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(54) **X-RAY SYSTEM AND METHOD WITH DIGITAL IMAGE ACQUISITION USING A PHOTOVOLTAIC DEVICE**

(75) Inventors: **Christopher Alden Hammond**, Farmington Hills, MI (US); **Ping Xue**, Pewaukee, WI (US); **Diego Fernando Freire Munoz**, Chicago, IL (US); **Amanda Lynn Pratt**, Hartland, WI (US); **Robert Carl Minnich**, Cortland, OH (US); **Gregory Donald Schumacher-Novak**, Milwaukee, WI (US); **Michael Lee Spohn**, Waukesha, WI (US)

(73) Assignee: **GENERAL ELECTRIC COMPANY**, Niskayuna, NY (US)

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H05G 1/44 (2006.01)
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A61B 6/00 (2006.01)

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(58) **Field of Classification Search**

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USPC 250/336.1, 370.04, 370.09; 378/96, 97

See application file for complete search history.

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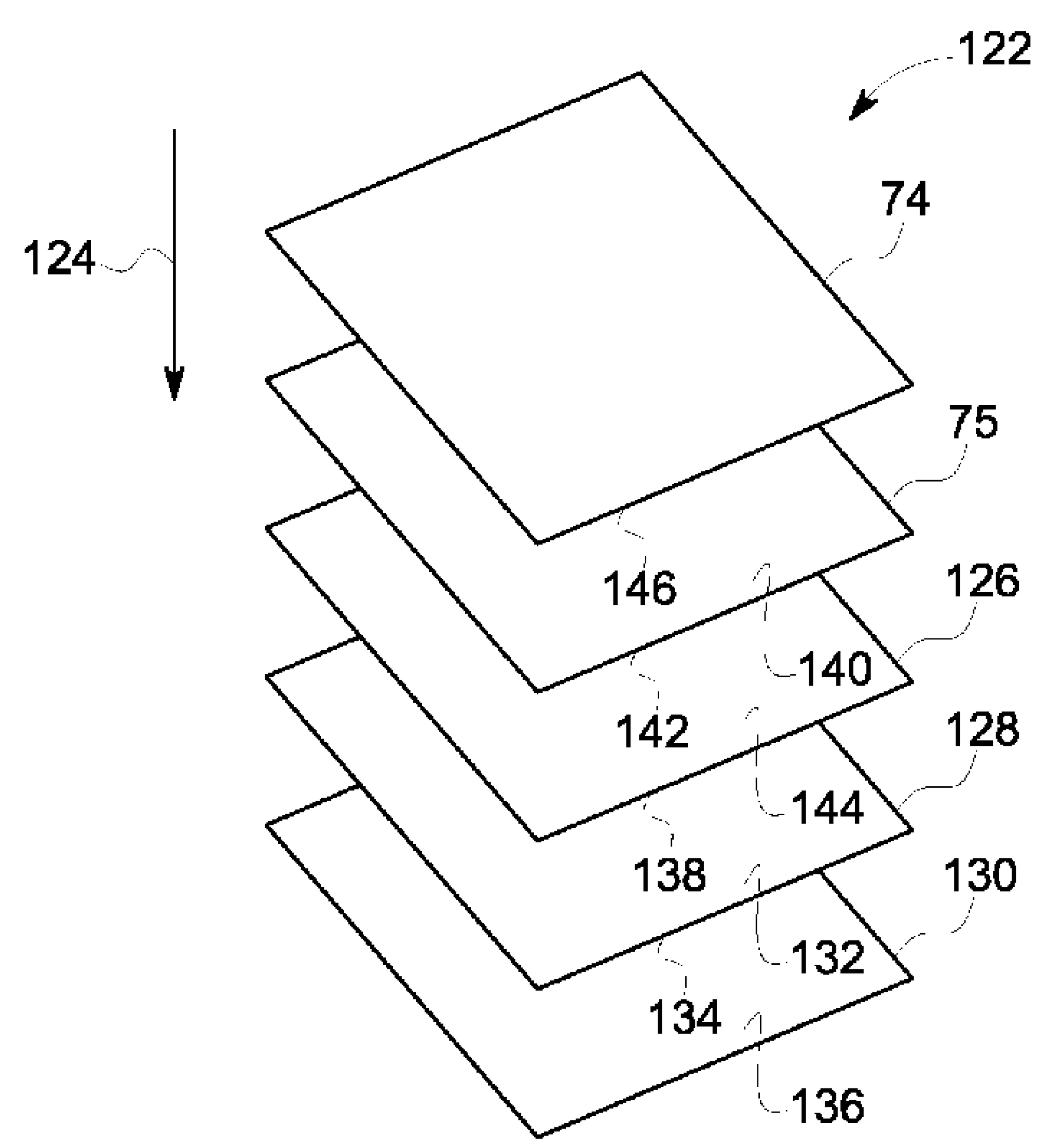
Primary Examiner — Wyatt Stoffa

(74) *Attorney, Agent, or Firm* — Fletcher Yoder, P.C.

(57) **ABSTRACT**

An X-ray imaging system is provided. The X-ray imaging system includes an X-ray radiation source. The X-ray imaging system also includes a source controller coupled to the source and configured to command emission of X-rays for image exposures. The X-ray imaging system further includes a digital X-ray detector configured to acquire X-ray image data without communication from the source controller, wherein the digital X-ray detector includes a photovoltaic device, and the digital X-ray detector is configured to determine one or more of a beginning, end, or duration of an image exposure via the photovoltaic device.

23 Claims, 8 Drawing Sheets



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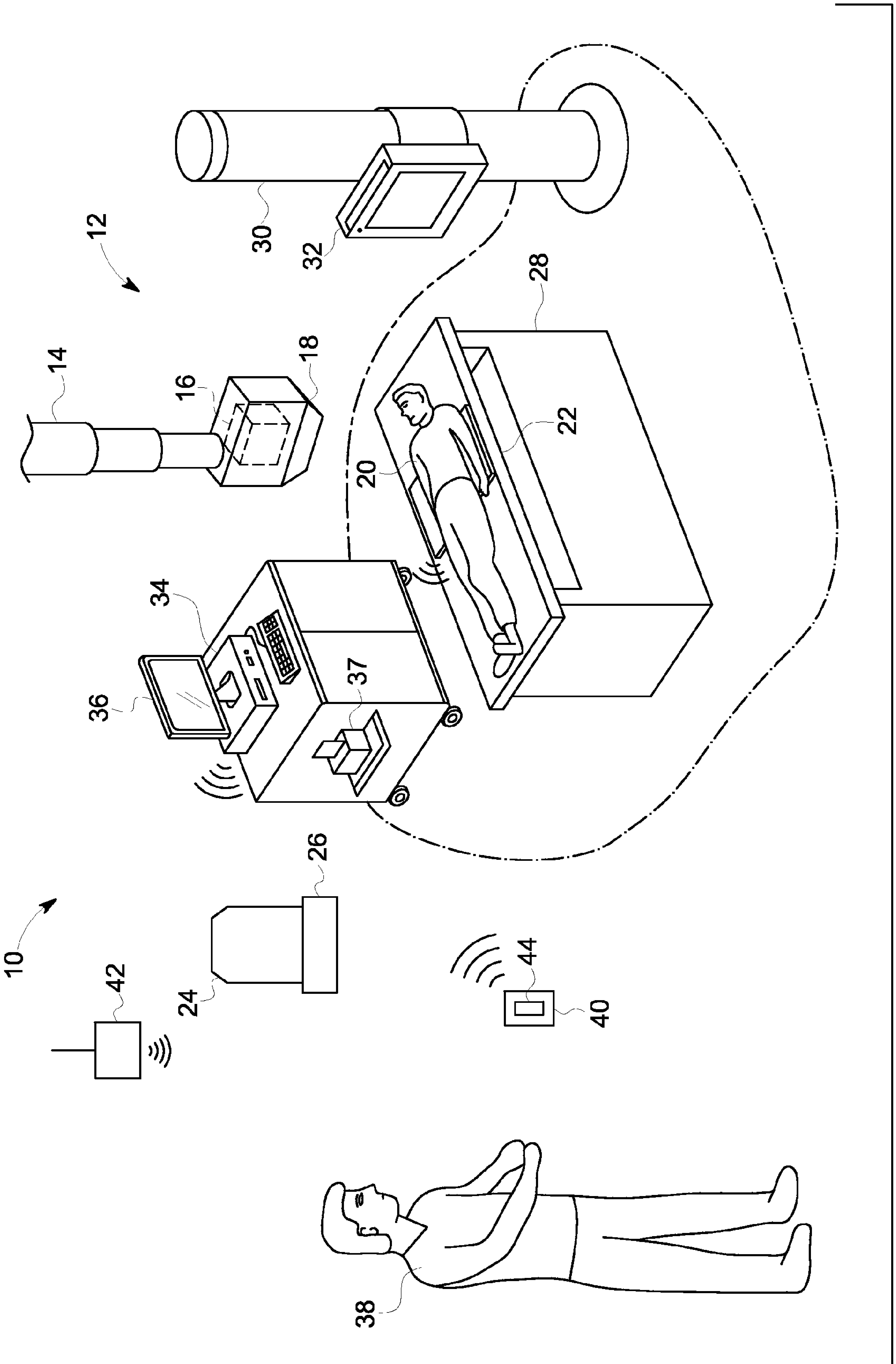


