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(54) **APPARATUS AND METHOD FOR REDUCING PARASITIC CAPACITIVE COUPLING AND NOISE IN FINGERPRINT SENSING CIRCUITS**

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(58) **Field of Classification Search**
None
See application file for complete search history.

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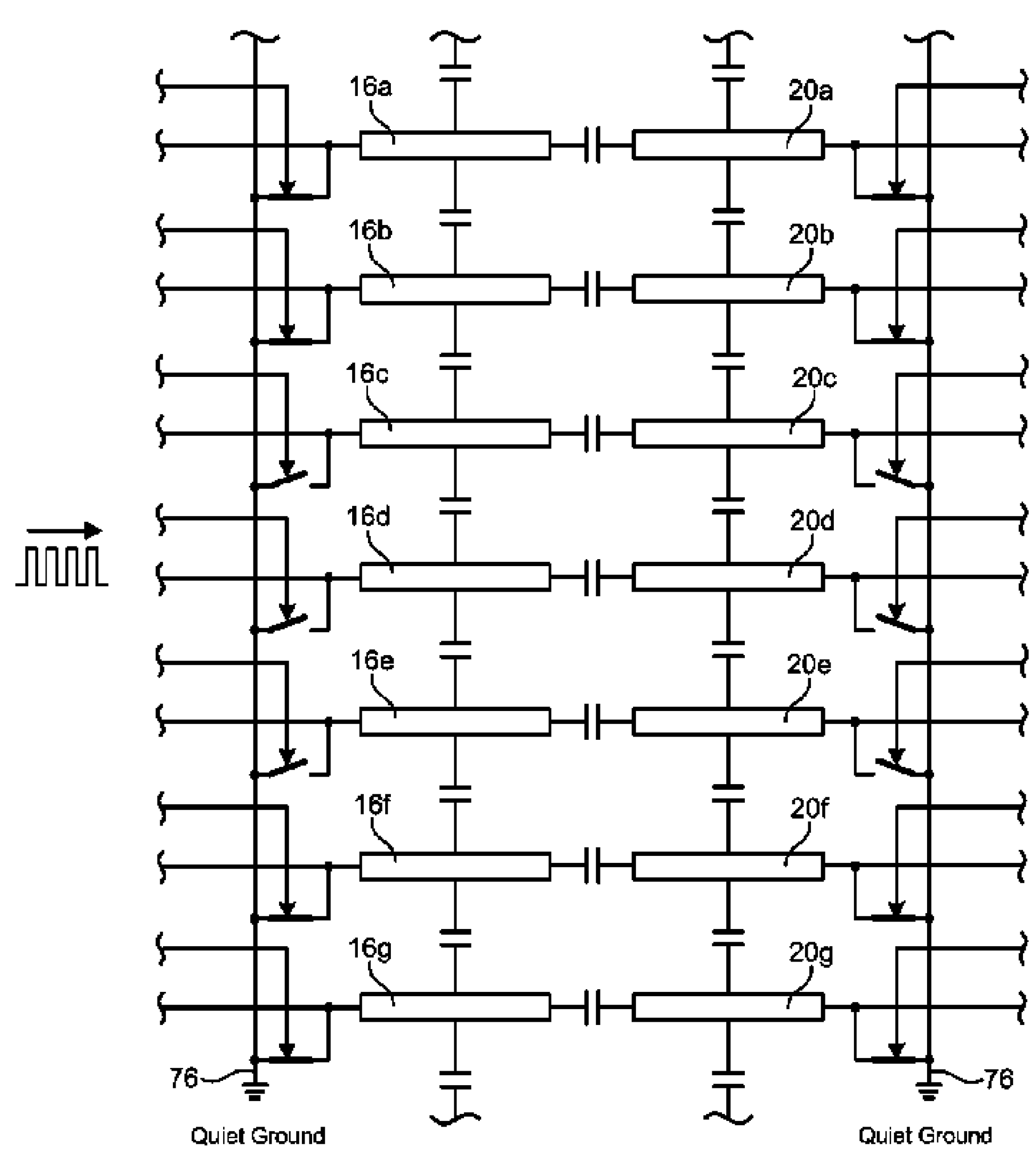
(57) **ABSTRACT**

A fingerprint sensing circuit for reducing noise and parasitic capacitive coupling is disclosed in one embodiment of the invention as including a plurality of transmitting elements to sequentially emit a probing signal. A digital ground is provided to ground digital components in the fingerprint sensing circuit. A quiet ground, separate from and quieter than the digital ground, is provided to ground transmitting elements that are not transmitting the probing signal. Similarly, control logic is provided to connect, to the quiet ground, transmitting elements that are not transmitting the probing signal, while disconnecting, from the quiet ground, transmitting elements that are emitting the probing signal. The quiet ground helps to reduce the adverse effects of parasitic capacitive coupling and noise on the inactive transmitting elements.

29 Claims, 6 Drawing Sheets



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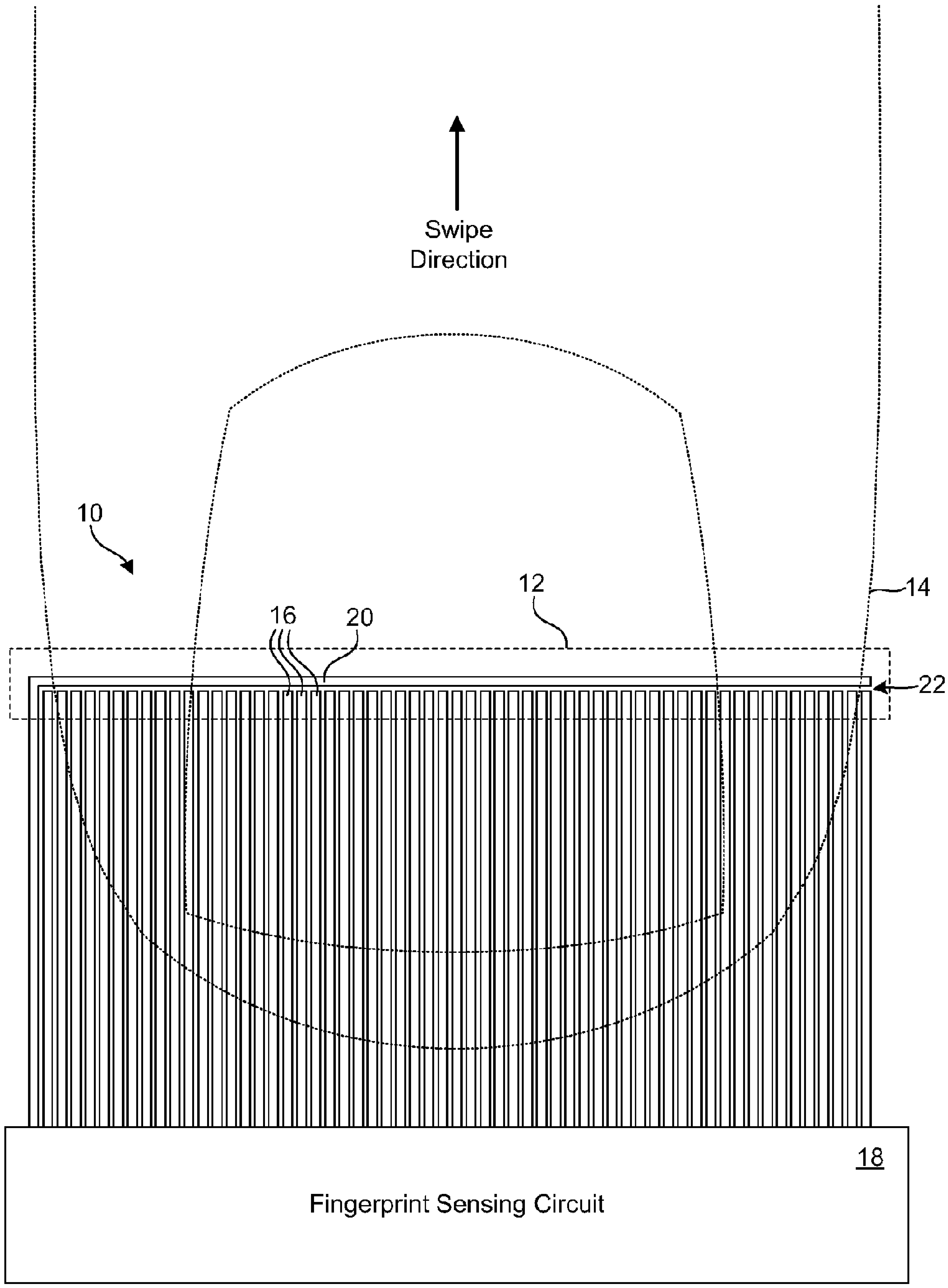

