United States Patent	12395127
Kind Code	B2
Date of Patent	August 19, 2025
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Audio amplifier with feedback control

Abstract

An audio amplifier includes a plurality of power stages, a driving circuit, and a power stage control circuit. The driving circuit is arranged to drive the power stages. The power stage control circuit includes a feedback circuit and a control circuit. The feedback circuit is coupled to the power stages, and is arranged to generate a feedback signal according to at least one detection input, wherein the at least one detection input includes at least one of a power, a voltage signal corresponding to a switching time of the power stages, and a voltage signal corresponding to a switching frequency of the power stages. The control circuit is coupled between the feedback circuit and the power stages, and is arranged to generate a control signal according to the feedback signal, wherein the control signal is arranged to dynamically control a number of turned-on power stages in the power stages.

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Appl. No.: **18/071581**

Filed: **November 29, 2022**

Prior Publication Data

Document Identifier	Publication Date
US 20240178796 A1	May. 30, 2024

Publication Classification

Int. Cl.: **H03F3/217** (20060101); **H03F1/02** (20060101)

U.S. Cl.:

CPC **H03F1/0205** (20130101); **H03F3/217** (20130101); H03F3/2173 (20130101); H03F2200/03 (20130101)

Field of Classification Search

CPC: H03F (3/217); H03F (3/2173); H03F (2200/351); H03F (3/2171)

USPC: 330/207A; 330/251

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Primary Examiner: Nguyen; Khanh V

Background/Summary

BACKGROUND OF THE INVENTION

1. Field of the Invention

(1) The present invention is related to an audio amplifier, and more particularly, to an audio amplifier with a power stage control circuit that utilizes a feedback mechanism to dynamically control the number of turned-on power stages.

2. Description of the Prior Art

(2) For a class-D amplifier, there may be a plurality of power stages connected in parallel with each other, wherein the power stages are arranged to receive a driving signal (e.g. a pulse width modulation (PWM) signal) obtained from an input signal (E.G. an audio signal) for driving, and drive a loudspeaker. For a traditional power stage control circuit, for example, a number of turned-on power stages may be determined and controlled according to the input signal. For another example, the number of turned-on power stages may be determined and controlled only according to voltages at output terminals of the power stages. Some problems may occur, however. In a case that the supply voltage supplied to the power stages varies, the traditional power stage control circuit may not be able to dynamically track the supply voltage to optimize the power stages. In addition, there may be a large power loss for the traditional power stage control circuit. As a result, a novel audio amplifier with a power stage control circuit that utilizes a feedback mechanism to dynamically control the number of turned-on power stages is urgently needed, to increase the

amplifier efficiency and minimize the power loss.

SUMMARY OF THE INVENTION

(3) It is therefore one of the objectives of the present invention to provide an audio amplifier with a power stage control circuit that utilizes a feedback mechanism to dynamically control the number of turned-on power stages, to address the above-mentioned issues.

(4) According to an embodiment of the present invention, an audio amplifier is provided. The audio amplifier comprises a plurality of power stages, a driving circuit, and a power stage control circuit. The plurality of power stages are coupled in parallel with each other, wherein each of the plurality of power stages comprises a first switch and a second switch, the first switch and the second switch are coupled in series between a first reference voltage and a second reference voltage, and the first reference voltage is higher than the second reference voltage. The driving circuit is coupled to the plurality of power stages, and is arranged to receive an input signal, and generate a driving signal to the plurality of power stages according to the input signal for driving the plurality of power stages. The power stage control circuit comprises a feedback circuit and a control circuit. The feedback circuit is coupled to the plurality of power stages, and is arranged to generate a feedback signal according to at least one detection input, wherein the at least one detection input comprises at least one of a power of the first reference voltage, a voltage signal corresponding to a switching time of the plurality of power stages, and a voltage signal corresponding to a switching frequency of the plurality of power stages. The control circuit is coupled between the feedback circuit and the plurality of power stages, and is arranged to generate a control signal according to the feedback signal, wherein the control signal is arranged to dynamically control a number of turned-on power stages in the plurality of power stages.

(5) According to an embodiment of the present invention, an audio amplifier is provided. The audio amplifier comprises a plurality of power stages, a driving circuit, and a power stage control circuit. The plurality of power stages are coupled in parallel with each other, wherein each of the plurality of power stages comprises a first switch and a second switch, the first switch and the second switch are coupled in series between a first reference voltage and a second reference voltage, and the first reference voltage is higher than the second reference voltage. The driving circuit is coupled to the plurality of power stages, and is arranged to receive an input signal, and generate a driving signal to the plurality of power stages according to the input signal for driving the plurality of power stages. The power stage control circuit comprises a feedback circuit and a control circuit. The feedback circuit is coupled to the plurality of power stages, and is arranged to generate a feedback signal according to at least one detection input, wherein the at least one detection input comprises a voltage signal corresponding to an output current of the plurality of power stages, and the output current is derived from a terminal coupled to the first reference voltage or a terminal coupled to the second reference voltage in each of the plurality of power stages. The control circuit is coupled between the feedback circuit and the plurality of power stages, and is arranged to generate a control signal according to the feedback signal, wherein the control signal is arranged to dynamically control a number of turned-on power stages in the plurality of power stages.

(6) One of the benefits of the present invention is that, by the class-D amplifier of the present invention, under a condition that the supply voltage supplied to the power stages varies, the power stage control circuit in the class-D amplifier of the present invention can be able to dynamically track the supply voltage to optimize the power stages. In addition, the power stage control circuit can generate the control signal under a condition that the power stages have the power loss with the minimum value, for dynamically controlling the number of turned-on power stages in the power stages, which can increase the amplifier efficiency.

(7) These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a diagram illustrating an audio amplifier according to an embodiment of the present invention.

(2) FIG. **2** is a diagram illustrating a current sensing circuit according to an embodiment of the present invention.

(3) FIG. **3** is a diagram illustrating a switching time extraction circuit according to an embodiment of the present invention.

(4) FIG. **4** is a diagram illustrating a switching frequency extraction circuit according to an embodiment of the present invention.

(5) FIG. **5** is a diagram illustrating associated signals of the switching frequency extraction circuit shown in FIG. **4** according to an embodiment of the present invention.

(6) FIG. **6** is a diagram illustrating a digital control circuit according to an embodiment of the present invention.

(7) FIG. **7** is a diagram illustrating an analog control circuit according to an embodiment of the present invention.

(8) FIG. **8** is a diagram illustrating an audio amplifier according to another embodiment of the present invention.

(9) FIG. **9** is a diagram illustrating a current sensing circuit according to another embodiment of the present invention.

(10) FIG. **10** is a diagram illustrating an audio amplifier according to yet another embodiment of the present invention.