FIG. 1

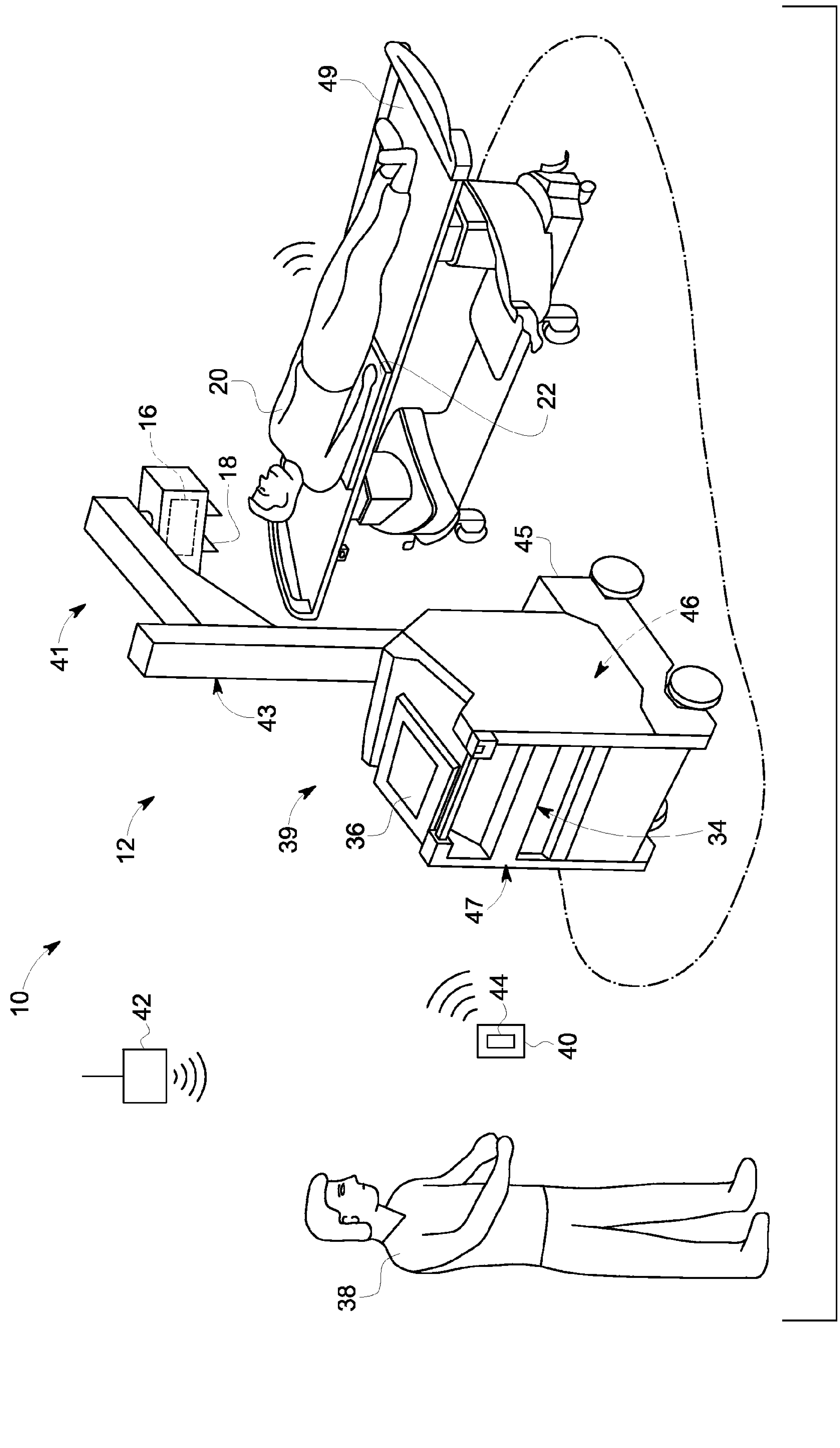


FIG. 2

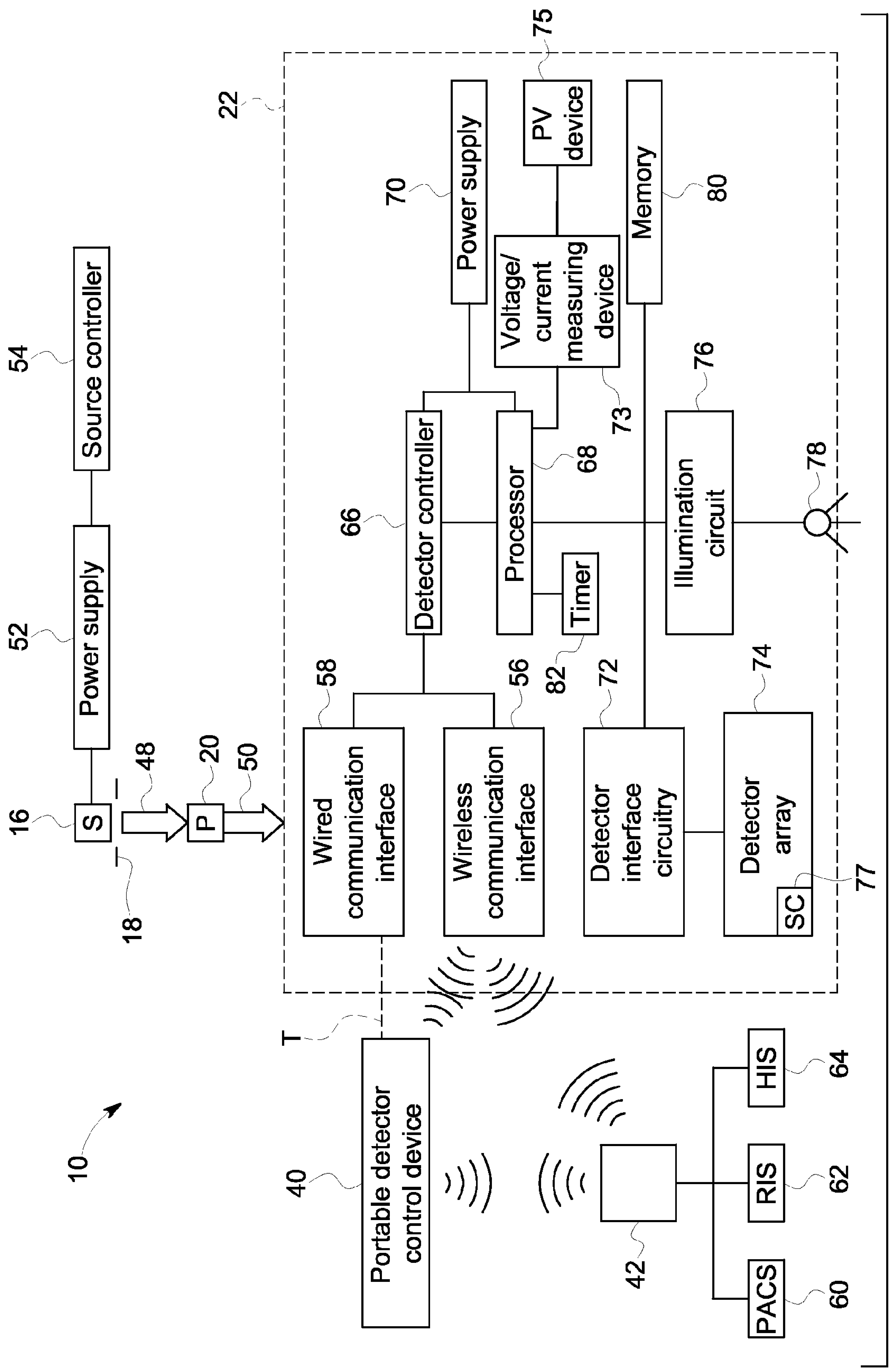

10
16
S
18
48
P
20
50
52
Power supply
54
Source controller
22
Wired communication interface
58
Wireless communication interface
56
Detector controller
66
Processor
68
Timer
82
Power supply
70
Voltage/ current measuring device
73
PV device
75
Memory
80
Illumination circuit
76
78
Detector interface circuitry
72
Detector array
74
SC
77
T
Portable detector control device
40
42
PACS
60
RIS
62
HIS
64

FIG. 3

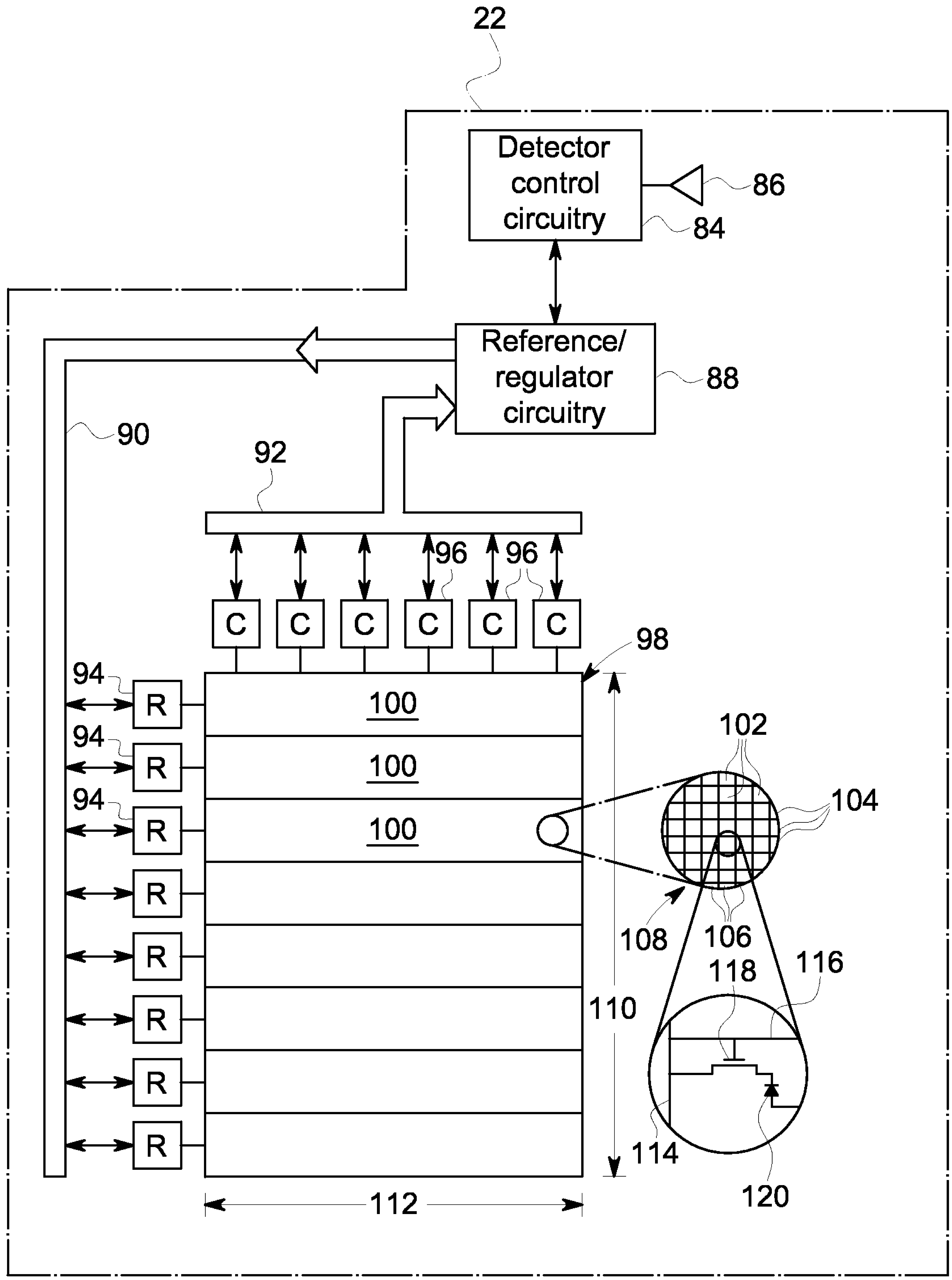

22
Detector control circuitry
86
84
Reference/ regulator circuitry
88
90
92
96
96
C
C
C
C
C
C
98
94
R
94
R
94
R
R
R
R
R
R
100
100
100
102
104
108
106
118
116
110
114
120
112

