset the operational amplifier output and/or do output signal blanking as shown in Figures 2a and 2b.

SUMMARY

Therefore, what is needed is a way to track maximum and/or minimum waveform
25 amplitudes in real time with increased common mode range and without requiring external diodes and/or switches coupled to the peak detection operational amplifier.

According to an embodiment, an operational amplifier having controllable output modes may comprise: a differential input transistor pair; a first multiplexer having a first input coupled to a supply voltage, a second input coupled to the differential input transistor pair, a
30 third input coupled to a supply common return and an output coupled to an input of a first

output transistor; a second multiplexer having a first input coupled to the supply voltage, a second input coupled to the differential input transistor pair, a third input coupled to the supply common return and an output coupled to an input of a second output transistor; and a control circuit coupled to the first and second multiplexers for selecting the inputs thereof.

5 According to a further embodiment, the first and second output transistors may be totem pole configured with an output therebetween, wherein the first output transistor may be coupled to the supply voltage and the second output transistor may be coupled to the supply common return. According to a further embodiment, the first output transistor may be hard on when the first input of the first multiplexer may be selected. According to a further embodiment, the
10 first output transistor may be controlled by the differential input transistor pair when the second input of the first multiplexer may be selected. According to a further embodiment, the first output transistor may be off when the third input of the first multiplexer may be selected. According to a further embodiment, the second output transistor may be off when the first input of the second multiplexer may be selected. According to a further embodiment, the second
15 output transistor may be controlled by the differential input transistor pair when the second input of the second multiplexer may be selected. According to a further embodiment, the second output transistor may be hard on when the third input of the second multiplexer may be selected.

 According to a further embodiment, an external connection to the control circuit may
20 be used for externally controlling the selection of the inputs of the first and second multiplexers. According to a further embodiment, a core independent peripheral (CIP) may be coupled to the control circuit. According to a further embodiment, the CIP may have inputs coupled to inputs of the differential input transistor pair for measuring voltages thereon. According to a further embodiment, the CIP may have an input coupled to an output of the first and second output
25 transistors for measuring an output voltage therefrom.

 According to another embodiment, a circuit for at least partially tracking an input signal may comprise: a differential input transistor pair having inputs coupled to a signal; a first multiplexer having a first input coupled to a supply voltage, a second input coupled to the differential input transistor pair, a third input coupled to a supply common return and an output
30 coupled to an input of a first output transistor; a second multiplexer having a first input coupled to the supply voltage, a second input coupled to the differential input transistor pair, a third

input coupled to the supply common return and an output coupled to an input of a second output transistor; the first and second output transistors may be totem pole configured with an output therebetween, wherein the first output transistor may be coupled to the supply voltage and the second output transistor may be coupled to the supply common return; and a control circuit
5 coupled to the first and second multiplexers for selecting the inputs thereof; wherein selection of a certain combination of the first and second multiplexer inputs determines what part of the signal may be tracked.

According to a further embodiment, a positive input voltage amplitude tracking circuit may be configured when the second input of the first multiplexer and the first input of the
10 second multiplexer may be selected. According to a further embodiment, a negative input voltage amplitude tracking circuit may be configured when the third input of the first multiplexer and the second input of the second multiplexer may be selected.

According to a further embodiment, a positive input voltage tracking and hold circuit may comprise: a capacitor coupled between the output of the first and second output transistors
15 and the supply common return; the second input of the first multiplexer may be selected; and the first input of the second multiplexer may be selected; whereby the capacitor may be charged when a voltage input to the differential input transistor pair may be positive. According to a further embodiment, the capacitor may be discharged when the third input of the first multiplexer and the third input of the second multiplexer may be selected.

According to a further embodiment, a negative voltage tracking and hold circuit may
20 comprise: a capacitor coupled between the output of the first and second output transistors and the supply voltage; the third input of the first multiplexer may be selected; and the second input of the second multiplexer may be selected; whereby the capacitor may be charged when a voltage input to the differential input transistor pair may be negative. According to a further
25 embodiment, the capacitor may be discharged when the first input of the first multiplexer and the first input of the second multiplexer may be selected.

According to a further embodiment, a maximum and minimum DC amplitude tracking and hold circuit may comprise: a capacitor may be coupled between the output of the first and second output transistors and the supply common return, the capacitor may be charged when
30 the second input of the first multiplexer and the first input of the second multiplexer may be

selected and a voltage input to the differential input transistor pair may be positive, and the capacitor may be discharged when the third input of the first multiplexer and the second input of the second multiplexer may be selected and the voltage input to the differential input transistor pair may be negative. According to a further embodiment, a control circuit may be coupled to the first and second multiplexers and control the selection of the first and second multiplexer inputs.

According to yet another embodiment, a method for configuring operation of an operational amplifier output may comprise the steps of: providing a first multiplexer having a first input coupled to a supply voltage, a second input coupled to a differential input transistor pair, a third input coupled to a supply common return and an output coupled to an input of a first output transistor; providing a second multiplexer having a first input coupled to the supply voltage, a second input coupled to the differential input transistor pair, a third input coupled to the supply common return and an output coupled to an input of a second output transistor; and selecting inputs of the first and second multiplexers to configure operation of the first and second output transistors. According to a further embodiment of the method, the step of selecting the inputs of the first and second multiplexers may be done with a core independent peripheral (CIP).

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present disclosure may be acquired by referring to the following description taken in conjunction with the accompanying drawings wherein:

Figure 1 illustrates prior art schematic and waveform diagrams of maximum and minimum DC amplitude tracking circuits comprising operational amplifiers and diode/transistors in the output path;

Figure 2 illustrates prior art schematic diagrams of maximum and minimum DC amplitude detection circuits with reset comprising operational amplifiers, diode/transistors and switches in the output path;

Figure 3 illustrates a schematic diagram of a typical operational amplifier;

Figure 4 illustrates a schematic diagram of an operational amplifier having controllable output modes, according to specific example embodiments of this disclosure;

Figure 5 illustrates schematic and waveform diagrams of maximum and minimum DC amplitude tracking circuits, according to specific example embodiments of this disclosure;

Figure 6 illustrates schematic and waveform diagrams of maximum and minimum DC amplitude tracking and hold circuits with reset capabilities, according to specific example
5 embodiments of this disclosure;

Figure 7 illustrates schematic and waveform diagrams of a maximum and minimum DC amplitude tracking and hold circuit with direction control, according to specific example embodiments of this disclosure; and

Figure 8 illustrates a schematic diagram of the operational amplifier shown in Figure 4
10 and a core independent peripheral, according to specific example embodiments of this disclosure.

While the present disclosure is susceptible to various modifications and alternative forms, specific example embodiments thereof have been shown in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific
15 example embodiments is not intended to limit the disclosure to the forms disclosed herein.

DETAILED DESCRIPTION

Embodiments of the present disclosure may comprise a device having an operational amplifier and multiplexers to control output configurations thereof. According to the teachings of this disclosure, this embodiment does not require an external device for maximum or
20 minimum peak waveform detection and has the added advantage that the output thereof may be tristate (switched to high impedance) to implement output blanking in the event of fast transient noise occurrences.