(11) FIG. **11** is a diagram illustrating a current sensing circuit according to yet another embodiment of the present invention.

DETAILED DESCRIPTION

(12) FIG. **1** is a diagram illustrating an audio amplifier (e.g. a class-D amplifier **10**) according to an embodiment of the present invention. As shown in FIG. **1**, the class-D amplifier **10** may include a driving circuit **100**, a plurality of power stages **102_1-102_**N, and a power stage control circuit **104**, wherein the power stage control circuit **104** may include a feedback circuit **106** and a control circuit **108**. The driving circuit **100** may be coupled to the power stages **102_1-102_**N, and may be arranged to receive an input signal (e.g. an audio signal A_IN), and generate and transmit a driving signal DRV to the power stages **102_1-102_**N according to the audio signal A_IN for driving the power stages **102_1-102_**N. For example, the driving signal DRV may be generated according to a pulse width modulation (PWM) signal corresponding to the audio signal A_IN. The power stages **102_1-102_**N may be coupled in parallel with each other, and may be arranged to drive a loudspeaker **12**, wherein N is an integer greater than 1 (i.e. N>1), each of the power stages **102_1-102_**N may include a P-type transistor and an N-type transistor, and the P-type transistor and the N-type transistor are coupled in series between a supply voltage V.sub.DD and a ground voltage GND. Take the power stage **102_1** as an example. The power stage **102_1** may include a P-type transistor **103** and an N-type transistor **105**, wherein a source terminal of the P-type transistor **103** is coupled to the supply voltage V.sub.DD, a drain terminal of the P-type transistor **103** is coupled to a drain terminal of the N-type transistor **105**, a source terminal of the N-type transistor **105** is coupled to the ground voltage GND, both of a gate terminal of the P-type transistor **103** and a gate terminal of the N-type transistor **105** are coupled to the driving circuit **100** for receiving the driving signal DRV, and the configuration of P-type transistors and N-type transistors in the power stages **102_2-102_**N is the same as that in the power stage **102_1**. The present invention is not limited thereto, however. In some embodiments, each of the power stages **102_1-102_**N may include two N-type transistors, and the two N-type transistors are coupled in series between the supply voltage

V.sub.DD and the ground voltage GND.

(13) The feedback circuit **106** may be coupled to the power stages **102_1-102**_N, and may include a current sensing circuit (labeled as “CS circuit” in FIG. **1**) **107**, a switching time extraction circuit (labeled as “STE circuit” in FIG. **1**) **109**, and a switching frequency extraction circuit (labeled as “SFE circuit” in FIG. **1**) **111**. The current sensing circuit **107** may be coupled to an output terminal OT between the drain terminal of the P-type transistor and the drain terminal of the N-type transistor in each of the power stages **102_1-102**_N, and may be arranged to sense and derive an output current of the power stages **102_1-102**_N, and generate a voltage signal V.sub.CS corresponding to the output current, where the voltage signal V.sub.CS may serve as one detection input. It should be noted that, in some embodiments, the current sensing circuit **107** may be coupled to a high side terminal at the source terminal of the P-type transistor in each of the power stages **102_1-102**_N, and may be arranged to sense and derive an output current at the high side terminal, and generate the voltage signal V.sub.CS corresponding to the output current, where the voltage signal V.sub.CS may serve as one detection input. In some embodiments, the current sensing circuit **107** may be coupled to a low side terminal at the source terminal of the N-type transistor in each of the power stages **102_1-102**_N, and may be arranged to sense and derive an output current at the low side terminal, and generate the voltage signal V.sub.CS corresponding to the output current, where the voltage signal V.sub.CS may serve as one detection input. The switching time extraction circuit **109** may be coupled to the output terminal OT, and may be arranged to derive a switching time of the power stages **102_1-102**_N, and generate a voltage signal V.sub.SW corresponding to the switching time, where the voltage signal V.sub.SW may serve as one detection input. The switching frequency extraction circuit **111** may be coupled to the output terminal OT, and may be arranged to derive a switching frequency of the power stages **102_1-102**_N, and generate a voltage signal V.sub.FREQ Corresponding to the switching frequency, where the voltage signal V.sub.FREQ may serve as one detection input. In addition, the feedback circuit **106** may be further arranged to derive a power PV.sub.DD of the supply voltage V.sub.DD from the power stages **102_1-102**_N, where the power PV.sub.DD may serve as one detection input.

(14) It should be noted that at least one detection input may include at least one of the voltage signal V.sub.CS, the voltage signal V.sub.SW, the voltage signal V.sub.FREQ, and the power PV.sub.DD, and the feedback circuit **106** may be arranged to generate a feedback signal FS according to the at least one detection input. For example, the at least one detection input may only include the power PV.sub.DD, and each of the voltage signals V.sub.CS, V.sub.SW, and V.sub.FREQ may be set as a predetermined parameter (e.g. a constant). For another example, the at least one detection input may include the power PV.sub.DD and the voltage signal V.sub.CS, and each of the voltage signals V.sub.SW, and V.sub.FREQ may be set as a predetermined parameter (e.g. a constant). In this embodiment, the at least one detection input includes all of the power PV.sub.DD and the voltage signals V.sub.CS, V.sub.SW, and V.sub.FREQ.

(15) FIG. **2** is a diagram illustrating a current sensing circuit **20** according to an embodiment of the present invention, wherein the current sensing circuit **107** shown in FIG. **1** may be implemented by the current sensing circuit **20**. As shown in FIG. **2**, the current sensing circuit **20** may sense and derive a sensing current I.sub.sen from the output terminal OT of the power stages **102_1-102**_N, and generate the voltage signal V.sub.CS according to the sensing current I.sub.sen and a resistor R.sub.SEN. Specifically, the current sensing circuit **20** may include a plurality of resistors R.sub.1, R.sub.2, R.sub.3, R.sub.4, and R.sub.SEN and an operational amplifier **21**, wherein a resistance value of the resistor R.sub.1 is equal to that of the resistor R.sub.3, a resistance value of the resistor R.sub.2 is equal to that of the resistor R.sub.4, a resistance value of the resistor R.sub.SEN is much smaller than that of the resistors R.sub.1 and R.sub.2, and a positive power supply and a negative power supply of the operational amplifier **21** are the supply voltage V.sub.DD and the ground voltage GND, respectively. The resistor R.sub.1 has a first terminal coupled to the output terminal