FIG. 4

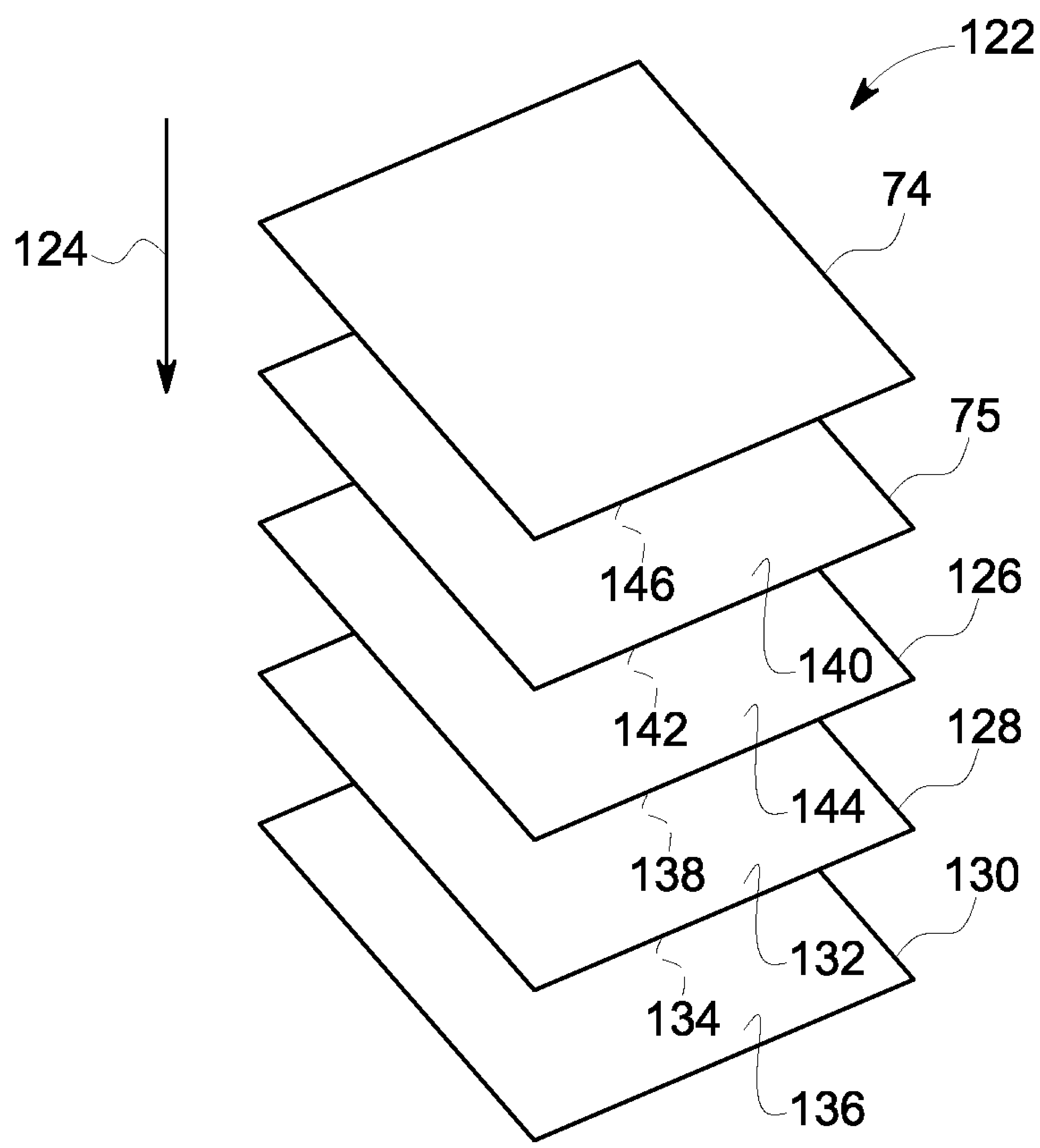
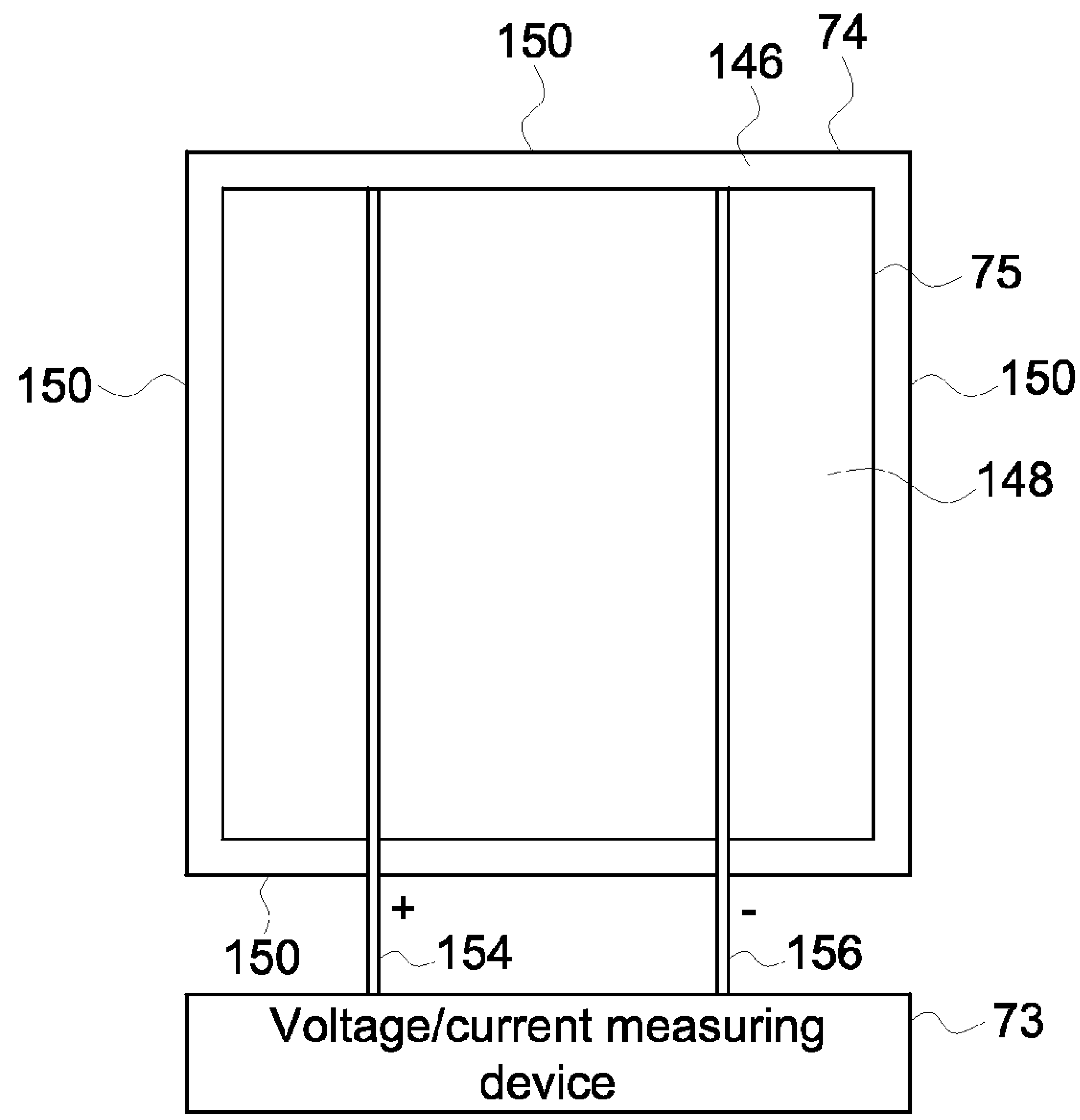


