



US007472437B2

(12) **United States Patent**  
**Riley et al.**

(10) **Patent No.:** **US 7,472,437 B2**  
(45) **Date of Patent:** **Jan. 6, 2009**

(54) **HOSPITAL BED OBSTACLE DETECTION DEVICE AND METHOD**

(75) Inventors: **Carl William Riley**, Milan, IN (US);  
**Keith Adam Huster**, Sunman, IN (US);  
**Greg Figel**, Sunman, IN (US); **Irvin J. Vanderpohl, III**, Greensburg, IN (US)

(73) Assignee: **Hill-Rom Services, Inc.**, Wilmington, DE (US)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 362 days.

(21) Appl. No.: **10/510,996**

(22) PCT Filed: **Apr. 21, 2003**

(86) PCT No.: **PCT/US03/12166**

§ 371 (c)(1),  
(2), (4) Date: **Jul. 20, 2005**

(87) PCT Pub. No.: **WO03/088885**

PCT Pub. Date: **Oct. 30, 2003**

(65) **Prior Publication Data**  
US 2006/0010601 A1 Jan. 19, 2006

**Related U.S. Application Data**

(60) Provisional application No. 60/373,819, filed on Apr. 19, 2002, provisional application No. 60/408,698, filed on Sep. 6, 2002.

(51) **Int. Cl.**  
**A61G 7/012** (2006.01)  
**A61G 7/018** (2006.01)  
**G08B 21/02** (2006.01)  
**G08B 23/00** (2006.01)

(52) **U.S. Cl.** ..... **5/600; 340/573.1; 250/221**

(58) **Field of Classification Search** ..... 5/600,  
5/613, 607-611, 616-618; 340/573.1; 250/221  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

2,900,521	A *	8/1959	Eames	187/317
3,704,396	A	11/1972	Macdonald	
3,742,222	A	6/1973	Endl	
3,746,863	A *	7/1973	Pronovost	250/222.1
3,805,061	A *	4/1974	De Missimy et al.	250/208.3
3,858,043	A *	12/1974	Sick et al.	250/221
3,875,403	A *	4/1975	Svensson	250/208.2
3,970,846	A *	7/1976	Schofield et al.	250/221
4,266,124	A *	5/1981	Weber et al.	250/221
4,325,061	A *	4/1982	Wolar	340/679
4,385,508	A *	5/1983	Schimko	66/157
4,403,214	A *	9/1983	Wolar	340/540
4,463,463	A *	8/1984	Kaneko	5/616
4,520,262	A *	5/1985	Denton	250/221
4,534,077	A *	8/1985	Martin	5/424
4,552,403	A *	11/1985	Yindra	297/330
4,645,920	A *	2/1987	Carroll et al.	250/221

(Continued)

**FOREIGN PATENT DOCUMENTS**

FR 2 770 396 5/1997

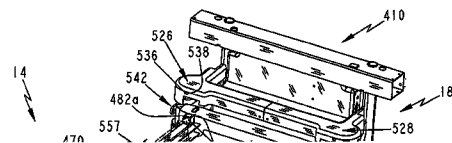
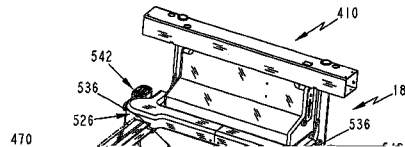
*Primary Examiner*—Robert G Santos

(74) *Attorney, Agent, or Firm*—Kenneth C. Baran

(57) **ABSTRACT**

A hospital bed obstacle detection device (412) and related method for detecting an obstacle between first and second components (24, 26) of a hospital bed (410).

**23 Claims, 25 Drawing Sheets**



# US 7,472,437 B2

Page 2

## U.S. PATENT DOCUMENTS

4,794,248	A *	12/1988	Gray	250/221	6,791,460	B2 *	9/2004	Dixon et al.	340/573.1
4,837,877	A *	6/1989	Hamada et al.	5/10.2	6,983,499	B2 *	1/2006	Gladney	5/424
4,882,566	A	11/1989	Koerber, Sr. et al.	340/825.69	7,089,612	B2 *	8/2006	Rocher et al.	5/613
4,960,271	A *	10/1990	Sebring	5/608	7,296,312	B2 *	11/2007	Menkedick et al.	5/611
5,020,169	A *	6/1991	Hamada et al.	5/10.2	2002/0080037	A1 *	6/2002	Dixon et al.	340/573.1
RE33,668	E *	8/1991	Gray	250/221	2004/0177445	A1	9/2004	Osborne et al.	5/600
5,156,166	A *	10/1992	Sebring	5/608	2004/0231052	A1 *	11/2004	Gladney	5/424
5,181,288	A *	1/1993	Heaton et al.	5/607	2005/0035871	A1 *	2/2005	Dixone et al.	340/686.1
5,317,769	A *	6/1994	Weismiller et al.	5/610	2005/0166324	A1 *	8/2005	Dixon et al.	5/616
5,468,216	A *	11/1995	Johnson et al.	601/24	2005/0172405	A1 *	8/2005	Menkedick et al.	5/618
5,495,228	A *	2/1996	Futsuhara et al.	340/507	2006/0010601	A1 *	1/2006	Riley et al.	5/600
5,567,931	A *	10/1996	Amend et al.	250/221	2006/0080777	A1 *	4/2006	Rocher et al.	5/618
5,696,362	A *	12/1997	Amend	187/317	2006/0107459	A1 *	5/2006	Gladney	5/424
5,758,371	A *	6/1998	VanDyke et al.	5/86.1	2006/0162079	A1 *	7/2006	Menkedick et al.	5/624
6,208,250	B1 *	3/2001	Dixon et al.	340/573.1	2006/0168730	A1 *	8/2006	Menkedick et al.	5/618
6,320,510	B2 *	11/2001	Menkedick et al.	340/573.1	2006/0168731	A1 *	8/2006	Menkedick et al.	5/618
6,354,716	B1 *	3/2002	Chen et al.	362/268	2007/0296600	A1 *	12/2007	Dixon et al.	340/573.1
					2008/0010748	A1 *	1/2008	Menkedick et al.	5/600