Swipe
Direction
10
12
14
16
20
22
18
Fingerprint Sensing Circuit

Fig. 1

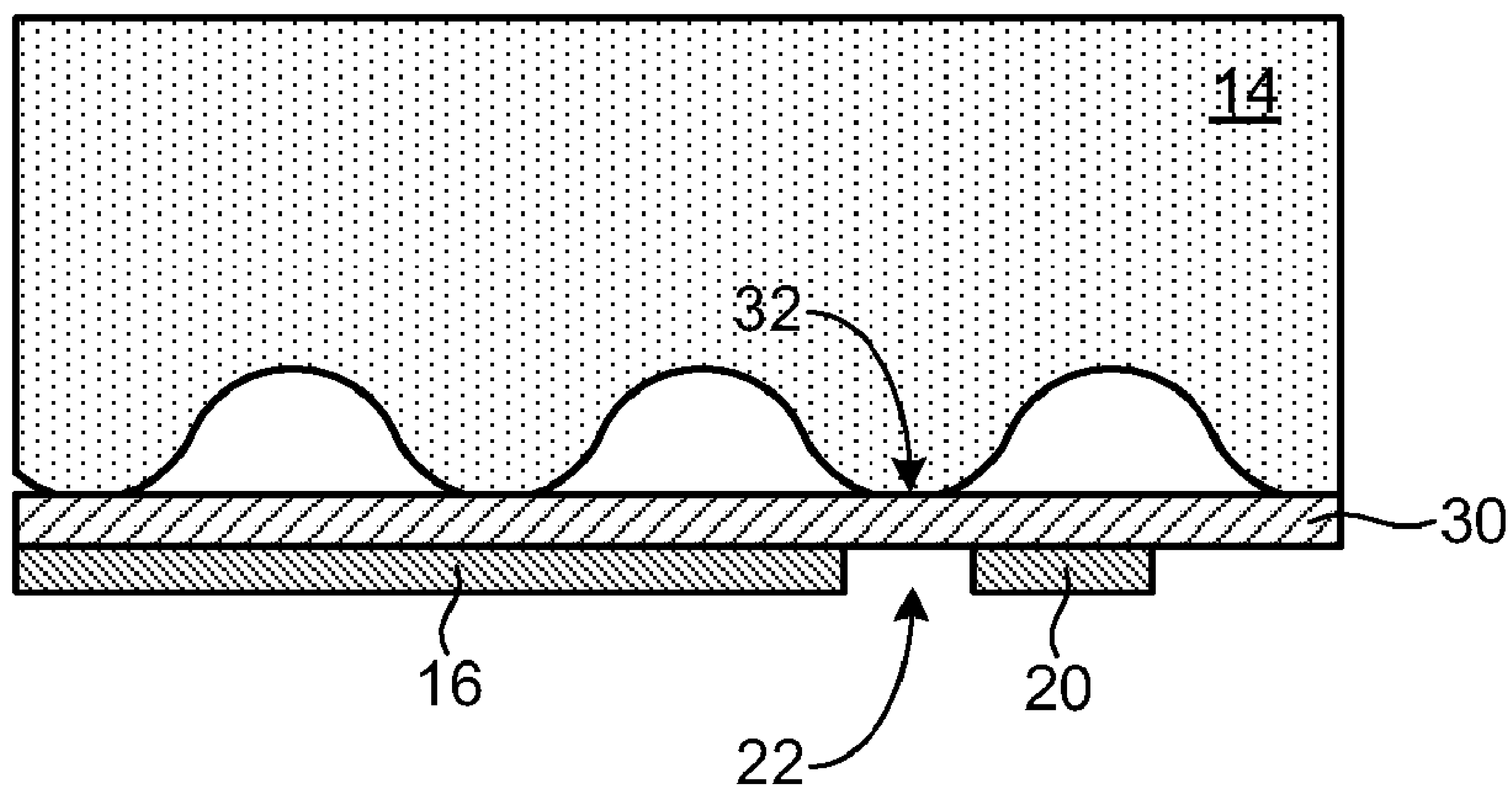


Fig. 2