FIG. 5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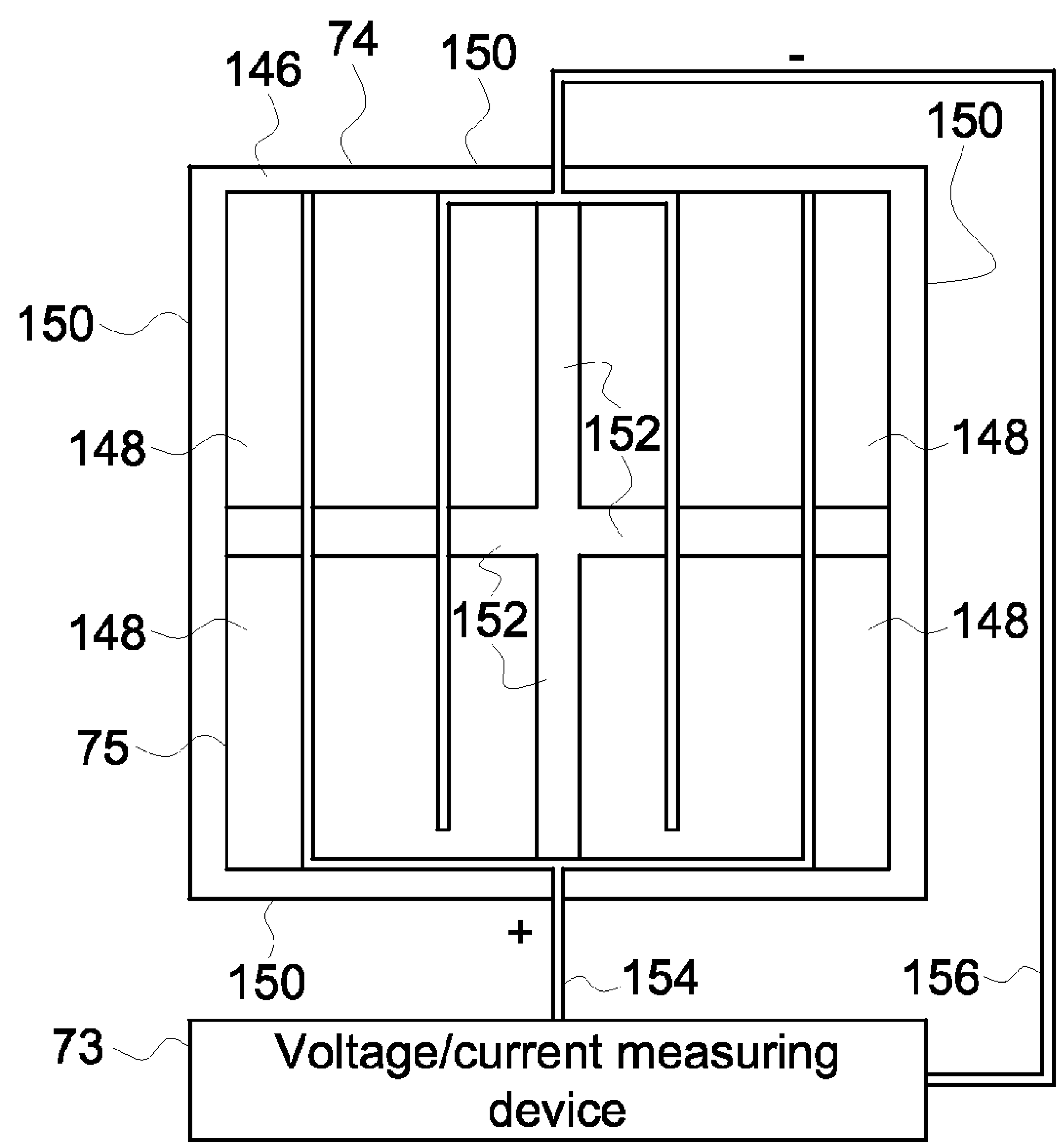
146
74
75
150
150
148
+
-
150
154
156
Voltage/current measuring device
73

FIG. 6


146
74
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148
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148
75
+
150
154
156
73
Voltage/current measuring device

FIG. 7

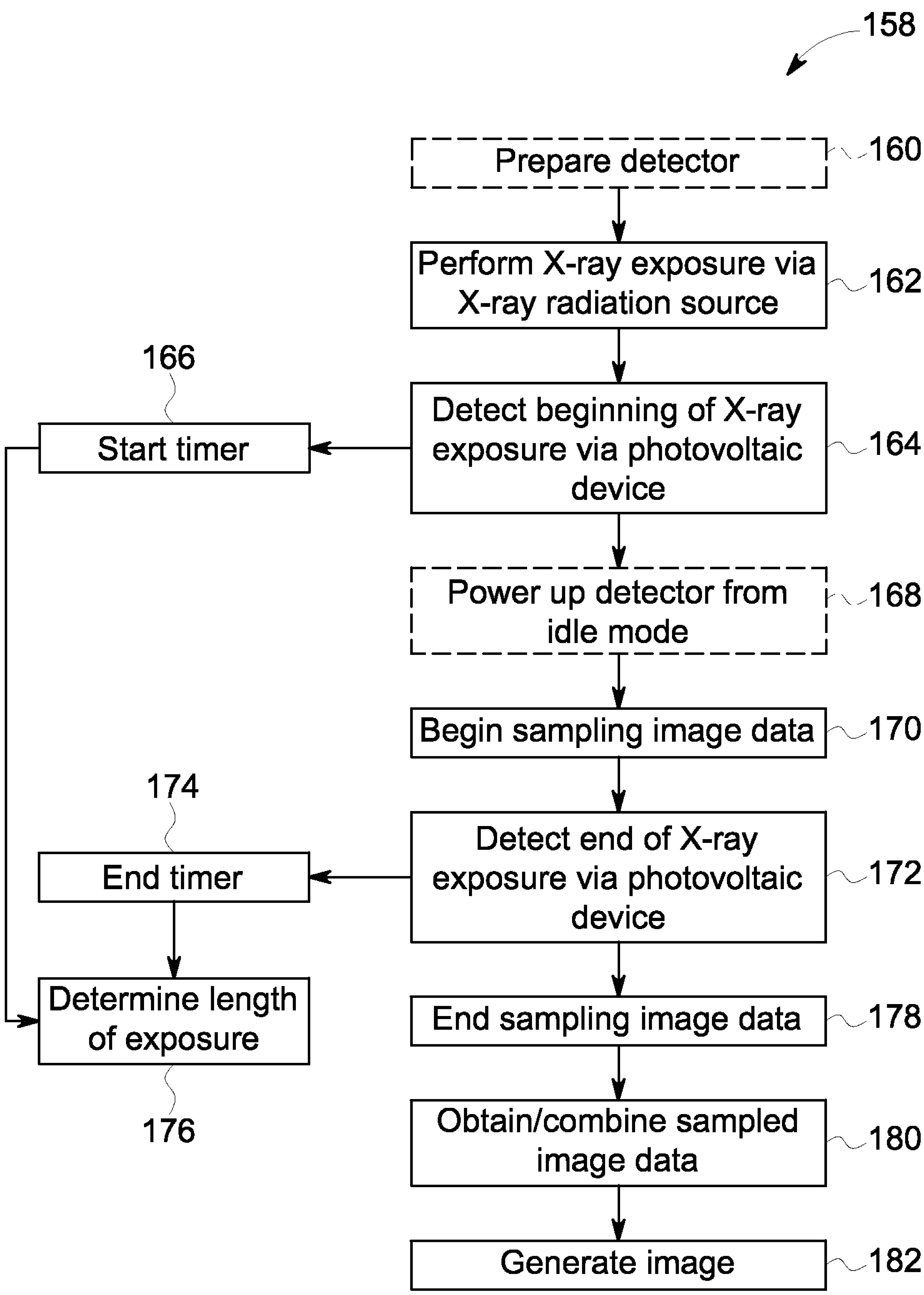
158
Prepare detector
160
Perform X-ray exposure via X-ray radiation source
162
166
Start timer
Detect beginning of X-ray exposure via photovoltaic device
164
Power up detector from idle mode
168
Begin sampling image data
170
174
End timer
Detect end of X-ray exposure via photovoltaic device
172
Determine length of exposure
176
End sampling image data
178
Obtain/combine sampled image data
180
Generate image
182

FIG. 8

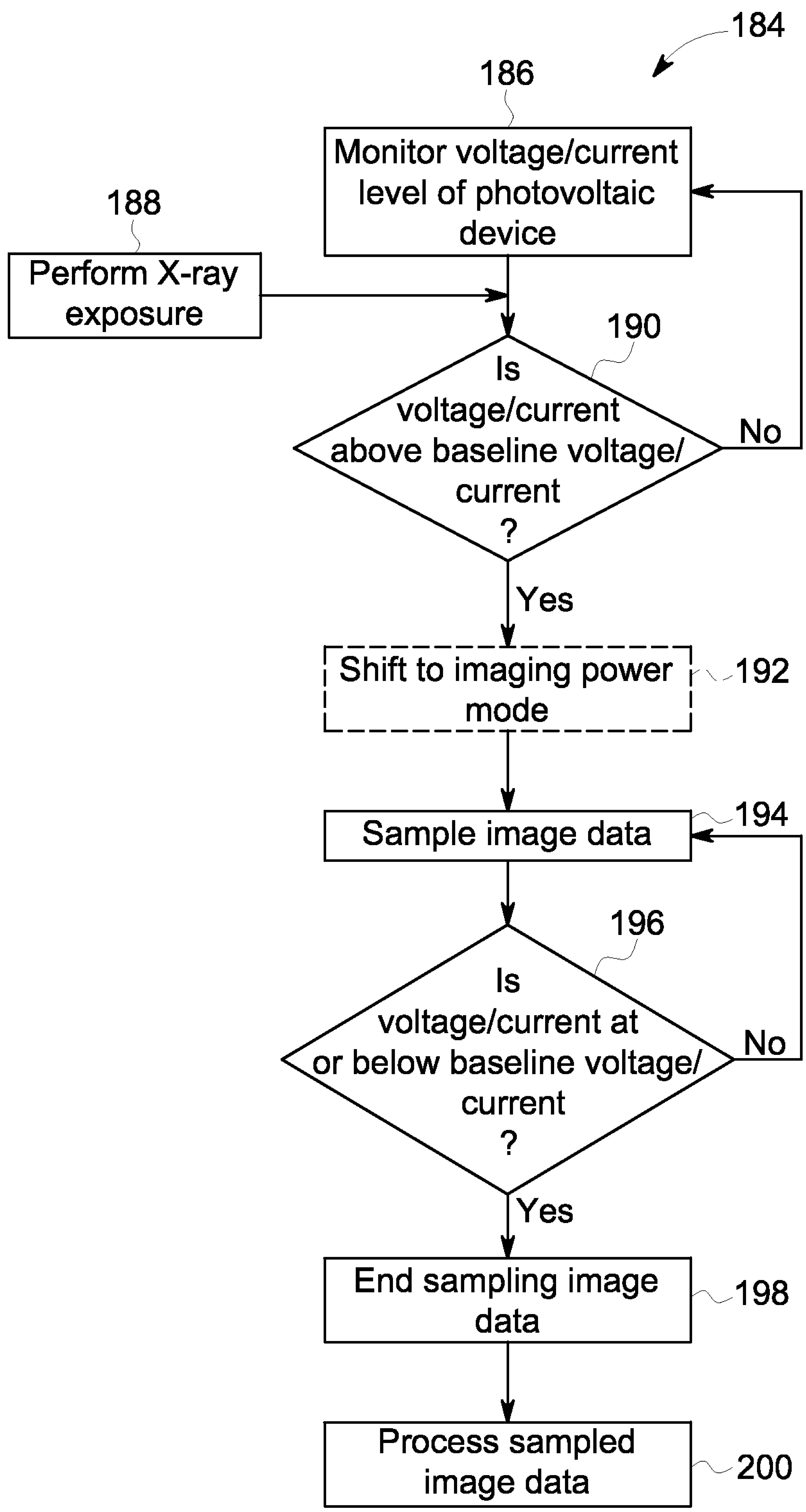
184
186
Monitor voltage/current level of photovoltaic device
188
Perform X-ray exposure
190
Is voltage/current above baseline voltage/ current ?
No
Yes
Shift to imaging power mode
192
Sample image data
194
196
Is voltage/current at or below baseline voltage/ current ?
No
Yes
End sampling image data
198
Process sampled image data
200

