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**Choi et al.**

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(54) **RECEIVER RESILIENT TO NOISE INPUT**

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**H03K 17/16** (2006.01)  
**H03F 3/45** (2006.01)

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CPC ..... **H03F 3/45977** (2013.01); **H03K 17/16** (2013.01); **H03F 2200/372** (2013.01)

(58) **Field of Classification Search**  
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USPC ..... 326/22  
See application file for complete search history.

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(57) **ABSTRACT**

A receiver includes a signal receiving part suitable for outputting a signal corresponding to a reception signal that is received through an input terminal, and controlling a DC voltage of a signal to be outputted, according to an offset signal, an amplifying part suitable for amplifying and outputting an output of the signal receiving part, and a feedback control part suitable for controlling the offset signal according to an output of the amplifying part.

**16 Claims, 9 Drawing Sheets**

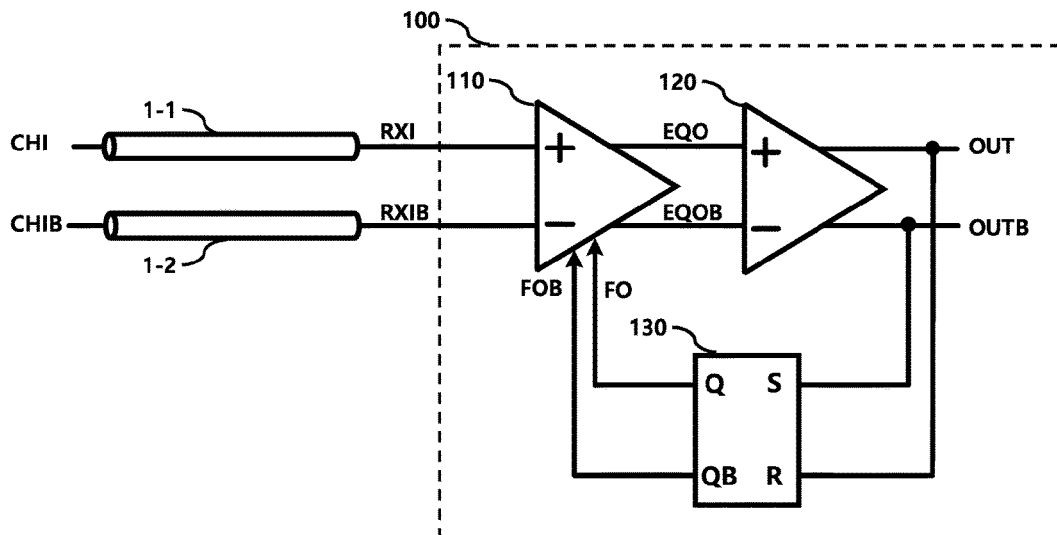
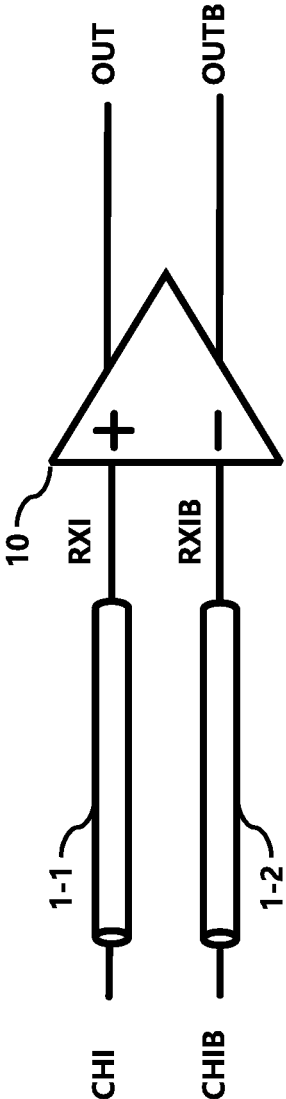


