US 20180364343A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2018/0364343 A1**

BAI (43) **Pub. Date: Dec. 20, 2018**

(54) **ULTRASOUND IMAGING RECEIVER CIRCUIT**

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(21) Appl. No.: **16/108,089**

(22) Filed: **Aug. 21, 2018**

Publication Classification

(51) **Int. Cl.**

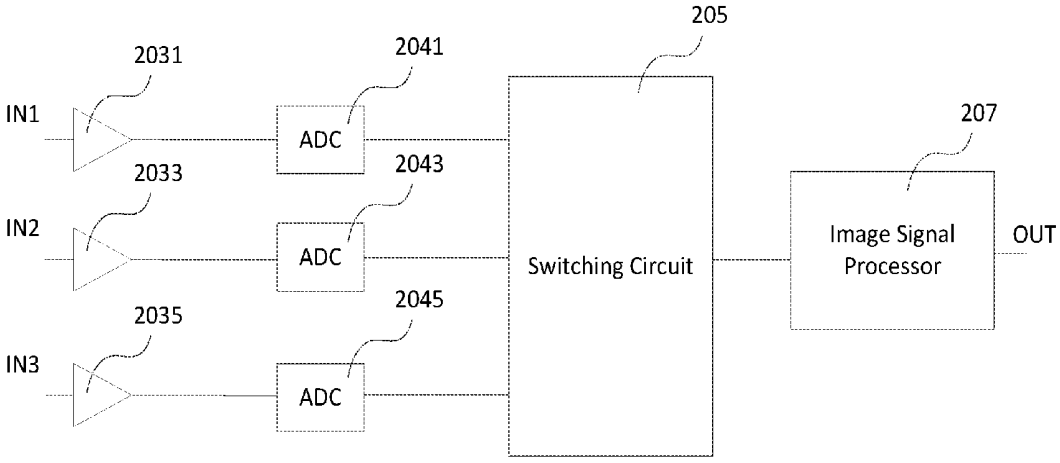
G01S 7/52	(2006.01)
A61B 8/08	(2006.01)
G01S 15/89	(2006.01)

(52) **U.S. Cl.**

CPC ***G01S 7/52028*** (2013.01); ***A61B 8/48*** (2013.01); ***G01S 15/8934*** (2013.01); ***G01S 7/5208*** (2013.01); ***G01S 7/52033*** (2013.01)

(57) **ABSTRACT**

An ultrasound imaging receiver circuit includes a plurality of amplifiers configured to receive input signals from a plurality of ultrasound transducer channels respectively; a plurality of ADCs connected with the amplifiers respectively; a switching circuit connected with the ADCs; an image signal processor connected with the switching circuit; and a control signal generator. Each amplifier includes a first input port configured for receiving one input signal from an ultrasound transducer channel, a second input port connected to the ground and an output port connected to one ADC, the first input port being connected to the output port through a first switch. The control signal generator is configured to compare the input signal with a first preset threshold and a second preset threshold and output control signals controlling the first switch and the second switch based on the comparisons.