FIG. 9

X-RAY SYSTEM AND METHOD WITH DIGITAL IMAGE ACQUISITION USING A PHOTOVOLTAIC DEVICE

BACKGROUND

The subject matter disclosed herein relates to X-ray imaging systems and more particularly to X-ray imaging systems using digital detectors having photovoltaic devices.

The advent of digital X-ray detectors has brought enhanced workflow and high image quality to medical imaging. However, many of the earlier radiographic imaging systems employ conventional X-ray imaging using film as the X-ray detection media. In order to obtain images from these systems, the imaging medium must be transported and processed after each exposure, resulting in a time delay in obtaining the desired images. Digital radiography provides an alternative that allows the acquisition of image data and reconstructed images on the spot for quicker viewing and diagnosis, and allows for images to be readily stored and transmitted to consulting and referring physicians and specialists. However, the cost of replacing the earlier conventional radiographic imaging systems with digital radiographic imaging systems may be imposing to a hospital or tertiary care medical center. Hence, there is a need to retrofit the earlier radiographic imaging systems for digital radiography in a cost effective manner involving as few components of the systems as possible.

BRIEF DESCRIPTION

In accordance with a first embodiment, an X-ray imaging system is provided. The X-ray imaging system includes an X-ray radiation source. The X-ray imaging system also includes a source controller coupled to the source and configured to command emission of X-rays for image exposures. The X-ray imaging system further includes a digital X-ray detector configured to acquire X-ray image data without communication from the source controller, wherein the digital X-ray detector includes a photovoltaic device, and the digital X-ray detector is configured to determine one or more of a beginning, end, or duration of an image exposure via the photovoltaic device.

In accordance with a second embodiment, a digital X-ray detector is provided. The detector includes circuitry configured to acquire X-ray image data without communication from an X-ray source controller. The detector also includes a photovoltaic device, wherein the circuitry is configured to determine one or more of a beginning, end, or duration of an image exposure via the photovoltaic device.

In accordance with a third embodiment, an X-ray imaging method is provided. The method includes monitoring a voltage or current level of a photovoltaic device of a digital X-ray detector. The method also includes commanding an X-ray radiation source to perform an X-ray exposure via a source controller coupled to the source, the source controller not being in communication with the X-ray detector. The method further includes determining one or more of a beginning, end, or duration of the X-ray exposure based on the voltage level of the photovoltaic device.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects, and advantages of the present subject matter will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

FIG. **1** is a perspective view of a fixed X-ray system, equipped in accordance with aspects of the present technique;

FIG. **2** is a perspective view of a mobile X-ray system, equipped in accordance with aspects of the present technique;

FIG. **3** is a diagrammatical overview of the X-ray system in FIGS. **1** and **2**;

FIG. **4** is a diagrammatical representation of functional components in a detector of the system of FIGS. **1-3**;

FIG. **5** is an exploded perspective view of an embodiment of a detector assembly having a photovoltaic device;

FIG. **6** is a bottom schematic view of an embodiment of a photovoltaic device (e.g., a single solar cell) disposed on a detector array;

FIG. **7** is a bottom schematic view of an embodiment of a photovoltaic device (e.g., multiple solar cells) disposed on a detector array;

FIG. **8** is a flow diagram illustrating an embodiment of a method for determining a beginning, end, and duration of an exposure; and

FIG. **9** is a flow diagram illustrating an embodiment of a method for monitoring a beginning and end of an exposure.

DETAILED DESCRIPTION OF THE INVENTION

Referring generally to FIG. **1**, an X-ray system is represented, referenced generally by reference numeral **10**. In the illustrated embodiment, the X-ray system **10**, as adapted, is a digital X-ray system. The X-ray system **10** is designed both to acquire image data and to process the image data for display in accordance with the present technique. Throughout the following discussion, however, while basic and background information is provided on the digital X-ray system used in medical diagnostic applications, it should be born in mind that aspects of the present techniques may be applied to digital detectors, including X-ray detectors, used in different settings (e.g., projection X-ray, computed tomography imaging, tomosynthesis imaging, etc.) and for different purposes (e.g., parcel, baggage, vehicle and part inspection, etc.).

In the embodiment illustrated in FIG. **1**, the X-ray system **10** includes an imaging system **12**. The imaging system **12** may be a conventional analog imaging system, retrofitted for digital image data acquisition and processing as described below. In one embodiment, the imaging system **12** may be a stationary system disposed in a fixed X-ray imaging room, such as that generally depicted in and described below with respect to FIG. **1**. It will be appreciated, however, that the presently disclosed techniques may also be employed with other imaging systems, including mobile X-ray units and systems in other embodiments. The imaging system **12** includes an overhead tube support arm **14** for positioning a radiation source **16**, such as an X-ray tube, and a collimator **18** with respect to a patient **20** and a detector **22**. The detector **22** includes a digital X-ray detector. In some embodiments, the detector **22** may be selected from a plurality of detectors **22**, represented by detector **24**, from a dock **26** (e.g., charging dock). Each detector **22** of the plurality of detectors **22** may be labeled and designed for a particular type of imaging (e.g., fluoroscopic and radiographic imaging). The detector **22** is configured to acquire X-ray image data without communication from a controller of the X-ray radiation source **16**. In other words, the detector **22** operates without communication of timing signals from the controller of the source **16** as to an X-ray exposure. Thus, the detector **22** is without a priori knowledge of the beginning and ending times of an exposure or the duration of the exposure. As a result, the detector **22** may include a photovoltaic device to enable the detector **22** to determine the beginning, end, and/or duration of an image exposure as described in greater detail below. Upon determining the end and/or beginning of the image exposure, the detector may begin and/or end sampling image data from the image exposure. Also, the detector **22** is configured to combine multiple imaging frames that include imaging data to generate X-ray images. In addition, the detector **22** is configured to at least partially process X-ray image data.

In one embodiment, the imaging system **12** may be used in concert with one or both of a patient table **28** and a wall stand **30** to facilitate image acquisition. Particularly, the table **28** and the wall stand **30** may be configured to receive detector **22**. For instance, detector **22** may be placed on an upper, lower or intermediate surface of the table **28**, and the patient **20** (more specifically, an anatomy of interest of the patient **20**) may be positioned on the table **28** between the detector **22** and the radiation source **16**. Also, the wall stand **30** may include a receiving structure **32** also adapted to receive the detector **22**, and the patient **20** may be positioned adjacent the wall stand **30** to enable the image data to be acquired via the detector **22**. The receiving structure **32** may be moved vertically along the wall stand **30**.

Also depicted in FIG. **1**, the imaging system **12** includes a workstation **34**, display **36**, and printer **37**. In one embodiment, the workstation **34** may include or provide the functionality of the imaging system **12** such that a user **38**, by interacting with the workstation **34** may control operation of the source **16** and detector **22**. In other embodiments, the functions of the imaging system **12** may be decentralized, such that some functions of the imaging system **12** are performed at the workstation **34** (e.g., controlling operation of the source **16**), while other functions (e.g., controlling operation of the detector **22**) are performed by another component of the X-ray system **10**, such as a portable detector control device **40**. The portable detector control device **40** may include a personal digital assistant (PDA), palmtop computer, laptop computer, smart telephone, tablet computer, or any suitable general purpose or dedicated portable interface device. The portable detector control device **40** is configured to be held by the user **38** and to communicate wirelessly with the detector **22**. It is noted that the detector **22** and portable detector control device **40** may utilize any suitable wireless communication protocol, such as an IEEE 802.15.4 protocol, an ultra wideband (UWB) communication standard, a Bluetooth communication standard, or any IEEE 802.11 communication standard. Alternatively, the portable detector control device **40** may be configured to be tethered or detachably tethered to the detector **22** to communicate via a wired connection.

The portable detector control device **40** is also configured to communicate instructions (e.g., detector operating mode) to the detector **22** for the acquisition of X-ray image data. In turn, the detector **22** is configured to prepare for an X-ray exposure in response to instructions from the portable detector control device **40**, and to transmit a detector ready signal to the device **40** indicating that the detector **22** is prepared to receive the X-ray exposure. The device **40** may also be configured to communicate patient information or X-ray technique information to the detector **22**. Similar to the detector **22**, the device **40** may be without communication from the controller of the X-ray source **16**. Further, the portable detector control device **40** is configured to receive X-ray image data from the detector **22** for processing and image reconstruction. Indeed, both the detector **22** and the portable detector control device **40** are configured to at least partially process the X-ray image data. However, in certain embodiments, the detector **22** and/or the portable detector control device **40** are configured to fully process the X-ray image data. Also, the detector **22** and/or the device **40** is configured to generate a DICOM compliant data file based upon the X-ray image data, patient information, and other information. Further, the detector **22** and/or the device **40** is configured to wirelessly transmit (or via a wired connection) processed X-ray image data (e.g., partially or fully processed X-ray image data) to an institution image review and storage system over a network **42**. The institution image review and storage system may include a hospital information system (HIS), a radiology information system (RIS), and/or picture archiving communication system (PACS). In some embodiments, the institution image review and storage system may process the X-ray image data. In one embodiment, the workstation **34** may be configured to function as a server of instructions and/or content on a network **42** of the medical facility. The detector **22** and/or device **40** are also configured to transmit, via a wired or wireless connection, processed X-ray images to the printer **37** to generate a copy of the image.