FIG. 1



<PRIOR ART>

FIG. 2

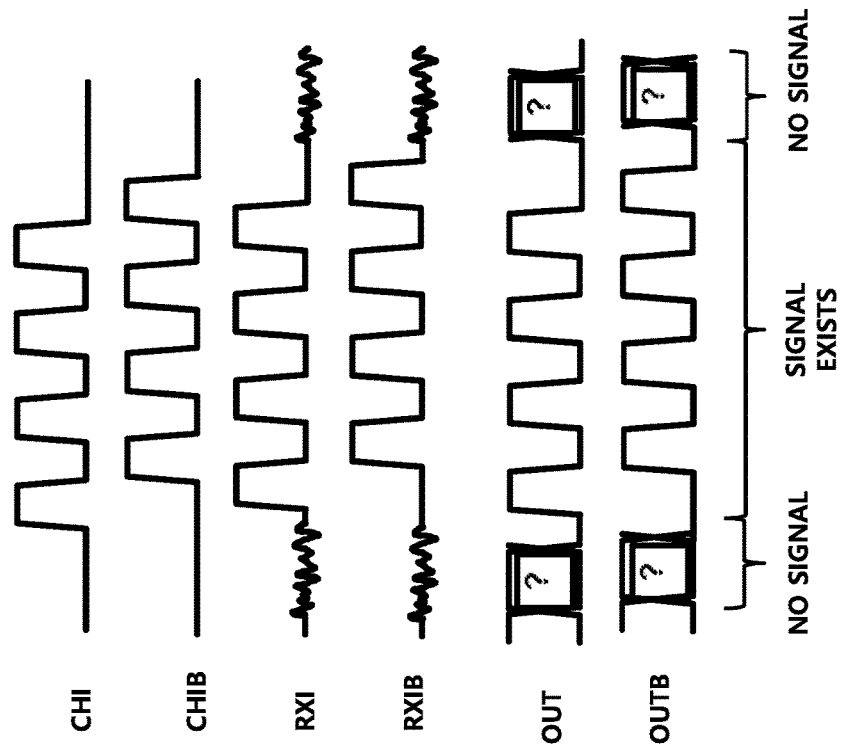


FIG. 3

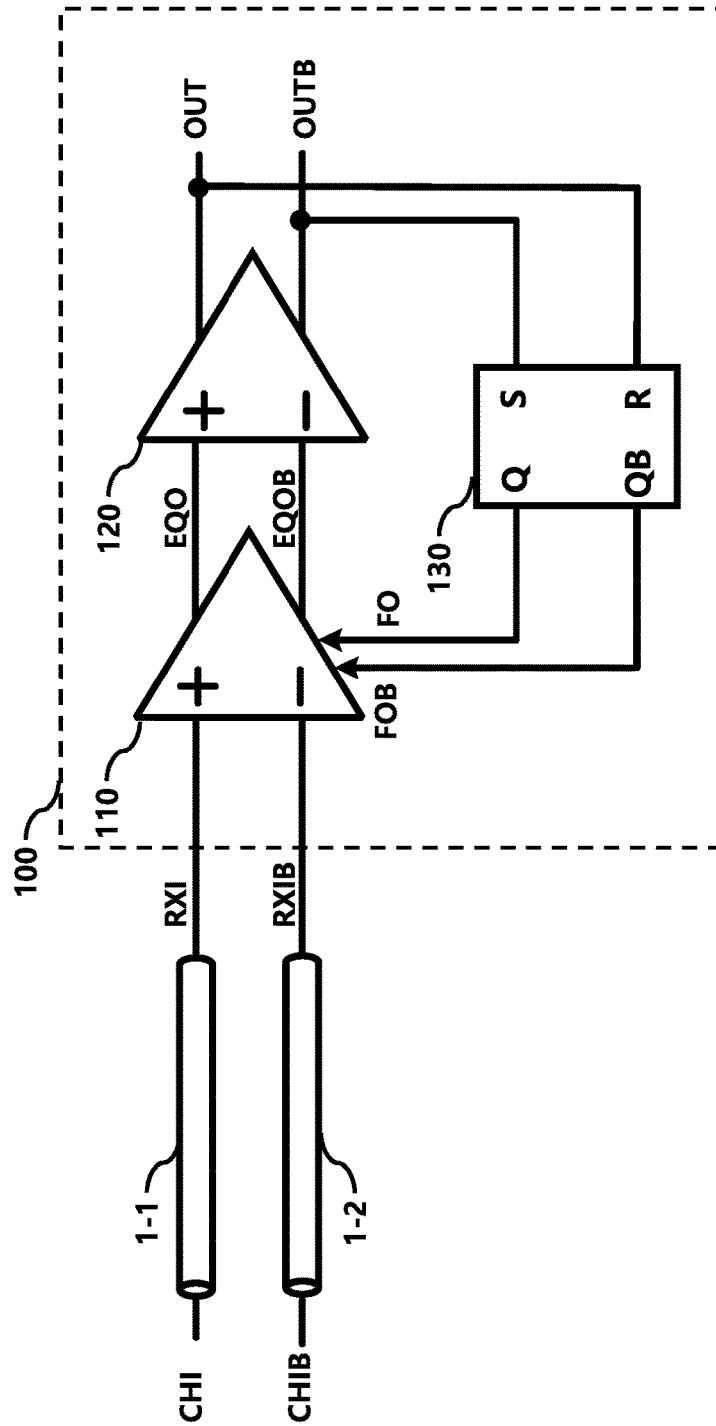


FIG. 4

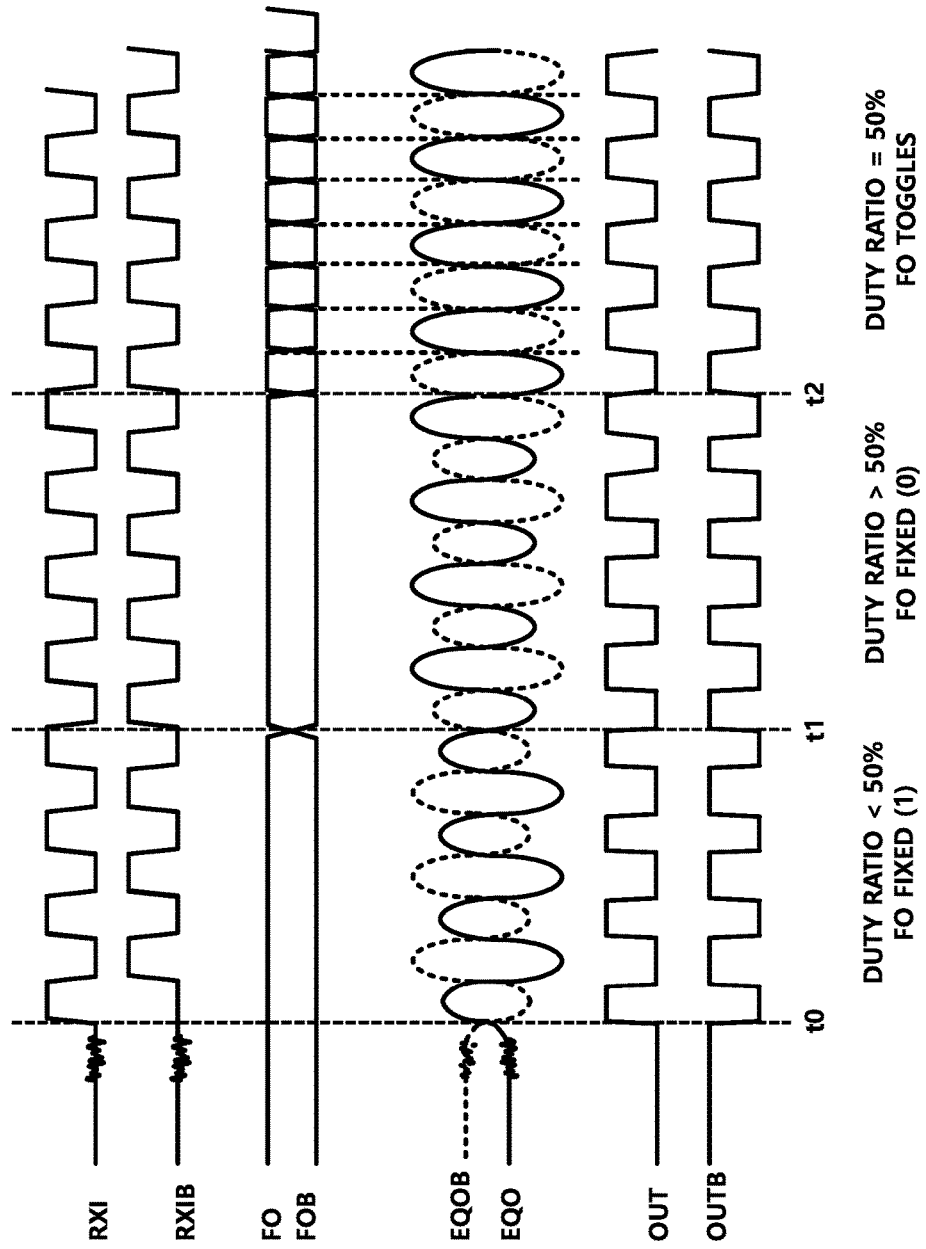