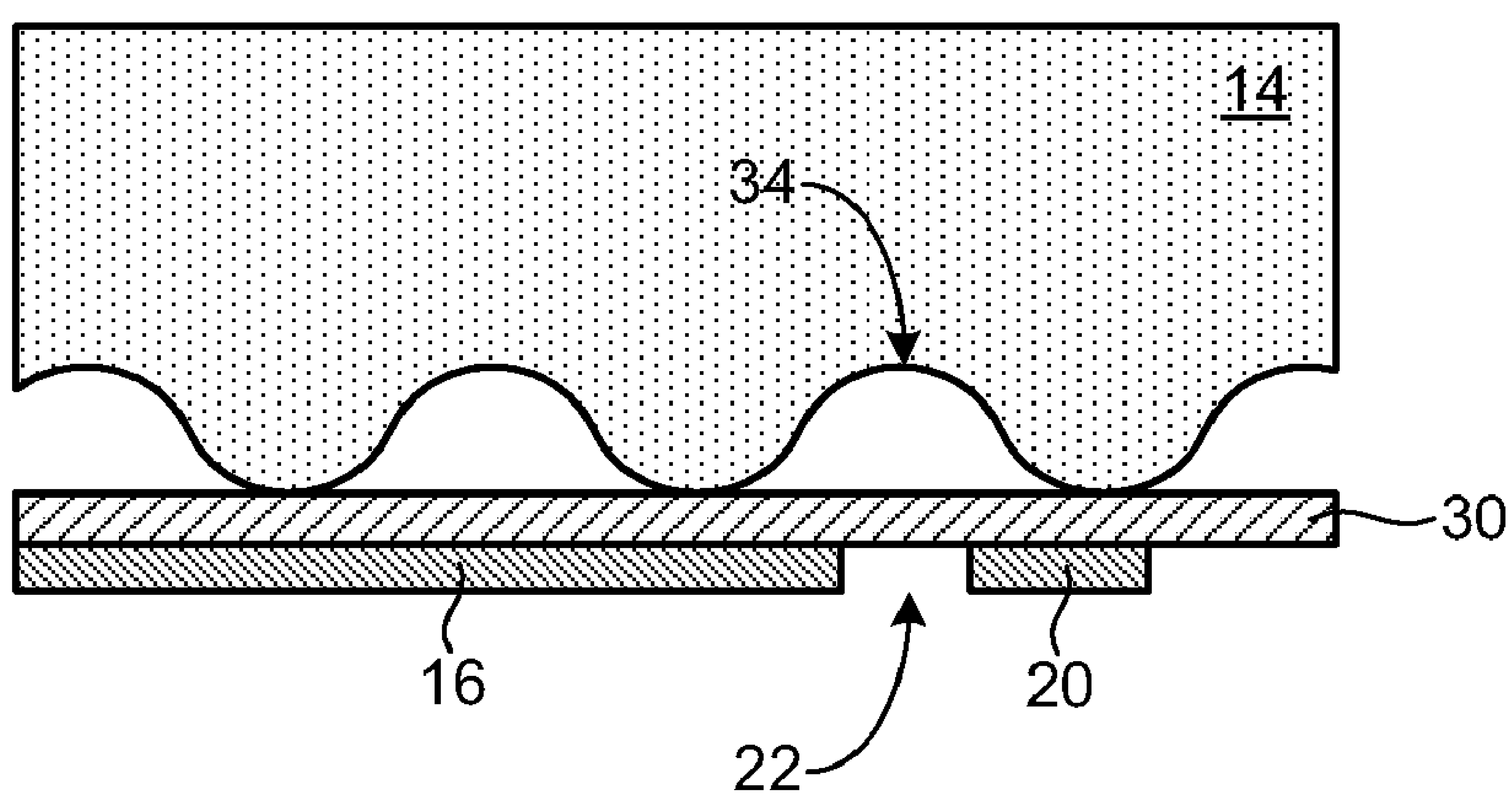


Fig. 3

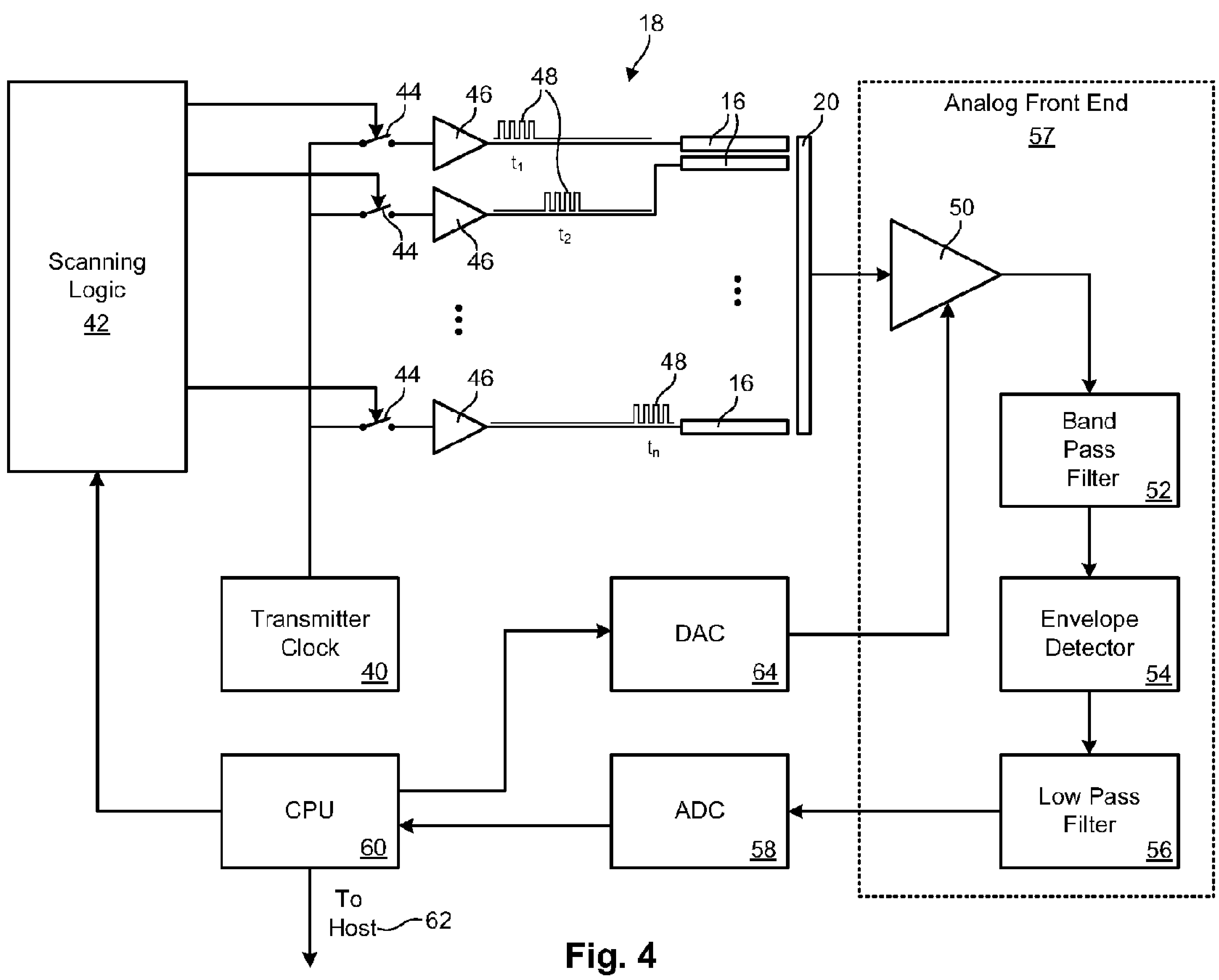
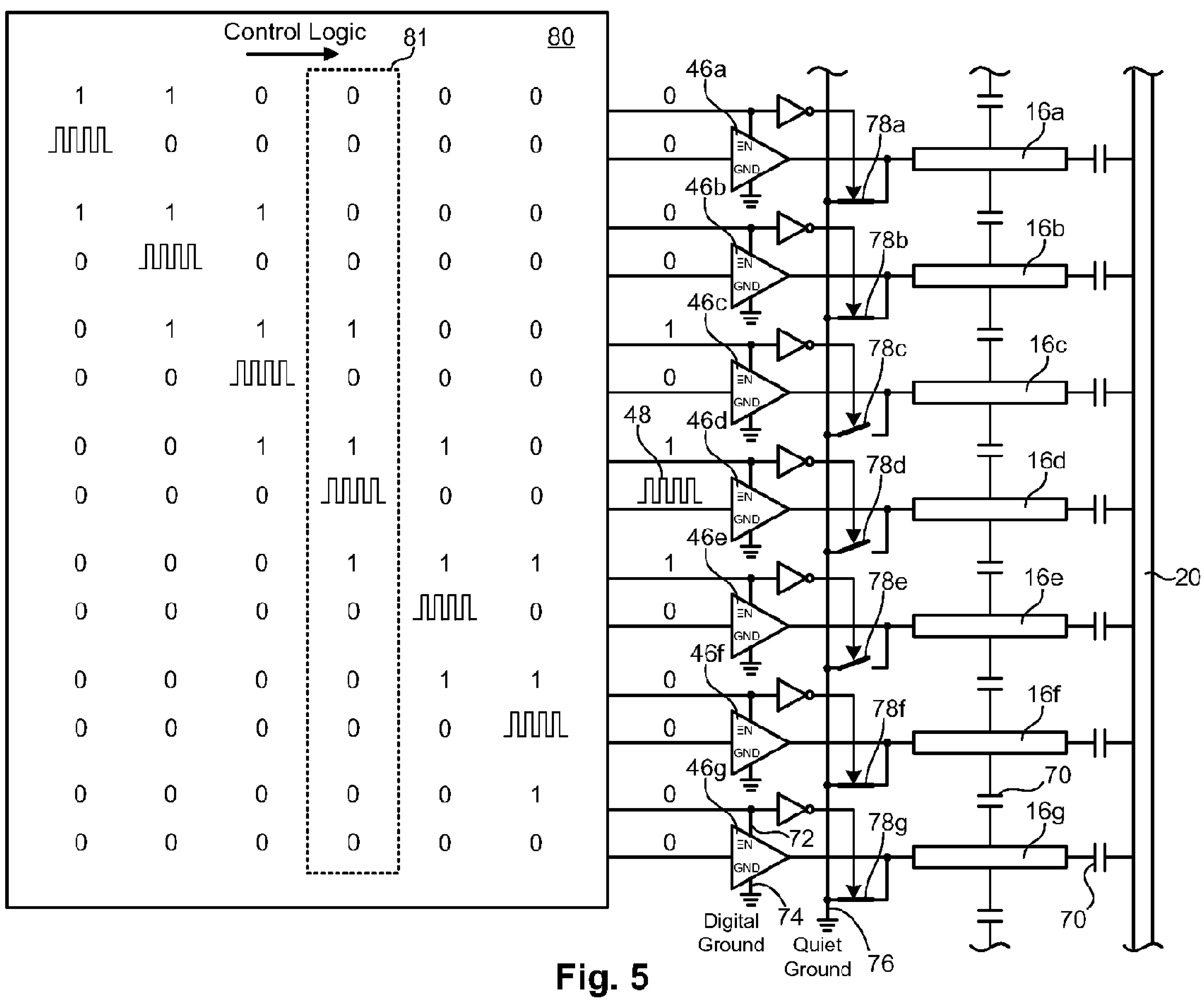