OT, and a second terminal coupled to a positive terminal (+) of the operational amplifier **21**. The resistor R.sub.2 has a first terminal coupled to the second terminal of the resistor R.sub.1, and a second terminal coupled to a reference voltage V.sub.REF. The resistor R.sub.SEN has a first terminal coupled to the first terminal of the resistor R.sub.1, and a second terminal coupled to a load **22** (e.g. the loudspeaker **12** shown in FIG. **1**). The resistor R.sub.3 has the first terminal coupled to the second terminal of the resistor R.sub.SEN, and a second terminal coupled to a negative terminal (−) of the operational amplifier **21**. The resistor R.sub.4 has a first terminal coupled to the second terminal of the resistor R.sub.3, and a second terminal coupled to an output terminal of the operational amplifier **21**. The voltage signal V.sub.CS can be obtained at the output terminal of the operational amplifier **21**, and can be expressed by the following equation:
(16) $V_{CS} = (V_1 - V_2) * (\frac{R_2}{R_1}) + V_{REF}$
wherein V.sub.1 is a voltage value at the first terminal of resistor R.sub.SEN, V.sub.2 is a voltage value at the second terminal of the resistor R.sub.SEN, R.sub.2 is the resistance value of the resistor R.sub.2, R.sub.1 is the resistance value of the resistor R.sub.1, and V.sub.REF is a voltage value of the reference voltage V.sub.REF.
(17) FIG. **3** is a diagram illustrating a switching time extraction circuit **300** according to an embodiment of the present invention, wherein the switching time extraction circuit **109** shown in FIG. **1** may be implemented by the switching time extraction circuit **300**. As shown in FIG. **3**, the switching time extraction circuit **300** may include multiple comparators **302** and **304**, an AND gate **306**, a current source **308**, multiple switch circuits **310**, **312**, and **314**, an inverter **316**, and multiple capacitors **318** and **320**. In this embodiment, the switching time extraction circuit **300** may be arranged to derive a switching time of the power stages **102_1-102_**N that is switched between 10%*V.sub.DD and 90%*V.sub.DD, and generate the voltage signal V.sub.SW corresponding to the switching time. However, this is for illustration only, and the present invention is not limited thereto. The switching time extraction circuit **300** may further include multiple resistors **322**, **324**, and **326**, wherein the supply voltage V.sub.DD is coupled to a first terminal of the resistor **322**, a first terminal of the resistor **324** is coupled to a second terminal of the resistor **322**, a second terminal of the resistor **324** is coupled to a first terminal of the resistor **326**, a second terminal of the resistor **326** is coupled to the ground voltage GND, a resistance value of the resistor **322** is equal to that of the resistor **326**, and a resistance value of the resistor **324** is 8 times as large as that of the resistor **322** (e.g. the resistance values of the resistors **322**, **324**, and **326** are labeled as "R.sub.o", "8R.sub.o", and "R.sub.o", respectively, in FIG. **3**).
(18) As shown in FIG. **3**, a reference voltage V.sub.REF9 corresponding to 90%*V.sub.DD can be derived at the first terminal of the resistor **324** and can be coupled to a positive terminal (+) of the comparator **302**, a reference voltage V.sub.REF1 corresponding to 10%*V.sub.DD can be derived at the second terminal of the resistor **324** and can be coupled to a negative terminal (−) of the comparator **304**, and an output voltage V.sub.o at the output terminal OT of the power stages **102_1-102_**N is coupled to a negative terminals (−) of the comparator **302** and a positive terminal (+) of the comparator **304**. By comparing the reference voltages V.sub.REF9 and V.sub.REF1 with the output voltage V.sub.o through the comparators **302** and **304**, two comparison results are generated and transmitted to the AND gate **306**, wherein a control signal ST is obtained at an output terminal of the AND gate **306**, wherein when a level of the control signal ST is high, a voltage value of the output voltage V.sub.o is between 10%*V.sub.DD and 90%*V.sub.DD, and when the level of the control signal ST is low, the voltage value of the output voltage V.sub.o is not between 10%*V.sub.DD and 90%*V.sub.DD. The control signal ST is then transmitted to the switch circuit **310** for controlling turn-on and turn-off of the switch circuit **310**. In addition, the control signal ST is further transmitted to an input terminal of the inverter **316**, and the inverter **316** may be arranged to invert the control signal ST to generate an inverted control signal ST′, and transmit the inverted control signal ST′ to the switch circuits **312** and **314** for controlling turn-on and turn-off of the switch circuits **312** and **314**. For example, during the high level of the control

signal ST, the switch circuit **310** is turned on and the switch circuits **312** and **314** are turned off, and during the low level of the switching time signal ST, the switch circuit **310** is turned off and the switch circuits **312** and **314** are turned on.

(19) The supply voltage V.sub.DD is coupled to a first terminal of the current source **308**, and a second terminal of the current source **308** is coupled to a first terminal of the switch circuit **310**, wherein the current source **308** is arranged to provide a current I.sub.c to the first terminal of the switch circuit **310**. When the switch circuit **310** is turned on, a second terminal of the switch circuit **310** is coupled to a first terminal of the capacitor **318**, a first terminal of the switch circuit **312**, and a first terminal of the switch circuit **314**. When the switch circuit **312** is turned on, a second terminal of the switch circuit **312** is coupled to a second terminal of the capacitor **318**, wherein the second terminal of the capacitor **318** is coupled to the ground voltage GND. When the switch circuit **314** is turned on, a second terminal of the switch circuit **314** is coupled to a first terminal of the capacitor **320**, wherein a second terminal of the capacitor **320** is coupled to the ground voltage GND.

(20) The voltage signal V.sub.SW corresponding to the switching time may be obtained at the first terminal of the capacitor **320**, and may be expressed by the following equation:

*Cc*V*.sub.SW=*I*.sub.C**ST*

wherein C.sub.c is a capacitance value of the capacitor **318**, I.sub.c is a current value of the current I.sub.c provided by the current source **308**, ST is a time during which the level of the control signal ST is high, and the equation can be simplified as:

(21) $V_{\mathrm{SW}} = \frac{\mathrm{ST} * I_c}{C_C}$

(22) Please refer to FIG. **4** in conjunction with FIG. **5**. FIG. **4** is a diagram illustrating a switching frequency extraction circuit **400** according to an embodiment of the present invention, wherein the switching frequency extraction circuit **111** shown in FIG. **1** may be implemented by the switching frequency extraction circuit **400**. FIG. **5** is a diagram illustrating associated signals of the switching frequency extraction circuit **400** shown in FIG. **4** according to an embodiment of the present invention. As shown in FIG. **4**, the switching frequency extraction circuit **400** may include a comparator **402**, a pulse generator **404**, multiple current sources **406** and **408**, a switch circuit **410**, and a capacitor **412**. The output voltage V.sub.o at the output terminal OT of the power stages **102_1-102_**N is coupled to a positive terminal (+) of the comparator **402**, and a reference voltage V.sub.REFFREQ is coupled to a negative terminal (−) of the comparator **402**. By comparing the output voltage V.sub.o with the reference voltage V.sub.REFFREQ through the comparator **402**, a square wave FREQ_SW with a higher slew rate is generated at an output terminal of the comparator **402**, wherein the switching frequency of the power stages **102_1-102_**N is an inverse of a time period of the square wave FREQ_SW. Afterwards, the square wave FREQ_SW is transmitted to the pulse generator **404**, and the pulse generator **404** may be arranged to generate a pulse signal FREQCTL according to the square wave FREQ_SW, wherein when a level of the square wave FREQ_SW is transferred from low to high, a level of the pulse signal FREQCTL is also transferred from low to high and is transferred from high to low after a time interval T.sub.PS, a time interval T.sub.P between a rising edge of each pulse in the pulse signal FREQCTL is equal to the time period of the square wave FREQ_SW, and the time interval T.sub.PS is much smaller than the time interval T.sub.P. The pulse signal FREQCTL is then transmitted to the switch circuit **410** for controlling turn-on and turn-off of the switch circuit **410**. For example, during the high level of the pulse signal FREQCTL, the switch circuit **410** is turned on, and during the low level of the pulse signal FREQCTL, the switch circuit **410** is turned off.