FIG. 5

S	R	Q	QB	
0	0	1	0	+OFFSET
0	1	0	1	- OFFSET
1	0	1	0	+OFFSET
1	1	X	X	X

FIG. 6

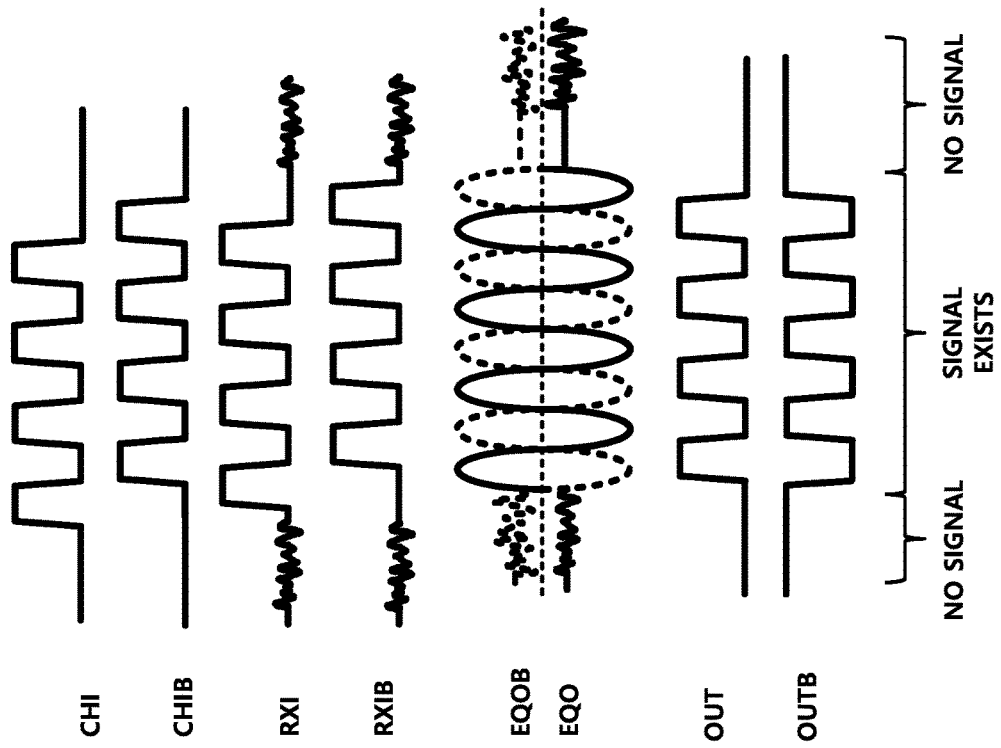
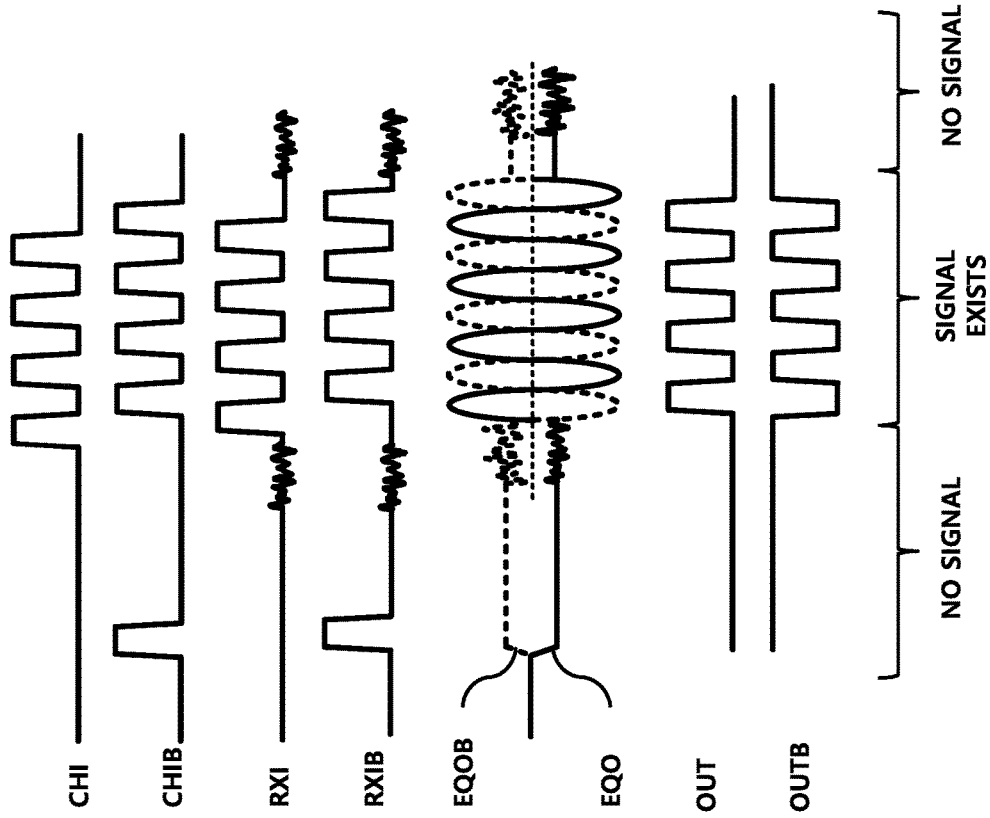