18
Scanning Logic 42
44
46
48
t_1
t_2
t_n
16
20
Analog Front End 57
50
Band Pass Filter 52
Envelope Detector 54
Low Pass Filter 56
Transmitter Clock 40
DAC 64
CPU 60
ADC 58
To Host
62

Fig. 4


Control Logic
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46e
46f
46g
48
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78b
78c
78d
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78f
78g
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16c
16d
16e
16f
16g
20
70
72
74
76
Digital Ground
Quiet Ground

Fig. 5

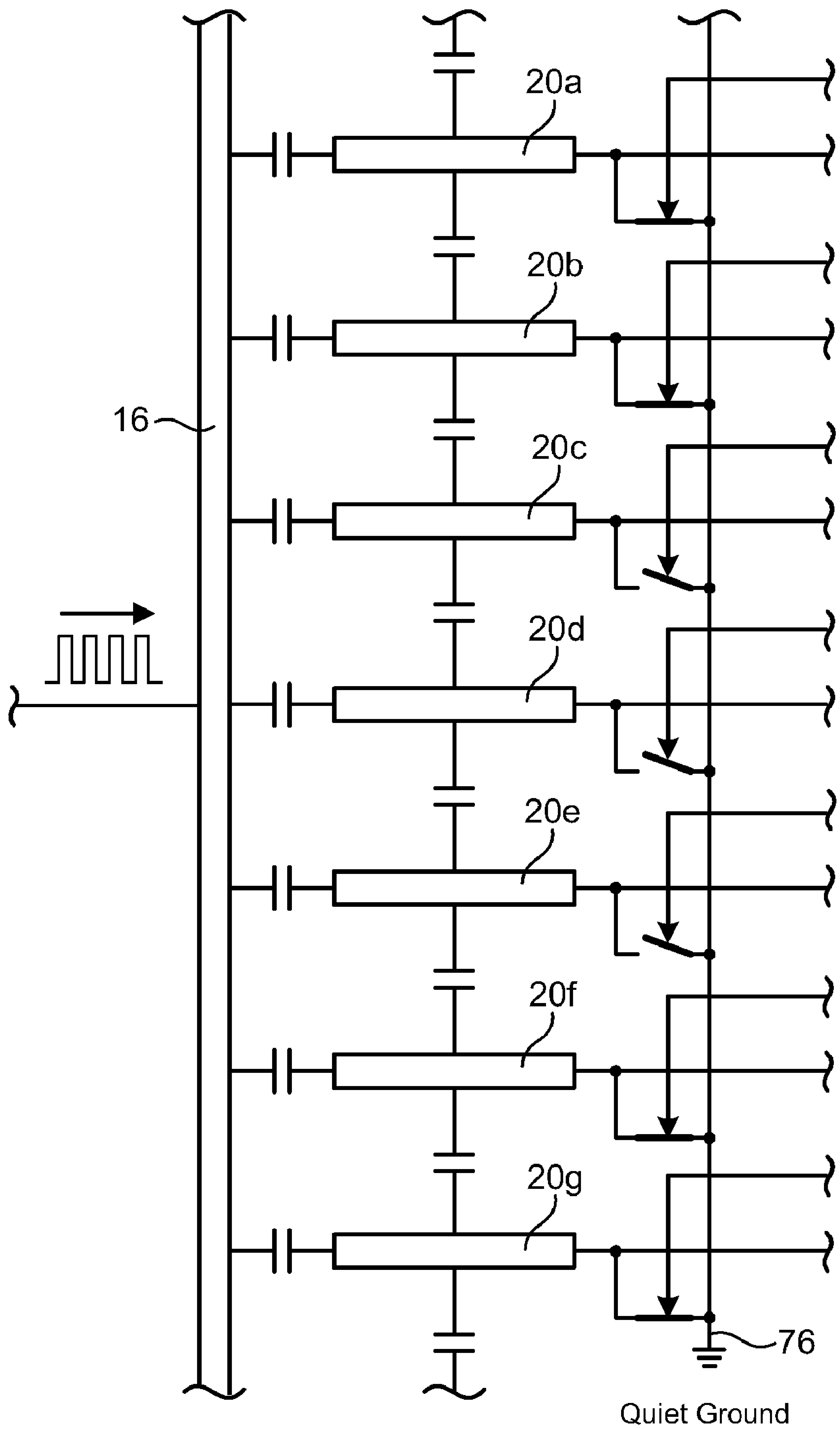
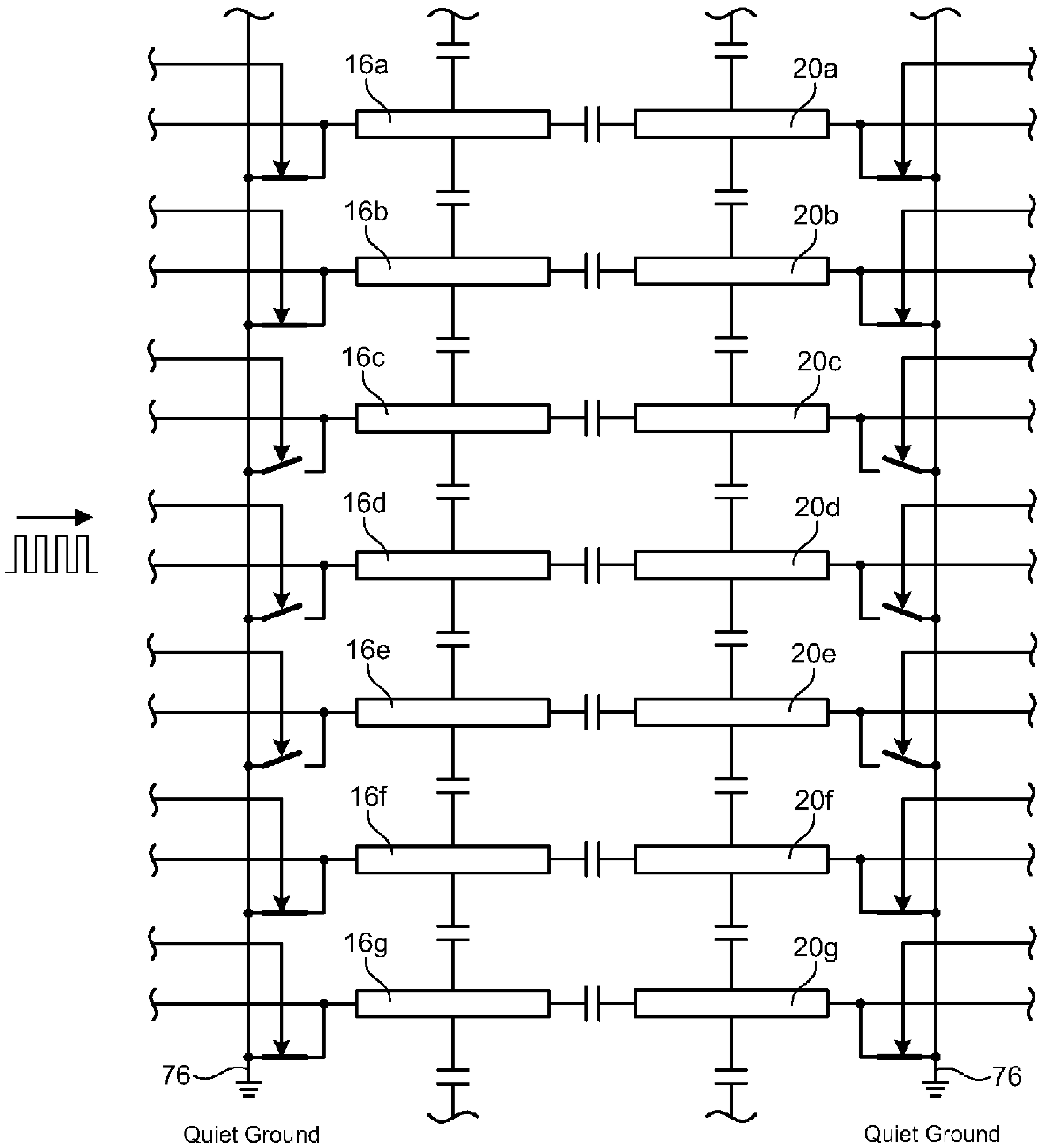