(23) The supply voltage V.sub.DD is coupled to a first terminal of the current source **406**, and a second terminal of the current source **406** is coupled to a first terminal of the switch circuit **410**, wherein the current source **406** is arranged to provide a current I.sub.UP to the first terminal of the switch circuit **410**. When the switch circuit **410** is turned on, a second terminal of the switch circuit **410** is coupled to a first terminal of the current source **408** and a first terminal of the capacitor **412**,

wherein the current source **408** is arranged to provide a current I.sub.DN, a second terminal of the current source **408** is coupled to a second terminal of the capacitor **412**, and the second terminal of the capacitor **412** is coupled to the ground voltage GND.

(24) The voltage signal V.sub.FREQ corresponding to the switching frequency may be obtained at the first terminal of the capacitor **412**, and may be expressed by the following equation:

$$Cc*V\text{.sub.FREQ}=T\text{.sub.PS}*I\text{.sub.UP}-T\text{.sub.P}*I\text{.sub.DN}$$

wherein C.sub.c is a capacitance value of the capacitor **412**, T.sub.PS is the time interval T.sub.PS, I.sub.UP is a current value of the current I.sub.UP provided by the current source **406**, T.sub.P is the time interval T.sub.P, and I.sub.DN is a current value of the current I.sub.DN provided by the current source **408**.

(25) Please refer back to FIG. **1**. The control circuit **108** may be coupled between the feedback circuit **104** and the power stages **102_1-102**_N, and may be arranged to generate a control signal CS according to the feedback signal FS, wherein the control signal CS is arranged to dynamically control a number of turned-on power stages in the power stages **102_1-102**_N. The control circuit **108** may be implemented by a digital circuit or an analog circuit, depending upon actual design considerations. In detail, please refer to FIG. **6**. FIG. **6** is a diagram illustrating a digital control circuit **60** according to an embodiment of the present invention, wherein the control circuit **108** shown in FIG. **1** may be implemented by the digital control circuit **60**. As shown in FIG. **6**, the digital control circuit **60** may include an input interface circuit **600**, a calculation circuit **602**, an addition circuit **604**, and an optimization circuit **606**.

(26) The input interface circuit **600** may include at least one analog to digital converter (ADC), and the at least one ADC may be arranged to convert the feedback signal FS into at least one digital signal. In this embodiment, under a condition that the feedback signal FS is generated according to all of the power PV.sub.DD and the voltage signals V.sub.CS, V.sub.SW, and V.sub.FREQ, the input interface circuit **600** may include 4 ADCs **608_1-608_4**, wherein the ADC **608_1** may be arranged to convert the voltage signal V.sub.CS into a digital signal D.sub.CS, the ADC **608_2** may be arranged to convert the voltage signal V.sub.SW into a digital signal D.sub.SW, the ADC **608_3** may be arranged to convert the voltage signal V.sub.FREQ into a digital signal D.sub.FREQ, and the ADC **608_4** may be arranged to convert the power PV.sub.DD into a digital signal D.sub.PVDD. In some embodiments, the feedback signal FS may be generated only according to one of the power PV.sub.DD, the voltage signal V.sub.CS, the voltage signal V.sub.SW, and the voltage signal V.sub.FREQ, and the input interface circuit **600** may only include one ADC for converting said one analog signal into a digital signal. In some embodiments, the feedback signal FS may be generated according to two of the power PV.sub.DD, the voltage signal V.sub.CS, the voltage signal V.sub.SW, and the voltage signal V.sub.FREQ, and the input interface circuit **600** may include two ADCs for converting said two analog signals into two digital signals, respectively. In some embodiments, the feedback signal FS may be generated according to three of the power PV.sub.DD, the voltage signal V.sub.CS, the voltage signal V.sub.SW, and the voltage signal V.sub.FREQ, and the input interface circuit **600** may include three ADCs for converting said three analog signals into three digital signals, respectively.

(27) The calculation circuit **602** may be coupled to the input interface circuit **600** (more particularly, the ADCs **608_1-608_4**), and may be arranged to calculate a power loss PL of the power stages **102_1-102**_N according to the digital signals D.sub.CS, D.sub.SW, D.sub.FREQ, and D.sub.PVDD. It is assumed that the number of turned-on power stages in the power stages **102_1-102**_N is n, wherein n is larger than or equal to 1, and is smaller than or equal to N (i.e. $1\leq n\leq N$). The power loss PL of the power stages **102_1-102**_N may include a conduction loss P.sub.LOSS_CON, a switching loss P.sub.LOSS_SW, and a gate switching loss P.sub.LOSS_SW_GATE (i.e. PL=P.sub.LOSS_CON+P.sub.LOSS_SW+P.sub.LOSS_SW_GATE). The conduction loss P.sub.LOSS_CON can be calculated by the following equation:

(28) $P_{LOSS_{CON}} = \frac{I_{CS}^2 * (R_{UP} + R_{DN})}{n}$

wherein I.sub.CS is a current flowing from the P-type transistor and the N-type transistor to the output terminal OT in each of the plurality of power stages **102_1-102**_N, R.sub.UP is an on-resistance of the P-type transistor in each of the plurality of power stages **102_1-102**_N, R.sub.DN is an on-resistance of the N-type transistor in each of the plurality of power stages **102_1-102**_N, and n is the number of turned-on power stages in the power stages **102_1-102**_N.