FIG. 7

S	R	Q	QB	
0	0	Q	QB	NO CHANGE
0	1	0	1	- OFFSET
1	0	1	0	+OFFSET
1	1	X	X	X



FIG. 8





1

**RECEIVER RESILIENT TO NOISE INPUT**CROSS-REFERENCE TO RELATED  
APPLICATIONS

The present application claims priority of Korean Patent Application No. 10-2016-0110461, filed on Aug. 30, 2016, which is incorporated herein by reference in its entirety.

## BACKGROUND

## 1. Field

Exemplary embodiments of the present disclosure relate to a receiver, and more particularly, to a receiver which reduces the possibility of a malfunction occurring due to noise applied to an input terminal of the receiver.

## 2. Description of the Related Art

FIG. 1 shows a conventional receiver **10**. The conventional receiver **10** receives receiving signals RXI and RXIB transmitted through first and second channels **1-1** and **1-2**, respectively, and generates output signals OUT and OUTB. Signals inputted to the first and second channels **1-1** and **1-2** are referred to as channel signals CHI and CHIB, respectively.

FIG. 2 is a waveform diagram which shows drawbacks of the receiver **10** in FIG. 1.

When the channel signals CHI and CHIB are applied to the first and second channels **1-1** and **1-2**, respectively, the receiving signals RXI and RXIB, which have passed through the first and second channels **1-1** and **1-2**, respectively, are applied to the receiver **10**.

In a time period in which the channel signals CHI and CHIB are not applied to the channels **1-1** and **1-2**, a noise may be applied to input terminals of the receiver **10**. The term "noise", as used herein, may refer to a noise component of a current or voltage signal. In this case, signals at the input terminals of the receiver **10** cannot maintain desired uniform levels because of the noise.

When similar noises are applied to the two input terminals of the receiver **10**, a difference between the signals at the input terminals may be substantially zero. Accordingly, a malfunction due to the noises does not occur in the receiver **10**.

However, when different noises are applied to the two input terminals of the receiver **10** because of a difference of characteristics of the first and second channels **1-1** and **1-2**, the receiver **10** may amplify the different noises, and may output the amplified signals as the output signals OUT and OUTB in pulse forms.

In the time period in which the channel signals CHI and CHIB are not applied to the channels **1-1** and **1-2**, the output signals OUT and OUTB may not have uniform levels because of noises, and may have unpredictable values.

Accordingly, the conventional receiver **10** may cause a malfunction in a system that uses the output signals of the conventional receiver **10**.

## SUMMARY

Various embodiments of the present disclosure are directed to a receiver which can prevent a noise from affecting an output signal thereof, the noise being applied to an input terminal of the receiver.

2

A receiver according to an embodiment may include: a signal receiving part suitable for outputting a signal corresponding to a receiving signal that is received to an input terminal, and controlling a DC voltage of a signal outputted in accordance with an offset signal; an amplifying part suitable for amplifying and outputting an output of the signal receiving part; and a feedback control part suitable for controlling an offset signal in accordance with the output of the amplifying part.