Fig. 6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16b
16c
16d
16e
16f
16g
20a
20b
20c
20d
20e
20f
20g
76
76
Quiet Ground
Quiet Ground

Fig. 7

APPARATUS AND METHOD FOR REDUCING PARASITIC CAPACITIVE COUPLING AND NOISE IN FINGERPRINT SENSING CIRCUITS

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

BACKGROUND

This invention relates to fingerprint sensing technology, and more particularly to apparatus and methods for reducing the effects of noise and parasitic capacitive coupling in fingerprint sensing circuits.

Fingerprint sensing technology is increasingly recognized as a reliable, non-intrusive way to verify individual identity. Fingerprints, like various other biometric characteristics, are based on unalterable personal characteristics and thus are believed to be more reliable when identifying individuals. The potential applications for fingerprints sensors are myriad. For example, electronic fingerprint sensors may be used to provide access control in stationary applications, such as security checkpoints. Electronic fingerprint sensors may also be used to provide access control in portable applications, such as portable computers, personal data assistants (PDAs), cell phones, gaming devices, navigation devices, information appliances, data storage devices, and the like. Accordingly, some applications, particularly portable applications, may require electronic fingerprint sensing systems that are compact, highly reliable, and inexpensive.

Various electronic fingerprint sensing methods, techniques, and devices have been proposed or are currently under development. For example, optical and capacitive fingerprint sensing devices are currently on the market or under development. Like a digital camera, optical technology utilizes visible light to capture a digital image. In particular, optical technology may use a light source to illuminate an individual's finger while a charge-coupled device (CCD) captures an analog image. This analog image may then be converted to a digital image.

There are generally two types of capacitive fingerprint sensing technologies: passive and active. Both types of capacitive technologies utilize the same principles of capacitance to generate fingerprint images. Passive capacitive technology typically utilizes an array of plates to apply an electrical current to the finger. The voltage discharge is then measured through the finger. Fingerprint ridges will typically have a substantially greater discharge potential than valleys, which may have little or no discharge.

Active capacitive technology is similar to passive technology, but may require initial excitation of the epidermal skin layer of the finger by applying a voltage. Active capacitive sensors, however, may be adversely affected by dry or worn minutia, which may fail to drive the sensor's output amplifier. By contrast, passive sensors are typically capable of producing images regardless of contact resistance and require significantly less power.

Although each of the fingerprint sensing technologies described above may generate satisfactory fingerprint images, each may be adversely affected by noise, interference, and other effects. For example, capacitive sensors may be particularly susceptible to noise and parasitic capacitive coupling, which may degrade the quality of the acquired fingerprint image. Accordingly, it would be an advance in the art to reduce the effects of noise, parasitic capacitive coupling, and other effects in capacitive-type fingerprint sensing circuits.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the advantages of the invention will be readily understood, a more particular description of the invention briefly described above will be rendered by reference to specific examples illustrated in the appended drawings. Understanding that these drawings depict only typical examples of the invention and are not therefore to be considered limiting of its scope, the invention will be described and explained with additional specificity and detail through use of the accompanying drawings, in which:

FIG. **1** is a high-level block diagram of one embodiment of a fingerprint sensing area containing an array of fingerprint sensing elements and interfacing with a fingerprint sensing circuit;

FIG. **2** is a partial cutaway profile view of a fingerprint sensing area showing the interaction between a finger and fingerprint sensing elements in a capacitive-type fingerprint sensor, with a fingerprint ridge lying substantially over the sensor gap;

FIG. **3** is a partial cutaway profile view of a fingerprint sensing area showing the interaction between a finger and fingerprint sensing elements in a capacitive-type fingerprint sensor, with a fingerprint valley lying substantially over the sensor gap;

FIG. **4** is a high-level block diagram of one embodiment of a fingerprint sensing circuit for use with the present invention;

FIG. **5** is a high-level block diagram showing one embodiment of an apparatus to connect and disconnect transmitting elements to and from a quiet ground in accordance with the invention;

FIG. **6** is a high-level block diagram showing an embodiment of an apparatus to connect and disconnect receiving elements to and from a quiet ground in accordance with the invention; and

FIG. **7** is a high-level block diagram showing an embodiment of an apparatus to connect and disconnect both transmitting and receiving elements to and from a quiet ground in accordance with the invention.

DETAILED DESCRIPTION

The invention has been developed in response to the present state of the art, and in particular, in response to the problems and needs in the art that have not yet been fully solved by currently available fingerprint sensors. Accordingly, the invention has been developed to provide novel apparatus and methods for reducing parasitic capacitive coupling and noise in fingerprint sensing circuits. The features and advantages of the invention will become more fully apparent from the following description and appended claims and their equivalents, and also any subsequent claims or amendments presented, or may be learned by practice of the invention as set forth hereinafter.

Consistent with the foregoing, a fingerprint sensing circuit having reduced parasitic capacitive coupling and noise is disclosed in one embodiment of the invention as including multiple transmitting elements, such as a linear array of transmitting elements, to sequentially emit a probing signal. A digital ground is provided to ground digital components in the fingerprint sensing circuit. A quiet ground, separate from and containing less noise than the digital ground, is provided to ground inactive transmitting elements (i.e., transmitting elements that are not currently emitting the probing signal). Control logic is provided to connect the inactive transmitting elements to the quiet ground, while disconnecting active transmitting elements (i.e., transmitting elements that are currently emitting the probing signal) from the quiet ground. The quiet ground is provided to reduce parasitic capacitive coupling and noise on inactive transmitting elements.

In selected embodiments, the fingerprint sensing circuit further includes multiple switches to selectively connect and disconnect each transmitting element from the quiet ground. The control logic may be used to control the operation of the switches. In certain embodiments, the control logic is further configured to connect, to the digital ground, transmitting elements that are adjacent to the active transmitting element. This may be performed to keep noise and other unwanted signals from adversely being transmitted onto the quiet ground.

In another embodiment in accordance with the invention, a method for reducing parasitic capacitive coupling and noise in fingerprint sensing circuits includes providing multiple transmitting elements to sequentially emit a probing signal, a digital ground to ground digital components in the fingerprint sensing circuit, and a quiet ground, separate from the digital ground, to ground inactive transmitting elements. The method further includes connecting inactive transmitting elements to the quiet ground and disconnecting active transmitting elements from the quiet ground. In this way, the quiet ground may be used to reduce parasitic capacitive coupling and noise on inactive transmitting elements.