(29) The switching loss P.sub.LOSS_SW can be calculated by the following equation:

(30) $P_{LOSS_{SW}} = 2 * T_{SW} * I_{CS} * \frac{PV_{DD}}{2} * Freq$

wherein T.sub.SW is the switching time of the power stages **102_1-102**_N, and is equal to (Q.sub.GD+Q.sub.GS2)/2*I.sub.G*n

(31) ($i.e.\ T_{SW} = \frac{Q_{GD} + Q_{GS2}}{2 * I_G * n}$),

Q.sub.GD is a gate-to-drain charge of the power stages **102_1-102**_N, Q.sub.GS2 is a post-threshold gate-to-source charge of the power stages **102_1-102**_N, I.sub.G is a current of the gate terminals of the N-type transistor and the P-type transistor in each of the power stages **102_1-102**_N, n is the number of turned-on power stages in the power stages **102_1-102**_N, I.sub.CS is the current flowing from the P-type transistor and the N-type transistor to the output terminal OT in each of the plurality of power stages **102_1-102**_N, and Freq is the switching frequency of the power stages **102_1-102**_N.

(32) The gate switching loss P.sub.LOSS_SW_GATE can be calculated by the following equation:

(33) $P_{LOSS_{SL_{GATE}}} = n * (C_{\mathrm{GATEUP}} + C_{\mathrm{GATEDN}}) * V_{\mathrm{DD}}^2 * \mathrm{Freq}$

wherein n is the number of turned-on power stages in the power stages **102_1-102**_N, C.sub.GATEUP and C.sub.GATEDN are a gate capacitance of the P-type transistor and a gate capacitance of the N-type transistor in each of the power stages **102_1-102**_N, respectively, and Freq is the switching frequency of the power stages **102_1-102**_N.

(34) The addition circuit **604** may be coupled to the calculation circuit **602**, and may be arranged to combine the conduction loss P.sub.LOSS_CON, the switching loss P.sub.LOSS_SW, and the gate switching loss P.sub.LOSS_SW_GATE, to generate an addition result, wherein the addition result can be regarded as the power loss PL of the power stages **102_1-102**_N. As a result, a function of the power loss PL can be expressed as follows:

(35) $\mathrm{PL} = \frac{I_{\mathrm{CS}}^2 * (R_{\mathrm{UP}} + R_{\mathrm{DN}})}{n} + 2 * T_{SW} * I_{CS} * \frac{PV_{\mathrm{DD}}}{2} * Freq + n * (C_{\mathrm{GATEUP}} + C_{\mathrm{GATEDN}}) * V_{\mathrm{DD}}^2 * \mathrm{Freq}$

(36) The optimization circuit **606** may be coupled to the addition circuit **604**, and may be arranged to minimize the power loss PL to generate a minimum result. For example, the optimization circuit **606** can differentiate the function of the power loss PL by n to obtain the minimum value, which can be expressed as follows:

(37) $\mathrm{PL}' = \frac{-[I_{\mathrm{CS}}^2 * (R_{\mathrm{UP}} + R_{\mathrm{DN}})]}{n^2} - \frac{K_{SW} * I_{CS} * PV_{DD} * \mathrm{Freq}}{n^2} + (C_{GATEUP} + C_{GATEDN}) * V_{\mathrm{DD}}^2 * \mathrm{Freq}$

wherein K.sub.SW is equal to (Q.sub.GD+Q.sub.GS2)/2*I.sub.G

(38) ($i.e.\ K_{SW} = \frac{Q_{GD} + Q_{GS2}}{2 * I_G}$),

Q.sub.GD is a gate-to-drain charge of the power stages **102_1-102**_N, Q.sub.GS2 is a post-threshold gate-to-source charge of the power stages **102_1-102**_N, and I.sub.G is a current of the gate terminals of the N-type transistor and the P-type transistor in each of the power stages **102_1-102**_N; and under a condition that PL′=0 (i.e. the power stages **102_1-102**_N has the power loss PL with the minimum value when PL′=0) and V.sub.DD, Freq, R.sub.UP, R.sub.DN, C.sub.GATEUP, C.sub.GATEDN, and K.sub.SW are constants, n can be expressed by the following equation:

n=*K**√{square root over (*I*.sub.CS*(*a**I*.sub.CS+*b**PV*.sub.DD))}

wherein all of K, a, b in the equation are constants.

(39) The optimization circuit **606** may be arranged to generate the control signal CS according to the minimum result (i.e. n=K*√{square root over (I.sub.CS*(a*I.sub.CS+b*PV.sub.DD))}), to dynamically control the number of turned-on power stages in the power stages **102_1-102**_N.

(40) Please refer to FIG. **7**. FIG. **7** is a diagram an analog control circuit **70** according to an embodiment of the present invention, wherein the control circuit **108** shown in FIG. **1** may be implemented by the analog control circuit **70**. As shown in FIG. **7**, the analog control circuit **70** may include an adder circuit **700**, a multiplier circuit **702**, a rooter circuit **704**, and an output interface circuit (e.g. an ADC **706**). The adder circuit **700** may include multiple operational amplifiers **701** and **703**, multiple N-type transistors **705** and **707**, multiple P-type transistors **709**, **711**, **713**, and **715**, and multiple resistors **717**, **719**, and **721**. The operational amplifier **701** has a positive interval (+) coupled to a voltage V.sub.i, wherein the voltage V.sub.i corresponds to the current flowing from the P-type transistor and the N-type transistor to the output terminal OT in each of the plurality of power stages **102_1-102_N** (i.e. I.sub.CS). The operational amplifier **703** has a positive interval (+) coupled to a voltage V.sub.v, wherein the voltage V.sub.v corresponds to the power PV.sub.DD Of the supply voltage V.sub.DD. The N-type transistor **705** has a gate terminal coupled to an output terminal of the operational amplifier **701** and a source terminal coupled to a negative terminal (−) of the operational amplifier **701**. The N-type transistor **707** has a gate terminal coupled to an output terminal of the operational amplifier **703** and a source terminal coupled to a negative terminal (−) of the operational amplifier **703**.
(41) The P-type transistor **709** has a source terminal coupled to the supply voltage V.sub.DD, a drain terminal coupled to a drain terminal of the N-type transistor **705**, and a gate terminal coupled to the drain terminal of the N-type transistor **705**. The P-type transistor **711** has a source terminal coupled to the supply voltage V.sub.DD and a gate terminal coupled to the gate terminal of the P-type transistor **709**. The P-type transistor **713** has a source terminal coupled to the supply voltage V.sub.DD, a drain terminal coupled to a drain terminal of the P-type transistor **711**, and a gate terminal coupled to a drain terminal of the N-type transistor **707**. The P-type transistor **715** has a source terminal coupled to the supply voltage V.sub.DD, a gate terminal coupled to the gate terminal of the P-type transistor **713**, and a drain terminal coupled to the drain terminal of the N-type transistor **707**.
(42) The resistors **717**, **719**, and **721** have resistance values R/a, R, and R/b, respectively, wherein a and b are the constants included in the above-mentioned equation n=K*√{square root over (I.sub.CS*(a*I.sub.CS+b*V.sub.DD))}. The resistor **717** has a first terminal coupled to the source terminal of the N-type transistor **705** and a second terminal coupled to the ground voltage GND. The resistor **719** has a first terminal coupled to the drain terminal of the P-type transistor **711** and a second terminal coupled to the ground voltage GND. The resistor **721** has a first terminal coupled to the source terminal of the N-type transistor **707** and a second terminal coupled to the ground voltage GND.
(43) Regarding the operation of the adder circuit **700**, a current
(44) $0 I_i\left(I_i = \frac{V_i}{\frac{R}{a}}\right)$
may flow from the left side of the adder circuit **700** (i.e. the left side of the P-type transistor **711**) to the first terminal of the resistor **719** through the P-type transistor **711**, and a current
(45) $I_V\left(I_V = \frac{V_V}{\frac{R}{b}}\right)$
may flow from the right side of the adder circuit **700** (i.e. the right side of the P-type transistor **713**) to the first terminal of the resistor **719** through the P-type transistor **713**. In this way, a voltage V.sub.iv at the first terminal of the resistor **719** may be expressed by the following equation:
V.sub.iv=(*a***V*.sub.i+*b***V*.sub.v)
wherein the voltage V.sub.iv may be provided to the multiplier circuit **702**.
(46) The multiplier circuit **702** may include multiple operational amplifiers **723** and **725**, an N-type transistor **727**, multiple P-type transistors **729** and **731**, a resistor **733** with a resistance value R, a capacitor **735** with a capacitance value C, multiple switch circuits **737** and **739**, an inverter **741**, and an SR latch circuit **743**. The operational amplifier **723** has a positive terminal (+) coupled to the voltage V.sub.i that corresponds to the current flowing from the P-type transistor and the N-type