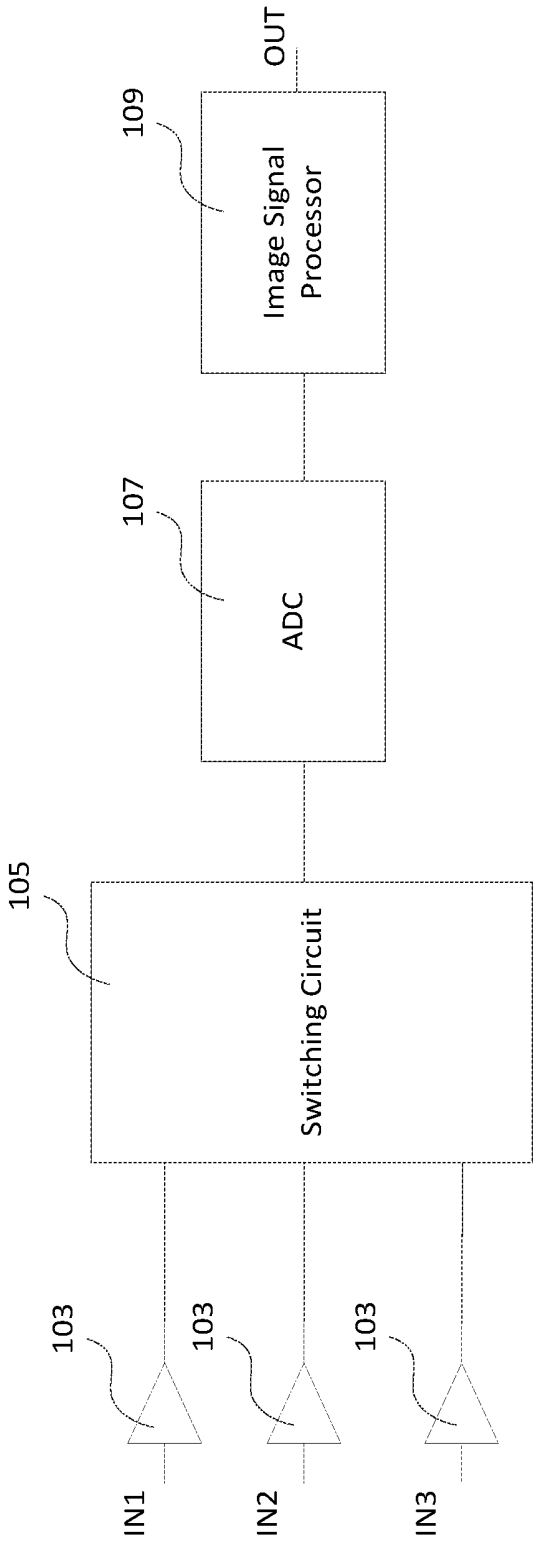


FIG. 1 (PRIOR ART)

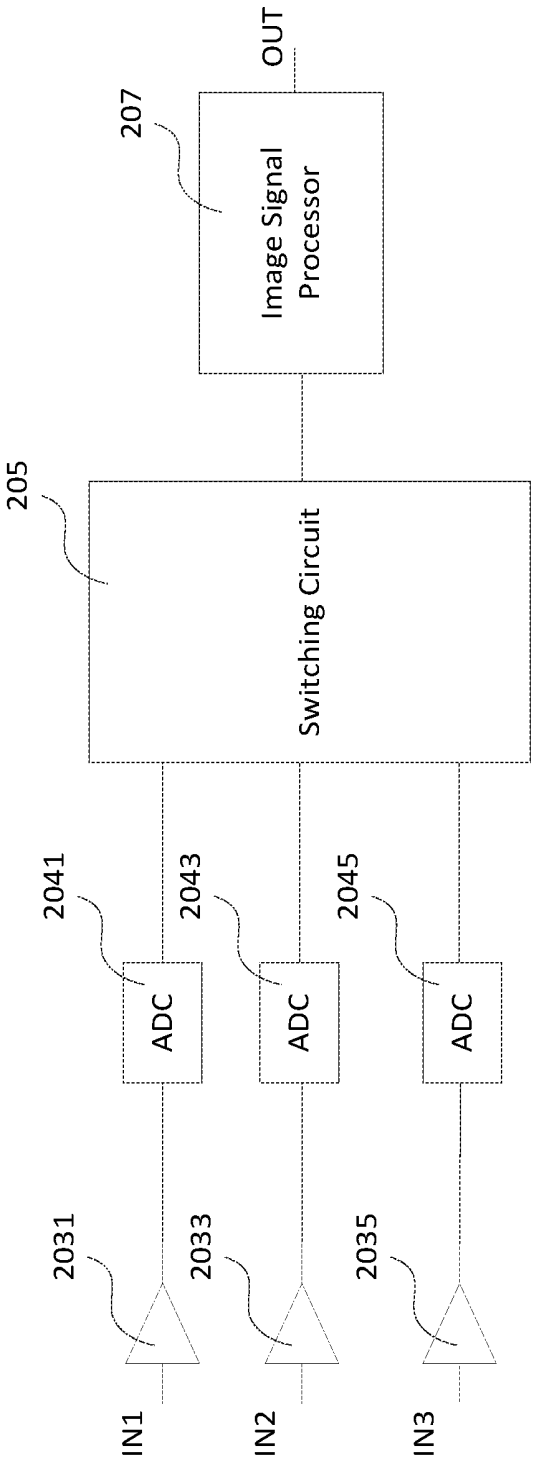

OUT
207
Image Signal Processor
205
Switching Circuit
2041
2043
2045
ADC
ADC
ADC
2031
2033
2035
IN1
IN2
IN3