\* cited by examiner



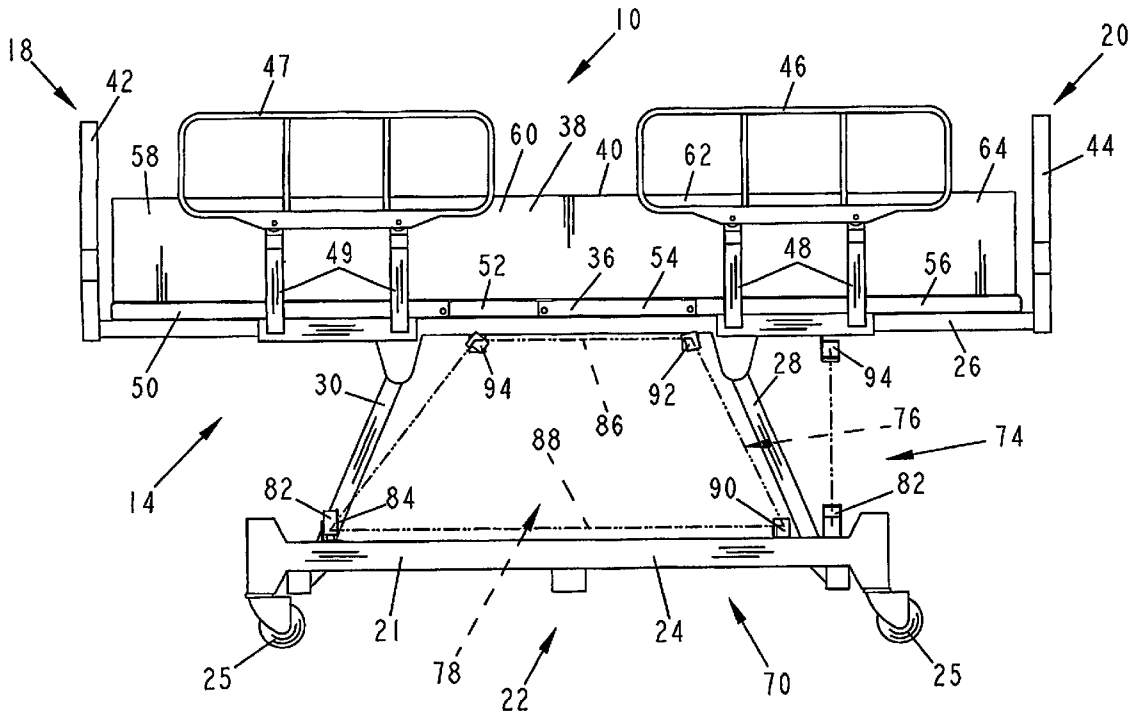


FIG. 2

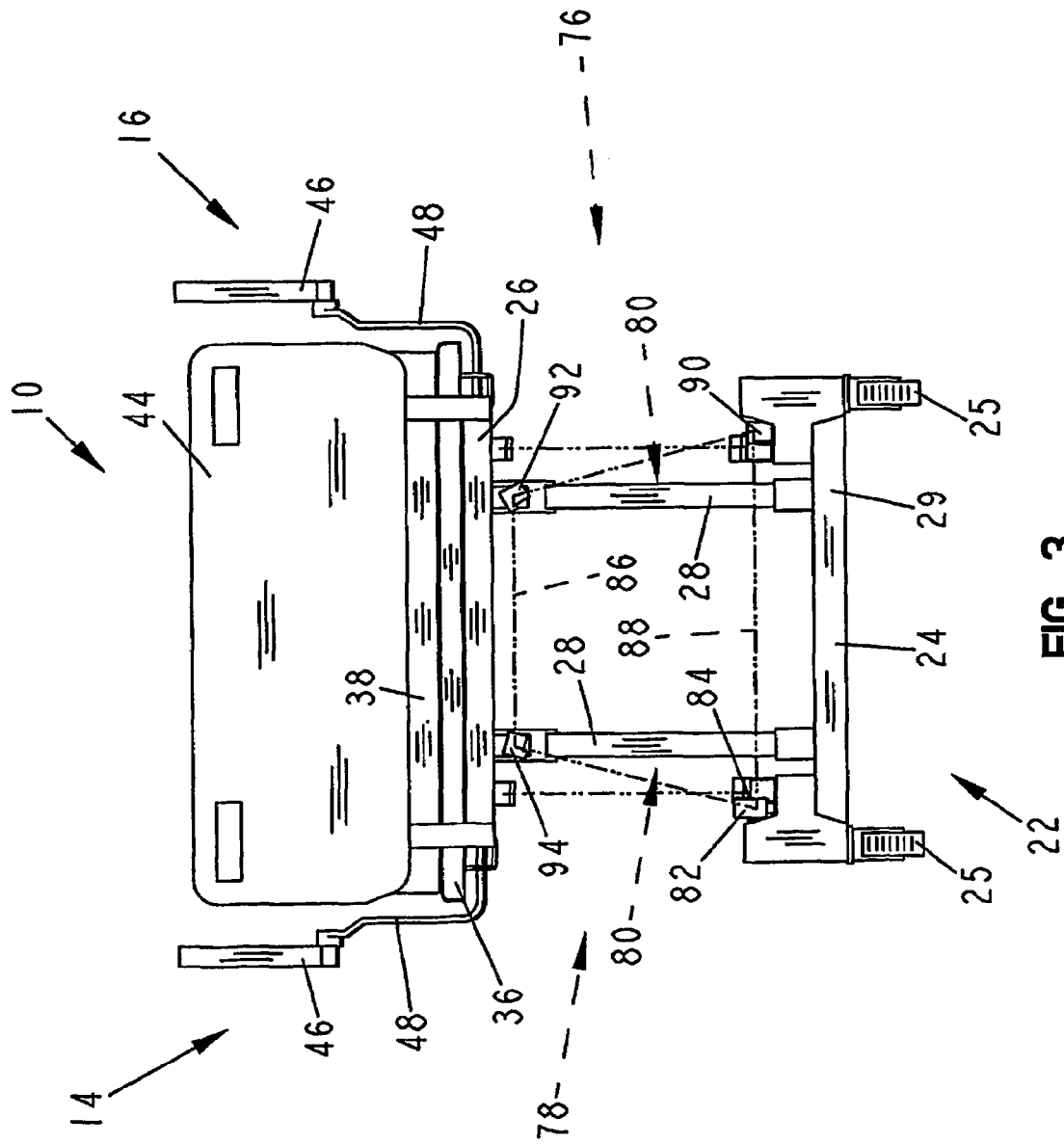


FIG. 3

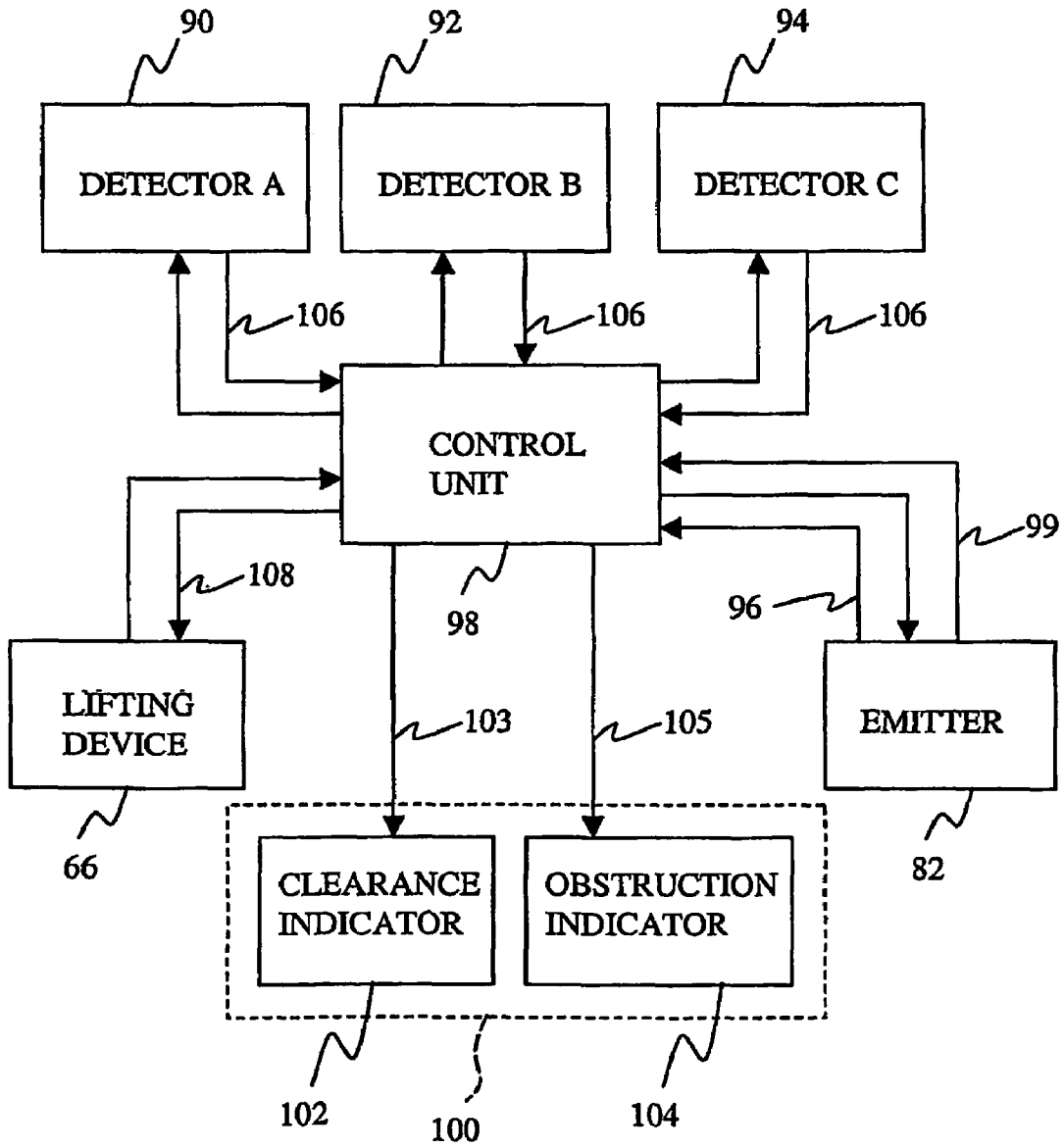


FIG. 4

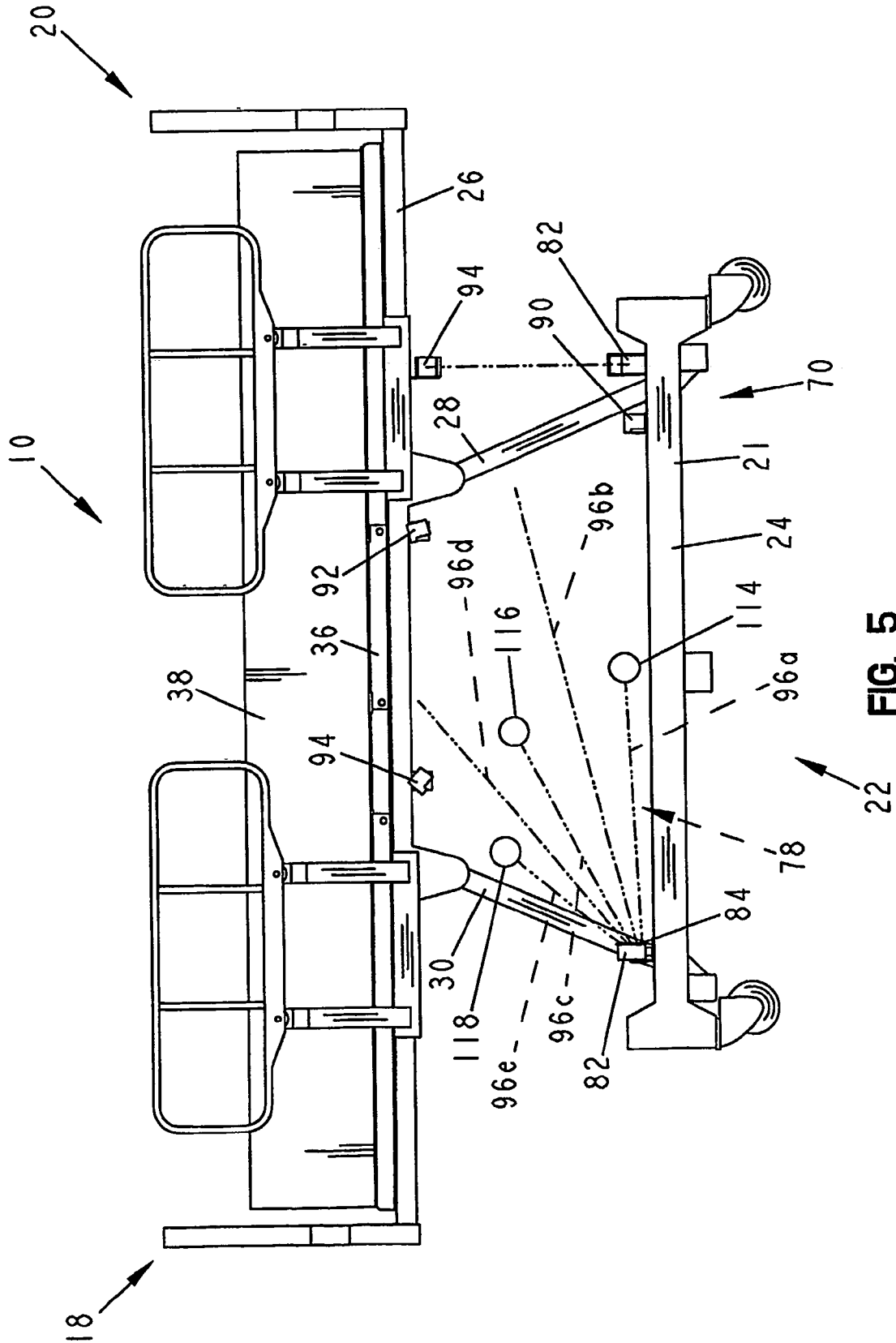


FIG. 5

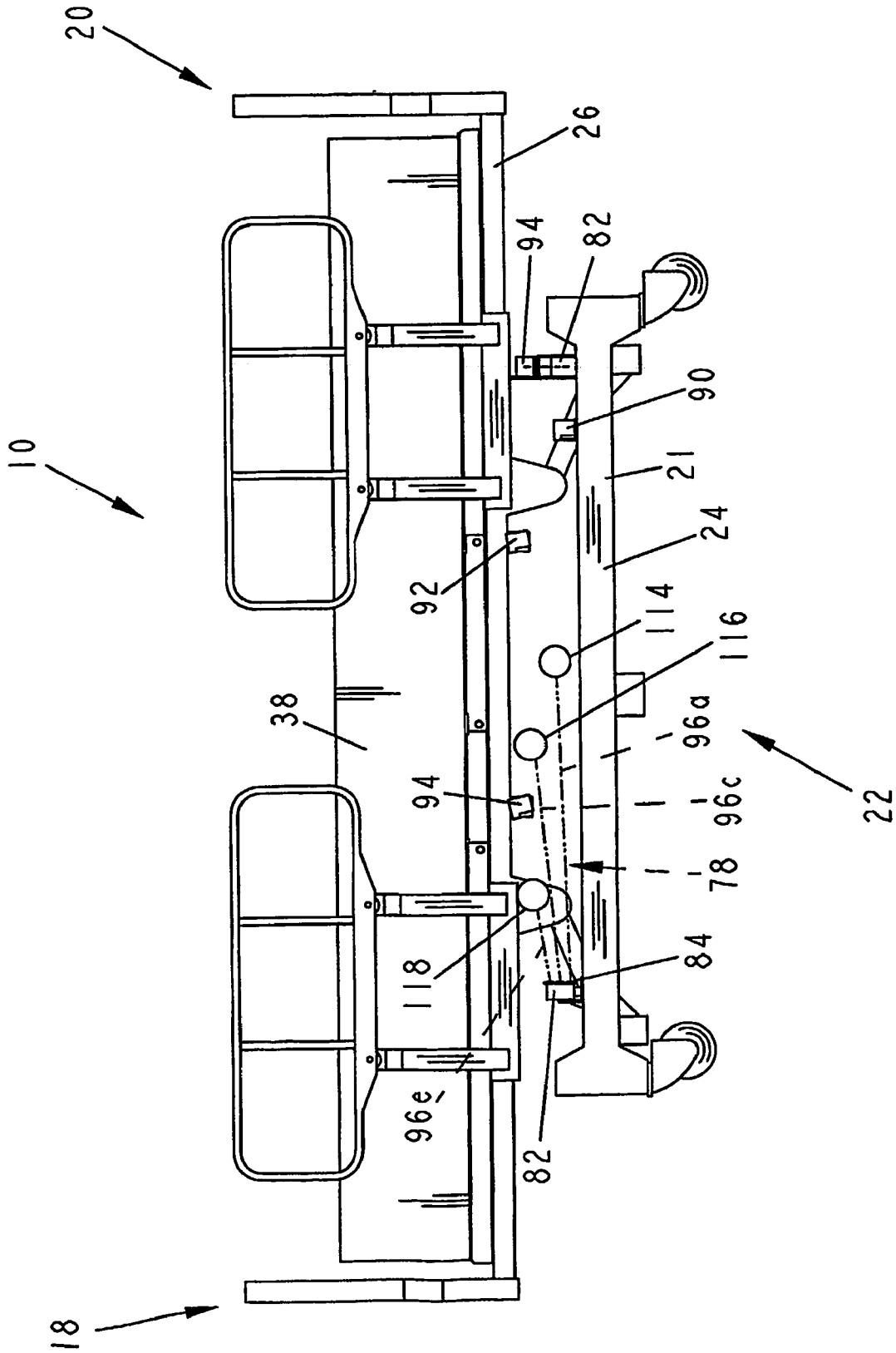


FIG. 6