A receiver according to an embodiment may substantially prevent the output of any noise by a noise applied to an input terminal of the receiver when a normal signal is not inputted to the receiver.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a conventional receiver.

FIG. 2 is a waveform diagram showing drawbacks of FIG. 1.

FIG. 3 is a block diagram of a receiver in accordance with an embodiment.

FIG. 4 is a waveform diagram showing an operation of the receiver in FIG. 3 in accordance with an embodiment.

FIG. 5 is a truth table showing an operation of a feedback control part in FIG. 3 in accordance with an embodiment.

FIG. 6 is a waveform diagram showing an operation of the receiver in FIG. 3 according to the truth table of FIG. 5.

FIG. 7 is a truth table showing an operation of the feedback control part in FIG. 3 in accordance with another embodiment.

FIG. 8 is a waveform diagram showing an operation of the receiver in FIG. 3 according to the truth table of FIG. 7.

FIG. 9 is a circuit diagram of a signal receiving part in FIG. 3 in accordance with an embodiment.

## DETAILED DESCRIPTION

Various embodiments will be described below in more detail with reference to the accompanying drawings. The present invention may, however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the present invention to those skilled in the art. Throughout the disclosure, like reference numerals refer to like parts throughout the various figures and embodiments of the present disclosure.

Hereinafter, embodiments will be described with reference to the accompanying drawings.

FIG. 3 is a block diagram of a receiver **100** according to an embodiment.

The receiver **100** generates a differential signal, which includes output signals OUT and OUTB, based on a differential signal, which includes receiving signals RXI and RXIB.

The receiving signal RXI may be described as a first receiving signal, and the receiving signal RXIB may be described as a second receiving signal.

The output signal OUT may be described as a first output signal, and the output signal OUTB may be described as a second output signal.

The first and second receiving signals RXI and RXIB are signals obtained by passing channel input signals CHI and CHIB through first and second channels **1-1** and **1-2**, respectively.

The receiver **100** includes a signal receiving part **110**, an amplifying part **120**, and a feedback control part **130**.

The signal receiving part **110** outputs a differential signal including signals EQO and EQOB based on the first and second receiving signals RXI and RXIB.

In the present embodiment, the signal receiving part **110** controls DC voltages of the signals EQO and EQOB in response to a differential signal, which includes offset signals FO and FOB that are provided by the feedback control part **130**.

The offset signal FO may be described as a first offset signal, and the offset signal FOB may be described as a second offset signal.

When EYE characteristics of the first and second receiving signals RXI and RXIB inputted to the signal receiving part **110** are not good, the signal receiving part **110** may further perform an equalization operation.

The equalization operation is well-known to people having ordinary skill in the art, and its description is therefore omitted.

In accordance with an embodiment, the signal receiving part **110** outputs the equalization signals EQO and EQOB, which are equalized signals of the first and second receiving signals RXI and RXIB, and the DC voltages of the equalization signals EQO and EQOB are controlled by the first and second offset signals FO and FOB.

The equalization signal EQO may be described as a first equalization signal, and the equalization signal EQOB may be described as a second equalization signal.

The amplifying part **120** amplifies a difference between the first and second equalization signals EQO and EQOB, and outputs the first and second output signals OUT and OUTB.

The first and second output signals OUT and OUTB may be digital signals.

For example, the amplifying part **120** may output a digital signal "1" when the difference (EQO-EQOB) is positive, and may output a digital signal "0" when the difference (EQO-EQOB) is negative or zero.

The feedback control part **130** outputs the first and second offset signals FO and FOB based on the first and second output signals OUT and OUTB of the amplifying part **120**.

In the present embodiment, the DC voltage of the first equalization signal EQO and the DC voltage of the second equalization signal EQOB are controlled differently in response to the first and second offset signals FO and FOB.

Accordingly, in a time period in which a meaningful signal is not applied to input terminals of the signal receiving part **110**, if a difference between signals at the input terminals of the signal receiving part **110** does not have a uniform value and changes unpredictably with respect to a ground level because of noises applied to the input terminals, the DC voltages of the first and second equalization signals EQO and EQOB may have different values from each other.

Accordingly, the difference between the first and second equalization signals EQO and EQOB (EQO-EQOB) inputted to the amplifying part **120** is fixed as being positive or negative, and therefore the first and second output signals OUT and OUTB have uniform values in the time period in which no meaningful signal is applied to the signal receiving part **110**.

When the first and second offset signals FO and FOB maintain uniform values, if normal signals are inputted to the signal receiving part **110**, a duty ratio of the first and second output signals OUT and OUTB does not have a desired value (for example, 50%), but may have a value more than or less than 50%.

To solve this problem, the feedback control part **130** controls the first and second offset signals FO and FOB in

response to the first and second output signals OUT and OUTB, thereby preventing the distortion of the duty ratio of the first and second output signals OUT and OUTB.

FIG. 4 is a wave diagram showing an operation of the receiver **100** in FIG. 3 in accordance with an embodiment.

Referring to FIG. 4, a meaningful signal is not applied to the signal receiving part **110** in a time period before a time  $t_0$ , and meaningful signals, e.g., the first and second receiving signals RXI and RXIB, are applied to the signal receiving part **110** in a time period after the time  $t_0$ .