FIG. 2

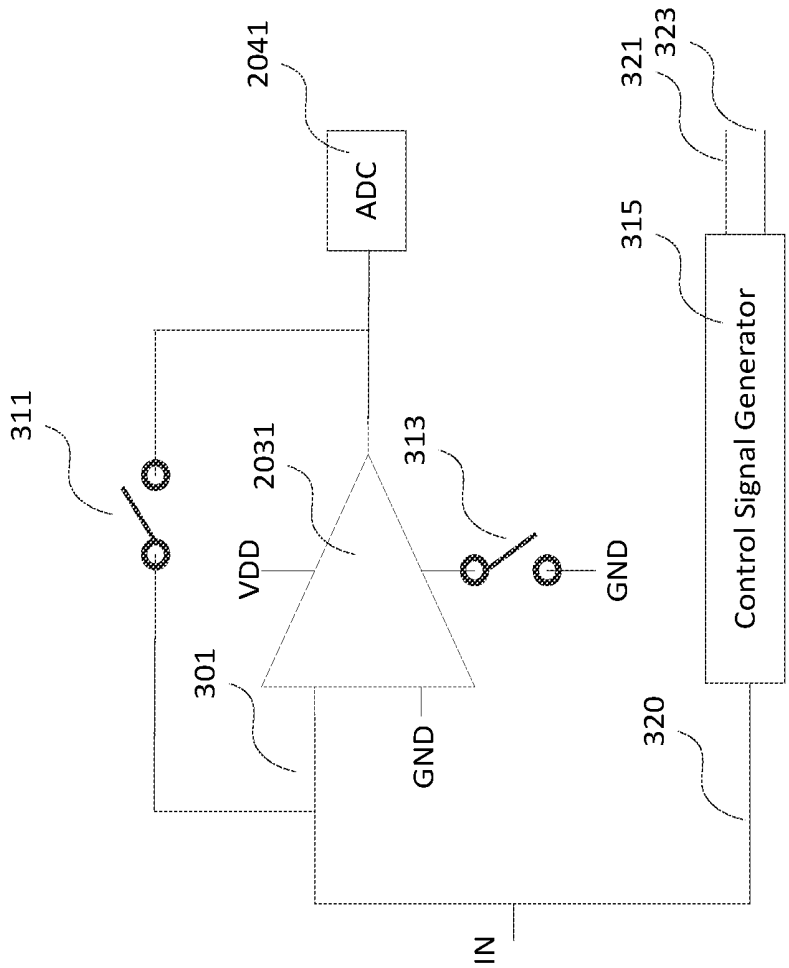

2041
ADC
321
323
315
Control Signal Generator
311
2031
313
VDD
GND
301
GND
320
IN

FIG. 3

ULTRASOUND IMAGING RECEIVER CIRCUIT

FIELD OF THE PATENT APPLICATION

[0001] The present patent application generally relates to medical electronics and more specifically to an ultrasound imaging receiver circuit.

BACKGROUND

[0002] Ultrasound probes of an ultrasound imaging system typically include one or more ultrasound transducers which sense ultrasound signals and produce corresponding electrical signals. The electrical signals are processed in the analog or digital domain and the processed electrical signals are then used to generate ultrasound images.