The portable detector control device **40** includes a user-viewable screen **44** and is configured to display patient data and reconstructed X-ray images based upon X-ray image data on the screen **44**. The screen **44** may include a touch-screen and/or input device (e.g., keyboard) configured to input data (e.g., patient data) and/or commands (e.g., to the detector). For example, the device **40** may be used to input patient information and other imaging related information (e.g., type of source **16**, imaging parameters, etc.) to form a DICOM image header. In one embodiment, the patient information may be transferred from a patient database via a wireless or wired connection from the network or the workstation **34** to the device **40**. The detector **22** and/or device may incorporate the information for the image header with the X-ray image to generate the DICOM compliant data file. Also, the device **40** may be used to navigate X-ray images displayed on the screen **44**. Further, the device **40** may be used to modify the X-ray images, for example, by adding position markers (e.g., "L"/"R" for left and right, respectively) onto the image. In one embodiment, metal markers may be placed on the detector **22** to generate position markers.

In one embodiment, the imaging system **12** may be a stationary system disposed in a fixed X-ray imaging room, such as that generally depicted in and described above with respect to FIG. **1**. It will be appreciated, however, that the presently disclosed techniques may also be employed with other imaging systems, including mobile X-ray units and systems, in other embodiments.

For instance, as illustrated in the X-ray system of FIG. **2**, the imaging system **12** may be moved to a patient recovery room, an emergency room, a surgical room, or any other space to enable imaging of the patient **20** without requiring transport of the patient **20** to a dedicated (i.e., fixed) X-ray imaging room. The imaging system **12** includes a mobile X-ray base station **39** and detector **22**. Similar to above, the imaging system **12** may be a conventional analog imaging system, retrofitted for digital image data acquisition and processing. In one embodiment, a support arm **41** may be vertically moved along a support column **43** to facilitate positioning of the radiation source **16** and collimator **18** with respect to the patient **20**. Further, one or both of the support arm **41** and support column **43** may also be configured to allow rotation of the radiation source **16** about an axis. Further, the X-ray base station **39** has a wheeled base **45** for movement of the station **39**. Systems electronic circuitry **46** with a base unit **47** both provides and controls power to the X-ray source **16** and the wheeled base **45** in the imaging system **12**. The base unit **47** also has the operator workstation **34** and display **36** that enables the user **38** to operate the X-ray system **10**. The operator workstation **34** may include buttons, switches, or the like to facilitate operation of the X-ray source **16**. Similar to the X-ray system **10** in FIG. **1**, the system **10** includes the portable control device **40**. The detector **22** and portable control device **40** are as described above. In the X-ray system, the patient **20** may be located on a bed **49** (or gurney, table or any other support) between the X-ray source **16** and the detector **22** and subjected to X-rays that pass through the patient **20** and are received by the detector **22**.

FIG. **3** is a diagrammatical overview of the X-ray system **10** in FIGS. **1** and **2** illustrating the components of the system **10** in more detail. The imaging system **10** includes the X-ray radiation source **16** positioned adjacent to a collimator **18**. Collimator **18** permits a stream of radiation **48** to pass into a region in which a subject **20**, such as a human patient **20**, is positioned. A portion of the radiation **50** passes through or around the subject **20** and impacts the digital X-ray detector **22**. As described more fully below, detector **22** converts the X-ray photons received on its surface to lower energy photons, and subsequently to electric signals which are acquired and processed to reconstruct an image of the features within the subject **20**.

The source **16** is coupled to a power supply **52** which furnishes power for examination sequences. The source **16** and power supply **52** are coupled to a source controller **54** configured to command X-ray emission of X-rays for image exposures. As mentioned above, the detector **22** is configured to acquire X-ray image data without communication from the source controller **54**. Also, the detector **22** is responsive to the portable detector control device **40** configured to communicate instructions the detector **22** for acquisition of the X-ray image data. In addition, the portable detector control device **40** is configured to receive the X-ray image data from the detector **22** for processing and imaging reconstruction.

The detector **22** includes a wireless communication interface **56** for wireless communication with the device **40**, as well as a wired communication interface **58**, for communicating with the device **40** when it is tethered to the detector **22**. The detector **22** and/or the device **40** may also be in communication with the institution image review and storage system over the network **42** via a wired or wireless connection. As mentioned above, the institution image review and storage system may include PACS **60**, RIS **62**, and HIS **64**. In certain embodiments, the detector **22** may also communicate with components of the imaging system **12** such as the operator workstation **34** via a wired or wireless connection. It is noted that the wireless communication interface **56** may utilize any suitable wireless communication protocol, such as an ultra wideband (UWB) communication standard, a Bluetooth communication standard, or any 802.11 communication standard. Moreover, detector **22** is coupled to a detector controller **66** which coordinates the control of the various detector functions. For example, detector controller **66** may execute various signal processing and filtration functions, such as for initial adjustment of dynamic ranges, interleaving of digital image data, and so forth. The detector controller **66** is responsive to signals from the device **40**. The detector controller **66** is linked to a processor **68**. The processor **68**, the detector controller **66**, and all of the circuitry receive power from a power supply **70**. The power supply **70** may include one or more batteries. Also, the processor **68** is linked to detector interface circuitry **72**.

The detector **22** converts X-ray photons received on its surface to lower energy photons such as light or optical photons (e.g., via a scintillator **77**). The detector **22** includes a detector array **74** (e.g., imaging panel) that includes an array of photodetectors to convert the light photons to electrical signals. In certain embodiments, the detector array **74** also includes the scintillator **77**. These electrical signals are converted to digital values by the detector interface circuitry **72** which provides the values to the processor **68** to be converted to imaging data and sent to the device **40** to reconstruct an image of the features within the subject **20**. In one embodiment, the detector **22** may at least partially process or fully process the imaging data. Alternatively, the imaging data may be sent from the detector **22** to a server to process the imaging data.

The processor **68** is also linked to a voltage/current measuring device **73**. The voltage/current measuring device **73** is coupled to a photovoltaic device **75**. The photovoltaic device **75**, via the photovoltaic effect or photoconductive effect (if reverse biased), generates a voltage or current in response to optical photons and/or X-rays received, e.g., from the scintillator, on a surface of the device **75**. Thus, the voltage or current of the photovoltaic device **75** may be monitored to determine the beginning, end, and/or duration of an image exposure. In certain embodiments, the voltage or current of the photovoltaic device may be monitored to control an auto-exposure control. The voltage measuring device **73** measures the voltage or current generated by the photovoltaic device **75**. The voltage/current measuring device **73** may include any type of data collecting or measuring device such as an analog-to-digital converter, field-programmable gate array, and so forth. The photovoltaic device **75** may include one or more solar panels as described in greater detail below. In certain embodiments, the solar panels may include semiconductor materials reactive to X-ray or visible light spectrum. In other embodiments, the device **75** may include a semiconductor device arranged to serve a similar function as the solar panels (i.e., collect the optical photons and/or X-rays to enable determining the beginning, end, and/or duration of an image exposure).

The processor **68** is further linked to an illumination circuit **76**. The detector controller **66**, in response to a signal received from the device **40**, may send a signal to the processor **68** to signal the illumination circuit **76** to illuminate a light **78** to indicate the detector **22** is prepared to receive an X-ray exposure in response to the signal. Indeed, in response to a signal from the device **40**, the detector **22** may be turned on or awoken from an idle state. Alternatively, the detector **22** may be turned on directly or awoken from an idle state by the user (e.g., pressing an on/off button located on the detector **22**). As another alternative, the detector **22** may be awoken from an idle or lower-powered state upon detecting the beginning of an exposure via the photovoltaic device **75**.

Further, the processor is linked to a memory **80**. The memory **80** may store various configuration parameters, calibration files, and detector identification data. In addition, the memory **80** may store patient information received from the device **40** to be combined with the image data to generate a DICOM compliant data file. Further, the memory **80** may store sampled data gathered during the imaging mode as well as X-ray images. As mentioned above, in some embodiments, the device **40** may conduct the image processing and incorporate a DICOM header to generate a DICOM compliant data file. Still further, the processor **68** is linked to a timer **82** to monitor times for multiple purposes such as determining the duration of an exposure.

FIG. **4** is a diagrammatical representation of functional components of digital detector **22**. As illustrated, detector control circuitry **84** receives DC power from a power source, represented generally at reference numeral **86**. Detector control circuitry **84** is configured to originate timing and control commands for row and column electronics used to acquire image data during data acquisition phases of operation of the system. Circuitry **84** therefore transmits power and control signals to reference/regulator circuitry **88**, and receives digital image pixel data from circuitry **88**.

In a present embodiment, detector **22** consists of a scintillator that converts X-ray photons received on the detector surface during examinations to lower energy (light) photons. An array of photodetectors then converts the light photons to electrical signals which are representative of the number of photons or the intensity of radiation impacting individual pixel regions or picture elements of the detector surface. Readout electronics convert the resulting analog signals to digital values that can be processed, stored, and displayed, such as on device **40** following reconstruction of the image. In a present form, the array of photodetectors is formed of amorphous silicon. The array of photodetectors or discrete picture elements is organized in rows and columns, with each discrete picture element consisting of a photodiode and a thin film transistor. The cathode of each diode is connected to the source of the transistor, and the anodes of all diodes are connected to a negative bias voltage. The gates of the transistors in each row are connected together and the row electrodes are connected to the scanning electronics as described below. The drains of the transistors in a column are connected together and the electrode of each column is connected to an individual channel of the readout electronics. As described in greater detail below, the detector control circuitry **84** is configured to sample data from the discrete picture elements during receipt of X-ray radiation in response to the photovoltaic device **75** detecting the beginning of the exposure and to cease sampling upon detecting the end of the exposure.