The first offset signal FO is set to "1" until a time  $t_1$ , the first offset signal FO is set to "0" during a time period between the time  $t_1$  to a time  $t_2$ , and then the first offset signal FO toggles in accordance with the first output signal OUT after the time  $t_2$ .

If the first offset signal FO is set to "1", the DC voltage of the second equalization signal EQOB, outputted from the signal receiving part **110**, increases. If the first offset signal FO is set to "0", the DC voltage of the first equalization signal EQO increases.

If the normal signals are not applied to the signal receiving part **110** before the time  $t_0$ , the first offset signal FO is set to "1", and the DC voltage of the second equalization signal EQOB increases.

Accordingly, although noises are applied to the input terminals of the signal receiving part **110**, the first and second equalization signals EQO and EQOB may not cross, and thus the difference of the first and second equalization signals EQO and EQOB (EQO-EQOB) may be maintained to be negative.

Therefore, referring to FIG. 4, before the time  $t_0$ , the first output signal OUT of the amplifying part **120** is constantly maintained as "0".

This means that noises applied to the receiver **100** do not cause malfunction in the output signal OUT.

After the time  $t_0$ , the receiving signals RXI and RXIB are applied to the signal receiving part **110**.

In the present embodiment, it is assumed that the duty ratio of the receiving signals RXI and RXIB is 50% and that the receiving signals RXI and RXIB are toggling clock signals.

From the time  $t_0$  to the time  $t_1$ , the offset signal FO is maintained as "1".

As described above, when the offset signal FO is set to "1", the DC voltage of the equalization signal EQOB increases.

Referring to FIG. 4, it is described that the DC voltages of the equalization signals EQO and EQOB change in accordance with the offset signals FO and FOB.

When one of the DC voltages of the equalization signals EQO and EQOB changes, a time, at which the difference of the equalization signals EQO and EQOB (EQO-EQOB) changes sign from positive to negative or vice versa, is changed. Accordingly, the duty ratio of the output signals OUT and OUTB of the amplifying part **120** is also changed.

From the time  $t_0$  to the time  $t_1$ , the DC voltage of the equalization signal EQOB increases because the offset signal FO is set to "1". Therefore, a time period, in which the difference of the equalization signals EQO and EQOB (EQO-EQOB) is positive, becomes narrower as the DC voltage of the equalization signal EQOB increases, and thus the duty ratio of the output signals OUT and OUTB becomes less than 50%.

On the other hand, from the time  $t_1$  to the time  $t_2$ , the offset signal FO is set to "0".

When the offset signal FO is set to "0", the DC voltage of the equalization signal EQO increases.

5

Therefore, in FIG. 4, from the time t1 to the time t2, the DC voltage of the equalization signal EQO increases. Accordingly, the time period in which the difference of the equalization signals EQO and EQOB (EQO-EQOB) is positive becomes wider than the time period from the time t0 to the time t1, because the DC voltage of the equalization signal EQO increases, and thus the duty ratio of the output signals OUT and OUTB exceeds 50%.

After the time t2, the offset signal FO toggles in accordance with the output signal OUT.

Therefore, the offset signal FO is set to "0" when the output signal OUT is "1", and the offset signal FO is set to "1" when the output signal OUT is "0".

As described above, the duty ratio exceeds 50% when the offset signal FO is set to "0", and the duty ratio becomes less than 50% when the offset signal FO is set to "1". The duty ratio increases or decreases when the output signal OUT toggles, such that the duty ratio of the output signal OUT finally converges on 50%.

To obtain a desirable duty ratio of the output signal OUT, an amount of changes in the DC voltage of the equalization signal EQO needs to be controlled in accordance with the offset signal FO. The amount of changes in the DC voltage can be determined in advance by using a simulation or by using an experiment.

Therefore, in the present embodiment, the offset signal FO is uniformly maintained even though no signal is applied to the receiver 100 before the time t0. The present embodiment prevents noises from being outputted to the output signals OUT and OUTB. When the receiving signals RXI and RXIB are inputted to the receiver 100, the offset signal FO toggles in accordance with the output signal OUT. Therefore, the duty ratio of the output signals OUT and OUTB finally converges on 50% without distortion.

FIG. 5 is a truth table showing an operation of the feedback control part 130 in FIG. 3 in accordance with an embodiment.

The second output signal OUTB of the amplifying part 120 is applied to a set terminal S of the feedback control part 130, and the first output signal OUT of the amplifying part 120 is applied to a reset terminal R of the feedback control part 130.

The first offset signal FO is outputted at an output terminal Q of the feedback control part 130. The second offset signal FOB is outputted at an output terminal QB of the feedback control part 130.

In FIG. 5, a positive offset value (+OFFSET) means that the first offset signal FO is set to "1", and a negative offset value (-OFFSET) means that the first offset signal FO is set to "0".

In an embodiment, the first output signal OUT of the amplifying part 120 is normally maintained as "0" when the first input signal RXI is not applied to the receiver 100.

The second output signal OUTB has an opposite level to the first output signal OUT. Accordingly, there is no embodiment in which "1" is applied to both of the set terminal S and the reset terminal R.

In FIG. 4, at the beginning of the operation of the receiver 100, both of the first and second output signals OUT and OUTB can be "0" temporarily. When "0" is applied to both of the set terminal S and the reset terminal R, the first offset signal FO becomes "1".