[0003] FIG. **1** is a schematic circuit diagram of a conventional ultrasound imaging receiver circuit. Referring to FIG. **1**, the ultrasound imaging receiver circuit includes a plurality of amplifiers **103** configured to receive input signals (IN**1**, IN**2** and IN**3** as shown in FIG. **1**) from a plurality of ultrasound transducer channels respectively, a switching circuit **105** connected with the amplifiers **103**, an ADC **107** connected with the switching circuit **105**, and an image signal processor **109** connected with the ADC **107**. The system requires only one ADC **107** for handling signals coming from all ultrasound transducer channels, which helps to reduce power consumption. However, because the digital conversion is executed only after the input signals IN**1**, IN**2** and IN**3** are amplified by the amplifier **103** and selected by the switching circuit **105**, finer adjustments and digital manipulation of the input signals cannot be implemented with this architecture.

[0004] Some digital beamforming imaging systems have been proposed in recent years but their relatively high power consumption and relatively low dynamic range are the key bottlenecks for such systems.

SUMMARY

[0005] The present patent application is directed to an ultrasound imaging receiver circuit. In one aspect, the ultrasound imaging receiver circuit includes a plurality of amplifiers configured to receive input signals from a plurality of ultrasound transducer channels respectively; a plurality of ADCs connected with the amplifiers respectively; a switching circuit connected with the ADCs; an image signal processor connected with the switching circuit; and a control signal generator. Each amplifier includes a first input port configured for receiving one input signal from an ultrasound transducer channel, a second input port connected to the ground and an output port connected to one ADC, the first input port being connected to the output port through a first switch. The amplifier further includes a first bias port connected to a power supply voltage and a second bias port connected to the ground through a second switch. The control signal generator is electrically connected with the first switch and the second switch and including an input port configured for receiving the input signal; a first output port configured for outputting a first control signal controlling the first switch; and a second output port configured for outputting a second control signal controlling the second switch. The control signal generator is configured to compare the input signal with a first preset threshold; if the input signal is greater than the first preset threshold, the control signal generator is configured to output a first control signal that turns on the first switch through the first output port and a second control signal that turns off the second switch through the second output port; and the control signal generator is configured to compare the input signal with a second preset threshold; if the input signal is less than the second preset threshold, the control signal generator is configured to output a first control signal that turns off the first switch through the first output port, and a second control signal that turns on the second switch through the second output port.

[0006] The control signal generator may include at least a comparator. The ADC may be reconfigurable and when the input signal is greater than the first preset threshold, the gain of the ADC may be configured to increase with attenuation of the input signal so that the SNR of the signal output from the ADC may be roughly constant.

[0007] The gain of the amplifier may be tunable and adjusted to be increasing with the attenuation of the input signal so that when the input signal is less than the second preset threshold the SNR of the signal output from the ADC may be roughly constant.

[0008] In another aspect, the present patent application provides an ultrasound imaging receiver circuit. The ultrasound imaging receiver circuit includes a plurality of amplifiers configured to receive input signals from a plurality of ultrasound transducer channels respectively; a plurality of ADCs connected with the amplifiers respectively; a switching circuit connected with the ADCs; an image signal processor connected with the switching circuit; and a control signal generator. Each amplifier includes a first input port configured for receiving one input signal from an ultrasound transducer channel, a second input port connected to the ground and an output port connected to one ADC, the first input port being connected to the output port through a first switch. The amplifier further includes a first bias port connected to a power supply voltage and a second bias port connected to the ground through a second switch. The control signal generator is connected with the first switch and the second switch and comprising an input port configured for receiving the input signal; a first output port configured for outputting a first control signal controlling the first switch; and a second output port configured for outputting a second control signal controlling the second switch.

[0009] The control signal generator may be configured to compare the input signal with a first preset threshold; if the input signal is greater than the first preset threshold, the control signal generator may be configured to output a first control signal that turns on the first switch through the first output port and a second control signal that turns off the second switch through the second output port.

[0010] The control signal generator may be configured to compare the input signal with a second preset threshold; if the input signal is less than the second preset threshold, the control signal generator may be configured to output a first control signal that turns off the first switch through the first output port, and a second control signal that turns on the second switch through the second output port. The control signal generator may include at least a comparator.