The operational amplifier may have multiple output modes; *e.g., inter-alia*, disable high side driver (off), disable low side driver (off), high side output transistor continuously on to rail voltage, low side output transistor continuously on to common, or tristate. If the low side
25 transistor is driven off, the operational amplifier may become a peak (maximum) track and hold amplifier. If the high side transistor is driven off, the operational amplifier may become a minimum amplitude track and hold amplifier. Because the operational amplifier configuration controls may be implemented as a core independent peripheral (CIP), external

logic may dynamically control both high and low drivers for peak/minimum hold with noise blanking.

A core independent peripheral (CIP) handles tasks with no code or supervision required by a central processing unit (CPU), *e.g.*, microcontroller core unit (MCU), to maintain operation thereof. Once initialized in a system, CIPs can provide steady-state closed loop embedded control with zero intervention from the MCU's core. The CPU can then be idled or put into SLEEP mode to save system power while the CIP may still maintain operation. CIPs may be, for example but are not limited to, a configurable operational amplifier, a numerically controlled oscillator (NCO), a configurable logic cell (CLC), an analog-to-digital converter (ADC) with state machines that don't need the CPU to transfer converted data, a pulse width modulator (PWM), a cyclic redundancy check (CRC), a math accelerator, a programmable switch mode controller, a watch dog timer, an angular timer, a complementary waveform generator (CWG), or timers, and the like. Microchip Technology Incorporated, the assignee of this application, provides more information on their CIPs at <https://www.microchip.com/design-centers/8-bit/peripherals/core-independent>.

The preferred embodiments disclosed herein simplify the implementation of a peak/min track and hold for automatic gain control (AGC) systems, DC level restoration, and peak hold systems that may comprise, but is not limited to, an integrated circuit function with only an external capacitor and/or resistor required.

Preferred embodiments of the present disclosure may comprise an operational amplifier CIP peripheral with the ability to disable the high side output driver and/or the low side driver using either software, and/or two internal CIP connections to timers/configurable logic cells (CLCs).

Only one component, *e.g.*, resistor or capacitor, need be coupled with the operational amplifier and the ability to dynamically change the output mode selection of the operational amplifier based upon internal digital controls. This also eliminates the need for an output switch to implement a noise blanking function.

Referring now to the drawings, the details of example embodiments are schematically illustrated. Like elements in the drawings will be represented by like numbers, and similar elements will be represented by like numbers with a different lower-case letter suffix.

Referring to Figures 1(a) and 1(b), depicted are prior art schematic and waveform diagrams of maximum and minimum DC amplitude tracking circuits comprising operational amplifiers and diode/transistors in the output path. The operational amplifier with an output diode shown in Figure 1(a) is a maximum amplitude waveform tracker and will provide positive going input voltages at its output referenced to a common voltage potential. The operational amplifier with an output diode shown in Figure 1(b) is a minimum amplitude waveform tracker and will provide negative going input voltages at its output referenced to a +V (e.g., 5 vdc) voltage potential.

Referring to Figures 2(a) and 2(b), depicted are prior art schematic diagrams of maximum and minimum DC detection circuits with reset comprising operational amplifiers, diode/transistors and switches in the output path. The external switches are necessary to perform the reset function. The operational amplifier with an output diode, capacitor and reset switches shown in Figure 2(a) is a maximum (peak) amplitude waveform detector and will provide positive going input voltages at its output referenced to a common voltage potential. The capacitor charges up to the maximum (peak) amplitude of the input waveform and will hold this maximum amplitude voltage until discharged by a switch shorting it to the common voltage potential. The operational amplifier with an output diode, capacitor and reset switches shown in Figure 2(b) is a minimum amplitude waveform detector and will provide negative going input voltages at its output referenced to a +V (e.g., 5 vdc) voltage potential. The capacitor charges up to the minimum amplitude of the input waveform and will hold this minimum amplitude voltage until discharged by a switch shorting it to the +V voltage potential.

Referring to Figure 3, depicted is a schematic diagram of a typical operational amplifier. The operational amplifier shown in Figure 3 may comprise differentially connected input transistors 302 and 304, and totem pole connected single ended output transistors 306 and 308. This operational amplifier may amplify the difference between the input voltages V_{in+} and V_{in-} and output that voltage difference as V_{out} (with or without amplification).

Referring to Figure 4, depicted is a schematic diagram of an operational amplifier having controllable output modes, according to specific example embodiments of this disclosure. An operational amplifier with controllable output modes, generally represented by the numeral 400, may be adaptable for maximum and minimum peak voltage detection, track and hold output modes. The operational amplifier 400 may comprise differential input

transistors 402 and 404, multiplexers 410 and 412, a control circuit 414, totem pole coupled output transistors 406 and 408, and other operational amplifier circuit components. The multiplexer 410 may be used to select what signal or voltage is provided to the base/gate of the transistor 406, and the multiplexer 412 may be used to select what signal or voltage is provided to the base/gate of the transistor 408. Control lines (two signals each) are used to couple the control circuit 414 to the multiplexers 410 and 412 for input selection thereof. By applying external control commands to the Ext input, *e.g.*, I²C, SPI, *etc.*, the output of the operational amplifier 400 may be configured as required. Example output configurations are described in Table I hereinbelow. Transistors 406 and 408 are shown in Figure 4 as bipolar junction transistors, however, metal oxide field effect transistors MOSFETs may be used equally effectively, wherein a drain is substantially equivalent to a collector, a gate is substantially equivalent to a base, and a source is substantially equivalent to an emitter.

When input a of multiplexer 410 is selected then transistor 406 is turned on hard and V_{out} is force to +V. When input b of multiplexer 410 is selected then the output of transistor 406 will be controlled by the differential input V_{in}, and V_{out} will follow V_{in}, as in the operational amplifier of Figure 3, unless transistor 408 is turned on hard (input f of multiplexer 412 is selected). When input c of multiplexer 410 is selected then transistor 406 will remain off.

When input d of multiplexer 412 is selected then transistor 408 will remain off. When input e of multiplexer 412 is selected then the output of transistor 408 will be controlled by the differential input V_{in}, and V_{out} will follow V_{in}, as in the operational amplifier of Figure 3, unless transistor 406 is turned on hard (input a of multiplexer 410 is selected). When input f of multiplexer 412 is selected then transistor 408 is turned on hard and V_{out} is force to a common voltage potential.

To set the output of operational amplifier 400 to a high impedance state (tristate), the following configuration may be used. When input c of multiplexer 410 is selected transistor 406 will be off, and when input d of multiplexer 412 is selected transistor 408 will be off, thereby putting the junction between transistors 406 and 408 (V_{out}) into a high impedance state. The various combinations of inputs a-f may be used to perform a high or a low reset, output signal blanking, tristate, open collector/drain, open emitter/source and totem pole output of the operational amplifier 400 as described in Table I below.