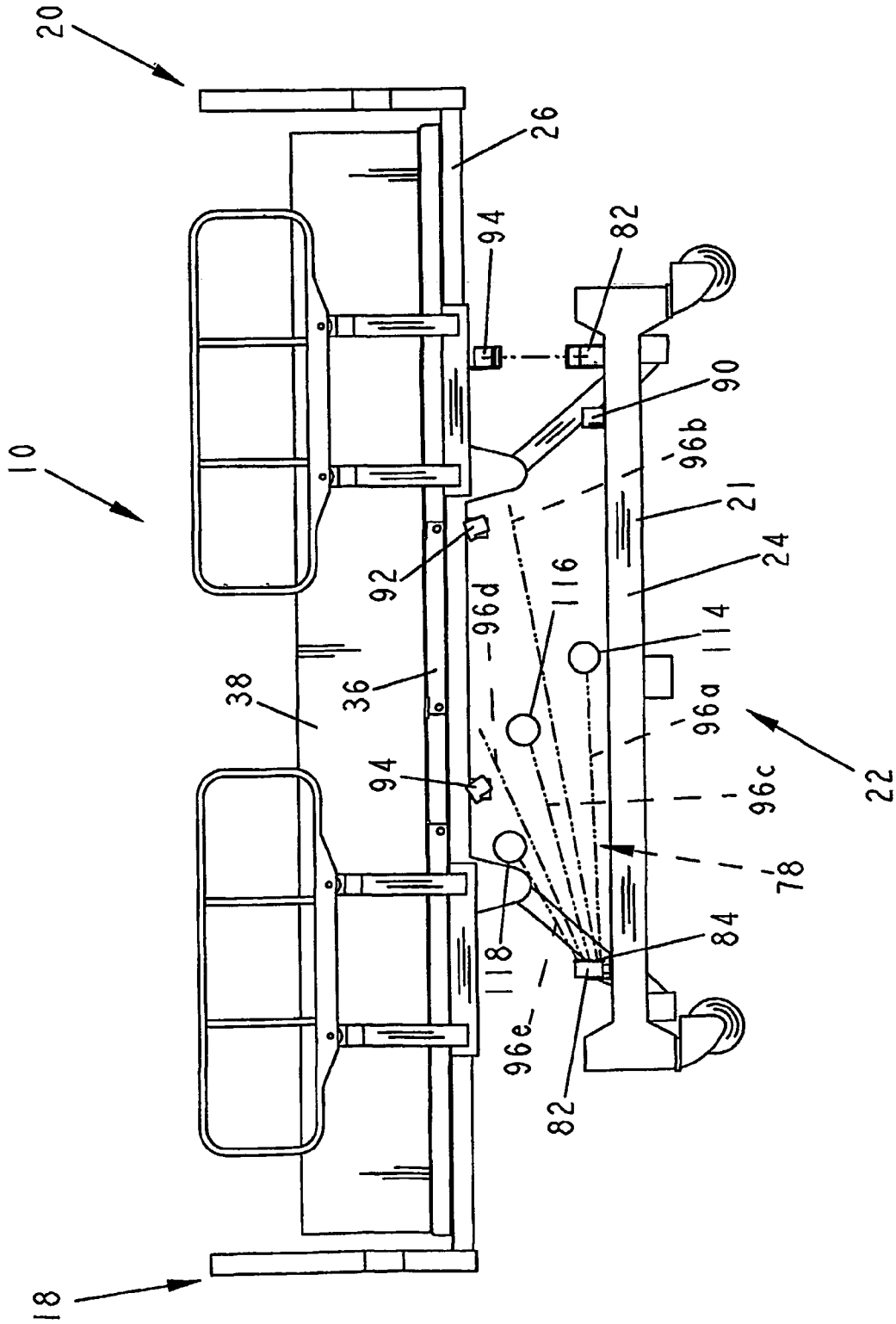


FIG. 7

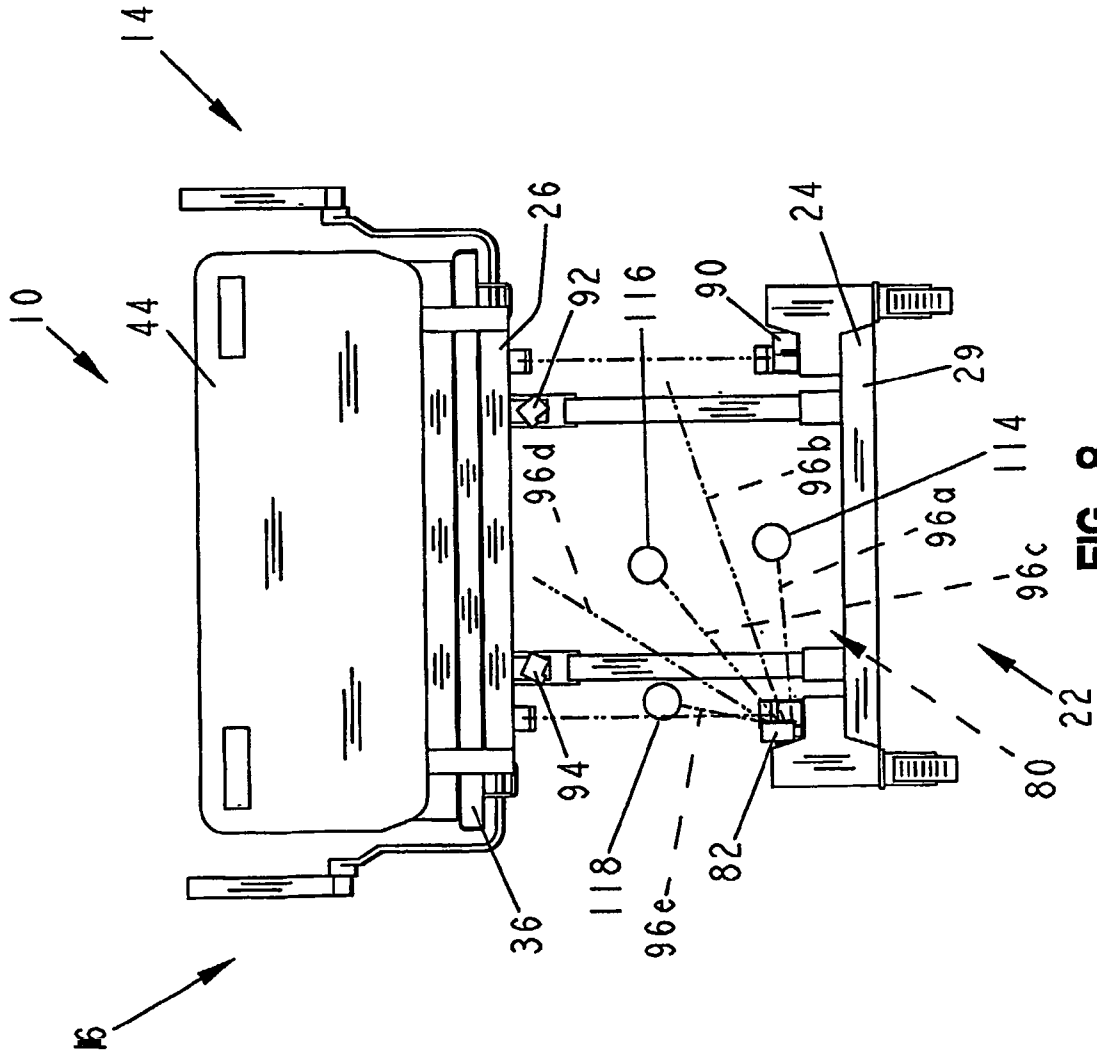


FIG. 8

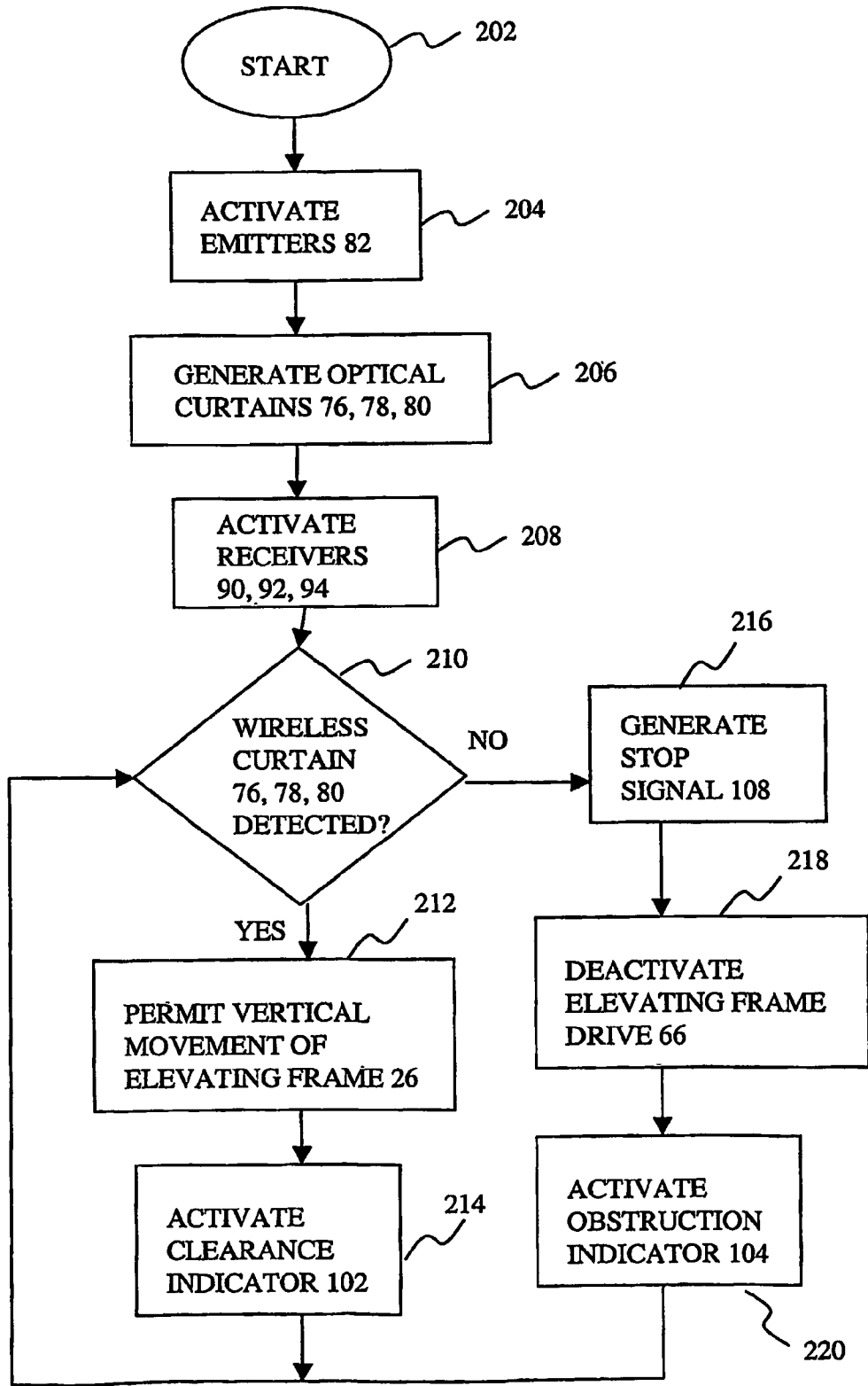


FIG. 9

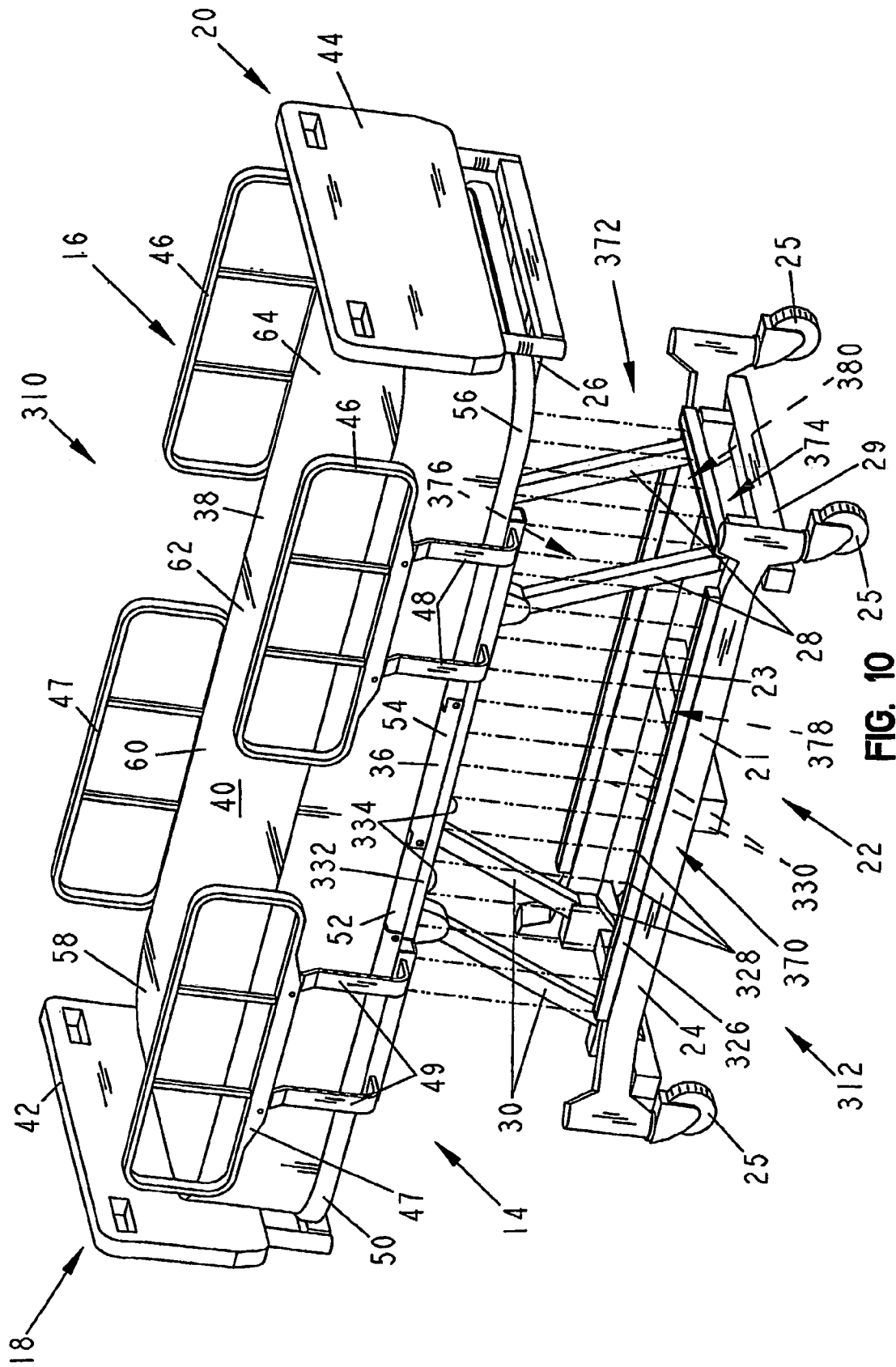


FIG. 10

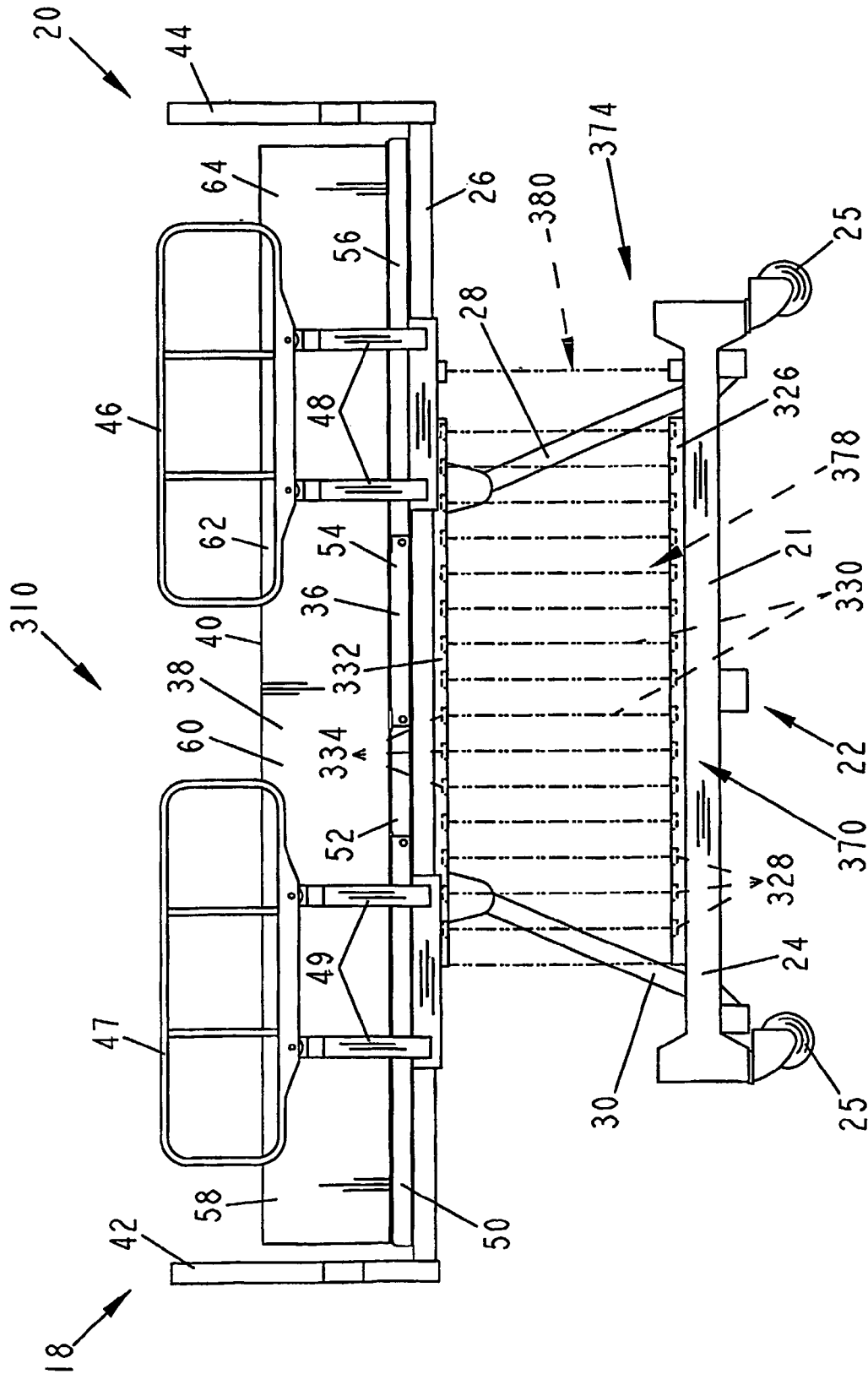


FIG. 11