[0011] The ADC may be reconfigurable and when the input signal is greater than the first preset threshold, the gain of the ADC may be configured to increase with attenuation of the input signal so that the SNR of the signal output from the ADC may be roughly constant.

[0012] The gain of the amplifier may be tunable and adjusted to be increasing with the attenuation of the input signal so that when the input signal is less than the second preset threshold the SNR of the signal output from the ADC may be roughly constant.

[0013] In yet another aspect, the ultrasound imaging receiver circuit includes a plurality of amplifiers configured to receive input signals from a plurality of ultrasound transducer channels respectively; a plurality of ADCs connected with the amplifiers respectively; a switching circuit connected with the ADCs; an image signal processor connected with the switching circuit; and a control signal generator. Each amplifier includes a first input port configured for receiving one input signal from an ultrasound transducer channel, a second input port connected to the ground and an output port connected to one ADC, the first input port being connected to the output port through a first switch. The amplifier further includes a first bias port connected to a power supply voltage and a second bias port connected to the ground through a second switch. The control signal generator is connected with the first switch and the second switch and including an input port configured for receiving the input signal; a first output port configured for outputting a first control signal controlling the first switch; and a second output port configured for outputting a second control signal controlling the second switch. The control signal generator is configured to compare the input signal with a first preset threshold and a second preset threshold and output control signals controlling the first switch and the second switch based on the comparisons.

[0014] If the input signal is greater than the first preset threshold, the control signal generator may be configured to output a first control signal that turns on the first switch through the first output port and a second control signal that turns off the second switch through the second output port.

[0015] If the input signal is less than the second preset threshold, the control signal generator may be configured to output a first control signal that turns off the first switch through the first output port, and a second control signal that turns on the second switch through the second output port.

[0016] The control signal generator may include at least a comparator. The ADC may be reconfigurable and when the input signal is greater than the first preset threshold, the gain of the ADC may be configured to increase with attenuation of the input signal so that the SNR of the signal output from the ADC may be roughly constant.

[0017] The gain of the amplifier may be tunable and adjusted to be increasing with the attenuation of the input signal so that when the input signal is less than the second preset threshold the SNR of the signal output from the ADC may be roughly constant.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. **1** is a schematic circuit diagram of a conventional ultrasound imaging receiver circuit.

[0019] FIG. **2** is a schematic circuit diagram of an ultrasound imaging receiver circuit in accordance with an embodiment of the present patent application.

[0020] FIG. **3** is a schematic circuit diagram illustrating the configuration of an amplifier of the ultrasound imaging receiver circuit as depicted in FIG. **2**.

DETAILED DESCRIPTION

[0021] Reference will now be made in detail to a preferred embodiment of the ultrasound imaging receiver circuit disclosed in the present patent application, examples of which are also provided in the following description. Exemplary embodiments of the ultrasound imaging receiver circuit disclosed in the present patent application are described in detail, although it will be apparent to those skilled in the relevant art that some features that are not particularly important to an understanding of the ultrasound imaging receiver circuit may not be shown for the sake of clarity.

[0022] Furthermore, it should be understood that the ultrasound imaging receiver circuit disclosed in the present patent application is not limited to the precise embodiments described below and that various changes and modifications thereof may be effected by one skilled in the art without departing from the spirit or scope of the protection. For example, elements and/or features of different illustrative embodiments may be combined with each other and/or substituted for each other within the scope of this disclosure.

[0023] FIG. **2** is a schematic circuit diagram of an ultrasound imaging receiver circuit in accordance with an embodiment of the present patent application. Referring to FIG. **2**, the ultrasound imaging receiver circuit includes a plurality of amplifiers (**2031**, **2033** and **2035**) configured to receive input signals (IN**1**, IN**2** and IN**3** as shown in FIG. **2**) from a plurality of ultrasound transducer channels respectively; a plurality of ADCs (**2041**, **2043** and **2045**) connected with the amplifiers (**2031**, **2033** and **2035**) respectively; a switching circuit **205** connected with the ADCs (**2041**, **2043** and **2045**); and an image signal processor **207** connected with the switching circuit **205**.