transistor to the output terminal OT in each of the plurality of power stages **102_1-102**_N (i.e. I.sub.CS). The N-type transistor **727** has a gate terminal coupled to an output terminal of the operational amplifier **723** and a source terminal coupled to a negative terminal (−) of the operational amplifier **723**. The resistor **733** has a first terminal coupled to the source terminal of the N-type transistor **727** and a second terminal coupled to the ground voltage GND. The operational amplifier **725** has a positive terminal (+) coupled to the first terminal of the resistor **719** in the adder circuit **700**, for receiving the voltage V.sub.iv.
(47) The P-type transistor **729** has a source terminal coupled to the supply voltage V.sub.DD, a drain terminal coupled to a drain terminal of the N-type transistor **727**, and a gate terminal coupled to the drain terminal of the N-type transistor **727**. The P-type transistor **731** has a source terminal coupled to the supply voltage V.sub.DD and a gate terminal coupled to the gate terminal of the P-type transistor **729**. The capacitor **735** has a first terminal coupled to a negative terminal of the operational amplifier **725** and a second terminal coupled to the ground voltage GND. The switch circuit **737** has a first terminal coupled to a drain terminal of the P-type transistor **731**, wherein when the switch circuit **737** is turned on, a second terminal of the switch circuit **737** is coupled to the first terminal of the capacitor **735**. The switch circuit **739** has a first terminal coupled to the first terminal of the capacitor **735**, wherein when the switch circuit **739** is turned on, a second terminal of the switch circuit **739** is coupled to the second terminal of the capacitor **735**. The SR latch circuit **743** has an input terminal S, a reset terminal R, and an output terminal, wherein the input terminal S is coupled to an output terminal of the operational amplifier **725**, the reset terminal R is arranged to receive a reset signal RE for resetting the SR latch circuit **743**, and the output terminal is coupled to the switch circuit **737** and is arranged to transmit a control signal SR for controlling turn-on and turn-off of the switch circuit **737**. In addition, the output terminal of the SR latch circuit **743** is further coupled to an input interval of the inverter **741**, and is further arranged to transmit the control signal SR to the input interval of the inverter **741**, wherein the inverter **741** may be arranged to invert the control signal SR to generate an inverted control signal SR′, and transmit the inverted control signal SR′ to the switch circuit **739** for controlling turn-on and turn-off of the switch circuit **739**. For example, during a high level of the control signal SR, the switch circuit **737** is turned on and the switch circuit **739** is turned off, and during a low level of the control signal SR, the switch circuit **737** is turned off and the switch circuit **739** is turned on.
(48) In addition, a current
(49) $I_i\,(=\frac{V_i}{R})$
may flow from the left side of the multiplier circuit (i.e. the left side of the P-type transistor **731**) to the first terminal of the switch circuit **737** through the P-type transistor **731**. In this way, a time T.sub.iiv that represents a turned-on time of the switch circuit **737** (i.e. during the time T.sub.iiv, the level of the control signal SR is high) may be expressed by the following equation:
(50) $C*V_{iv}=(\frac{R}{V_i})*T_{iiv}$
wherein the equation can be simplified as:
(51) $T_{iiv}=(\frac{C}{R})*(V_i*V_{iv})$
(52) The rooter circuit **704** may include an operational amplifier **745**, an N-type transistor **747**, multiple P-type transistors **749** and **751**, a capacitor **753** with a capacitance value C, a resistor **755** with a resistance value R, multiple switch circuits **757** and **759**, an inverter **761**, and a sample and hold circuit (for brevity, labeled as “S/H” in FIG. **7**) **763**. The operational amplifier **745** has a positive terminal (+) coupled to the sample and hold circuit **763**, a negative terminal (−) coupled to a first terminal of the resistor **755**, and an output terminal coupled to a gate terminal of the N-type transistor **747**. The N-type transistor **747** has a source terminal coupled to the first terminal of the resistor **755**. The resistor **755** has a second terminal coupled to the ground voltage GND. The P-type transistor **749** has a source terminal coupled to the supply voltage V.sub.DD. The P-type transistor **751** has a source terminal coupled to the supply voltage V.sub.DD, a gate terminal coupled to a gate terminal of the P-type transistor **749**, and a drain terminal coupled to the gate