Referring to Table I below, depicted is a table summary of output configurations based upon multiplexer input selections for the operational amplifier circuit shown in Figure 4, according to specific example embodiments of this disclosure. Using the appropriate control signals from the control circuit 414, combinational input selections of multiplexer 410 inputs a, b or c; and multiplexer 412 inputs d, e or f may be selected (responsive to internal or external commands) resulting in the operation of the operational amplifier 400 having an output configured as, but is not limited to, what is listed in Table I below.

Table I

Output Configurations	Multiplexer Input Selections
Hi-Z Tristate (output transistors off)	Mux 410 (c), Mux 412 (d)
Totem pole output	Mux 410 (b), Mux 412 (e)
Open Collect/Drain	Mux 410 (c), Mux 412 (e)
Open Emitter/Source	Mux 410 (b), Mux 412 (d)
Force output to supply common return	Mux 410 (c), Mux 412 (f)
Force output to supply voltage	Mux 410 (a), Mux 412 (d)

Referring to Figures 5(a) and 5(b), depicted are schematic and waveform diagrams of maximum and minimum DC amplitude tracking circuits, according to specific example embodiments of this disclosure. The circuits shown in Figures 5(a) and 5(b) utilize the operational amplifier 400 having controllable output modes, as more fully described hereinabove. The circuit of Figure 5(a) may be used as a maximum amplitude waveform tracker by selecting (see Figure 4) the b input of multiplexer 410 and the d input of multiplexer 412. This configuration effectively allows the output of transistor 406 (V_{out}) to follow the positive excursions of the input V_{in} with the output V_{out} being pulled to common (ground) otherwise through the resistor coupled between the output and common, since transistor 408 is kept off responsive to the selected d input.

The circuit of Figure 5(b) may be used as a minimum amplitude tracker by selecting (see Figure 4) the c input of multiplexer 410 and the e input of multiplexer 412. This configuration effectively allows the output of transistor 408 (Vout) to follow the negative excursions of the input Vin with the output Vout being pulled to +V otherwise through the resistor coupled between the output and +V, since transistor 406 is kept off responsive to the selected c input.

Referring to Figures 6(a) and 6(b), depicted are schematic and waveform diagrams of maximum and minimum DC amplitude tracking and hold circuits with reset capabilities, according to specific example embodiments of this disclosure. The circuits shown in Figures 6(a) and 6(b) utilize the operational amplifier 400 having controllable output modes, as more fully described hereinabove. The operational amplifier circuit of Figure 6(a) may be used as a maximum amplitude tracking and hold circuit by selecting (see Figure 4) the b input of multiplexer 410 and the d input of multiplexer 412. This configuration effectively allows the output of transistor 406 (Vout) to follow the positive excursions of the input Vin and charge up the capacitor coupled between the output and common. Transistor 408 is kept off responsive to the selected d input. The voltage on the capacitor may be discharged by selecting the c input of multiplexer 410 and the f input of multiplexer 412.

The circuit of Figure 6(b) may be used as a minimum amplitude tracking and hold circuit by selecting (see Figure 4) the c input of multiplexer 410 and the e input of multiplexer 412. This configuration effectively allows the output of transistor 408 (Vout) to follow the negative excursions of the input Vin and charge the capacitor coupled between the output and +V. The voltage on the capacitor may be discharged by selecting the a input of multiplexer 410 to pull Vout up to +V (5 volts) via transistor 406, and the d input of multiplexer 412 to set transistor 408 to off.

Referring to Figure 7, depicted are schematic and waveform diagrams of a maximum and minimum DC amplitude tracking and hold circuit with direction control, according to specific example embodiments of this disclosure. The operational amplifier configuration shown in Figure 8 may be used during a positive half cycle to charge up a capacitor coupled between the output and the common voltage potential, and the capacitor may be discharged during a negative half cycle. The capacitor may be charged during a positive input voltage half cycle by selecting input b of the multiplexer 410 and input d of the multiplexer 412. The

capacitor may be discharged during a negative half cycle by selecting input c of the multiplexer 410 and input e of the multiplexer 412. This control may be accomplished using a direction control signal (Dir) to change input selections of the multiplexers 410 and 412. The direction control signal at input Dir and may be controlled for example with a timer (not shown) configured for the period of the input waveform and/or a voltage comparator (not shown) measuring the input voltage.

Figure 8 illustrates a schematic diagram of the operational amplifier 400 shown in Figure 4 and a core independent peripheral, according to specific example embodiments of this disclosure. A core independent peripheral (CIP) 416 may be coupled to the operational amplifier 400 shown in Figure 4. The CIP 416 may comprise at least one or more voltage comparator, a configurable logic cell (CLC), a voltage reference, an analog-to-digital converter (ADC), adder, subtractor, multiplier, divider, register, and the like. The CIP 416 may provide control signals to the control circuit 414 based upon voltage inputs V_{in+} and/or V_{in-} , voltage output V_{out} , and/or external control signals from the external port (Ext).

The output of preferred embodiments of the operational amplifier 400 disclosed herein may be put into a high impedance tristate mode by selecting input c of multiplexer 410 and input d of multiplexer 412. The tristate mode may be used for output signal blanking. Reset to common voltage potential may be done by selecting input c of multiplexer 410 and input f of multiplexer 412. Reset to +V may be done by selecting input a of multiplexer 410 and input d of multiplexer 412. These various multiplexer input combinations may be selected by external control signals (Ext node) to the control circuit 414, which may also be provided from the CIP 416. It is contemplated and within the scope of this disclosure that the supply common potential may be a negative supply voltage or power supply common return.

The present disclosure has been described in terms of one or more embodiments, and it should be appreciated that many equivalents, alternatives, variations, and modifications, aside from those expressly stated, are possible and within the scope of the disclosure. While the present disclosure is susceptible to various modifications and alternative forms, specific example embodiments thereof have been shown in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific example embodiments is not intended to limit the disclosure to the particular forms disclosed herein.

CLAIMS

What is claimed is:

1. An operational amplifier having controllable output modes, comprising:
a differential input transistor pair;
5 a first multiplexer having a first input coupled to a supply voltage, a second input coupled to the differential input transistor pair, a third input coupled to a supply common return and an output coupled to an input of a first output transistor;
a second multiplexer having a first input coupled to the supply voltage, a second input coupled to the differential input transistor pair, a third input coupled to the supply
10 common return and an output coupled to an input of a second output transistor; and
a control circuit coupled to the first and second multiplexers for selecting the inputs thereof.
2. The operational amplifier according to claim 1, wherein the first and second output transistors are totem pole configured with an output therebetween, wherein the first
15 output transistor is coupled to the supply voltage and the second output transistor is coupled to the supply common return.
3. The operational amplifier according to any of claims 1-2, wherein the first output transistor is hard on when the first input of the first multiplexer is selected.
4. The operational amplifier according to any of claims 1-3, wherein the first
20 output transistor is controlled by the differential input transistor pair when the second input of the first multiplexer is selected.
5. The operational amplifier according to any of claims 1-4, wherein the first output transistor is off when the third input of the first multiplexer is selected.
6. The operational amplifier according to any of claims 1-5, wherein the second
25 output transistor is off when the first input of the second multiplexer is selected.