[0024] It is noted that in the above system each ultrasound transducer channel has a dedicated ADC (**2041**, **2043** or **2045**). As a result, finer adjustments and digital manipulation of the input signal from each ultrasonic transducer channel can be implemented.

[0025] FIG. **3** is a schematic circuit diagram illustrating the configuration of the amplifier **2031** as depicted in FIG. **2**. Referring to FIG. **3**, the amplifier **2031** includes a first input port **301** configured for receiving the input signal IN**1**, a second input port connected to the ground (GND) and an output port connected to the corresponding ADC **2041**. The first input port **301** is also connected to the output through a first switch **311**. The amplifier **2031** further includes a first bias port connected to a power supply voltage VDD and a second bias port connected to the ground through a second switch **313**.

[0026] The ultrasound imaging receiver circuit further includes a control signal generator **315** electrically connected with the first switch **311** and the second switch **313** (the connections are not shown in FIG. **3**). The control signal generator **315** includes an input port **320** configured for receiving the input signal IN**1**; a first output port **321** configured for outputting a first control signal controlling the first switch **311**; and a second output port **323** configured for outputting a second control signal controlling the second switch **313**. In this embodiment, the control signal generator **315** includes at least a comparator.

[0027] At the beginning of each signal cycle, the input signal IN**1**, for example, is relatively strong. The control signal generator **315** is configured to compare the input signal IN**1** with a first preset threshold T**1**. If the input signal IN**1** is greater than the first preset threshold T**1**, the control

signal generator **315** is configured to output an output signal (i.e. a first control signal) "1" through the first output port **321**, which turns on the first switch **311**, and an output signal (i.e. a second control signal) "0" through the second output port **323**, which turns off the second switch **313**. Under this condition, referring to FIG. **2** and FIG. **3**, the amplifier **2031** is bypassed and the input signal IN**1** is directly fed to the ADC **2041**. Since the second switch **313** is turned off, the amplifier **2031** is turned off and not consuming any power.

[0028] Preferably, in this embodiment, the ADC **2041** is reconfigurable and the gain of the ADC **2041** is configured to increase with the attenuation of the input signal IN**1** so that the SNR of the signal output from the ADC **2041** is roughly constant. As a result, the dynamic range of the system is kept constant without being narrowed by the attenuation of the input signal IN**1**.

[0029] As time passes by, the input signal IN**1** attenuates and becomes weaker and weaker. The control signal generator **315** is configured to compare the input signal IN**1** with a second preset threshold T**2**. If the input signal IN**1** is less than the second preset threshold T**2**, the control signal generator **315** is configured to output an output signal (i.e. a first control signal) "0" through the first output port **321**, which turns off the first switch **311**, and an output signal (i.e. a second control signal) "1" through the second output port **323**, which turns on the second switch **313**. Under this condition, referring to FIG. **2** and FIG. **3**, the amplifier **2031** is working and the input signal IN**1** is first amplified by the corresponding amplifier **2031** and then fed to the ADC **2041**.

[0030] Preferably, the gain of the amplifier **2031** is tunable and adjusted to be increasing with the attenuation of the input signal IN**1** so that the SNR of the signal output from the ADC **2041** is roughly constant. As a result, the dynamic range of the system is kept constant without being narrowed by the attenuation of the input signal IN**1**.

[0031] Although the amplifier **2031** and the ADC **2041**, which correspond to one ultrasound transducer channel, are described above as an example, as all ultrasound transducer channels are identical, it is understood that the configuration and the working principle of the amplifiers **2033** and **2035** are similar to those of the amplifier **2031**, while the configuration and the working principle of the ADCs **2043** and **2045** are similar to those of the ADC **2041**.

[0032] It is further understood that, in an alternative embodiment, the number of ultrasound transducer channels may be more or less than 3.