In yet another embodiment in accordance with the invention, a fingerprint sensing circuit for reducing the adverse effects of parasitic capacitive coupling and noise includes multiple receiving elements to sequentially sense a probing signal. A digital ground is provided to ground digital components in the fingerprint sensing circuit. A quiet ground, separate from the digital ground, is provided to ground inactive receiving elements (i.e., receiving elements that are not currently sensing the probing signal). Control logic is provided to connect inactive receiving elements to the quiet ground while disconnecting active receiving elements (i.e., receiving elements that are currently sensing the probing signal) from the quiet ground. In this way, the quiet ground may reduce the adverse effects of parasitic capacitive coupling and noise on receiving elements configured to sense or detect a probing signal.

It will be readily understood that the components of the present invention, as generally described and illustrated in the Figures herein, may be arranged and designed in a wide variety of different configurations. Thus, the following more detailed description of the embodiments of the systems and methods of the present invention, as represented in the Figures, is not intended to limit the scope of the invention, as claimed, but is merely representative of selected embodiments of the invention.

Some of the functional units or method steps described in this specification may be embodied or implemented as modules. For example, a module may be implemented as a hardware circuit comprising custom VLSI circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices, or the like.

Modules may also be implemented in software for execution by various types of processors. An identified module of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions which may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module need not be physically located together, but may comprise disparate instructions stored in different locations which, when joined logically together, comprise the module and achieve the stated purpose of the module.

Indeed, a module of executable code could be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within modules, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network.

Reference throughout this specification to "one embodiment," "an embodiment," or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment may be included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment.

Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. One skilled in the relevant art will recognize, however, that the invention can be practiced without one or more of the specific details, or with other methods, components, etc. In other instances, well-known structures, or operations are not shown or described in detail to avoid obscuring aspects of the invention.

The illustrated embodiments of the invention will be best understood by reference to the drawings, wherein like parts are designated by like numerals throughout. The following description is intended only by way of example, and simply illustrates certain selected embodiments of apparatus and methods that are consistent with the invention as claimed herein.

Referring to FIG. **1**, in selected embodiments, a fingerprint sensor **10** useable with an apparatus and method in accordance with the invention may include a fingerprint sensing area **12** to provide a surface onto which a user can swipe a fingerprint. A dotted outline of a finger **14** is shown superimposed over the fingerprint sensing area **12** to provide a general idea of the size and scale of one embodiment of a fingerprint sensing area **12**. The size and shape of the fingerprint sensing area **12** may vary, as needed, to accommodate different applications.

In certain embodiments, the fingerprint sensing area **12** may include an array of transmitting elements **16**, such as a linear array of transmitting elements **16**, to assist in scanning lines of "pixels" as a fingerprint is swiped across the fingerprint sensing area **12**. In this embodiment, the transmitting elements **16** are shown as a linear array of conductive traces **16** connected to a fingerprint sensing circuit **18**. The transmitting elements **16** are not drawn to scale and may include several hundred transmitting elements **16** arranged across the width of a fingerprint, one transmitting element **16** per pixel. A fingerprint image may be generated by scanning successive lines of pixels as a finger is swiped over the array. These lines may then be assembled to generate a fingerprint image, similar to the way a fax image is generated using line-by-line scanning.

In certain embodiments, the transmitting elements **16** are configured to sequentially emit, or burst, a probing signal, one after the other. As will be explained in more detail hereafter, the probing signal may include a burst of probing pulses, such as a burst of square waves. This probing signal may be sensed on the receiving end by a receiving element **20**. Like the transmitting elements **16**, the receiving element **20** is shown as a conductive trace **20** connected to the fingerprint sensing circuit **18**. Although shown as a single receiving element **20**, in other embodiments, pairs of receiving elements **20** may be used to differentially cancel out noise.

At the receiving element **20**, a response signal may be generated in response to the probing signal. The magnitude of the response signal may depend on factors such as whether a finger is present over the fingerprint sensing area **12** and, more particularly, whether a ridge or valley of a fingerprint is immediately over the gap **22** between a transmitting element **16** and the receiving element **20**. The magnitude of the signal generated at the receiving element **20** may be directly related to the RF impedance of a finger ridge or valley placed over the gap **22** between the corresponding transmitting element **16** and receiving element **20**.

By using a single receiving element **20** (or a small number of receiving elements **20**) and a comparatively larger number of transmitting elements **16**, a receiver that is coupled to the receiving element **20** may be designed to be very high quality and with a much better dynamic range than would be possible using an array of multiple receiving elements. This design differs from many conventional fingerprint sensors, which may employ a single large transmitting element with a large array of receiving elements and receivers. Nevertheless, the apparatus and methods described herein are not limited to the illustrated transmitter and receiver design. Indeed, the apparatus and methods disclosed herein may be used with fingerprint sensors using a small number of transmitting elements and a relatively large number of receiving elements, a large number of transmitting elements and a relatively small number of receiving element, or a roughly equal number of transmitting and receiving elements.

As shown in FIG. **1**, the fingerprint sensing area **12** (including the transmitting and receiving elements **16**, **20**) may be physically decoupled from the fingerprint sensing circuit **18**. Positioning the sensing elements **16**, **20** off the silicon die may improve the reliability of the fingerprint sensor **10** by reducing the sensor's susceptibility to electrostatic discharge, wear, and breakage. This may also allow the cost of the sensor **10** to be reduced over time by following a traditional die-shrink roadmap. This configuration provides a distinct advantage over direct contact sensors (sensors that are integrated onto the silicon die) which cannot be shrunk to less than the width of an industry standard fingerprint. Nevertheless, the apparatus and methods disclosed herein are applicable to fingerprint sensors with sensing elements that are located either on or off the silicon die.

Referring generally to FIGS. **2** and **3**, in selected embodiments, the transmitting and receiving elements **16**, **20** discussed above may be adhered to a non-conductive substrate **30**. For example, the substrate **30** may be constructed of a flexible polyimide material marketed under the trade name Kapton® and with a thickness of between about 25 and 100 μm. The Kapton® polymer may allow the fingerprint sensor **10** to be applied to products such as touchpads and molded plastics having a variety of shapes and contours while providing exceptional durability and reliability.

In selected embodiments, a user's finger may be swiped across the side of the substrate **30** opposite the transmitting and receiving elements **16**, **20**. Thus, the substrate **30** may electrically and mechanically isolates a user's finger from the transmitting element **16** and receiving element **20**, thereby providing some degree of protection from electrostatic discharge (ESD) and mechanical abrasion.

The capacitive coupling between the transmitting element **16** and the receiving element **20** may change depending on whether a fingerprint ridge or valley is immediately over the gap **22**. This is because the dielectric constant of a finger is typically ten to twenty times greater than the dielectric constant of air. The dielectric constant of the ridges of a finger may vary significantly from finger to finger and person to person, explaining the significant range of dielectric constants. Because a fingerprint ridge has a dielectric constant that differs significantly from that of air, the capacitive coupling between the transmitting element **16** and receiving element **20** may vary significantly depending on whether a ridge or valley is present over the sensor gap **22**.

For example, referring to FIG. **2**, when a fingerprint ridge **32** is over the gap **22**, the capacitive coupling between the transmitting element **16** and receiving element **20** may be increased such that the probing signal emitted by the transmitting element **16** is detected at the receiving element **20** as a stronger response signal. It follows that a stronger response signal at the receiving element **20** indicates the presence of a ridge **32** over the gap **22**. On the other hand, as shown in FIG. **3**, the capacitive coupling between the transmitting element **16** and receiving element **20** may decrease when a valley is present over the gap **22**. Thus, a weaker response signal at the receiving element **20** may indicate that a valley **34** is over the gap **22**. By measuring the magnitude of the response signal at the receiving element **20**, ridges and valleys may be detected as a user swipes his or her finger across the sensing area **12**, allowing a fingerprint image to be generated.