7. The operational amplifier according to any of claims 1-6, wherein the second output transistor is controlled by the differential input transistor pair when the second input of the second multiplexer is selected.

8. The operational amplifier according to any of claims 1-7, wherein the second
5 output transistor is hard on when the third input of the second multiplexer is selected.

9. The operational amplifier according to any of claims 1-8, further comprising an external connection to the control circuit for externally controlling the selection of the inputs of the first and second multiplexers.

10. The operational amplifier according to any of claims 1-9, further comprising a
10 core independent peripheral (CIP) coupled to the control circuit.

11. The operational amplifier according to claim 10, wherein the CIP has inputs coupled to inputs of the differential input transistor pair for measuring voltages thereon.

12. The operational amplifier according to any of claims 1-22, wherein the CIP has an input coupled to an output of the first and second output transistors for measuring an output
15 voltage therefrom.

13. A circuit for at least partially tracking an input signal, comprising:
a differential input transistor pair having inputs coupled to a signal;
a first multiplexer having a first input coupled to a supply voltage, a second input coupled to the differential input transistor pair, a third input coupled to a supply
20 common return and an output coupled to an input of a first output transistor;
a second multiplexer having a first input coupled to the supply voltage, a second input coupled to the differential input transistor pair, a third input coupled to the supply common return and an output coupled to an input of a second output transistor;
the first and second output transistors are totem pole configured with an output
25 therebetween, wherein the first output transistor is coupled to the supply voltage and the second output transistor is coupled to the supply common return; and
a control circuit coupled to the first and second multiplexers for selecting the inputs thereof;

wherein selection of a certain combination of the first and second multiplexer inputs determines what part of the signal is tracked.

14. The circuit according to claim 13, wherein a positive input voltage amplitude tracking circuit is configured when the second input of the first multiplexer and the first input of the second multiplexer are selected.

15. The circuit according to any of claims 13-14, wherein a negative input voltage amplitude tracking circuit is configured when the third input of the first multiplexer and the second input of the second multiplexer are selected.

16. The circuit according to any of claims 13-15, wherein a positive input voltage tracking and hold circuit comprises:

a capacitor coupled between the output of the first and second output transistors and the supply common return;

the second input of the first multiplexer is selected; and

the first input of the second multiplexer is selected;

whereby the capacitor is charged when a voltage input to the differential input transistor pair is positive.

17. The circuit according to claim 16, wherein the capacitor is discharged when the third input of the first multiplexer and the third input of the second multiplexer are selected.

18. The circuit according to any of claims 13-17, wherein a negative voltage tracking and hold circuit comprises:

a capacitor coupled between the output of the first and second output transistors and the supply voltage;

the third input of the first multiplexer is selected; and

the second input of the second multiplexer is selected;

whereby the capacitor is charged when a voltage input to the differential input transistor pair is negative.

19. The circuit according to claim 18, wherein the capacitor is discharged when the first input of the first multiplexer and the first input of the second multiplexer are selected.

20. The circuit according to any of claims 13-20, wherein a maximum and minimum DC amplitude tracking and hold circuit comprises:

5 a capacitor is coupled between the output of the first and second output transistors and the supply common return,

the capacitor is charged when the second input of the first multiplexer and the first input of the second multiplexer are selected and a voltage input to the differential input transistor pair is positive, and

10 the capacitor is discharged when the third input of the first multiplexer and the second input of the second multiplexer are selected and the voltage input to the differential input transistor pair is negative.

21. The circuit according to claim 20, wherein a control circuit is coupled to the first and second multiplexers and control the selection of the first and second multiplexer inputs.

22. A method for configuring operation of an operational amplifier output, said method comprising the steps of:

providing a first multiplexer having a first input coupled to a supply voltage, a second input coupled to a differential input transistor pair, a third input coupled to a supply common return and an output coupled to an input of a first output transistor;

20 providing a second multiplexer having a first input coupled to the supply voltage, a second input coupled to the differential input transistor pair, a third input coupled to the supply common return and an output coupled to an input of a second output transistor; and

25 selecting inputs of the first and second multiplexers to configure operation of the first and second output transistors.

23. The method according to claim 22, further comprising the step of selecting the inputs of the first and second multiplexers with a core independent peripheral (CIP).

24. A circuit for at least partially tracking an input signal, comprising:

any of the operational amplifiers of claims 1-12;

wherein:

the differential input transistor pair includes inputs coupled to a signal;

5

the circuit further includes a control circuit coupled to the first and second multiplexers for selecting the inputs thereof; and

selection of a certain combination of the first and second multiplexer inputs is configured to determine what part of the signal is tracked.

10

25. A method of operating an operational amplifier, comprising operating any of the operational amplifiers of claims 1-12.