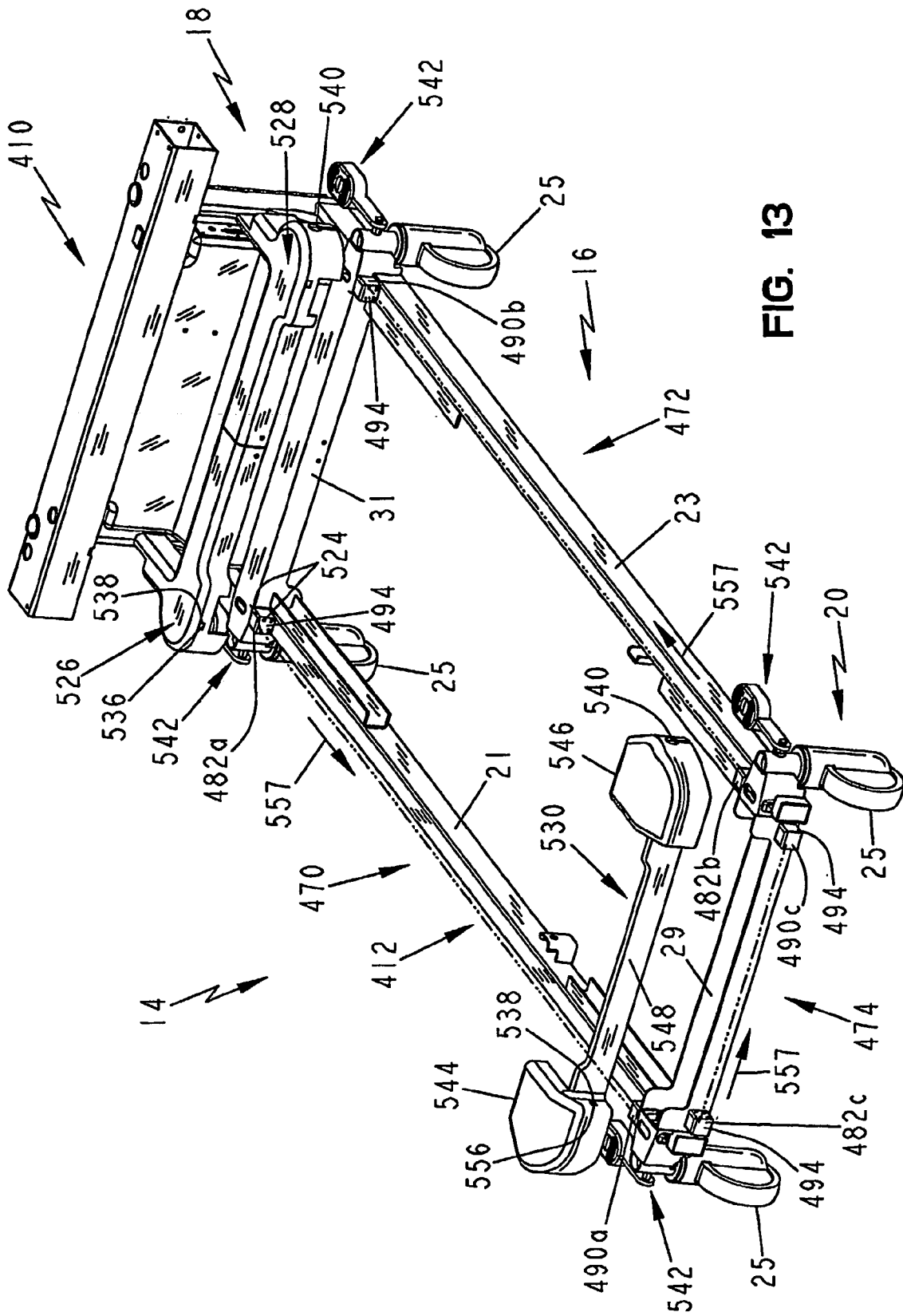


FIG. 13

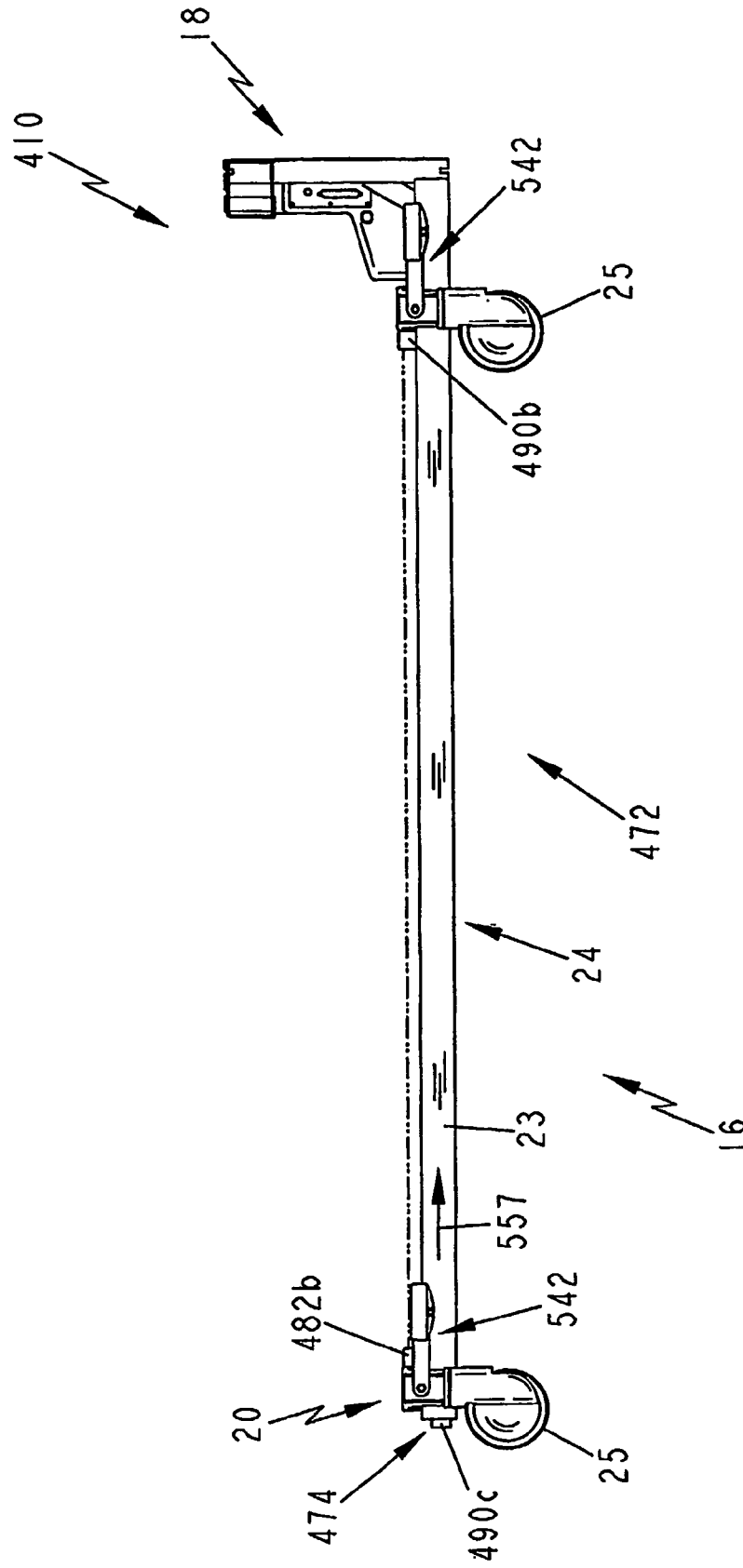


FIG. 14



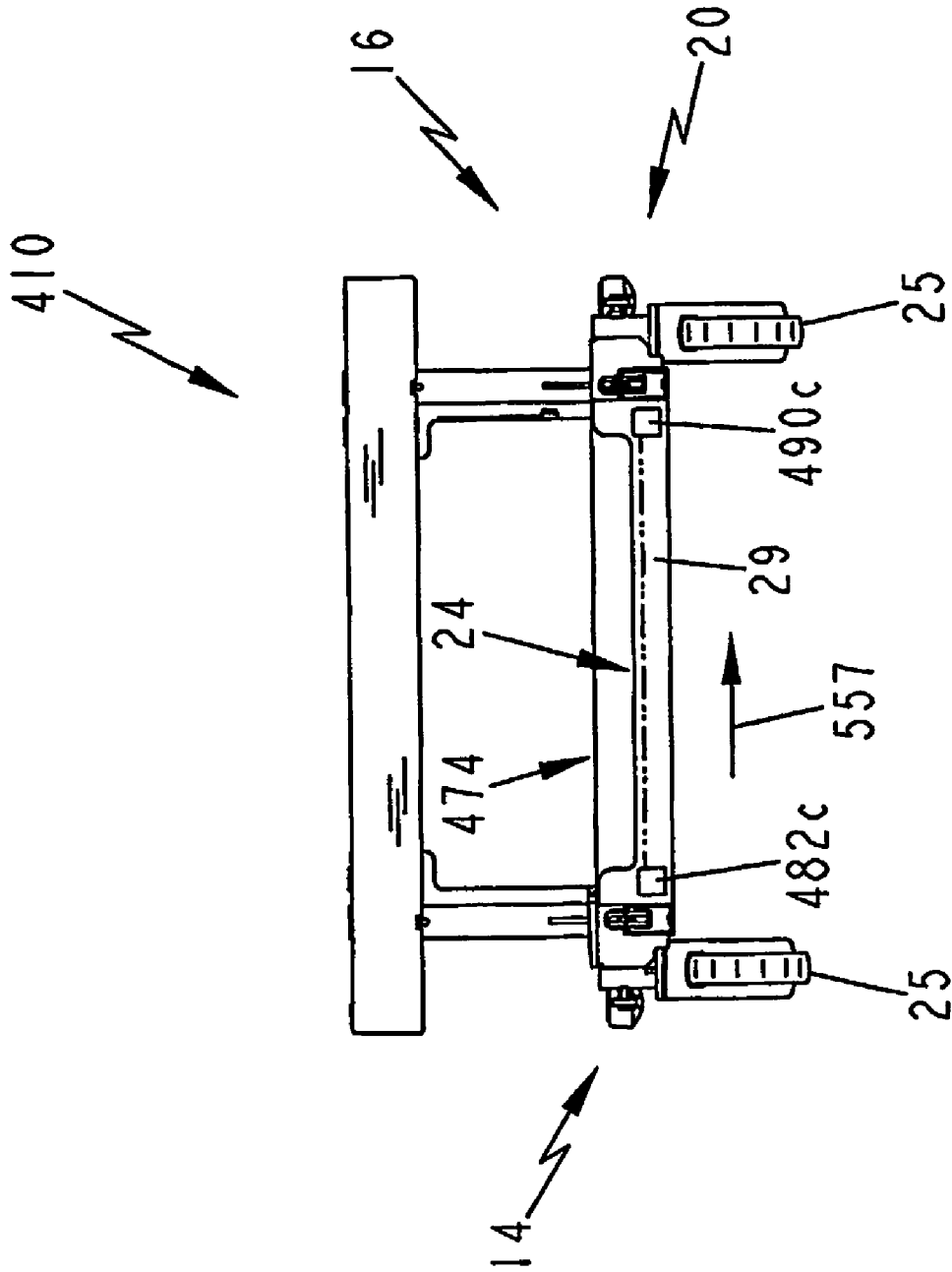


FIG. 15

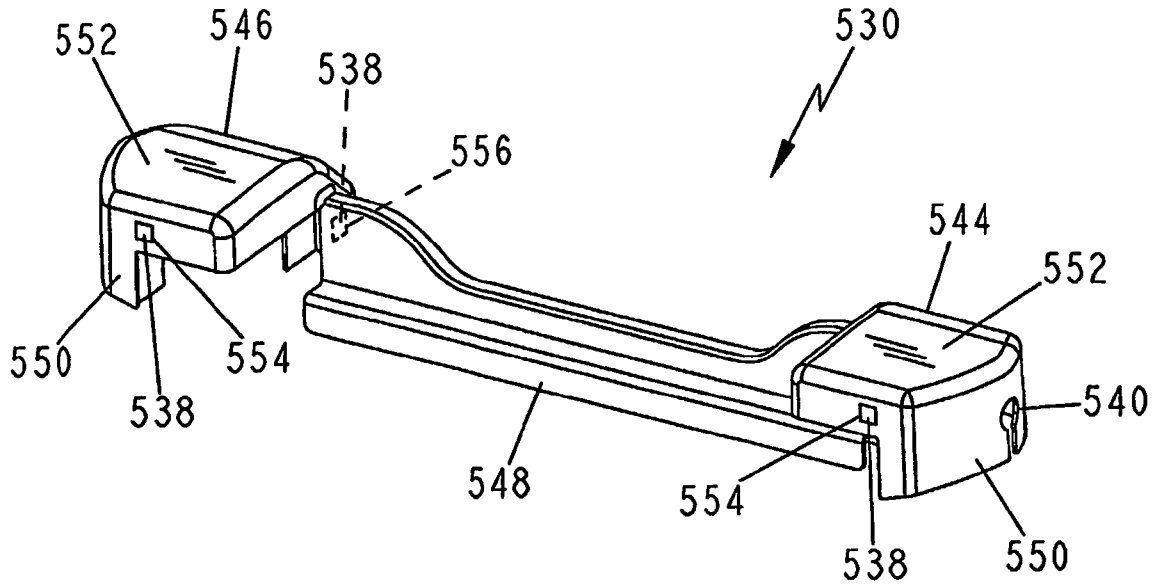


FIG. 16

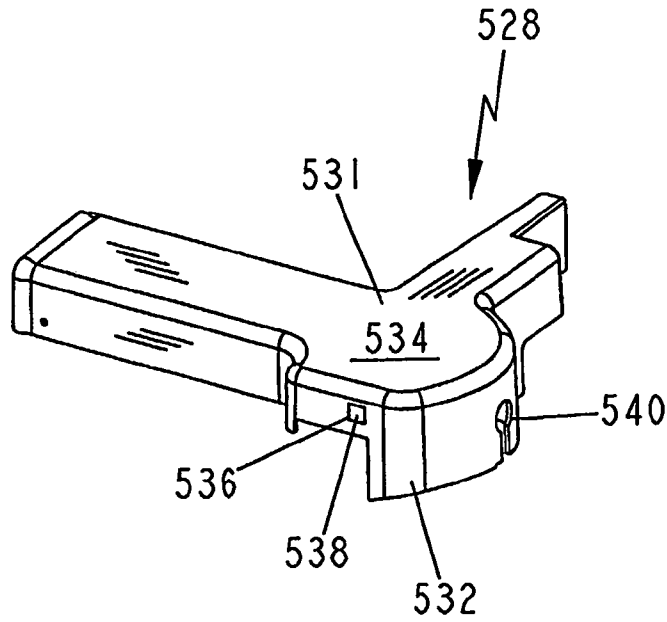
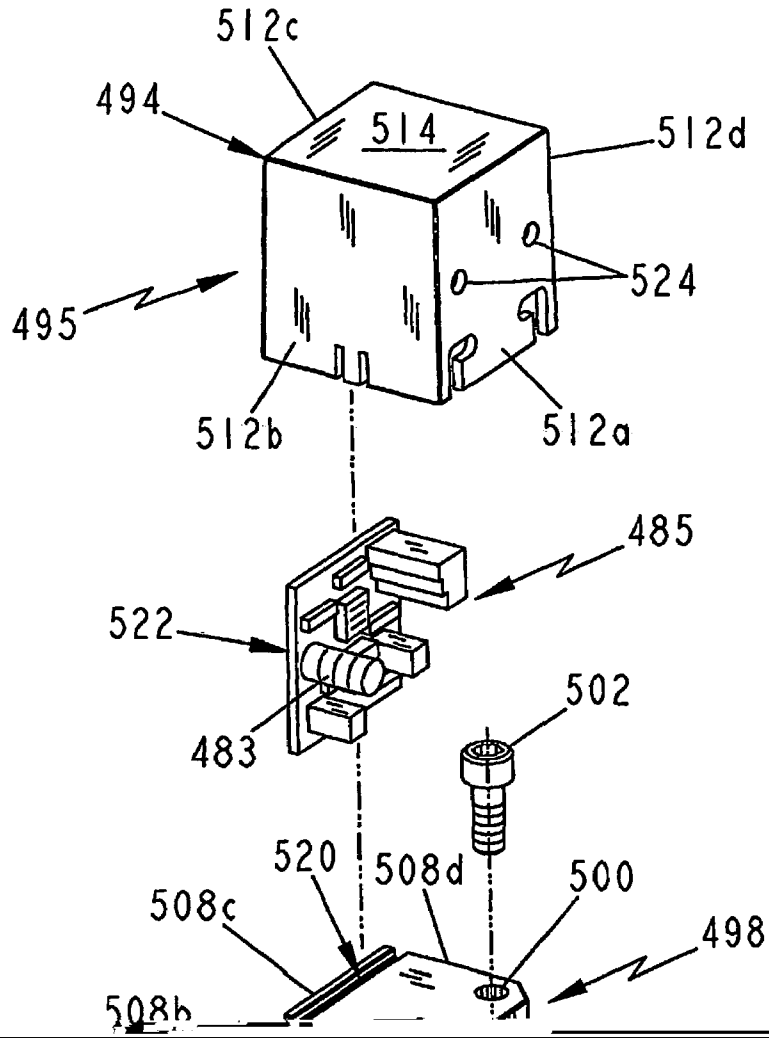