Turning back to the embodiment illustrated in FIG. **4**, by way of example, a row bus **90** includes a plurality of conductors for enabling readout from various rows of the detector **22**, as well as for disabling rows and applying a charge compensation voltage to selected rows, where desired. A column bus **92** includes additional conductors for commanding readout from the columns while the rows are sequentially enabled. Row bus **90** is coupled to a series of row drivers **94**, each of which commands enabling of a series of rows in the detector **22**. Similarly, readout electronics **96** are coupled to column bus **92** for commanding readout of all columns of the detector.

In the illustrated embodiment, row drivers **94** and readout electronics **96** are coupled to a detector panel **98** which may be subdivided into a plurality of sections **100**. Each section **100** is coupled to one of the row drivers **94**, and includes a number of rows. Similarly, each column driver **96** is coupled to a series of columns. The photodiode and thin film transistor arrangement mentioned above thereby define a series of pixels or discrete picture elements **102** which are arranged in rows **104** and columns **106**. The rows and columns define an image matrix **108**, having a height **110** and a width **112**.

As also illustrated in FIG. **4**, each picture element **102** is generally defined at a row and column crossing, at which a column electrode **114** crosses a row electrode **116**. As mentioned above, a thin film transistor **118** is provided at each crossing location for each picture element, as is a photodiode **120**. As each row is enabled by row drivers **94**, signals from each photodiode **120** may be accessed via readout electronics **96**, and converted to digital signals for subsequent processing and image reconstruction. Thus, an entire row of picture elements **102** in the array is controlled simultaneously when the scan line attached to the gates of all the transistors **118** of picture elements **102** on that row is activated. Consequently, each of the picture elements **102** in that particular row is connected to a data line, through a switch, which is used by the readout electronics to restore the charge to the photodiode **120**.

It should be noted that in certain systems, as the charge is restored to all the picture elements **102** in a row simultaneously by each of the associated dedicated readout channels, the readout electronics is converting the measurements from the previous row from an analog voltage to a digital value. Furthermore, the readout electronics may transfer the digital values from rows previous to the acquisition subsystem, which will perform some processing prior to displaying a diagnostic image on a monitor or writing it to film.

The circuitry used to enable the rows may be referred to in a present context as row enable or field effect transistor (FET) circuitry based upon the use of field effect transistors for such enablement (row driving). The FETs associated with the row enable circuitry described above are placed in an "on" or conducting state for enabling the rows, and are turned "off" or placed in a non-conducting state when the rows are not enabled for readout. Despite such language, it should be noted that the particular circuit components used for the row drivers and column readout electronics may vary, and the present invention is not limited to the use of FETs or any particular circuit components.

FIG. **5** depicts an exploded view of a detector assembly **122** for the detector **22**. It should be noted that the following detector assembly **122** may include other components not described (e.g., an outer cover or sleeve, handle, etc.). Arrow **124** indicates a direction of the X-ray path relative to the detector assembly **122**. The detector includes the detector array **74**, photovoltaic device **75**, backscattered X-ray blocking layer **126**, panel support **128**, and motherboard **130**. The panel support **128** supports the motherboard **130** and the detector array **74**. In addition, the panel support **128** mechanically isolates the imaging components of the detector array **74** from the electronics of the motherboard **130**. Generally, the panel support **128** may be formed of a metal, a metal alloy, a plastic, a composite material, or a combination of the above material. In one embodiment, the panel support **128** may be substantially formed of a carbon fiber reinforced plastic material or a graphite fiber-epoxy composite. In another embodiment, the panel support **128** may be substantially formed of composite materials in combination with a foam core in a laminated sandwich construction so as to provide a lightweight yet stiff assembly to serve as the panel support **128**.

The panel support **128** includes a surface **132** (e.g., front or top surface) and a surface **134** (e.g., rear or bottom surface) disposed opposite from each other. The backscattered X-ray blocking layer **126** and motherboard **130** are disposed on or coupled to surfaces **132**, **134**, respectively, of the panel support **128**. In particular, surface **134** of the panel support **128** is disposed on or coupled to surface **136** (e.g., front or top surface) of the motherboard **130**. Also, surface **138** (e.g., rear or bottom surface) of the backscattered X-ray blocking layer **126** is disposed on or coupled to surface **132** of the panel support **128**. The motherboard **130** includes a circuit board and electronics including row drivers **94** and readout electronics **96** to acquire signals from the detector array **74**. The backscattered X-ray blocking layer **126** may include lead to minimize X-ray backscattering. X-rays may pass through the detector array **74** and reflect back off whatever is found behind the detector array **74** such as the electronics or panel support **128**. The reflected X-rays may be detected by the scintillator layer, converted to light, and detected by the photosensitive layer in the detector elements. The backscattered X-ray blocking layer **126** may absorb the X-rays passing through the detector array **74** and any backscattered X-rays.

The photovoltaic device **75** includes a surface **140** (e.g., front or top surface) and a surface **142** (e.g., rear or bottom surface) disposed opposite from each other. The detector array **74** and backscattered X-ray blocking layer **126** are disposed on or coupled to surfaces **140**, **142**, respectively, of the photovoltaic device **75**. In particular, surface **142** of the photovoltaic device **75** is disposed on or coupled to the surface **144** (e.g., front or top surface) of the backscattered X-ray blocking layer **126**. Also, surface **146** (e.g., rear or bottom surface) of the detector array **74** is disposed on or coupled to surface **140** of the photovoltaic device **75**. The photovoltaic device **75** is disposed between the detector array **74** and the backscattered X-ray blocking layer **126** so that the photovoltaic device **75** does not obstruct X-ray detection by the detector array **74**.

FIGS. **6** and **7** illustrate embodiments of the photovoltaic device **75** disposed on the photodetector array **74** and coupled to the voltage/current measuring device **73**. The photovoltaic device **75** may include solar panels or any other type of photovoltaic device **75** (e.g., utilizing the photovoltaic effect or photoconductive effect (if reverse biased)). The photovoltaic device **75** may include one or more solar panels. As depicted in FIG. **6**, the photovoltaic device **75** includes a single solar panel **148**. As depicted in FIG. **7**, the photovoltaic device **75** includes four solar panels **148**. It should be noted, the photovoltaic device **75** may include any number of solar panels **148**. The solar panels **148** in FIGS. **6** and **7** may include monocrystalline solar cells (e.g., monocrystalline silicon), polycrystalline solar cells (e.g., polycrystalline silicon), flexible solar cells (e.g., amorphous silicon), or any combination thereof, or any other type solar panel or cell. Further, the solar cells may include a variety of materials such cadmium telluride, copper indium gallium selenide, or gallium arsenide, or any other material. In certain embodiments, the solar panels may include semiconductor materials reactive to X-ray or visible light spectrum. In other embodiments, the device **75** may include a semiconductor device arranged to serve a similar function as the solar panels (i.e., collect the optical photons and/or X-rays to enable determining the beginning, end, and/or duration of an image exposure).

For illustrative purposes, the photovoltaic device **75** of FIGS. **6** and **7** does not cover the entire surface **146** of the detector array **74**. However, in one embodiment, the photovoltaic device **75** will cover or extend across the entire surface **146** of the detector array **74** to edges **150** of the array **74**. In embodiments with multiple solar cells **148** such as FIG. **6**, there may be gaps **152** (e.g., of approximately 1 cm or less) between the solar cells **148**. However, the area of the gaps **152** is substantially small (e.g., less than approximately 1 percent) relative to the surface area of the photovoltaic device **75** extending across the array **74**. Thus, the photovoltaic device **75** extends substantially across the entire surface **146** of the array **74** in such embodiments. In other embodiments, the photovoltaic device **75** may extend across less than the entire surface **146** of the array **74**. Indeed, the photovoltaic device **75** may extend across as little as a single pixel of the array **74**. In certain embodiments, the photovoltaic device **75** may include the solar panels **148** in handful of locations or discontinuously scattered on the surface **146** of the array **74**.

As depicted in FIGS. **6** and **7**, the voltage/current measuring device **73** is coupled to the photovoltaic device **75** via lines or leads **154** and **156**, positive and negative leads, respectively, to measure any voltage or current generated by the device **75**. As depicted in FIG. **7**, the leads **154**, **156** branch off to couple to the individual solar cells **148**. The voltage/current measuring device **73** may include any type of data collecting or measuring device such as an analog-to-digital converter, field-programmable gate array, and so forth.

As mentioned above, the detector **22** is without communication from the source controller **54** and, thus, is without a priori knowledge of the beginning and ending times of an exposure. In one embodiment, the detector **22** is configured to automatically determine or detect the beginning, end, and/or duration of the exposure utilizing the photovoltaic device **75** without communication from the source controller **54** and/or detector control device **40**.

FIGS. **8** and **9** describe various embodiments of methods employing the photovoltaic device **75** to determine the beginning, end, and/or duration of an image exposure. FIG. **8** illustrates a method **158** for determining the beginning, end, and duration of an exposure. The method **158** may include preparing the detector **22** for the X-ray exposure (block **160**). In certain embodiments, the user commands a detector preparation signal from the device **40** to the detector **22**. Alternatively, the user may press a button on the detector **22** to begin preparation. Once the detector **22** receives the command to prepare from the device **40** or button, the detector **22** prepares for the acquisition of X-ray image data. For example, the detector **22** may switch from an idle mode to imaging power mode and begin scrubbing (i.e., preparing and refreshing the detector circuitry) the panel of the detector **22** to equilibrate the panel. After scrubbing, the detector **22** reads or acquires one or more offset frames prior to exposure. In certain embodiments, the offset frames may be acquired after the X-ray exposure. After preparation, the detector **22** sends to the device **40** the detector ready signal. In one embodiment, the detector **22** may also provide a visible indication (e.g., flashing light) or an audio indication to indicate the detector **22** is ready. In another embodiment, the detector control device **40** may provide a visible indication and/or audio indication. The user then commands the X-ray radiation source **16** to perform an X-ray exposure via the source controller **54** coupled to the source **16** (block **162**). Upon beginning the exposure, the detector **22** converts incident radiation from the source **16** into optical photons, and the photovoltaic device **75** receives the optical photons and/or X-rays and generates a voltage or current in response to the received optical photons and/or X-rays. The generated voltage (e.g., in the range of approximately 1-20 millivolts) or current is measured by the voltage/current measuring device **73** and this enables the processor **68** to determine or detect the beginning of the X-ray exposure (block **164**). In certain embodiments, the voltage or current signal collected from the photovoltaic device **75** may be amplified.