After that, when the first and second output signals OUT and OUTB change, the feedback control part 130 outputs "0" as the first offset signal FO when the output signal OUT is "1", and the feedback control part 130 outputs "1" as an offset signal FOB when an output signal OUTB is "0". The

6

feedback control part 130 outputs "1" as the first offset signal FO when the output signal OUT is "0", and the feedback control part 130 outputs "0" as an offset signal FOB when an output signal OUTB is "1".

A digital circuit that operates according to the truth table in FIG. 5 can be easily designed by a person having ordinary skill in the art, and therefore a detailed configuration thereof is omitted.

FIG. 6 is a waveform diagram showing an operation of the receiver 100, including the feedback control part 130 in FIG. 3, according to the truth table of FIG. 5.

As described above, both of the output signals OUT and OUTB may correspond to "0" in a beginning stage when a power is on.

Referring to FIG. 5, when the output signal OUT is "0", i.e., "0" is applied to the reset terminal R of the feedback control part 130, the offset signal FO is always maintained as "1".

Since the offset signal FO is maintained as "1" in a time period, in which no signal is input to the receiver 100, including an initialization period of the receiver 100, the DC voltage of the equalization signal EQOB increases, whereas the DC voltage of the equalization signal EQO does not increase.

Accordingly, the output signals OUT and OUTB of the amplifying part 120 are not affected by noises, and thus can maintain uniform levels.

In a time period in which the receiving signals RXI and RXIB are inputted to the receiver 100, the offset signals FO and FOB toggle in accordance with the output signal OUT as previously described, and therefore the duty ratio of the output signals OUT and OUTB is not distorted.

FIG. 7 is a truth table showing an operation of the feedback control part 130 in FIG. 3 in accordance with another embodiment.

In FIG. 7, the feedback control part 130 operates like a general SR latch.

When both of a set signal and a reset signal are "0", the feedback control part 130 maintains its previous output value.

In the present embodiment, an initial value of the feedback control part 130 may not be determined in a beginning stage of the operation of the receiver 100, and thus an initial value of the offset signal FO may not be determined in the beginning stage.

In the present embodiment, the initial values of the offset signals FO and FOB can be determined by receiving initialization signals in the beginning stage of the operation of the receiver 100.

FIG. 8 is a waveform diagram showing an operation of the receiver 100 in FIG. 3 according to the truth table of FIG. 7.

In a time period in which no signal is input to the receiver 100 shown in the left side of FIG. 8, initialization signals having pulse forms are applied to the receiver 100. In this time period, "0" is applied as a channel input signal CHI, and "1" is applied as a channel input signal CHIB.

The initialization signals are transmitted through the channels 1-1 and 1-2, and provided to the signal receiving part 110 as the receiving signals RXI and RXIB.

Before the initialization signals are applied, the equalization signals EQO and EQOB, which are outputted from the signal receiving part 110, can be initialized to correspond to VDD/2.

When the initialization signals pass through the signal receiving part 110 and the amplifying part 120, the output signal OUT may correspond to "0", and the output signal

OUTB may correspond to “1”. Accordingly, the feedback control part **130** outputs the offset signal FO corresponding to “1”.

As the offset signal FO corresponds to “1”, the DC voltage of the equalization signal EQOB increases, the output signal OUT of the amplifying part **120** is maintained as “0”, and the output signal OUTB is maintained as “1”.

As a result, the offset signal FO, which is outputted from the feedback control part **130**, is maintained as “1”.

Afterwards, in a stage when a normal signal is not applied to the receiver **100**, the difference of the equalization signals EQO and EQOB (EQO-EQOB) is maintained as a negative difference, and the output signals OUT and OUTB are constantly maintained, even though noises are applied to the receiver **100**.

In a time period in which normal signals are applied to the receiver **100**, the offset signals FO and FOB toggle in accordance with the output signals OUT and OUTB, and the distortion of the duty ratio of the output signals OUT and OUTB is prevented, as described above.

FIG. 9 is a circuit diagram showing the signal receiving part **110** of FIG. 3 in accordance with an embodiment.

The signal receiving part **110** includes an equalization part **111**, a first offset control part **112**, and a second offset control part **113**. The first and second offset control part **112** and **113** are coupled to output terminals of the equalization part **111**, respectively. The equalization signals EQOB and EQO are output through the output terminals of the equalization part **111**.

The equalization part **111** equalizes the input signals RXI and RXIB and outputs the equalization signals EQO and EQOB through the output terminals. The first offset control part **112** controls a DC voltage of the equalization signal EQOB in accordance with the offset signal FOB, and the second offset control part **113** controls a DC voltage of the equalization signal EQO in accordance with the offset signal FO.

The equalization part **111** includes a continuous time linear equalizer (CTLE). Since a structure and an operation of the CTLE are well-known to people having ordinary skill in the art, the detailed description thereof is omitted.

The first offset control part **112** includes a current source **1121** and a switch **1122** that are coupled in series between a power supply terminal VDD and the first output terminal of the equalization part **111**. The equalization signal EQOB is output through first output terminal of the equalization part **111**.

In the first offset control part **112**, the switch **1122** is turned on when the offset signal FOB is “0”. Accordingly, a current provided by the current source **1121** flows through a resistor **1111** in the equalization part **111**, and thus the DC voltage of the equalization signal EQOB increases. The resistor **1111** is coupled between the first output terminal of the equalization part **111** and a ground voltage terminal.