Referring to FIG. **4**, in certain embodiments, a fingerprint sensing circuit **18** useable with an apparatus and method in accordance with the invention may include a transmitter clock **40** configured to generate an oscillating signal, such as an oscillating square-wave signal. Scanning logic **42** may be used to sequentially route the oscillating signal to buffer amplifiers **46**, one after the other, using switches **44**. The buffer amplifiers **46** may amplify the oscillating signal to generate the probing signal. As shown, the buffer amplifiers **46** may sequentially burst the probing signal **48** to each of the transmitting elements **16**, one after the other. A response signal, generated in response to the probing signal **48**, may be sensed at the receiving element **20** and may be routed to a variable-gain amplifier **50** to amplify the response signal. The amplified response signal may then be passed to a band pass filter **52** centered at the frequency of the transmitter clock **40**.

The output from the band pass filter **52** may then be supplied to an envelope detector **54**, which may detect the envelope of the response signal. This envelope may provide a baseband signal, the amplitude of which may vary depending on whether a ridge or valley is over the sensor gap **22**. The baseband signal may be passed to a low pass filter **56** to remove unwanted higher frequencies. The variable-gain amplifier **50**, band pass filter **52**, envelope detector **54**, low pass filter **56**, as well as other analog components may be collectively referred to as an analog front end **57**.

The output from the low pass filter **56** may be passed to an analog-to-digital converter (ADC) **58**, which may convert the analog output to a digital value. The ADC **58** may have, for example, a resolution of 8 to 12 bits and may be capable of resolving the output of the low pass filter **56** to 256 to 4096 values. The magnitude of the digital value may be proportional to the signal strength measured at the receiving element **20**. Likewise, as explained above, the signal strength may be related to the capacitive coupling between the transmitting element **16** and receiving element **20**, which may depend on the RF impedance of the feature over the sensor gap **22**.

The resulting digital value may be passed to a CPU **60** or other digital components, which may eventually pass digital fingerprint data to a host system **62**. The host system **62**, in selected embodiments, may process the fingerprint data using various matching algorithms in order to authenticate a user's fingerprint.

In addition to processing the digital data, the CPU **60** may control the gain of the variable-gain amplifier **50** using a digital-to-analog converter (DAC) **64**. The gain may be adjusted to provide a desired output power or amplitude in the presence of variable sensing conditions. For example, in selected embodiments, the gain of the variable-gain amplifier **50** may be adjusted to compensate for variations in the impedance of different fingers. In selected embodiments, the CPU **60** may also control the operation of the scanning logic **42**.

Referring to FIG. **5**, as described herein, various fingerprint-sensing technologies may be adversely affected by noise, interference, and other effects. For example, capacitive sensors may be particularly susceptible to noise and parasitic capacitive coupling, which may degrade the quality of the acquired fingerprint image. Accordingly, apparatus and methods are needed to reduce the effects of noise and parasitic capacitive coupling in fingerprint sensing circuits.

As shown in FIG. **5**, parasitic capacitance may be present between each of the transmitting elements **16**, as well as between the transmitting elements **16** and the receiving element **20**. The parasitic capacitance between the transmitting and receiving elements **16**, **20** is represented by capacitor symbols **70**. The parasitic capacitance may be exacerbated by the close spacing of the transmitting elements **16** and the receiving element **20**.

For example, the width and spacing of the transmitting elements **16** may determine the resolution of the acquired fingerprint image. To achieve an industry standard resolution of 500 dots per inch, for example, the width of each transmitting element **16** may be approximately 25 microns. Similarly, the gap between adjacent transmitting elements **16** may be approximately 25 microns. The sensor gap **22** between the transmitting elements **16** and the receiving element **20** may be approximately 25 microns. This results in a center-to-center spacing of adjacent transmitting elements **16** of approximately 50 microns. Nevertheless, these dimensions are provided only by way of example and are not intended to be limiting.

As previously mentioned, the transmitting elements **16** may be coupled to output buffer amplifiers **46** to amplify the probing signal and accommodate a change in electrical impedance. More particularly, the output buffer amplifiers **46** may sequentially burst a probing signal **48** to each of the transmitting elements **16**, one after the other, as described in FIG. **4**. Input lines **72** may be enabled with a high logic value when the output buffer amplifiers **46** are transmitting the probing signal **48**. When the output buffer amplifiers **46** are not transmitting the probing signal **48**, the output buffer amplifiers **46** may be configured to drive the associated transmitting element **16** to digital ground **74**.

In addition to providing a ground for the transmitting elements **16**, the digital ground **74** may provide a ground for various digital components in the fingerprint sensing circuit **18**, such as the CPU **60** and other digital components such as the ADC **58**, DAC **64**, oscillator **40**, and the like. This may allow any parasitic capacitive fields between the active transmitting element **16** and the inactive transmitting elements **16** to be shorted to the digital ground **74**.

Although the digital ground **74** may reduce much of the undesired parasitic capacitive coupling between the transmitting and receiving elements **16**, **20**, the digital ground **74** may have the undesired effect of transmitting noise onto the transmitting elements **16**. This noise may be the result of switching noise generated by digital components such as the CPU **60**, memory, or other digital components when they change state. This noise may be capacitively coupled to other transmitting elements **16** or the receiving element **20**, thereby degrading the acquired fingerprint image. Thus, apparatus and methods are needed to reduce the noise that is transmitted from the digital ground **74** onto the transmitting and receiving elements **16**, **20**.

In selected embodiments in accordance with the invention, a quiet ground **76** separate from and isolated from the digital ground **74** may be used to reduce noise on the transmitting and receiving elements **16**, **20**. In certain embodiments, the quiet ground **76** and digital ground **74** may not be totally separated, but may, for example, connect at a single point. The single point may keep the ground potentials of the ground planes substantially the same, but may keep the transfer of digital noise to a minimum. Switches **78** may be used to selectively connect and disconnect the transmitting elements **16** to and from the quiet ground **76**. In certain embodiments, control logic **80** may be used to open and close the switches **78** as the probing signal is sequentially transmitted to each transmitting element **16**.

The dotted line **81** in the control logic **80** is used to show the current column of logic values which is output to the buffer amplifiers **46**a-g. These logic values will change as the fingerprint sensing circuit **18** sequentially moves from one transmitting element **16**a-g to the next. In certain embodiments, the control logic **80** may output the illustrated logic values, moving left to right, column-by-column, to the buffer amplifiers **46**a-g.

In certain embodiments in accordance with the invention, the control logic **80** may be configured to connect inactive transmitting elements **16**c, **16**e that are adjacent to the active transmitting element **16**d to the digital ground **74**, while connecting all other inactive transmitting elements **16**a, **16**b, **16**f, **16**g to the quiet ground **76**. This technique may reduce the amount of noise that would otherwise be parasitically coupled from the active transmitting element **16**d to the adjacent transmitting elements **16**c, **16**e and ultimately onto the quiet ground **76**. In other words, this technique may help ensure that the quiet ground **76** is maintained as quiet as possible.

For example, as illustrated in FIG. **5**, when an amplifier buffer **46**d is transmitting the probing signal to the active transmitting element **16**d, the adjacent inactive transmitting element **16**c, **16**e may be coupled to the digital ground **74** and decoupled from the quiet ground **76** (as indicated by the "1" on the enable line of the buffer **46**d and the open switches **78**c, **78**e). The remaining inactive transmitting elements **16**a, **16**b, **16**f, **16**g may be coupled to the quiet ground **76** (as indicated by the "0" on the enable lines and the closed switches **78**a, **78**b, **78**f, **78**g). In this way, any signal that is parasitically coupled from the active transmitting element **16**d to the adjacent transmitting elements **16**c, **16**e may be conducted to digital ground **74** rather than to quiet ground **76**. This ensures that the quiet ground **76** is maintained as quiet as possible.

Apparatus and methods in accordance with the invention are not limited to the illustrated embodiment. For example, in other embodiments, transmitting elements **16**c, **16**e that are adjacent to the active transmitting element **16**d may be coupled to the quiet ground **76** just like other transmitting elements **16**a, **16**b, **16**f, **16**g. In this embodiment, only the active transmitting element **16**d is decoupled from the quiet ground **76**. Whether adjacent transmitting elements **16**c, **16**e are or are not coupled to the quiet ground **76** may depend on the amount of parasitic capacitance between the active transmitting element **16**d and the adjacent transmitting elements **16**c, **16**d.