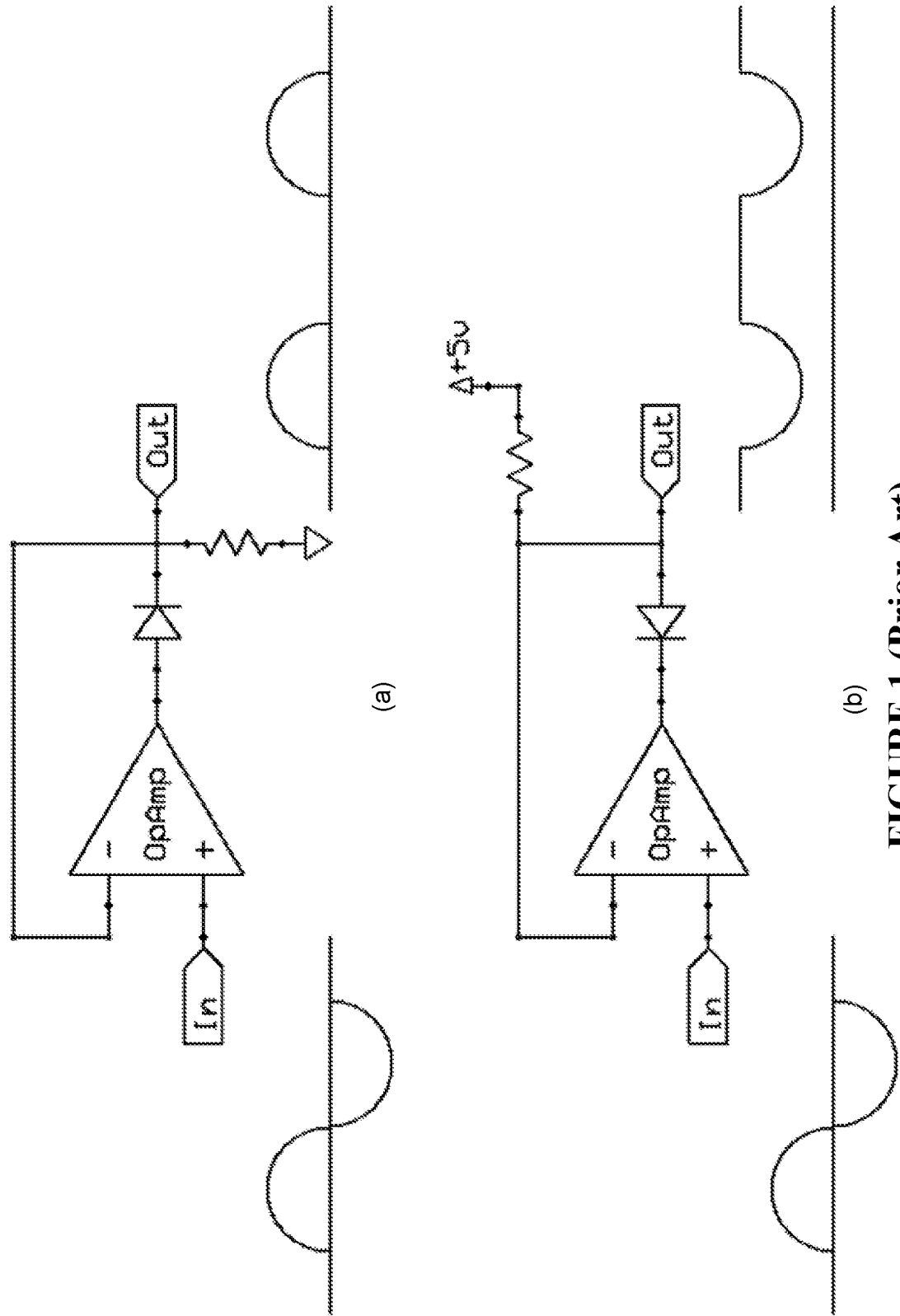


FIGURE 1 (Prior Art)

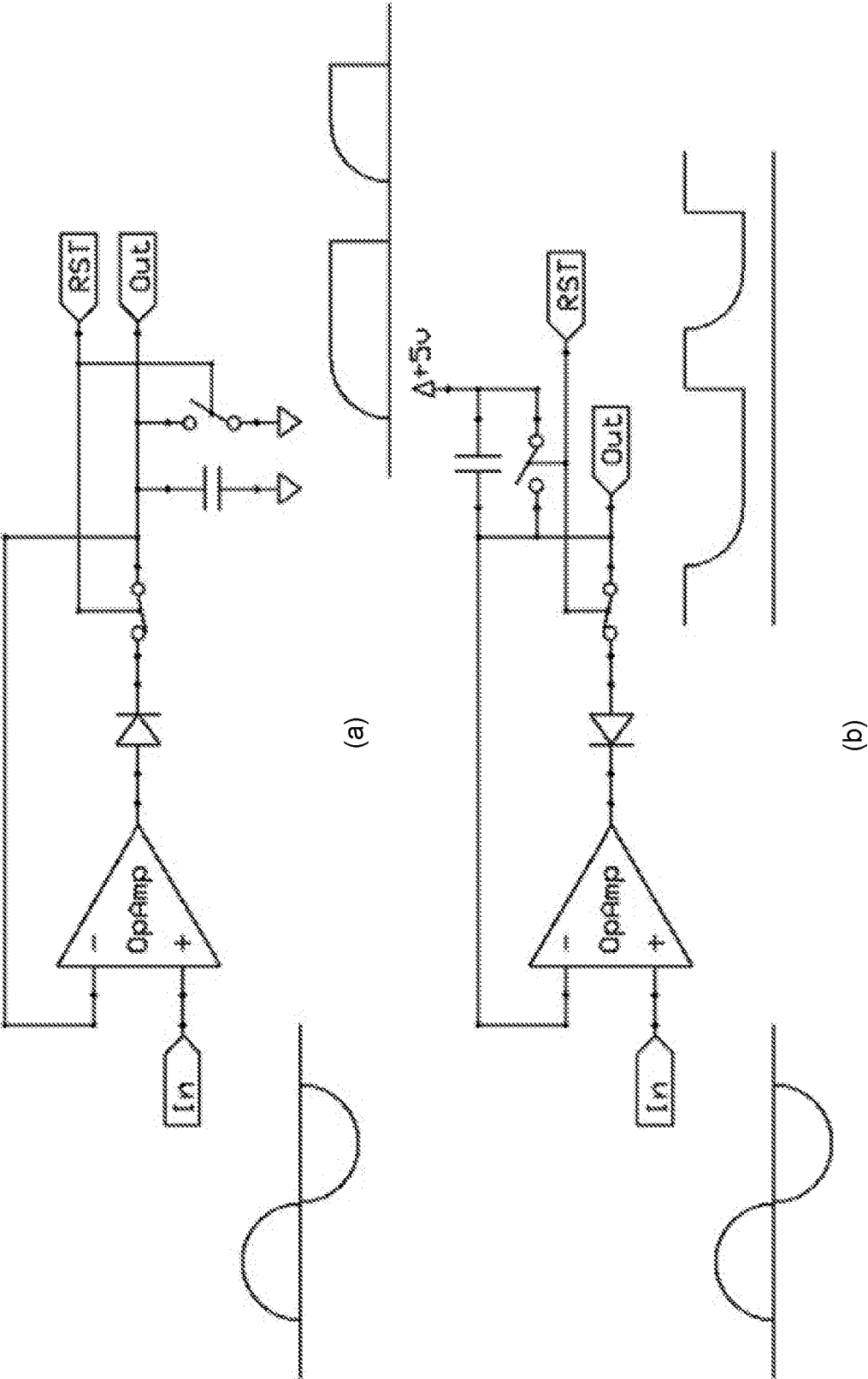


FIGURE 2 (Prior Art)