[0033] In the above embodiments, since each ultrasound transducer channel has a dedicated ADC (**2041**, **2043** or **2045**), finer adjustments and digital manipulation of the input signals from ultrasound transducer channels can be implemented with the ultrasound imaging receiver circuit. When the input signal IN**1** (or IN**2**, IN**3**, . . .) is relatively strong and greater than the first preset threshold, the amplifier **2031** (or **2033**, **2035** . . .) is turned off and not consuming any power, and therefore the average power consumption of the system is relatively low. With the conditional combinational use of the amplifier **2031** (or **2033**, **2035** . . .) and the ADC **2041** (or **2043**, **2045**, . . .), the SNR of the output signal of the system is kept roughly constant. As a result, the dynamic range of the system is kept roughly constant without being narrowed by the attenuation of the input signal IN**1** (or IN**2**, IN**3**,).

[0034] Therefore, the ultrasound imaging receiver circuit offers the possibility of finer adjustments and digital manipulation of the input signals while enjoying the benefits of low power consumption and wide dynamic range.

[0035] While the present patent application has been shown and described with particular references to a number of embodiments thereof, it should be noted that various other changes or modifications may be made without departing from the scope of the present invention.

What is claimed is:

1. An ultrasound imaging receiver circuit comprising:

a plurality of amplifiers configured to receive input signals from a plurality of ultrasound transducer channels respectively;

a plurality of ADCs connected with the amplifiers respectively;

a switching circuit connected with the ADCs;

an image signal processor connected with the switching circuit and a control signal generator; wherein:

each amplifier comprises a first input port configured for receiving one input signal from an ultrasound transducer channel, a second input port connected to the ground and an output port connected to one ADC, the first input port being connected to the output port through a first switch;

the amplifier further comprises a first bias port connected to a power supply voltage and a second bias port connected to the ground through a second switch;

the control signal generator is electrically connected with the first switch and the second switch and comprising an input port configured for receiving the input signal; a first output port configured for outputting a first control signal controlling the first switch; and a second output port configured for outputting a second control signal controlling the second switch;

the control signal generator is configured to compare the input signal with a first preset threshold; if the input signal is greater than the first preset threshold, the control signal generator is configured to output a first control signal that turns on the first switch through the first output port and a second control signal that turns off the second switch through the second output port; and

the control signal generator is configured to compare the input signal with a second preset threshold; if the input signal is less than the second preset threshold, the control signal generator is configured to output a first control signal that turns off the first switch through the first output port, and a second control signal that turns on the second switch through the second output port.

2. The ultrasound imaging receiver circuit of claim **1**, wherein the control signal generator comprises at least a comparator.

3. The ultrasound imaging receiver circuit of claim **1**, wherein the ADC is reconfigurable and when the input signal is greater than the first preset threshold, the gain of the ADC is configured to increase with attenuation of the input signal so that the SNR of the signal output from the ADC is roughly constant.

4. The ultrasound imaging receiver circuit of claim **1**, wherein the gain of the amplifier is tunable and adjusted to be increasing with the attenuation of the input signal so that when the input signal is less than the second preset threshold the SNR of the signal output from the ADC is roughly constant.

5. An ultrasound imaging receiver circuit comprising:
a plurality of amplifiers configured to receive input signals from a plurality of ultrasound transducer channels respectively;
a plurality of ADCs connected with the amplifiers respectively;
a switching circuit connected with the ADCs;
an image signal processor connected with the switching circuit and a control signal generator; wherein:
each amplifier comprises a first input port configured for receiving one input signal from an ultrasound transducer channel, a second input port connected to the ground and an output port connected to one ADC, the first input port being connected to the output port through a first switch;
the amplifier further comprises a first bias port connected to a power supply voltage and a second bias port connected to the ground through a second switch; and
the control signal generator is connected with the first switch and the second switch and comprising an input port configured for receiving the input signal; a first output port configured for outputting a first control signal controlling the first switch; and a second output port configured for outputting a second control signal controlling the second switch.

6. The ultrasound imaging receiver circuit of claim 5, wherein the control signal generator is configured to compare the input signal with a first preset threshold; if the input signal is greater than the first preset threshold, the control signal generator is configured to output a first control signal that turns on the first switch through the first output port and a second control signal that turns off the second switch through the second output port.