FIG. 17



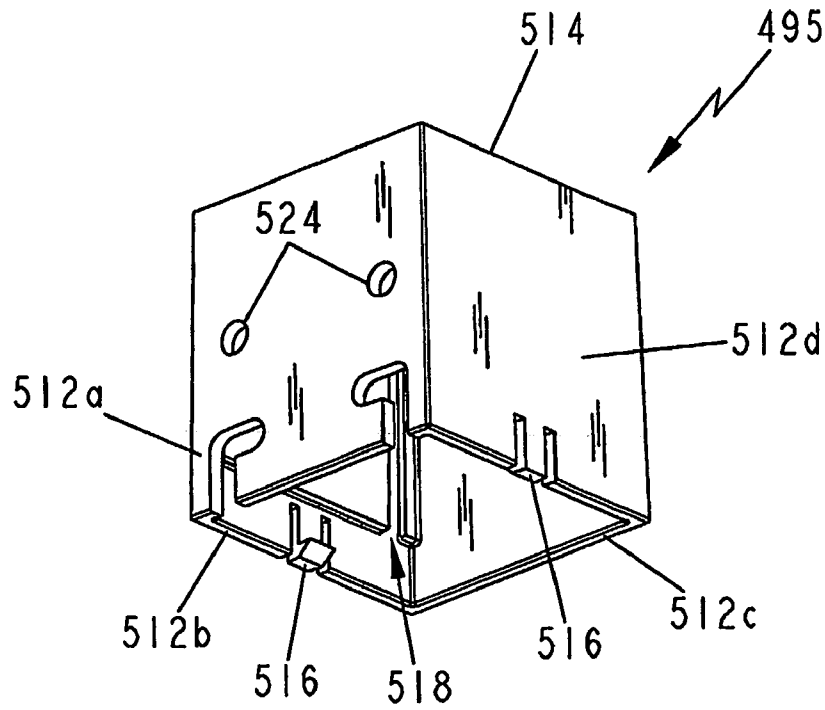


FIG. 19

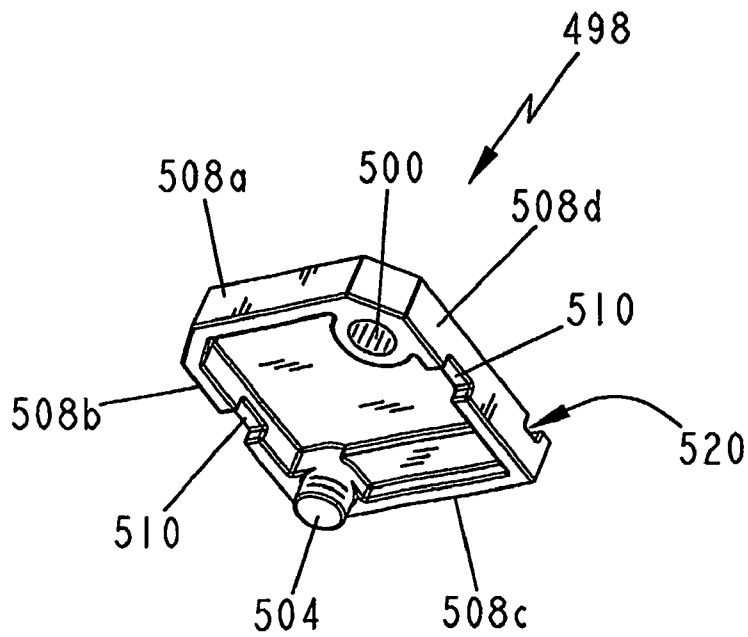


FIG. 20

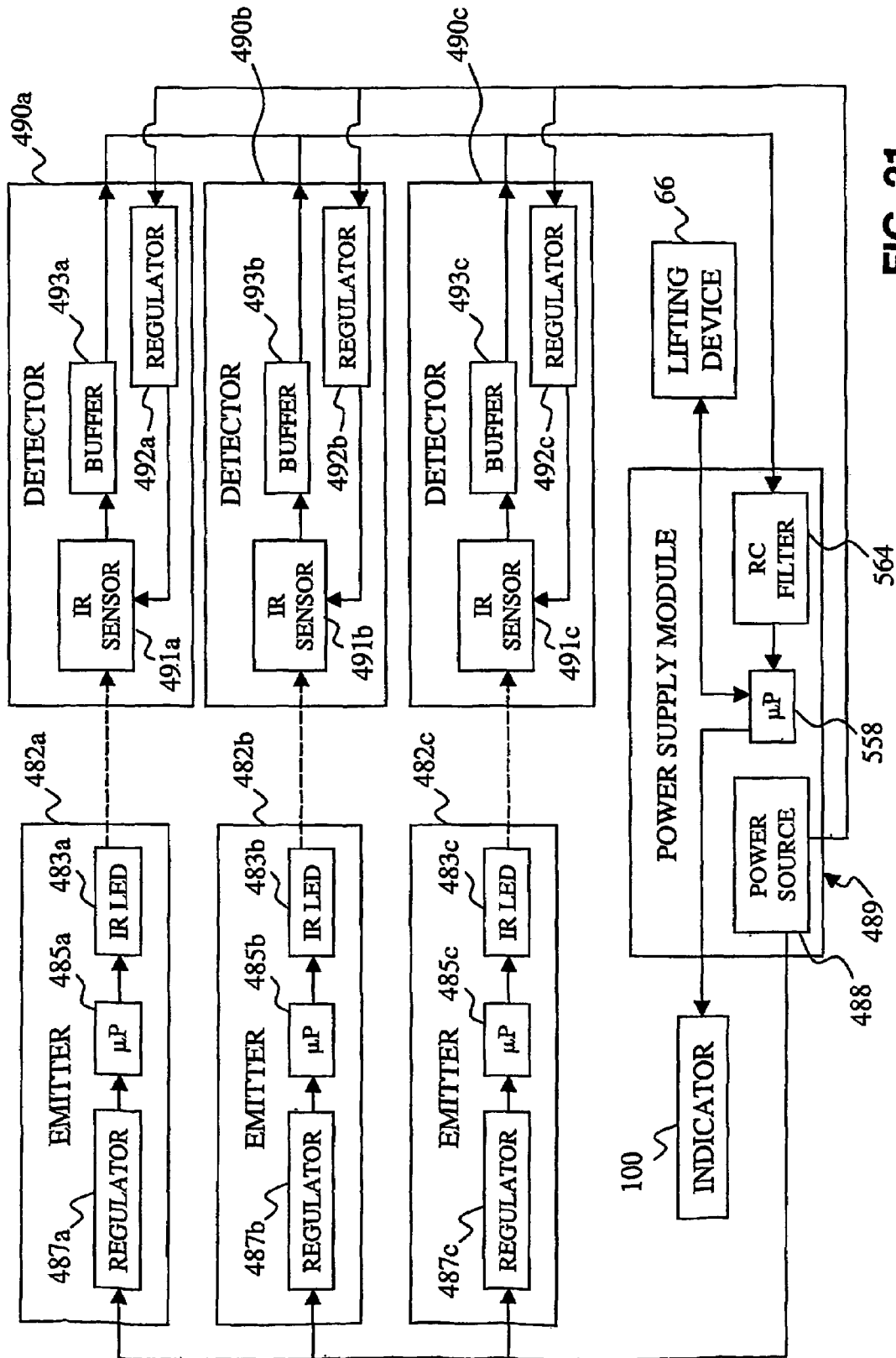


FIG. 21

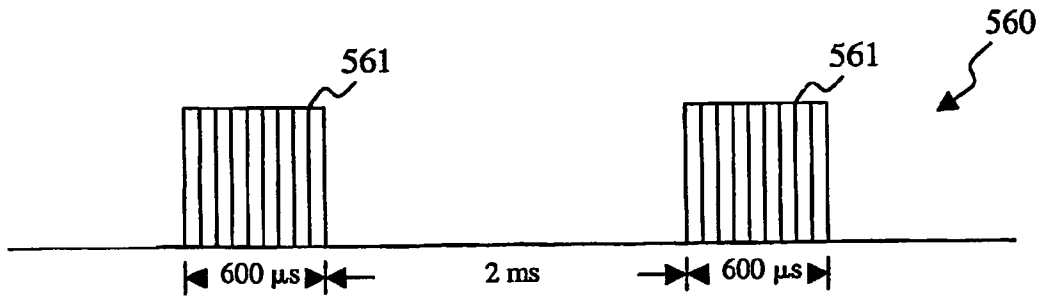


FIG. 22

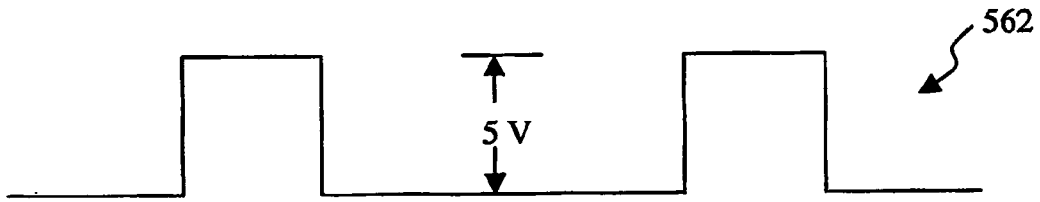


FIG. 23

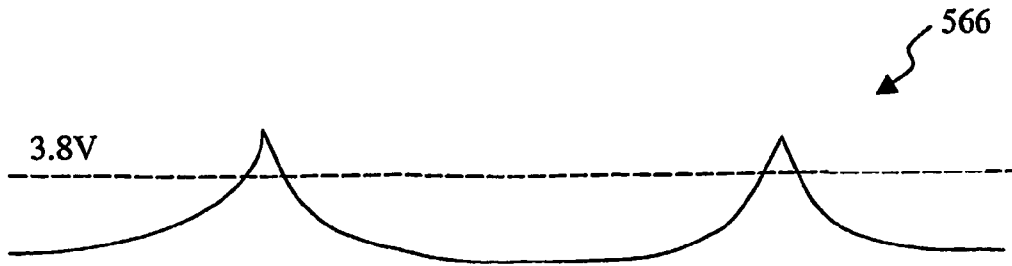


FIG. 24

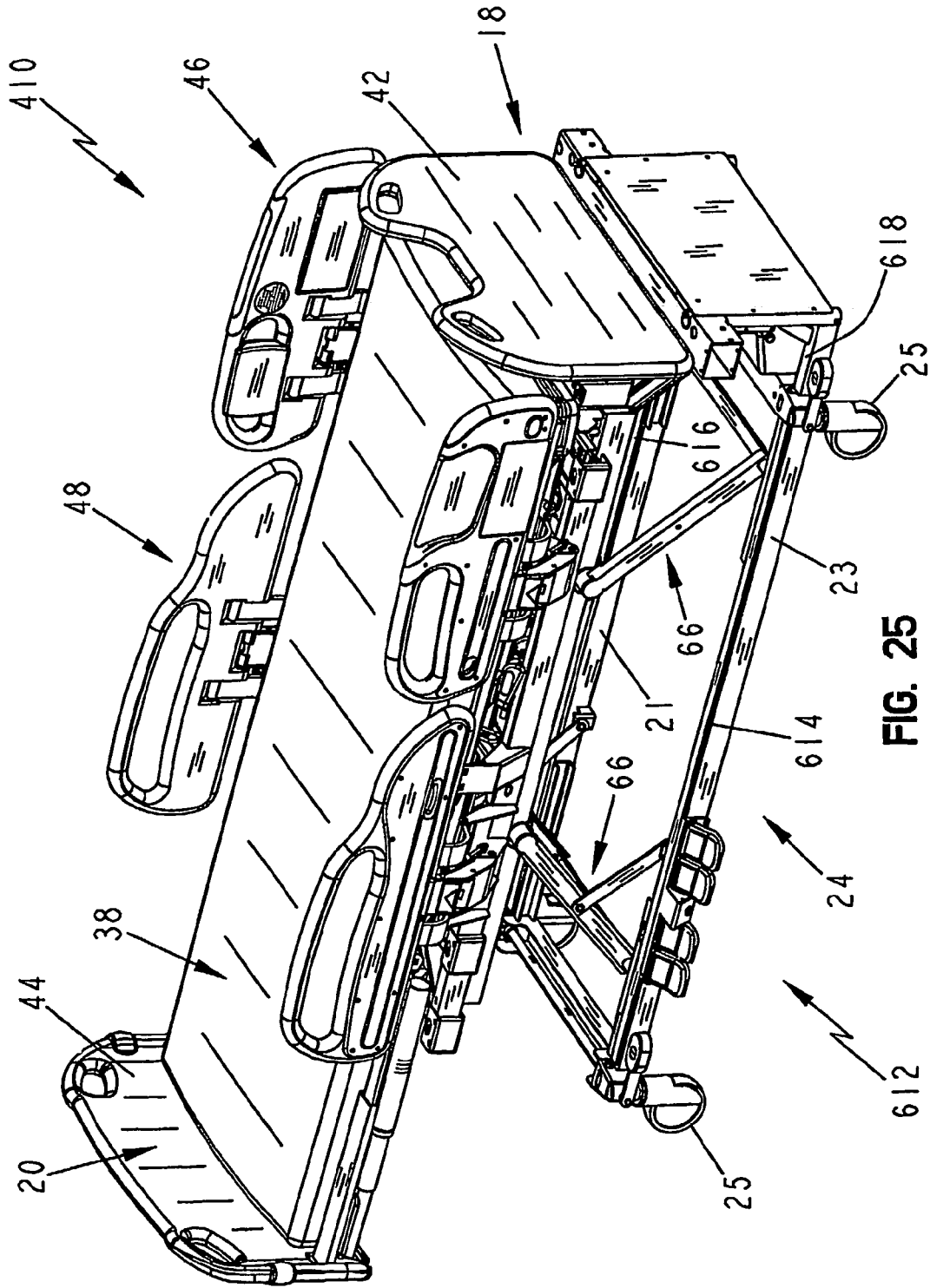


FIG. 25

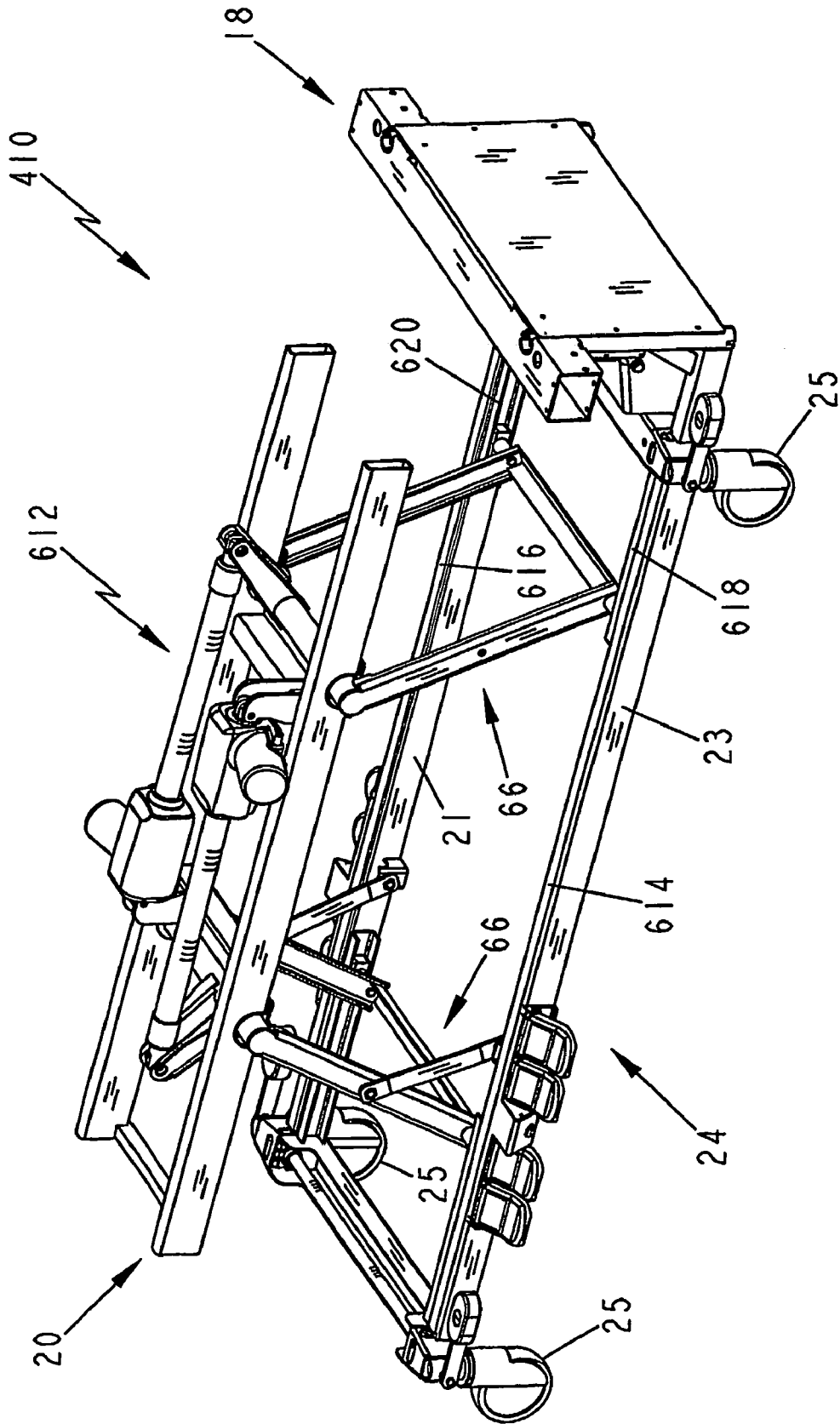


FIG. 26



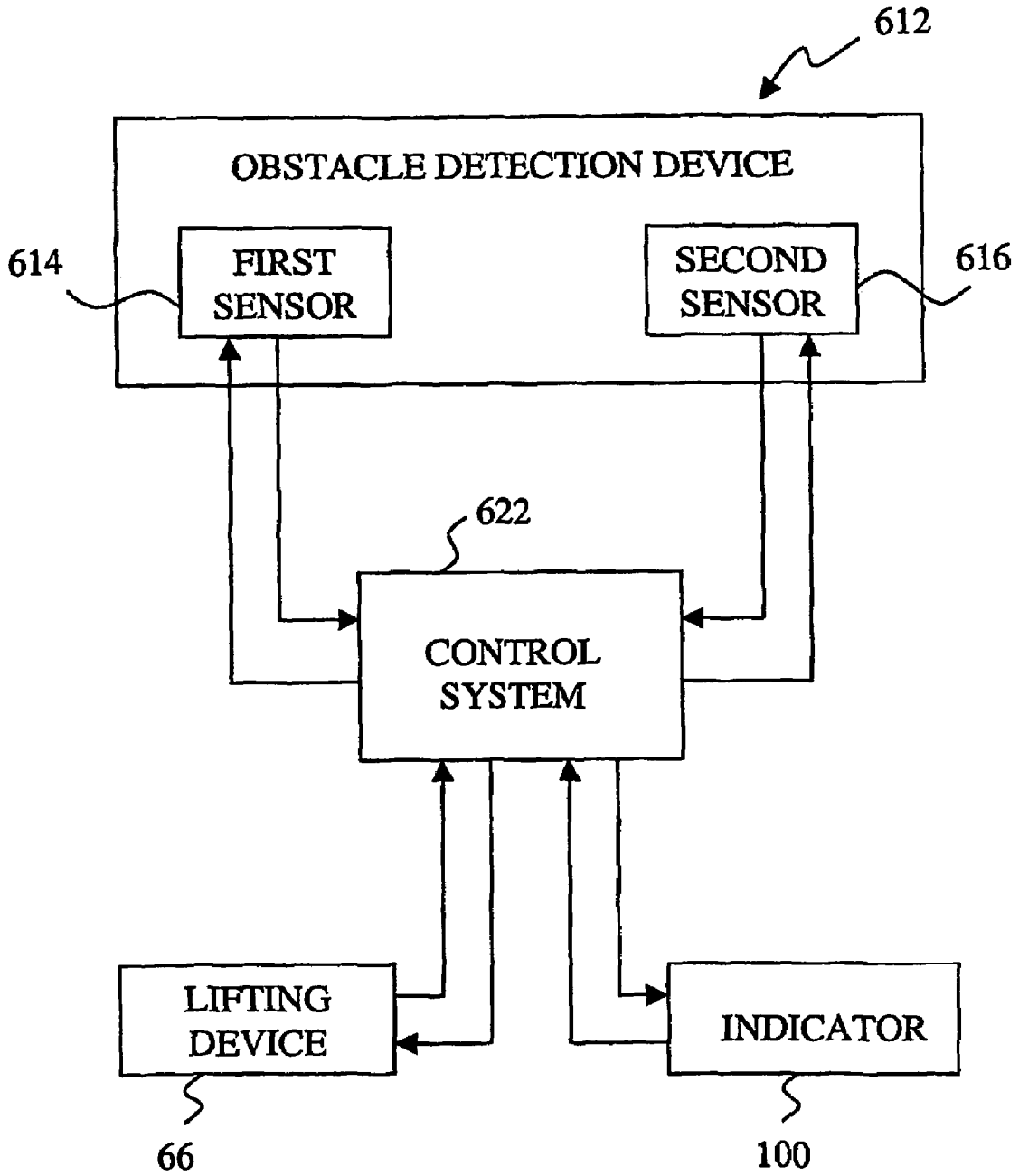


FIG. 27



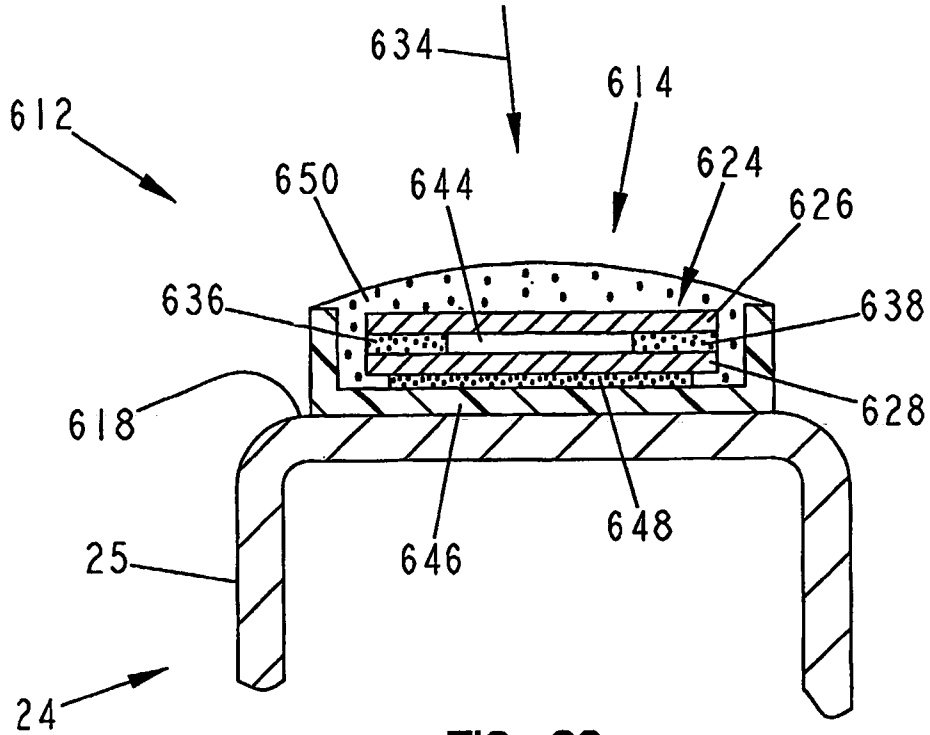