terminal of the P-type transistor **749** and a drain terminal of the N-type transistor **747**.
(53) The SR latch circuit **743** may be further arranged to transmit the control signal SR to the rooter circuit **704** (more particularly, the switch circuit **757** and an input terminal of the inverter **761**), wherein the control signal SR may be arranged to control turn-on and turn-off of the switch circuit **757**, and the inverter **761** may be arranged to invert the control signal SR to generate the inverted control signal SR′, and transmit the inverted control signal SR′ to the switch circuit **759** for controlling turn-on and turn-off of the switch circuit **759**. For example, during the high level of the control signal SR, the switch circuit **757** is turned on and the switch circuit **759** is turned off, and during the low level of the control signal SR, the switch circuit **757** is turned off and the switch circuit **759** is turned on. The switch circuit **757** has a first terminal coupled to a drain terminal of the P-type transistor **749**, wherein when the switch circuit **757** is turned on, a second terminal of the switch circuit **757** is coupled to the sample and hold circuit **763** and a first terminal of the capacitor **753**, wherein a second terminal of the capacitor **753** is coupled to the ground voltage GND. The switch circuit **759** has a first terminal coupled to the sample and hold circuit **763** and the first terminal of the capacitor **753**, wherein when the switch circuit **759** is turned on, a second terminal of the switch circuit **759** is coupled to the second terminal of the capacitor **753**.
(54) In addition, a current
(55) $I_n\left(=\frac{V_n}{R}\right)$
may flow from the right side of the multiplier circuit (i.e. the right side of the P-type transistor **749**) to the first terminal of the switch circuit **757** through the P-type transistor **749**, wherein V.sub.n is a voltage value at the first terminal of the resistor **755**, and corresponds to the number of turned-on power stages in the power stages **102_1-102_**N. In this way, V.sub.n can be expressed by the following equation:
(56) $C*V_n=\frac{R}{V_n}*T_{iiv}$
wherein T.sub.iiv represents a turned-on time of the switch circuit **757**, and since
(57) $T_{iiv}=\left(\frac{C}{R}\right)*(V_i*V_{iv})$
(which is obtained by the multiplier circuit **702**) and V.sub.iv=(a*V.sub.i+b*V.sub.v) (which is obtained by the adder circuit **700**), the equation can be simplified as:
V.sub.n=√{square root over (*V*.sub.i*(*a***V*.sub.i+*b***V*.sub.v))}
(58) The ADC **706** may be coupled to the rooter circuit **704** (more particularly, the first terminal of the resistor **755**), and may be arranged to convert V.sub.n into the control signal CS, wherein the control signal CS is arranged to dynamically control a number of turned-on power stages in the power stages **102_1-102_**N.
(59) FIG. **8** is a diagram illustrating an audio amplifier (e.g. a class-D amplifier **80**) according to another embodiment of the present invention. The difference between the class-D amplifier **80** and the class-D amplifier **10** shown in FIG. **1** is that the class-D amplifier **80** may include a current sensing circuit **807** (labeled as “CS circuit” in FIG. **8**) that takes the place of the current sensing circuit **107**, wherein the current sensing circuit **807** may be coupled to a low side terminal LT at the source terminal of the N-type transistor in each of the power stages **102_1-102_**N, and may be arranged to sense and derive an output current at the low side terminal LT, and generate the voltage signal V.sub.CS corresponding to the output current as the at least one detection input. In detail, please refer to FIG. **9**. FIG. **9** is a diagram illustrating a current sensing circuit **90** according to another embodiment of the present invention, wherein the current sensing circuit **807** shown in FIG. **8** may be implemented by the current sensing circuit **90**. As shown in FIG. **9**, the current sensing circuit **90** may sense and derive a sensing current I.sub.sen from the low side terminal LT of the power stages **102_1-102_**N, and generate the voltage signal V.sub.CS according to the sensing current I.sub.sen and a resistor R.sub.SEN. The current sensing circuit **90** may include a plurality of resistors R.sub.1, R.sub.2, R.sub.3, R.sub.4, and R.sub.SEN and an operational amplifier **91**, wherein a resistance value of the resistor R.sub.1 is equal to that of the resistor R.sub.3, a resistance value of the resistor R.sub.2 is equal to that of the resistor R.sub.4, a

resistance value of the resistor R.sub.SEN is much smaller than that of the resistors R.sub.1 and R.sub.2, and a positive power supply and a negative power supply of the operational amplifier **91** are the supply voltage V.sub.DD and the ground voltage GND, respectively. Since the operations of the current sensing circuit **90** are similar to that of the current sensing circuit **20** shown in FIG. **2**, similar descriptions are not repeated in detail here for brevity.
(60) FIG. **10** is a diagram illustrating an audio amplifier (e.g. a class-D amplifier **1000**) according to yet another embodiment of the present invention. The difference between the class-D amplifier **1000** and the class-D amplifier **10** shown in FIG. **1** is that the class-D amplifier **1000** may include a current sensing circuit **1007** (labeled as “CS circuit” in FIG. **10**) that takes the place of the current sensing circuit **107**, wherein the current sensing circuit **1007** may be coupled to a high side terminal HT at the source terminal of the P-type transistor in each of the power stages **102_1-102**_N, and may be arranged to sense and derive an output current at the high side terminal HT, and generate the voltage signal V.sub.CS corresponding to the output current as the at least one detection input. In detail, please refer to FIG. **11**. FIG. **11** is a diagram illustrating a current sensing circuit **1100** according to yet another embodiment of the present invention, wherein the current sensing circuit **1007** shown in FIG. **10** may be implemented by the current sensing circuit **1100**. As shown in FIG. **11**, the current sensing circuit **1100** may sense and derive a sensing current I.sub.sen from the high side terminal HT of the power stages **102_1-102**_N, and generate the voltage signal V.sub.CS according to the sensing current I.sub.sen and a resistor R.sub.SEN. The current sensing circuit **1100** may include a plurality of resistors R.sub.1, R.sub.2, R.sub.3, R.sub.4, and R.sub.SEN and an operational amplifier **1101**, wherein a resistance value of the resistor R.sub.1 is equal to that of the resistor R.sub.3, a resistance value of the resistor R.sub.2 is equal to that of the resistor R.sub.4, a resistance value of the resistor R.sub.SEN is much smaller than that of the resistors R.sub.1 and R.sub.2, and a positive power supply and a negative power supply of the operational amplifier **1101** are the supply voltage V.sub.DD and the ground voltage GND, respectively. Since the operations of the current sensing circuit **1100** are similar to that of the current sensing circuit **20** shown in FIG. **2**, similar descriptions are not repeated in detail here for brevity.
(61) In summary, by the class-D amplifier **10**/**80**/**1000** of the present invention, under a condition that the supply voltage V.sub.DD supplied to the power stages **102_1-102**_N varies, the power stage control circuit **104** in the class-D amplifier **10**/**80**/**1000** can be able to dynamically track the supply voltage V.sub.DD to optimize the power stages **102_1-102**_N. In addition, the power stage control circuit **104** can generate the control signal CS under a condition that the power stages **102_1-102**_N have the power loss PL with the minimum value, for dynamically controlling the number of turned-on power stages in the power stages **102_1-102**_N, which can increase the amplifier efficiency.
(62) Those skilled in the art will readily observe that numerous modifications and alterations of the device and method may be made while retaining the teachings of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.