7. The ultrasound imaging receiver circuit of claim 5, wherein the control signal generator is configured to compare the input signal with a second preset threshold; if the input signal is less than the second preset threshold, the control signal generator is configured to output a first control signal that turns off the first switch through the first output port, and a second control signal that turns on the second switch through the second output port.

8. The ultrasound imaging receiver circuit of claim 5, wherein the control signal generator comprises at least a comparator.

9. The ultrasound imaging receiver circuit of claim 5, wherein the ADC is reconfigurable and when the input signal is greater than the first preset threshold, the gain of the ADC is configured to increase with attenuation of the input signal so that the SNR of the signal output from the ADC is roughly constant.

10. The ultrasound imaging receiver circuit of claim 5, wherein the gain of the amplifier is tunable and adjusted to be increasing with the attenuation of the input signal so that when the input signal is less than the second preset threshold the SNR of the signal output from the ADC is roughly constant.

11. An ultrasound imaging receiver circuit comprising:
a plurality of amplifiers configured to receive input signals from a plurality of ultrasound transducer channels respectively;
a plurality of ADCs connected with the amplifiers respectively;
a switching circuit connected with the ADCs;
an image signal processor connected with the switching circuit and
a control signal generator; wherein:
each amplifier comprises a first input port configured for receiving one input signal from an ultrasound transducer channel, a second input port connected to the ground and an output port connected to one ADC, the first input port being connected to the output port through a first switch;
the amplifier further comprises a first bias port connected to a power supply voltage and a second bias port connected to the ground through a second switch;
the control signal generator is connected with the first switch and the second switch and comprising an input port configured for receiving the input signal; a first output port configured for outputting a first control signal controlling the first switch; and a second output port configured for outputting a second control signal controlling the second switch; and
the control signal generator is configured to compare the input signal with a first preset threshold and a second preset threshold and output control signals controlling the first switch and the second switch based on the comparisons.

12. The ultrasound imaging receiver circuit of claim 11, wherein if the input signal is greater than the first preset threshold, the control signal generator is configured to output a first control signal that turns on the first switch through the first output port and a second control signal that turns off the second switch through the second output port.

13. The ultrasound imaging receiver circuit of claim 11, wherein if the input signal is less than the second preset threshold, the control signal generator is configured to output a first control signal that turns off the first switch through the first output port, and a second control signal that turns on the second switch through the second output port.

14. The ultrasound imaging receiver circuit of claim 11, wherein the control signal generator comprises at least a comparator.

15. The ultrasound imaging receiver circuit of claim 11, wherein the ADC is reconfigurable and when the input signal is greater than the first preset threshold, the gain of the ADC is configured to increase with attenuation of the input signal so that the SNR of the signal output from the ADC is roughly constant.

16. The ultrasound imaging receiver circuit of claim 11, wherein the gain of the amplifier is tunable and adjusted to be increasing with the attenuation of the input signal so that when the input signal is less than the second preset threshold the SNR of the signal output from the ADC is roughly constant.

* * * * *

专利名称(译)	超声成像接收器电路		
公开(公告)号	US20180364343A1	公开(公告)日	2018-12-20
申请号	US16/108089	申请日	2018-08-21
[标]发明人	BAI YAHUI		
发明人	BAI, YAHUI		
IPC分类号	G01S7/52 A61B8/08 G01S15/89		
CPC分类号	G01S7/52028 A61B8/48 G01S7/52033 G01S7/5208 G01S15/8934 A61B8/5207 G01S7/5205		
外部链接	Espacenet USPTO		

摘要(译)

一种超声成像接收器电路，包括多个放大器，被配置为分别从多个超声换能器通道接收输入信号;多个ADC分别与放大器连接;与ADC连接的开关电路;与开关电路连接的图像信号处理器;和控制信号发生器。每个放大器包括：第一输入端口，配置为从超声换能器通道接收一个输入信号;第二输入端口，连接到地;以及输出端口，连接到一个ADC，第一输入端口通过第一开关连接到输出端口。控制信号发生器被配置为将输入信号与第一预设阈值和第二预设阈值进行比较，并基于比较输出控制第一开关和第二开关的控制信号。