By contrast, in other embodiments, more than two adjacent transmitting elements may be coupled to the digital ground **74** and decoupled from the quiet ground **76**. For example, two transmitting elements **16**b, **16**c, **16**e, **16**f on either side of the active transmitting element **16**d may be coupled to the digital ground **74** and decoupled from the quiet ground **76** to ensure that the quiet ground **76** is maintained as quiet as possible. Similarly, any number of transmitting elements **16** on either side of the active transmitting element **16**d may be coupled to the digital ground **74** and decoupled from the quiet ground **76**.

Referring to FIGS. **6** and **7**, as mentioned previously, the apparatus and methods disclosed herein are not limited to the illustrated fingerprint sensor. Indeed, the apparatus and methods disclosed herein may be used with fingerprint sensors using a small number of transmitting elements and a relatively large number of receiving elements, a large number of transmitting elements and a relatively small number of receiving element, or a roughly equal number of transmitting elements and receiving elements.

For example, FIG. **6** shows one embodiment of a fingerprint sensor using a single transmitting element **16** and multiple receiving elements **20**a-g. As shown, an isolated quiet ground **76**, separate from other grounds, may be used to ground receiving elements **20**a, **20**b, **20**f, **20**g that are inactive (not currently being used for sensing purposes). This may help to ensure that receiving elements **20** that are inactive do not parasitically capacitively couple signals, received from the transmitting element **16** or from a noisy ground, to the active receiving element **20**d.

FIG. **7** shows one embodiment of a fingerprint sensor using multiple transmitting elements **16**a-g and multiple receiving elements **20**a-g. In this embodiment, a quiet ground **76**, separate from other grounds, is used to ground transmitting elements **16**a, **16**b, **16**f, **16**g and receiving elements **20**a, **20**b, **20**f, **20**g that are inactive and not currently used for sensing purposes. This may ensure that transmitting elements **16** and receiving elements **20** that are inactive do not parasitically capacitively couple signals received from a noisy ground to the active transmitting and receiving elements **16**d, **20**d.

The invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described examples are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

The invention claimed is:

1. A fingerprint sensing circuit for reducing parasitic capacitive coupling and noise when scanning a fingerprint, the fingerprint sensing circuit comprising:

a plurality of transmitting elements configured to sequentially transmit a probing signal;

a digital ground to provide a ground for digital components in the fingerprint sensing circuit;

a quiet ground, different from the digital ground;

a grounding switch electrically connected between the quiet ground and a respective transmitting element; and

control logic configured to selectively connect each transmitting element to the quiet ground through the operation of the respective grounding switch.

2. The fingerprint sensing circuit of claim **1**, further comprising a plurality of switches configured to selectively connect each transmitting element to the quiet ground and disconnect each transmitting element from the quiet ground.

3. The fingerprint sensing circuit of claim **2**, wherein the control logic controls the operation of the switches.

4. The fingerprint sensing circuit of claim **1**, wherein the plurality of transmitting elements are arranged in a substantially linear array.

5. The fingerprint sensing circuit of claim **4**, wherein the control logic is further configured to connect transmitting elements that are adjacent to a transmitting element transmitting the probing signal, to the digital ground.

6. The fingerprint sensing circuit of claim **1**, wherein the digital ground and quiet ground are connected to one another at a ground plane.

7. The fingerprint sensing circuit of claim **1**, further comprising a receiving element configured to sense the probing signal from the plurality of transmitting elements.

8. A method for reducing parasitic capacitive coupling and noise in a fingerprint sensing circuit, the method comprising:

providing a plurality of transmitting elements to sequentially transmit a probing signal;

providing a digital ground to ground digital components in the fingerprint sensing circuit;

providing a quiet ground, different from the digital ground;

providing a grounding switch electrically connected between the quiet ground and a respective transmitting element;

selectively connecting, to the quiet ground, each transmitting element through the operation of the respective grounding switch; and

disconnecting, from the quiet ground, transmitting elements that are transmitting the probing signal.

9. The method of claim **8**, further comprising providing a plurality of switches to selectively connect and disconnect each transmitting element from the quiet ground.

10. The method of claim **9**, further comprising providing control logic to control the operation of the switches.

11. The method of claim **8**, further comprising arranging the plurality of transmitting elements in a substantially linear array.

12. The method of claim **11**, further comprising providing control logic to connect transmitting elements that are adjacent to a transmitting element emitting the probing signal, to the digital ground.

13. The method of claim **8**, further comprising connecting the digital ground and quiet ground to one another at a ground plane.

14. The method of claim **8**, further comprising providing a receiving element to sense the probing signal emitted by the plurality of transmitting elements.

15. A fingerprint sensing circuit for reducing parasitic capacitive coupling and noise when scanning a fingerprint, the fingerprint sensing circuit comprising:

a plurality of receiving elements configured to sequentially sense a probing signal;

a digital ground configured to provide a ground for digital components in the fingerprint sensing circuit;

a quiet ground, substantially separate from the digital ground, configured to provide a ground for selected receiving elements that are not currently sensing the probing signal;

a grounding switch electrically connected between the quiet ground and a respective receiving element; and

control logic configured to selectively disconnect a receiving element that is currently sensing the probing signal from the quiet ground, while selectively connecting receiving elements that are not sensing the probing signal to the quiet ground.

16. The fingerprint sensing circuit of claim **15**, further comprising a plurality of switches to selectively connect and disconnect each receiving element from the quiet ground.

17. The fingerprint sensing circuit of claim **16**, wherein the control logic controls the operation of the switches.

18. The fingerprint sensing circuit of claim **15**, wherein the plurality of receiving elements are arranged in a substantially linear array.

19. The fingerprint sensing circuit of claim **18**, wherein the control logic is further configured to connect, to the digital ground, receiving elements that are adjacent to a receiving element sensing the probing signal.

20. The fingerprint sensing circuit of claim **15**, wherein the digital ground and quiet ground are connected to one another at a ground plane.

21. A biometric sensing circuit comprising:

a plurality of probe signal transmitting elements;

a plurality of response signal receiving elements;

a digital ground connected to digital components in the fingerprint sensing circuit;

a quiet ground, substantially separate from the digital ground;

a respective grounding switch electrically connected between the quiet ground and a respective transmitting element or the quiet ground and a respective response signal receiving element; and

control logic configured to selectively connect at least one of each respective transmitting element to the quiet ground through the operation of the respective grounding switch and each respective response signal receiving element to the quiet ground through the operation of the respective grounding switch.

22. The sensing circuit of claim 21, further comprising a plurality of switches configured to selectively connect each respective probe signal transmitting element to the quiet ground and disconnect other probe signal transmitting elements from the quiet ground or to selectively connect each respective response signal receiving element to the quiet ground and disconnect other response signal receiving elements from the quiet ground.

23. The sensing circuit of claim 21, wherein the control logic controls the operation of the switches.

24. The sensing circuit of claim 21, wherein the plurality of transmitting elements are arranged in a substantially linear array.

25. The sensing circuit of claim 24, wherein the control logic is further configured to connect probe signal transmitting elements that are adjacent to an active probe signal transmitting element transmitting the probing signal, to the digital ground or to connect response signal receiving elements that are adjacent to an active response signal receiving element receiving the response signal, to the digital ground.

26. The sensing circuit of claim 21, wherein the digital ground and quiet ground are connected to one another at a ground plane.

27. The sensing circuit of claim 21, further comprising a receiving element configured to sense the probing signal from the plurality of transmitting elements.

28. The sensor of claim 21 wherein the sensing circuit comprises a biometric sensing circuit.

29. The sensor of claim 28 wherein the biometric sensing circuit comprises a fingerprint sensing circuit.

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