Claims

1. An audio amplifier, comprising: a plurality of power stages, wherein the plurality of power stages are coupled in parallel with each other, each of the plurality of power stages comprises a first switch and a second switch, the first switch and the second switch are coupled in series between a first reference voltage and a second reference voltage, and the first reference voltage is higher than the second reference voltage; a driving circuit, coupled to the plurality of power stages, and arranged to receive an input signal, and generate a driving signal to the plurality of power stages according to the input signal for driving the plurality of power stages; a power stage control circuit, comprising: a feedback circuit, coupled to the plurality of power stages, and arranged to generate a

feedback signal according to at least one detection input, wherein the at least one detection input comprises at least one of a power of the first reference voltage, a voltage signal corresponding to a switching time of the plurality of power stages, and a voltage signal corresponding to a switching frequency of the plurality of power stages; and a control circuit, coupled between the feedback circuit and the plurality of power stages, and arranged to generate a control signal according to the feedback signal, wherein the control signal is arranged to dynamically control a number of turned-on power stages in the plurality of power stages.

2. The audio amplifier of claim 1, wherein the first switch and the second switch are a P-type transistor and an N-type transistor, respectively.

3. The audio amplifier of claim 1, wherein both of the first switch and the second switch are N-type transistors.

4. The audio amplifier of claim 1, wherein the power of the first reference voltage is derived from a terminal coupled to the first reference voltage in each of the plurality of power stages.

5. The audio amplifier of claim 1, wherein the voltage signal corresponding to the switching time of the plurality of power stages and the voltage signal corresponding to the switching frequency of the plurality of power stages are derived from an output terminal between the first switch and the second switch in each of the plurality of power stages.

6. The audio amplifier of claim 1, wherein the at least one detection input further comprises a voltage signal corresponding to an output current of the plurality of power stages, and the output current is derived from an output terminal between the first switch and the second switch in each of the plurality of power stages.

7. The audio amplifier of claim 1, wherein the at least one detection input further comprises a voltage signal corresponding to an output current of the plurality of power stages, and the output current is derived from a terminal coupled to the first reference voltage in each of the plurality of power stages.

8. The audio amplifier of claim 1, wherein the at least one detection input further comprises a voltage signal corresponding to an output current of the plurality of power stages, and the output current is derived from a terminal coupled to the second reference voltage in each of the plurality of power stages.

9. The audio amplifier of claim 1, wherein the control circuit is a digital circuit, and comprises: at least one analog to digital converter (ADC), arranged to convert the feedback signal into at least one digital signal; a calculation circuit, arranged to calculate a power loss of the plurality of power stages according to the at least one digital signal; and an optimization circuit, arranged to minimize the power loss to generate a minimum result, and generate the control signal according to the minimum result.

10. The audio amplifier of claim 9, wherein the power loss comprises a conduction loss, a switching loss, and a gate switching loss; and the control circuit further comprises: an addition circuit, coupled between the calculation circuit and the optimization circuit, and arranged to combine the conduction loss, the switching loss, and the gate switching loss, to generate an addition result; wherein the optimization circuit is arranged to minimize the addition result to generate the minimum result.

11. The audio amplifier of claim 1, wherein the control circuit is an analog circuit, and comprises: an adder circuit, arranged to add a voltage corresponding to a current flowing from the first switch and the second switch to an output terminal between the first switch and the second switch in each of the plurality of power stages to a voltage corresponding to the power of the first reference voltage, to generate a first voltage; a multiplier circuit, coupled to the adder circuit, and arranged to obtain a first time according to the first voltage and the voltage corresponding to the current flowing from the first switch and the second switch to the output terminal between the first switch and the second switch in each of the plurality of power stages; a rooter circuit, coupled to the multiplier circuit, and arranged to obtain a second voltage according to the first time, wherein the

second voltage corresponds to a number of turned-on power stages in the plurality of power stages; and an analog to digital converter (ADC), coupled to the rooter circuit, and arranged to generate the control signal according to the second voltage.

12. The audio amplifier of claim 1, wherein the audio amplifier is a class-D amplifier.

13. An audio amplifier, comprising: a plurality of power stages, wherein the plurality of power stages are coupled in parallel with each other, each of the plurality of power stages comprises a first switch and a second switch, the first switch and the second switch are coupled in series between a first reference voltage and a second reference voltage, and the first reference voltage is higher than the second reference voltage; a driving circuit, coupled to the plurality of power stages, and arranged to receive an input signal, and generate a driving signal to the plurality of power stages according to the input signal for driving the plurality of power stages; a power stage control circuit, comprising: a feedback circuit, coupled to the plurality of power stages, and arranged to generate a feedback signal according to at least one detection input, wherein the at least one detection input comprises a voltage signal corresponding to an output current of the plurality of power stages, and the output current is derived from a terminal coupled to the first reference voltage or a terminal coupled to the second reference voltage in each of the plurality of power stages; and a control circuit, coupled between the feedback circuit and the plurality of power stages, and arranged to generate a control signal according to the feedback signal, wherein the control signal is arranged to dynamically control a number of turned-on power stages in the plurality of power stages.

14. The audio amplifier of claim 13, wherein the first switch and the second switch are a P-type transistor and an N-type transistor, respectively.

15. The audio amplifier of claim 13, wherein both of the first switch and the second switch are N-type transistors.

16. The audio amplifier of claim 13, wherein the control circuit is a digital circuit, and comprises: at least one analog to digital converter (ADC), arranged to convert the feedback signal into at least one digital signal; a calculation circuit, arranged to calculate a power loss of the plurality of power stages according to the at least one digital signal; and an optimization circuit, arranged to minimize the power loss to generate a minimum result, and generate the control signal according to the minimum result.

17. The audio amplifier of claim 16, wherein the power loss comprises a conduction loss, a switching loss, and a gate switching loss; and the control circuit further comprises: an addition circuit, coupled between the calculation circuit and the optimization circuit, and arranged to combine the conduction loss, the switching loss, and the gate switching loss, to generate an addition result; wherein the optimization circuit is arranged to minimize the addition result to generate the minimum result.

18. The audio amplifier of claim 13, wherein the control circuit is an analog circuit, and comprises: an adder circuit, arranged to add a voltage corresponding to a current flowing from the first switch and the second switch to an output terminal between the first switch and the second switch in each of the plurality of power stages to a voltage corresponding to the power of the first reference voltage, to generate a first voltage; a multiplier circuit, coupled to the adder circuit, and arranged to obtain a first time according to the first voltage and the voltage corresponding to the current flowing from the first switch and the second switch to the output terminal between the first switch and the second switch in each of the plurality of power stages; a rooter circuit, coupled to the multiplier circuit, and arranged to obtain a second voltage according to the first time, wherein the second voltage corresponds to a number of turned-on power stages in the plurality of power stages; and an analog to digital converter (ADC), coupled to the rooter circuit, and arranged to generate the control signal according to the second voltage.

19. The audio amplifier of claim 13, wherein the audio amplifier is a class-D amplifier.