FIG. 29

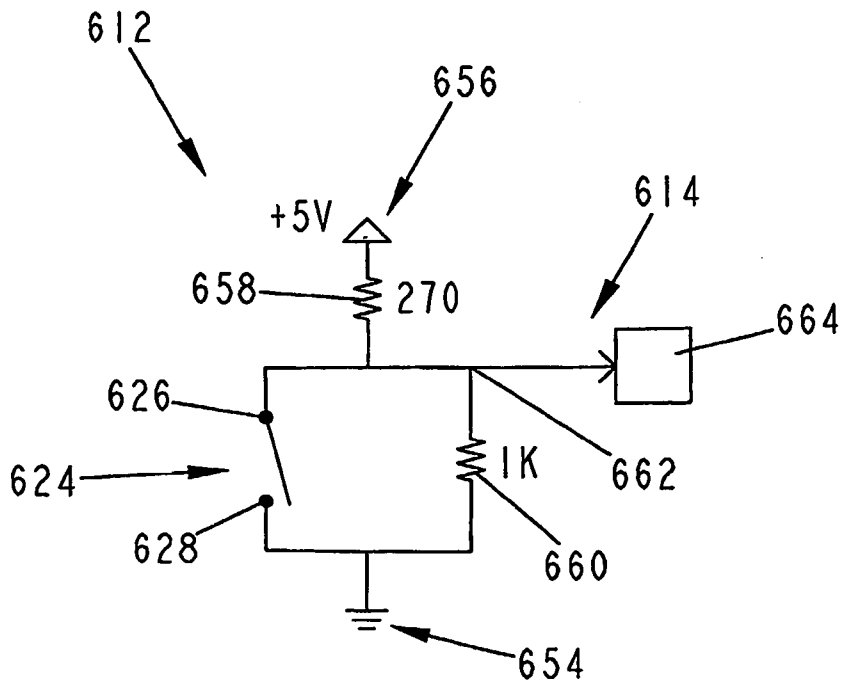


FIG. 30

## HOSPITAL BED OBSTACLE DETECTION DEVICE AND METHOD

This application is the national phase under 35 U.S.C. § 371 of PCT International Application No. PCT/US03/12166, which has an International filing date of Apr. 21, 2003, designating the United States of America, and claims the benefit of U.S. Provisional Patent Application Ser. No. 60/373,819, which was filed Apr. 19, 2002, and U.S. Provisional Patent Application Ser. No. 60/408,698, which was filed Sep. 6, 2002.

### BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates generally to a patient support and, more particularly, to a device and related method for detecting obstacles within a path of travel intermediate first and second components of a hospital bed. Further, the present invention relates to a device and related method for inhibiting the relative movement between first and second components of the hospital bed upon detection of an obstacle within the path of travel.

It is well known to provide a vertically movable patient support. More particularly, it is known to provide a hospital bed including a base frame and an elevating frame supporting a patient support surface. A lifting mechanism is configured to raise and lower the elevating frame relative to the base frame. Entry and exit from the bed is facilitated by placing the elevating frame in a lowered position. A raised position of the elevating frame, in turn, provides a convenient surface for the examination and treatment of the patient.

Additionally, conventional lifting mechanisms provide for the tilting of the elevating frame from a horizontal position into Trendelenburg and reverse Trendelenburg positions. A hospital bed incorporating such a lifting mechanism is illustrated in U.S. Pat. No. 3,958,283 to Adams et al., the disclosure of which is expressly incorporated by reference herein.

According to an illustrative embodiment of the invention, a hospital bed obstacle detection device is provided for use with a hospital bed including a base frame and an elevating frame coupled to a patient support surface. The obstacle detection device controls movement of the elevating frame relative to the base frame upon detecting an object within a path of travel of the elevating frame. The obstacle detection device comprises an emitter coupled to one of the base frame and the elevating frame. The emitter is configured to generate a wireless curtain extending below the elevating frame. The obstacle detection device further comprises a receiver coupled to one of the base frame and the elevating frame of the bed. The receiver is configured to detect the wireless curtain generated by the emitter. The obstacle detection device further comprises a control unit in communication with the receiver and configured to control movement of the elevating frame based on an output signal from the receiver.

Illustratively according to the invention, the emitter comprises an infrared light source and a lens positioned proximate the infrared light source configured to convert light emitted therefrom to form an optical curtain. Illustratively, the lens comprises a fresnel lens.

Further illustratively according to the invention, the wireless curtain includes a modulated signal and the receiver compares the modulated signal to a predefined verification signal in order to prevent interference from external light sources.

Illustratively according to the invention, the receiver is configured to move with the elevating frame within a pre-

defined vertical range. The predefined vertical range is illustratively from the base frame to the elevating frame when the elevating frame is in a fully raised position.

Further illustratively according to the invention, an indicator is provided in communication with the control unit. The indicator is configured to indicate failure of the receiver to detect the wireless curtain.

According to a further illustrative embodiment of the invention, a patient support apparatus comprises a base frame, an elevating frame configured to move along a path of travel above the base frame, a patient support surface supported by the elevating frame, and a detector supported by one of the elevating frame and the base frame, the detector being configured to detect an obstacle within the path of travel of the elevating frame and provide a control signal in response thereto. A control unit is provided in communication with the detector and is configured to prevent movement of the elevating frame in response to the control signal.

Illustratively according to the invention, an emitter is supported by one of the base frame and the elevating frame, wherein the emitter is configured to generate a wireless signal.

Further illustratively according to the invention, the emitter is supported by the base frame and the detector is supported for movement with the elevating frame.

Illustratively according to the invention, the detector comprises a camera configured to capture images of the elevating frame along the path of travel. The control unit is configured to compare the images captured by the camera to predefined images to determine the presence of an obstacle within the path of travel.

According to another illustrative embodiment of the invention, a patient support apparatus comprises a base frame, an elevating frame disposed in spaced relation to the base frame, a patient support surface supported by the elevating frame, and an emitter coupled to one of the base frame and the elevating frame and configured to generate a wireless signal. A receiver is coupled to one of the base frame and the elevating frame and is configured to detect the wireless signal.

Illustratively according to the invention, the patient support apparatus includes a lifting device configured to move the elevating frame relative to the base frame.

Further illustratively according to the invention, the patient support apparatus includes a control unit in communication with the lifting device and the receiver. The control unit is configured to prevent operation of the lifting device if the receiver fails to detect the wireless signal.

Illustratively according to the invention, the emitter generates an optical curtain positioned intermediate the base frame and the elevating frame. The emitter illustratively comprises an infrared light source and a lens is positioned proximate the infrared light source configured to convert light emitted therefrom to the optical curtain. Illustratively, the lens comprises a fresnel lens.

Further illustratively according to the invention, the wireless signal includes a modulated signal and the control unit compares the modulated signal to a predefined verification signal in order to prevent interference from external light sources.

Further illustratively according to the invention, the receiver is configured to move with the elevating frame within a predefined vertical range. The predefined vertical range is illustratively from the base frame to the elevating frame when the elevating frame is in a fully raised position.

3

Illustratively according to the invention, an indicator is provided in communication with the control unit. The indicator is configured to indicate failure of the receiver to detect a wireless signal.

Further illustratively according to the invention, the wireless signal includes a pulsed portion having a predefined frequency, and said receiver is configured to detect said predefined frequency. The pulsed portion illustratively has a

4

and an elevating frame coupled to a patient support surface. The obstacle detection device controls movement of the elevating frame relative to the base frame upon detecting an object within a path of travel of the elevating frame. The obstacle detection device comprises means for generating a wireless curtain within a path of travel of the elevating frame, means for detecting the wireless curtain and generating a signal in response thereto, and means for receiving the signal

frequency of approximately 57 MHz and has a duration of approximately 600 microseconds followed by a delay of approximately 2 milliseconds.

Further illustratively according to the invention, the emitter is configured to generate a plurality of wireless signals in a plurality of signal paths, and a plurality of receivers are configured to detect the wireless signals along different ones of the signal paths. The control unit is configured to prevent movement of the elevating frame when any of the plurality of receivers fail to detect a wireless signal.

Illustratively according to the invention, at least one of the receivers is supported for movement with the elevating frame and the emitter is supported by the base frame.

According to another illustrative embodiment of the invention, a hospital bed obstacle detection device is provided for use with a hospital bed including a base frame and an elevating frame coupled to a patient support surface. The obstacle detection device is configured to prevent vertical movement of the elevating frame relative to the base frame upon detecting an object within a path of travel of the elevating frame.

and controlling movement of the elevating frame in response thereto.

Illustratively according to the invention, the means for generating a wireless curtain comprises an infrared light source. A lens is illustratively positioned proximate the infrared light source and is configured to convert light emitted therefrom to the wireless curtain. Illustratively the lens comprises a fresnel lens.

Further illustratively according to the invention, the wireless curtain includes a modulated signal and the detecting means compares the modulated signal to a predefined signal to prevent interference from external light sources.

Further illustratively according to the invention, the detecting means is configured to move with the elevating frame within a predefined vertical range. The predefined vertical range is illustratively from the base frame to the elevating frame when the elevating frame is in a fully raised position.

Illustratively according to the invention, an indicating means is provided in communication with the control means. The indicating means is configured to indicate failure of the

5

supported by the elevating frame, and the second component is the other of the elevating frame and the articulating deck.

Illustratively according to the invention, the first component is one of a base frame and an elevating frame supported by the base frame, and the second component is the other of the base frame and the elevating frame.

Illustratively according to the invention, the first component is a first siderail and the second component is a second siderail.

Illustratively according to the invention, the first component is one of an elevating frame and a siderail supported by the elevating frame, and the second component is the other of the elevating frame and the siderail.

Illustratively according to the invention, the first component is one of a footboard and a siderail, and the second component is the other of the footboard and the siderail.

According to another illustrative embodiment of the invention, a hospital bed includes a first component, a second component configured to move relative to the first portion along a path of travel, and a detector supported by one of the first component and the second component, the detector configured to detect an obstacle within the path of travel of the second component and provide a control signal in response thereto. A control unit is in communication with the detector and is configured to prevent relative movement of the first and second components in response to the control signal.

Illustratively according to the invention, an emitter is supported by one of the first component and the second component, the emitter being configured to generate a wireless signal. The emitter is illustratively supported by the first component and the detector is supported for movement with the second component.

Further illustratively according to the invention, the detector comprises a camera configured to capture images of the second component along the path of travel. The control unit is configured to compare the images captured by the camera to predefined images to determine the presence of an obstacle within the path of travel.

According to a further illustrative embodiment of the invention, a patient support apparatus comprises a first component, a second component configured to move relative to the first component along a path of travel, and an emitter supported by one of the first component and the second component. The emitter is configured to transmit a wireless signal having a pulsed portion of a predetermined frequency and duration. A detector is configured to detect the wireless signal, the detector being configured to provide an indication if it fails to detect the pulsed portion of the wireless signal.

Illustratively according to the invention, a control unit is configured to prevent movement of the second component relative to the first component when the detector fails to detect the pulsed portion of the wireless signal. Further illustratively, the pulsed portion of the wireless signal has a frequency of approximately 57 MHz and a duration of approximately 600 microseconds.

According to another illustrative embodiment of the invention, a patient support apparatus comprises a first component, a second component configured to move relative to the first component along a path of travel, and a force sensing switch supported by one of the first component and the second component. The force sensing switch is configured to provide an indication if it detects the application of a predetermined force thereto.

Illustratively according to the invention, a control unit is configured to prevent movement of the second component relative to the first component when the force sensing switch detects the application of the predetermined force.

6

Additional features and advantages of the present invention will become apparent to those skilled in the art upon a consideration of the following detailed description of illustrative embodiments exemplifying the best mode of carrying out the invention as presently perceived.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The detailed description particularly refers to the accompanying figures in which:

FIG. 1 is a perspective view of a hospital bed incorporating an illustrative embodiment of the obstacle detection device of the present invention;

FIG. 2 is a side elevational view of the hospital bed of FIG. 1, the opposite side elevational view being a mirror image thereof;

FIG. 3 is a foot end view of the hospital bed of FIG. 1;

FIG. 4 is a block diagram representation of the obstacle detection device of FIG. 1;

FIG. 5 is a side elevational view in partial schematic of the hospital bed of FIG. 1, illustrating the bed in a fully raised position and with potential obstacles positioned in detection paths of the various receivers;

FIG. 6 is a side elevational view in partial schematic similar to FIG. 5, illustrating the bed in a lowered position;

FIG. 7 is a side elevational view in partial schematic similar to FIG. 5, illustrating the bed in an intermediate position;

FIG. 8 is a foot end view in partial schematic of the hospital bed of FIG. 5, illustrating the bed in a fully raised position and with potential obstacles positioned in detection paths of the various receivers;

FIG. 9 is a flow chart illustrating the method operation associated with the obstacle detection device of FIG. 1;

FIG. 10 is a perspective view of a hospital bed incorporating a further illustrative embodiment of the obstacle detection device of the present invention;

FIG. 11 is a side elevational view of the hospital bed of FIG. 10, the opposite side elevational view being a mirror image thereof;

FIG. 12 is a perspective view of a hospital bed, with certain components removed for clarity, incorporating a further illustrative embodiment obstacle detection device of the present invention;

FIG. 13 is a partially exploded perspective view similar to FIG. 12, with the frame covers raised to illustrate the emitters and the detectors of the obstacle detection device;

FIG. 14 is a side elevational view of the hospital bed of FIG. 12, with the frame covers removed for clarity, the opposite side elevational view being a mirror image thereof;

FIG. 15 is a foot end view of the hospital bed of FIG. 12, with the frame covers removed for clarity;

FIG. 16 is a rear perspective view of the foot end frame cover of the hospital bed of FIG. 12;

FIG. 17 is a perspective view of the left side head end frame cover of the hospital bed of FIG. 12, the right side head end frame cover being a mirror image thereof;

FIG. 18 is an exploded perspective view of a housing of the obstacle detection device of FIG. 12;

FIG. 19 is a perspective view of a cover of the housing of FIG. 18;

FIG. 20 is a perspective view of a base of the housing of FIG. 18;

FIG. 21 is a block diagram representation of the obstacle detection device of FIG. 12;

FIG. 22 is a timing diagram of an illustrative signal generated by the emitter of the obstacle detection device of FIG. 12;

FIG. 23 is an illustrative waveform generated by the detector of the obstacle detection device of FIG. 12 in response to the illustrative signal of FIG. 22:

46 and 47 move relative to each other as the foot section 56 and the head section 50 of the articulating deck 36 move relative to each other. The mattress 28 rests on the articulating

78, and 80. The predetermined height is defined to extend from an upper edge 86 to a lower edge 88 intermediate the base frame 24 and the elevating frame 26. Illustratively, the predetermined height is equal to the distance between the base frame 24 and the elevating frame 26 when the elevating frame 26 is in its uppermost position (FIG. 5) as defined by the lifting device 66.

A plurality of detectors 90, 92, 94 are associated with each emitter 82 and are configured to receive or detect the respective optical curtain 76, 78, and 80. The detectors 90, 92, and 94 are identified as Detector A, Detector B, and Detector C, respectively in FIG. 4. Moreover, each optical curtain 76, 78, 80 is illustratively formed by a plurality of individual wireless infrared signals 96 (FIGS. 5-8) emitting from the emitter 82 and detectable by the detectors 90, 92, 94. Illustratively, Opto Sensor Model No. BPW-34F from OSRAM Opto-Semiconductors of San Jose, Calif., may be used for detectors 90, 92, 94. However, it should be noted that other similar detectors may be readily substituted therefor. Moreover, as detailed below, detectors which are operable independently of an emitter, such as proximity sensors or cameras, may be substituted for the combined infrared detectors 90, 92, 94 and emitters 82.

Referring further to FIG. 4, a control unit 98 is provided in communication with each emitter 82 and detector 90, 92, 94. In one embodiment of the invention, each emitter 82 transmits randomly modulated wireless infrared light rays or signals 96 to form a respective optical curtain 76, 78, 80. A source modulation or verification signal 99 is then transmitted through a conventional communication link, such as hard wires (not shown) disposed within the bed base frame 24, to the control unit 98. If the intensity, spectrum or modulation of the received wireless signal 96 at the detector 90, 92, 94 does not match the verification signal 99, the control unit 98 inhibits movement of the bed 10 by the lifting device 66. As such, the verification signal 99 prevents external light sources, such as room lights or sunlight, from interfering with the operation of the obstacle detection device 12.