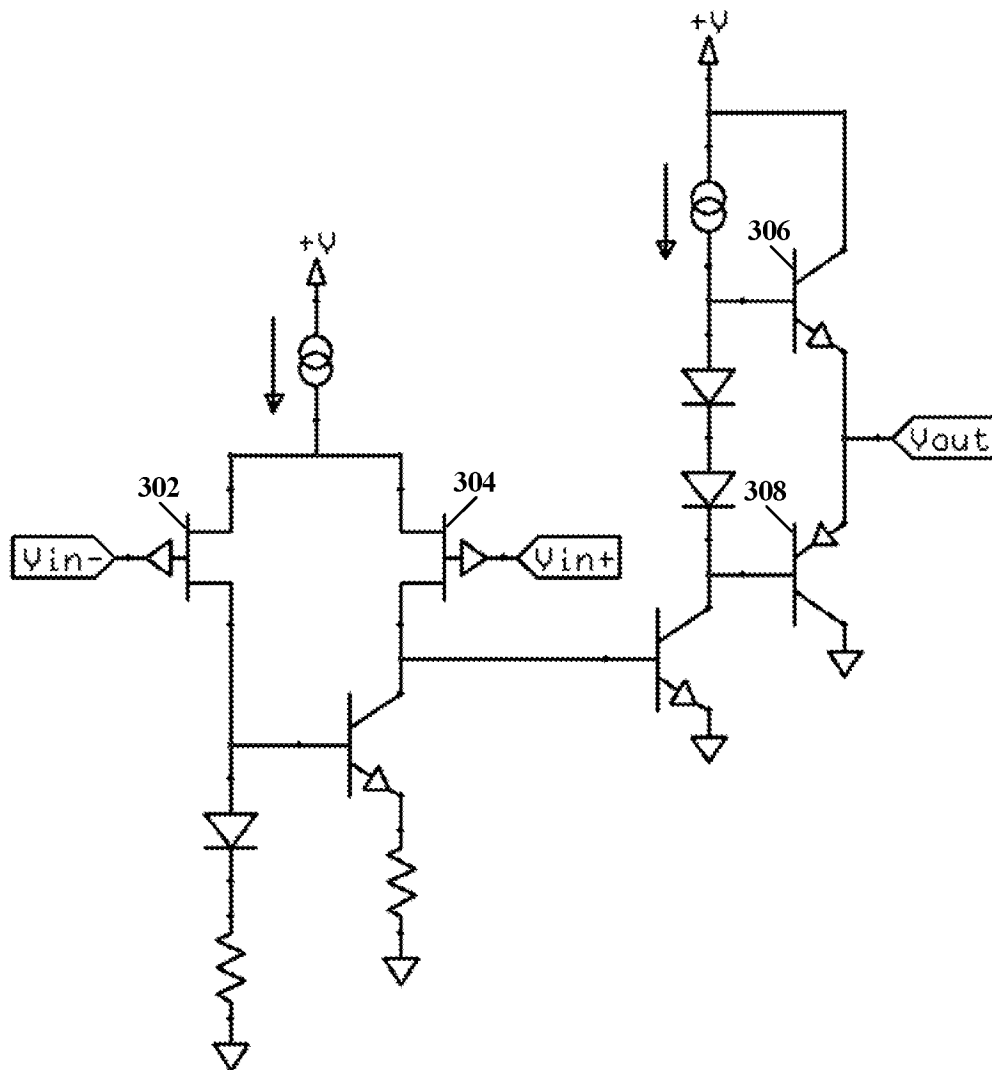


FIGURE 3

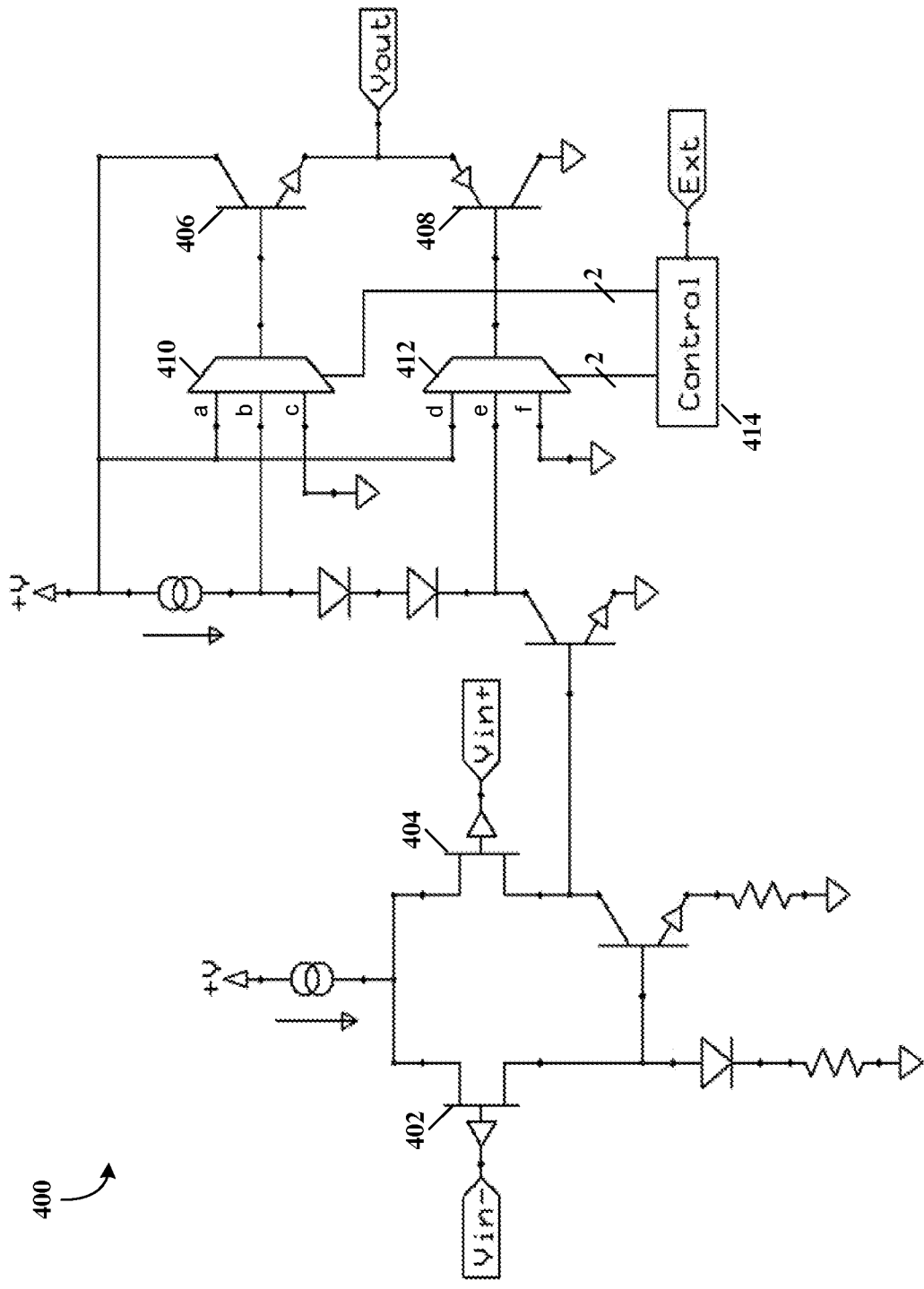


FIGURE 4

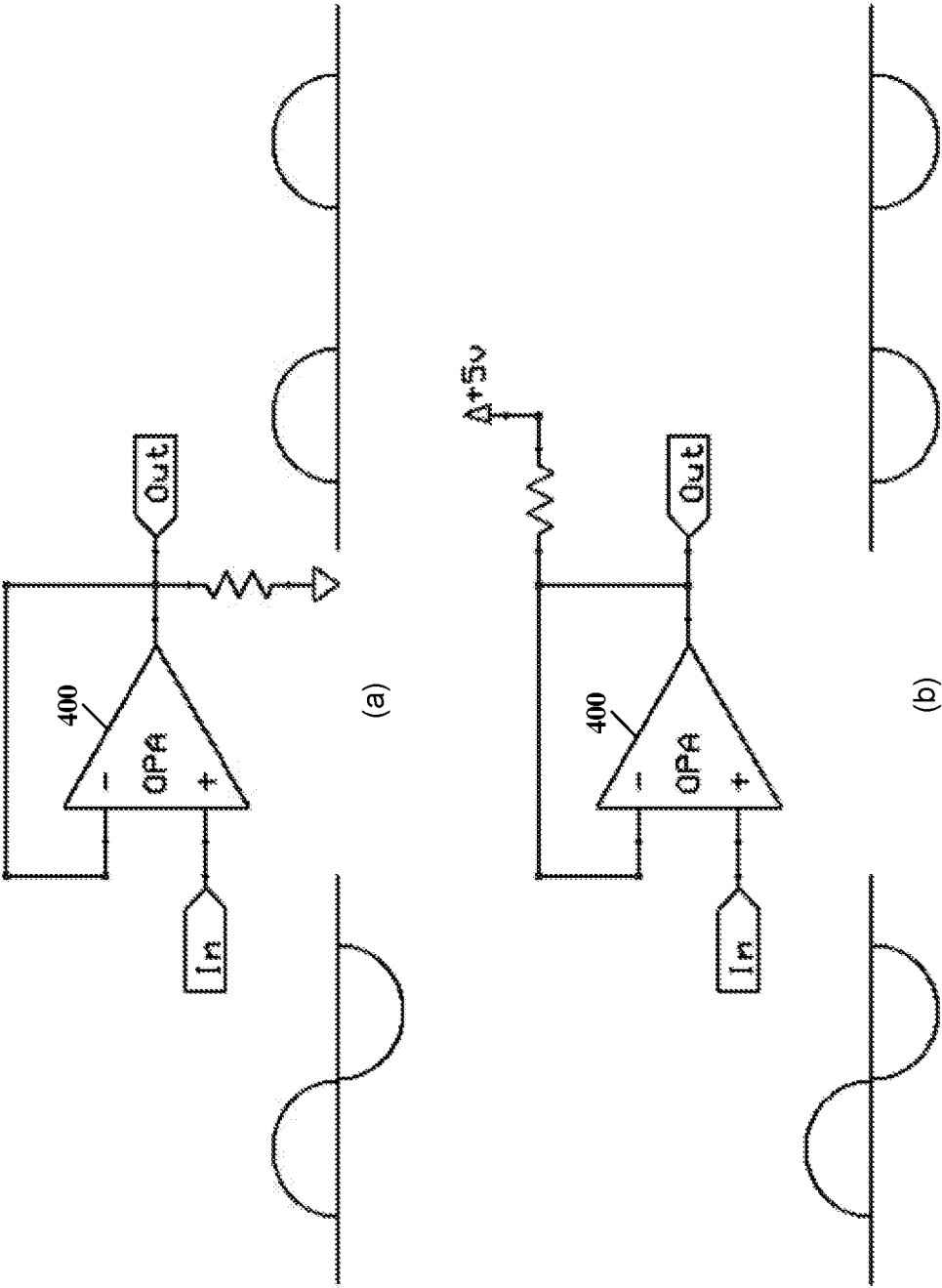


FIGURE 5

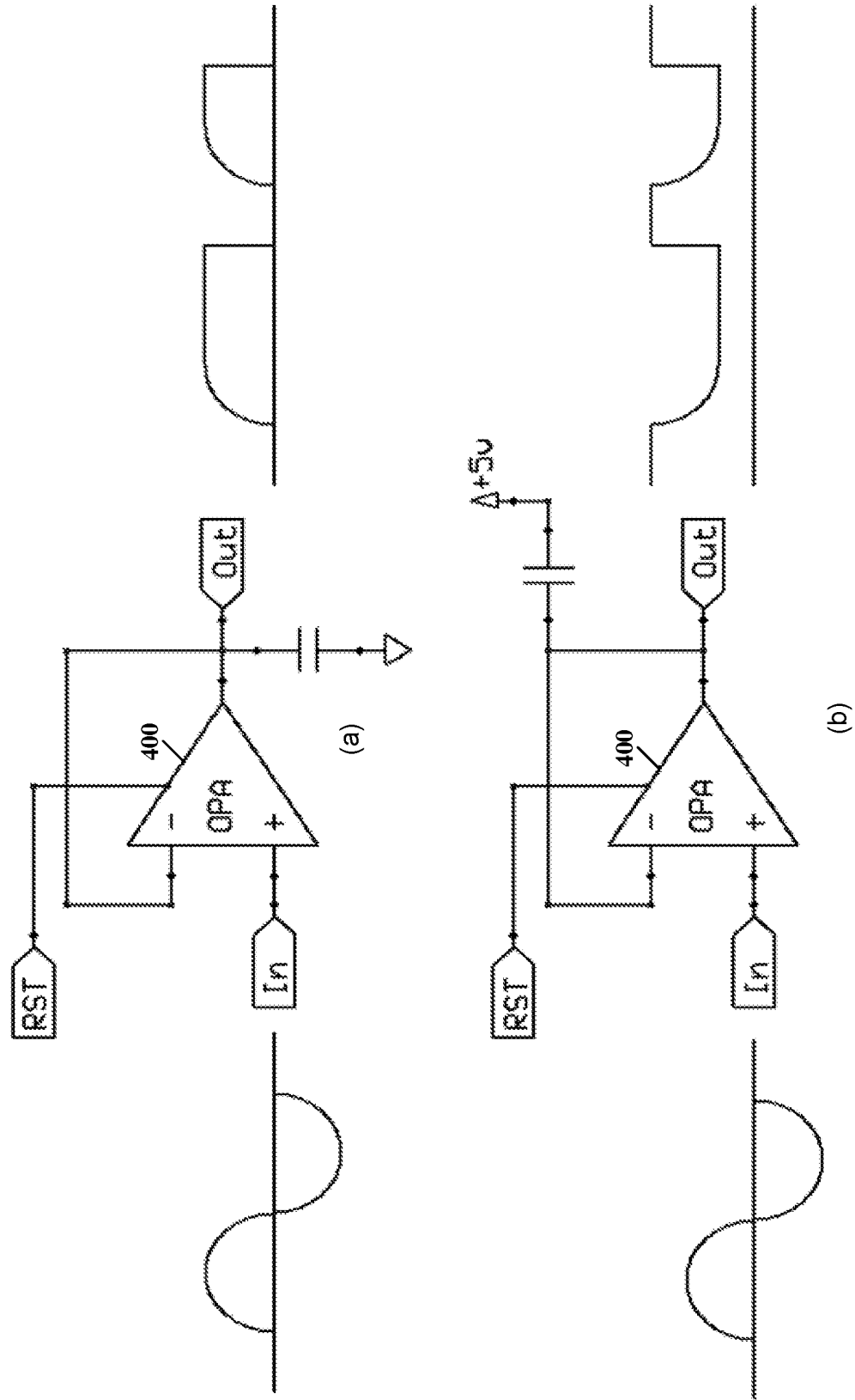


FIGURE 6

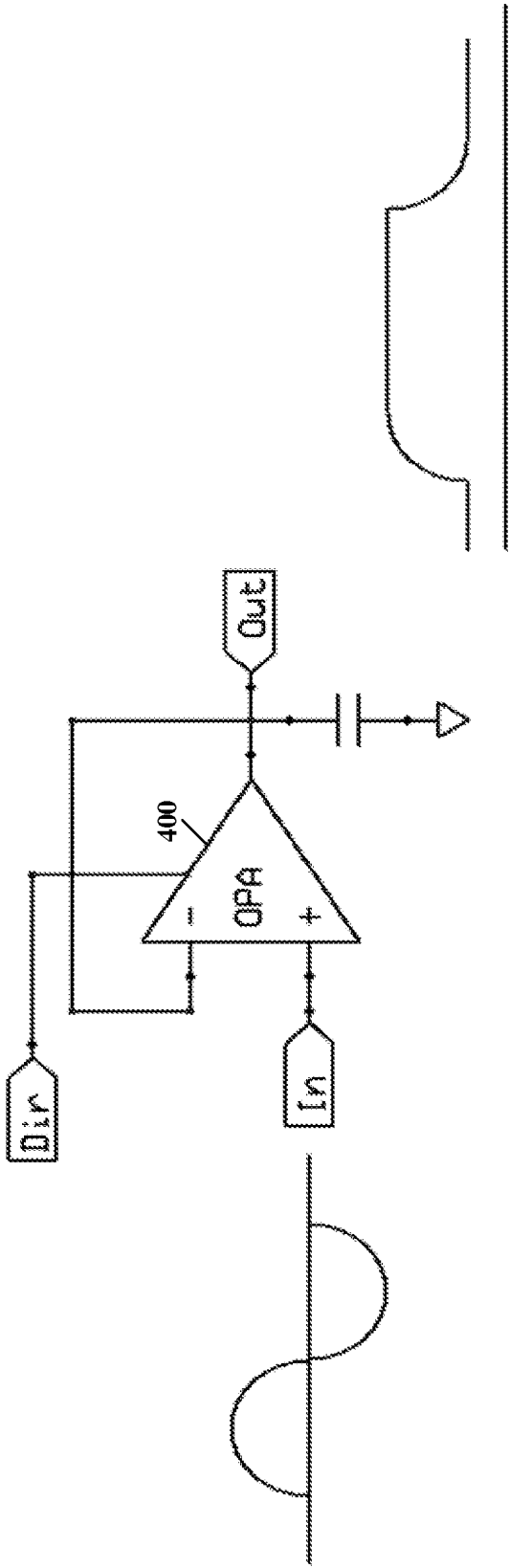


FIGURE 7

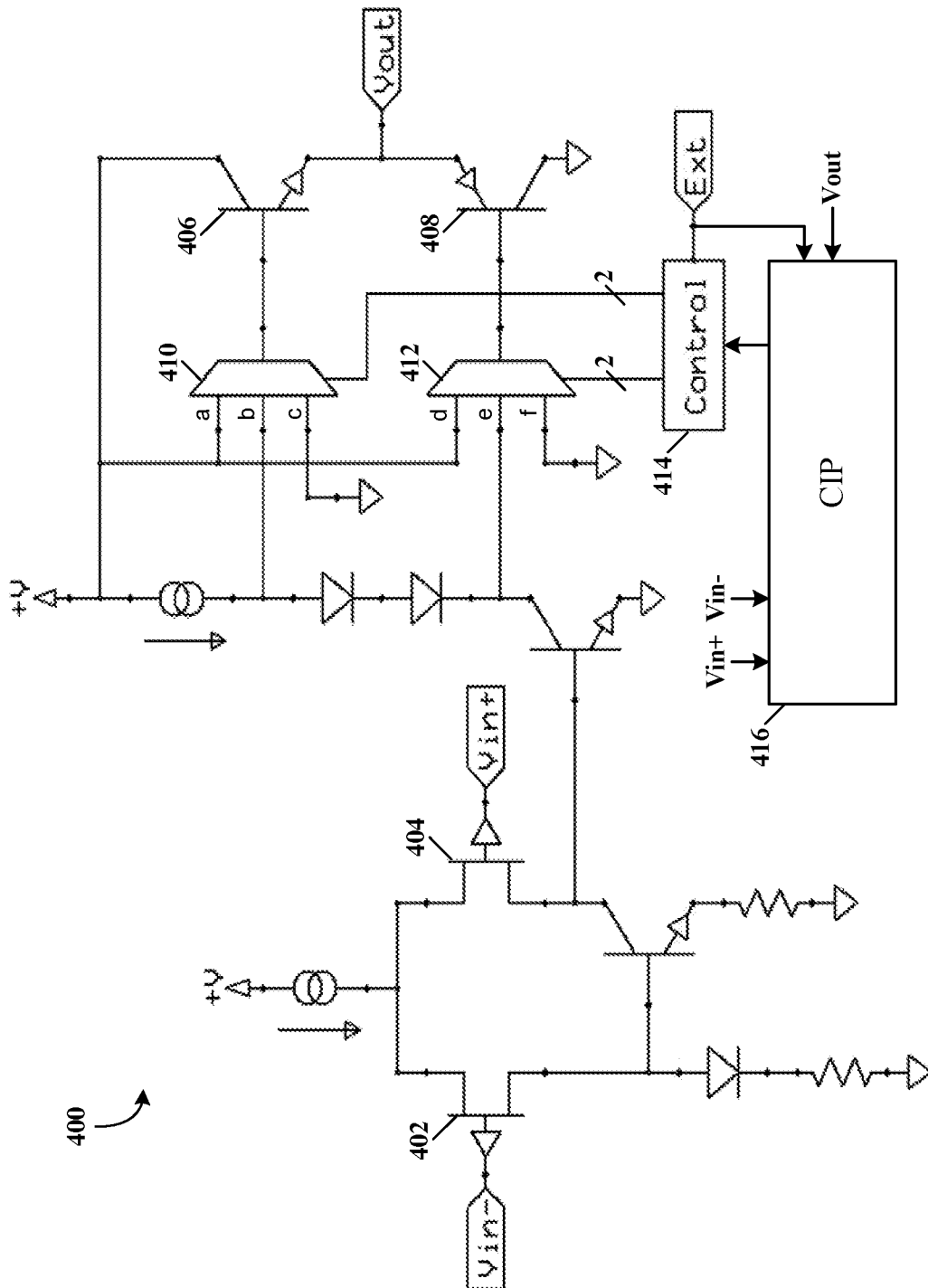


FIGURE 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/037864

A. CLASSIFICATION OF SUBJECT MATTER
INV. H03F3/45 G01R19/04 H03K5/1532
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 G01R H03K

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 5 331 210 A (MCCARROLL BENJAMIN J [US]) 19 July 1994 (1994-07-19) column 6, lines 6-26; figure 8 -----	1-25
A	US 2016/118970 A1 (KIM YOUNG HO [KR] ET AL) 28 April 2016 (2016-04-28) paragraph [0034]; figure 2 -----	1-25
A	US 6 177 814 B1 (TAGUCHI TOYOKI [JP]) 23 January 2001 (2001-01-23) abstract; figure 7 -----	1,13



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search

26 July 2019

Date of mailing of the international search report

02/08/2019

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Authorized officer

Zakharian, Andre

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2019/037864

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