Since, when the offset signal FOB is “1”, the switch **1122** is turned off, the DC voltage of the equalization signal EQOB is not affected by the current that the current source **1121** provides.

The second offset control part **113** includes a current source **1131** and a switch **1132** that are coupled in series between the power supply terminal VDD and the second output terminal of the equalization part **111**. The equalization signal EQO is output through the equalization part **111**.

In the second offset control part **113**, the switch **1132** is turned on when the offset signal FO is “0”. Accordingly, a current provided by the current source **1131** flows through a resistor **1112** in the equalization part **111**, and the DC voltage

of the equalization signal EQO increases. The resistor **1112** is coupled between the second output terminal of the equalization part **111** and the ground voltage terminal.

Since the switch **1132** is turned off when the offset signal FO is “1”, the DC voltage of the equalization signal EQO is not affected by the current provided by the current source **1131**.

Although various embodiments have been described for illustrative purposes, it will be apparent to those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of the invention as defined in the following claims.

What is claimed is:

1. A receiver comprising:

a signal receiving part suitable for providing an output signal corresponding to a receiving signal that is received through an input terminal, a DC voltage of the output signal being controlled according to an offset signal;

an amplifying part suitable for amplifying the output signal of the signal receiving part and outputting an amplified signal; and

a feedback control part suitable for providing the offset signal according to the amplified signal of the amplifying part,

wherein when the receiving signal is received by the signal receiving part, the feedback control part controls the offset signal so that a duty ratio of the amplified signal of the amplifying part decreases when the amplified signal of the amplifying part has a first level, and controls the offset signal so that the duty ratio of the amplified signal of the amplifying part increases when the amplified signal of the amplifying part has a second level.

2. The receiver of claim 1, wherein the feedback control part provides the offset signal having a constant value when the receiving signal is not received by the signal receiving part.

3. The receiver of claim 2, wherein the feedback control part provides the offset signal having a predetermined level in an initialization operation.

4. The receiver of claim 3, wherein the feedback control part controls the offset signal in correspondence to an initialization signal that is input to the signal receiving part in the initialization operation.

5. A receiver comprising:

a signal receiving part suitable for providing an output signal corresponding to a receiving signal that is received through an input terminal, a DC voltage of the output signal being controlled according to an offset signal;

an amplifying part suitable for amplifying the output signal of the signal receiving part and outputting an amplified signal; and

a feedback control part suitable for providing the offset signal according to the amplified signal of the amplifying part,

wherein the signal receiving part comprises:

an equalization part suitable for equalizing the receiving signal and providing the output signal; and

an offset control part suitable for controlling the DC voltage of the output signal of the equalization part according to the offset signal.

6. The receiver of claim 5,

wherein the receiving signal is a differential signal including a first receiving signal and a second receiving signal, and the output signal of the equalization part is

9

a differential signal including a first equalization signal and a second equalization signal, and

wherein the offset control part includes a first offset control part that controls a DC voltage of the second equalization signal according to the offset signal, and a second offset control part that controls a DC voltage of the first equalization signal according to the offset signal.

7. The receiver of claim 6, wherein the offset control part performs an offset control operation such that the DC voltage of the second equalization signal increases when the offset signal has a first level, and the DC voltage of the first equalization signal increases when the offset signal has a second level.

8. The receiver of claim 7, wherein the amplifying part differentially amplifies the first equalization signal and the second equalization signal, and outputs the amplified signal, which is a differential signal including a first output signal and a second output signal, and

wherein the feedback control part performs a control operation such that the offset signal has the second level when the first output signal has a first level and the offset signal has the first level when the first output signal has a second level.

9. The receiver of claim 8, wherein a duty ratio of an output signal of the amplifying part is smaller than 50% when the offset signal has the first level, and the duty ratio of the output signal of the amplifying part is larger than 50% when the offset signal has the second level.

10. The receiver of claim 5, wherein the equalization part comprises a continuous time linear equalizer.

11. The receiver of claim 6, wherein the first offset control part comprises:

a current source; and

a switch coupled between the current source and a first output terminal of the equalization part, the second

10

equalization signal being output through the first output terminal of the equalization part, the switch being controlled by the offset signal and providing a current from the current source to the first output terminal of the equalization part.

12. The receiver of claim 6, wherein the second offset control part comprises:

a current source; and

a switch coupled between the current source and a second output terminal of the equalization part, the first equalization signal being output through the second output terminal of the equalization part, the switch being controlled by the offset signal and providing a current from the current source to the second output terminal of the equalization part.

13. The receiver of claim 5, wherein the feedback control part provides the offset signal having a constant value when the receiving signal is not received by the signal receiving part.

14. The receiver of claim 13, wherein the feedback control part provides the offset signal having a predetermined level in an initialization operation.

15. The receiver of claim 14, wherein the feedback control part controls the offset signal in correspondence to an initialization signal that is input to the signal receiving part in the initialization operation.

16. The receiver of claim 5, wherein when the receiving signal is received by the signal receiving part, the feedback control part controls the offset signal so that a duty ratio of the amplified signal of the amplifying part decreases when the amplified signal of the amplifying part has a first level, and controls the offset signal so that the duty ratio of the amplified signal of the amplifying part increases when the amplified signal of the amplifying part has a second level.

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