Upon detecting the beginning of the exposure, the processor **68** sends a signal to the timer **82** to start timing (block **166**) the duration or length of the exposure. Also, in certain embodiments, upon detecting the beginning of the exposure, if the detector **22** is in an idle or low power mode prior to and during the beginning of the exposure, the detector **22** switches from the idle mode to imaging power mode (block **168**).

Further, upon detecting the beginning of the exposure, the detector **22** begins sampling image data from during the exposure (block **170**). During the exposure, the voltage/current measuring device **73** continues to monitor the voltage or current of the photovoltaic device **75**. Once the generated voltage or current returns to pre-exposure levels, this enables the processor **68** to determine or detect the end of the exposure (block **172**). Upon detecting the end of the exposure, the processor **68** sends a signal to the timer **82** to end or stop timing (block **174**) the duration or length of the exposure. Upon stopping the timer **82**, the processor **68** determines the duration or length of the exposure (block **176**).

Also, upon detecting the end of the exposure, the detector **22** ends sampling of image data obtained during the exposure (block **178**). In certain embodiments, the device **40** at least partially processes the X-ray image data. In some embodiments, the device **40** completely processes the X-ray image data. Alternatively, the device **40** acquires completely processed X-ray image data from the detector **22**. In other embodiments, neither the detector **22** nor the device **40** completely process the X-ray image data, but send the X-ray image data to the institution image review and storage system for subsequent processing. In either case, to obtain an X-ray image, the sampled X-ray image data is obtained and/or combined (block **180**) from one or more imaging frames. The combined data may be further processed (e.g., offset-corrected) prior to generating an X-ray image (block **182**).

FIG. **9** illustrates a method **184** illustrating a method for determining a beginning and end of an X-ray exposure. The method **184** includes monitoring a voltage or current level or signal of the photovoltaic device **75** of the detector **22** via the voltage/current measuring device (block **186**). At any time while monitoring the photovoltaic device **75**, an X-ray exposure may be performed (block **188**). The detector **22** (e.g., processor **68**) continuously compares the voltage or current level obtained from the photovoltaic device to a baseline voltage or current (e.g., threshold) to determine if the obtained voltage or current level is above the baseline voltage or current (block **190**). In some embodiments, the baseline voltage or current level may be zero. In other embodiments, the baseline voltage or current level may be set above zero to take into account any background voltage or current levels. If the obtained voltage or current level from the photovoltaic device **75** is not above the baseline voltage or current, this indicates an X-ray exposure has not begun and the detector **22** continues to monitor the voltage or current level of the photovoltaic device **75** (block **186**). If the obtained voltage or current level from the photovoltaic device **75** is above the baseline voltage or current, this indicates an X-ray exposure has begun and, if the detector **22** is in an idle or low power mode prior to and during the beginning of the exposure, the detector **22** switches from the idle mode to imaging power mode (block **192**). In addition, the obtained voltage or current level is above the baseline voltage or current, the detector **22** begins sampling image data from during the exposure (block **194**).

Upon the determining the beginning of the X-ray exposure, the detector **22** continues to monitor the voltage or current level of the photovoltaic device **75** and compares the voltage or current level obtained from the photovoltaic device **75** to the baseline voltage or current to determine if the obtained voltage or current level has returned to or fallen below the baseline voltage or current (block **196**). If the obtained voltage or current level from the photovoltaic device **75** has not returned to the baseline voltage or current, this indicates that the X-ray exposure is still occurring and the detector **22** continues to sample X-ray image data (block **194**). If the obtained voltage or current level from the photovoltaic device **75** does return to the baseline voltage or current, this indicates the X-ray exposure has ended and the detector **22** ends sampling image data from during the exposure (block **198**). The sampled X-ray image data may then be processed (block **200**) as described above.

Technical effects of the disclosed embodiments include providing systems and methods to allow for the retrofitting of conventional X-ray systems by replacing cassettes with a digital X-ray detector. In retrofitting the X-ray systems, the digital X-ray detector **22** does not communicate with the X-ray imaging system **12**. Since the detector **22** does not communicate with the X-ray imaging system **12**, the detector **22** lacks data indicating the timing signals for an X-ray exposure. Thus, the detector **22** utilizes the photovoltaic device **75** to monitor the beginning, end, and/or duration of the X-ray exposure.

This written description uses examples to disclose the present subject matter, including the best mode, and also to enable any person skilled in the art to practice the present approaches, including making and using any devices or systems and performing any incorporated methods. The patentable scope is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

The invention claimed is:

1. An X-ray imaging system comprising:

an X-ray radiation source;

a source controller coupled to the source and configured to command emission of X-rays for image exposures; and

a digital X-ray detector configured to acquire X-ray image data without communication from the source controller, wherein the digital X-ray detector comprises a photovoltaic device, a detector array having a plurality of pixels, a motherboard, and a panel support, the photovoltaic device being disposed between the detector array and the panel support, and the panel support being disposed between the photovoltaic device and the motherboard, and wherein the digital X-ray detector is configured to determine one or more of a beginning, end, or duration of an image exposure via the photovoltaic device.

2. The X-ray imaging system of claim **1**, wherein the photovoltaic device comprises at least one solar cell.

3. The X-ray imaging system of claim **2**, wherein the at least one solar cell comprises a monocrystalline solar cell, polycrystalline solar cell, flexible solar cell, cadmium telluride solar cell, copper indium gallium selenide solar cell, or gallium arsenide solar cell, or a combination thereof.

4. The X-ray imaging system of claim **1**, wherein the photovoltaic device extends substantially across an entire surface of the detector array facing the photovoltaic device.

5. The X-ray imaging system of claim **4**, wherein the photovoltaic device comprises a single solar panel that extends substantially across the entire surface of the detector array facing the solar panel.

6. The X-ray imaging system of claim **4**, wherein the photovoltaic device comprises a plurality of solar panels that extends substantially across the entire surface of the detector array facing the plurality of solar panels, the plurality of solar panels having gaps between adjacent solar panels, and an area of the gaps is less than approximately 1 percent of a surface area of the plurality of solar panels extending substantially across the entire surface of the detector array facing the plurality of solar panels.

7. The X-ray imaging system of claim **1**, wherein the photovoltaic device is configured to receive optical photons or X-rays and generate a voltage via the photovoltaic effect in response to the received optical photons or X-rays.

8. The X-ray imaging system of claim **7**, wherein the detector comprises a voltage measuring device coupled to the photovoltaic device, and the voltage measuring device is configured to measure the voltage generated by the photovoltaic device via the photovoltaic effect in response to the received optical photons or X-rays.

9. The X-ray imaging system of claim 8, wherein the detector is configured both to detect the beginning of the image exposure and to begin sampling image data upon the voltage exceeding a baseline threshold.

10. The X-ray imaging system of claim 9, wherein the detector is configured both to detect the end of the image exposure and to end sampling image data upon the voltage returning to the baseline threshold.

11. The X-ray imaging system of claim 1, wherein the detector is configured to determine the beginning, end, and duration of the image exposure via the photovoltaic device.

12. The X-ray imaging system of claim 1, wherein the photovoltaic device is disposed directly underneath the detector array when the digital X-ray detector is oriented so that the detector array is configured to encounter the X-rays before the photovoltaic device.

13. The X-ray imaging system of claim 12, wherein the digital X-ray detector comprises a backscattered X-ray blocking layer configured to absorb X-rays that pass through the detector array, and wherein photovoltaic device comprises a first surface and a second surface disposed opposite the first surface, and the first surface of the photovoltaic device contacts a third surface of the detector array and the second surface of the photovoltaic device contacts a fourth surface of the backscattered X-ray blocking layer.

14. A digital X-ray detector comprising:

a detector array having a plurality of pixels;

a motherboard;

a panel support disposed between the detector array and the motherboard;

circuitry configured to acquire X-ray image data without communication from an X-ray source controller; and

a photovoltaic device disposed between the detector array and the panel support, wherein the circuitry is configured to determine one or more of a beginning, end, or duration of an image exposure via the photovoltaic device.

15. The digital X-ray detector of claim 14, wherein the photovoltaic device is configured to receive optical photons or X-rays and generate a voltage or current in response to the received optical photons or X-rays.

16. The digital X-ray detector of claim 15, wherein the detector comprises a voltage/current measuring device coupled to the photovoltaic device, and the voltage measuring device is configured to measure the voltage or current generated by the photovoltaic device in response to the received optical photons or X-rays.

17. The digital X-ray detector of claim 16, wherein the circuitry is configured both to detect the beginning of the image exposure and to begin sampling image data upon the voltage or current exceeding a baseline threshold.

18. The digital X-ray detector of claim 17, wherein the circuitry is configured both to detect the end of the image exposure and to end sampling image data upon the voltage or current returning to the baseline threshold.

19. The digital X-ray detector of claim 14, wherein the circuitry is configured to determine the beginning, end, and duration of the image exposure via the photovoltaic device.

20. The digital X-ray detector of claim 14, wherein the photovoltaic device extends substantially across an entire surface of the detector array facing the photovoltaic device.

21. An X-ray imaging method comprising:

monitoring a voltage or current level of a photovoltaic device disposed between a detector array having a plurality of pixels and a panel support of a digital X-ray detector, wherein the panel support is disposed between the detector array and a motherboard of the digital X-ray detector;

commanding an X-ray radiation source to perform an X-ray exposure via a source controller coupled to the source, the source controller not being in communication with the X-ray detector; and

determining one or more of a beginning, end, or duration of the X-ray exposure based on the voltage or current level of the photovoltaic device.

22. The method of claim 21, comprising, if the voltage or current level exceeds a baseline threshold, detecting the beginning of the X-ray exposure and starting sampling of image data.

23. The method of claim 22, comprising, if the voltage or current level returns to the baseline threshold, detecting the end of the X-ray exposure and ending sampling of image data.

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