An indicator 100 may be supported by the hospital bed 10 for providing an indication of the detection of the optical curtain 76, 78, 80 by the detectors 90, 92, 94. More particularly, the indicator 100 may include a clearance indicator, illustratively in the form of a green light 102, which is activated by a clearance signal 103 supplied by the control unit 98 to provide an indication of a clear detection path between the emitter 82 and the detectors 90, 92, 94. An obstruction indicator, illustratively in the form of a red light 104, may be provided to indicate a failure of one of the detectors 90, 92, 94 to receive the appropriate wireless signal 96 of the optical curtains 76, 78, 80. The obstruction indicator 104 is activated by an obstruction signal 105 supplied by the control unit 98. It should be appreciated that the indicator 100 may comprise a single bi-color red/green status indicator. Alternatively, other indicators, such as an audible alarm or any other device which may provide an indication of the presence of an obstacle in the detection path, may be readily substituted for the obstruction indicator light 104.

With reference to FIGS. 5-9, the operation of the obstacle detection device 12 of the present invention is described in greater detail. As illustrated in FIG. 9, the process begins at block 202 upon activation of the obstacle detection device 12. The process continues to block 204 where the respective emitters 82 are activated. At block 206, the optical curtains 76, 78, 80 are formed by passing a light beam containing rays or signals 96 produced by the respective emitters 82 through the associated beam shaping lenses 84.

Continuing at block 208, the respective receivers 90, 92, 94 are activated. The receivers 90, 92, 94 determine whether the respective wireless curtain 76, 78, 80 is detected. If the curtain 76, 78, 80 is detected, then the process continues to block 212 where vertical movement of the elevating frame is permitted by the control unit 98. At block 214, the clearance indicator 102 is activated in response to the clearance signal 103 supplied by the control unit 98.

If one of the wireless curtain 76, 78, 80 is not detected by the respective detectors 90, 92, 94 at block 210, then the respective detector 90, 92, 94 sends an interruption signal 106 to the control unit 98. The process continues to block 216 where the control unit 98 generates a stop signal 108. At block 218, the elevating frame lifting device 66 is deactivated in response to the stop signal 108. At block 220, the obstruction indicator 104 is activated in response to the obstruction signal 105 supplied by the control unit 98.

FIG. 5 illustrates the hospital bed 10 in a fully raised position. Moreover, the elevating frame 26 is raised to its uppermost position by the lifting device 66 coupled 5 to the lift arms 28, 30. FIG. 6, in turn, illustrates the elevating frame 26 of the hospital bed 10 in its lowermost position wherein the elevating frame 26 is lowered to its position nearest the base frame 24 through operation of the lifting device 66 and the lift arms 28, 30, 32, 34. FIG. 7 illustrates the hospital bed 10 with the elevating frame 26 in an intermediate position between the uppermost position of FIG. 5 to the lowermost position of FIG. 6.

It should be noted that the lifting device 66 may be provided with position sensors (not shown) configured to provide feedback position signals to the control unit 98 providing an indication of the relative vertical position of the elevating frame 26. Such position sensors are well-known in the art and may be utilized with the obstacle detection device 12 of the present invention to prevent the elevating frame 26 from moving outside of the range of the optical curtains 76, 78 and 80.

As noted above, the receivers 90, 92, 94 for each optical curtain 76, 78, 80 are configured to receive wireless signals 96 making up or forming the respective curtains 76, 78, 80. The wireless signals 96 travel along a plurality of detection paths from the emitter 82 to the receivers 90, 92, 94. Representative wireless signals 96a, 96b, 96c, 96d and 96e are illustrated in FIGS. 5 and 8. Potential obstacles are represented by reference numerals 114, 116 and 118 in FIG. 5 and are placed within the respective detection paths of signals 96a, 96c, and 96e. The obstacles 114, 116, 118 prevent the wireless signals 96a, 96c, and 96e of the optical curtains 78 and 80 from reaching the respective detectors 90, 92, 94. The obstacles 114, 116, 118 may comprise a person, medical instruments or any other object found within a hospital room.

FIGS. 10 and 11 illustrate a hospital bed 310 including an alternative embodiment obstacle detection device 312 of the present invention. The obstacle detection device 312 includes a first or right side detection unit 370 associated with the right longitudinal side edge 14 of the hospital bed 310, a second or left side detection unit 372 associated with the left longitudinal side edge 16 of the bed 310, and a third or foot end detection unit 374 associated with the foot end 20 of the bed 310. The right side detection unit 370 is configured to generate a first optical curtain 376, while the left side detection unit 372 is configured to generate a second optical curtain 378. Likewise, the foot end detection unit 374 is configured to generate a third optical curtain 380. A fourth or head end detection unit (not shown) may be provided adjacent the head end 18 of the bed 310 for generating a fourth optical curtain (not shown) similar to the optical curtains 376, 378, and 380.



## 11

Illustratively, each detection unit **370**, **372**, and **374** of the obstacle detection device **312** includes a first or lower support **326** including a plurality of spaced apart emitters **328**. Each emitter **328** preferably comprises a self-contained infrared light-emitting diode. The emitters produce a beam of light **330** upwardly toward the elevating frame of the bed **10**. As illustrated in FIGS. **10** and **11**, each beam of light **330** is discrete and spaced apart from adjacent beams of light **330**. Collectively, the plurality of beams of light **330** define the respective optical curtains **376**, **378**, and **380**.

Each detection unit **370**, **372**, and **374** of the optical detection device **312** further includes a second or upper support **332** including a plurality of detectors **334**. Each detector **334** is associated with one of the emitters **328** and is configured to receive or detect the respective light beam **330** defining the optical curtains **376**, **378**, and **380**.

In a manner similar to that detailed above, if an obstacle is located in the optical curtain **376**, **378**, **380** between one of the emitters **328** and detectors **334**, such that one of the light beams **330** is interrupted, then the control unit **98** prevents the lifting device **66** from vertically moving the elevating frame **26**.

It should be noted that the optical curtains **376**, **378**, and **380** of the obstacle detection device **312** require that the light beams **330** be accurately aligned between the emitters **328** and the detectors **334** throughout the full path of travel of the elevating frame **26**. It may be appreciated, non-linear movement of the elevating frame **26** relative to the base frame **24** may cause the respective emitters **328** and detectors **334** to become mis-aligned, thereby resulting in a signal to the control unit **98** that an obstacle is positioned within the optical curtain **376**, **378**, **380**. Such false optical detection signals are less likely to occur using the earlier embodiment having substantially uniform optical curtains **76**, **78**, **80**.

The individual detection units **370**, **372**, and **374** of the obstacle detection device **312** may comprise the EASY-GUARD™ grid system available from Banner Engineering Corp. of Minneapolis, Minn. However, it should be appreciated that other similar devices may be substituted therefor.

FIGS. **12** and **13**, illustrate portions of a hospital bed **410** including a further illustrative embodiment obstacle detection device **412** of the present invention. The obstacle detection device **412** includes a first or right side detection unit **470** associated with the right longitudinal side edge **14** of the hospital bed **410**, a second or left side detection unit **472** associated with the left longitudinal side edge **16** of the bed **410**, and a third or foot end detection unit **474** associated with the foot end **20** of the bed **410**. The right side detection unit **470** is configured to detect an obstacle proximate the top of the right side member **21** of the base frame **24**, while the left side detection unit **472** is configured to detect an obstacle along the top of the left side **23** of the base frame **24**. Likewise, the foot end detection unit **474** is configured to detect an obstacle in front of the foot end cross member **29** of the base frame **24** at the foot end **20** of the bed **410**. It should be appreciated that a fourth or head end detection unit (not shown) may be provided adjacent the head end **18** of the bed **410** for detecting an obstacle behind the head end cross member **31** of the base frame **24** of the bed **410**.

As shown in FIGS. **13-15** and **21**, each detection unit **470**, **472**, **474** of the obstacle detection device **412** includes an emitter **482a**, **482b**, **482c** and an associated detector **490a**, **490b**, **490c**. Each emitter **482** illustratively comprises a self-contained infrared (IR) light-emitting diode (LED) **483** coupled to an emitter microprocessor **485** which generates an infrared (R) signal that is configured to be received by the associated detector **490**. The microprocessor **485** illustratively

## 12

comprises a conventional eight-bit microprocessor and may comprise Part No. MC68HC908QT1CDW available from Motorola of Schaumburg, Ill. A voltage regulator **487** is used to interface the microprocessor **485** to an 8.2 volt input provided by the power source **488** of a power supply module **489**. The output of the microprocessor **485** interfaces with the LED **483**, which converts the electrical signal into an optical one.

The detector **490** includes an IR sensor **491** which is configured to receive the optical signal emitted from the emitter **482** and convert the optical signal to an electrical signal. Illustratively, the sensor **491** is an infrared photo diode configured to observe a specific signal frequency and may comprise infrared detector Part No. GP1UM267XK available from Sharp Microelectronics of Camas, Wash. The IR sensor **491** is interfaced to the 8.2 volt power source **488** via a conventional regulator **492**. The output of the detector **490** is routed through a buffer **493** and to the power supply module **489** for processing in the manner described herein.

While the illustrative emitters **482** and detectors **490** utilize infrared light, it should be appreciated that other wireless signals may be substituted therefore. More particularly, other forms of electromagnetic radiation, such as ultrasonic, radar, and microwave, may be substituted for IR light.

With reference to FIGS. **12**, **13**, and **16-20**, each emitter **482** and detector **490** is received within a housing **494**. Each housing **494** includes a cover **495** coupled to a base **498**. The base **498** includes a mounting aperture **500** configured to receive a fastener **502** for securing the base **498** to an aperture **503** formed in the base frame **24** of the bed **410**. A locating peg **504** extends downwardly from a lower surface of the base **498** and is configured to be received within an aperture **506** formed in the base frame **24** of the bed **410**. As such, the combination of the fastener **502** received within the aperture **503** and the locating peg **504** received within the aperture **506** provides for the proper orientation and coupling of the housing **494** relative to the base frame **24**. The base **498** further includes four side walls **508** having a pair of notches or slots **510** formed in a pair of opposing ones of the side walls **508b** and **508d**.

The cover **496** includes four side walls **512** and a top wall **514**. A pair of locking tabs **516** are resiliently supported by an opposing pair of the side walls **512b** and **512d** and are configured to lockingly engage with the notches **510** of the base **498**. Cooperating slots **518** and **520** are formed within the cover **496** and base **498** and are configured to receive components, as supported on a circuit board **522**, of the respective emitter **482** and detector **490**. A pair of apertures **524** are formed within one of the side walls **512a** of the cover **496** and are aligned with the LED **483** of the emitter **482** or the sensor **491** of the detector **490**. The apertures **524** are positioned and sized for the efficient transmission of infrared light without incurring substantial interference from external light sources. Illustratively, the apertures **524** have a diameter of 3.18 millimeters (0.125 inches) and are positioned approximately 24.2 mm (0.953 inches) in front of the mounting slots **518** and **520** for the respective circuit board **522**.

With reference to FIGS. **12**, **13**, **16**, and **17**, the respective housings **440** are protected from fluid ingress by caster or frame covers **526**, **528**, **530** that cover portions of the base frame **24** proximate the head and foot ends **18** and **20**. Each head end frame cover **526** and **528** includes a housing **531** having side walls **532** connected to a top wall **534**. One of the side walls **532** includes an opening **536** aligned with one of the apertures **524** in one of the housings **494** associated with the right and left side detection units **470** and **472**. A transparent window **538**, illustratively a clear thermoplastic mate-

rial, is fixed within the opening 536 to prevent the passage of fluid therethrough, while permitting the passage of infrared light from the emitter 482 to the detector 490. The window 538 may be fixed in place using conventional methods, such as ultrasonic welding or adhesives. A clearance slot 540 may be formed in another one of the side walls 532 of the frame covers 526 and 528 to provide clearance for the brake/steer pedals 542 of the hospital bed 410, as needed.

The foot end frame cover 530 includes first and second housings 544 and 546 coupled together by a connecting member 548. Each housing 544 and 546 includes side walls 550 coupled to a top wall 552, and a pair of openings 554 and 556 formed within different ones of the side walls 550. The openings 554 are associated with one of the apertures 524 of the foot end housings 494 of the right and left side detection units 470 and 472. The openings 556 are associated with one of the apertures 524 of the housings 494 associated with the foot end detection unit 474. Windows 538 are illustratively fixed within the openings 554 and 556 as detailed above.

As illustrated in FIGS. 12 and 13, the right and left side detection units 470 and 472 may have their emitters 482 positioned at the head end 18 and foot end 20 of the hospital bed 410, respectively. As such, the transmission of infrared light from the emitters 482 of the right side detection unit 470 and the left side detection unit 472 will be in opposite directions (as shown by arrows 557 in FIG. 13) in order to reduce the possibility of cross talk between the two detection units 470 and 472. Likewise, the emitter 482 of the foot end detection unit 474 does not direct infrared light toward the detectors 490 of the right and left side detection units 470 and 472.

To begin operation of the obstacle detection device 412, a controller or microprocessor 558 of the power supply module 489 initializes the various parameters and disables all interrupts. The power source 488 of the power supply module 489 supplies each emitter 482 with the required power of 8.2 volts. The microprocessor 485 of each emitter 482 is used to cause the LED 483 to generate an IR pulse signal 560 of the type illustrated in FIG. 22. Illustratively, the signal 560 includes a 600 microsecond pulsed portion 561 having a 57 kHz signal with a 50 percent duty cycle. A two millisecond delay follows the 57 kHz pulse with the output low. Such a pulse sequence repeats indefinitely. An internal bus clock (not shown) illustratively runs at 3.2 MHz. As such, this provides an instruction cycle time of 312.5 nanoseconds.

The detector 490 is configured to look for a 056.8 kHz signal, which translates into 17.66 microseconds per pulse, or 8.803 microseconds per state. The number of instruction cycles per state is determined by the following formula:

$$\text{Instruction cycles} = \text{total time} / \text{instruction cycle time}$$

By inserting the above values for total time of 8.803 microseconds and instruction cycle time of 312.5 nanoseconds, the number of instruction cycles is determined to be 28.17. Using 28 cycles per state provides a total pulse time of 17.5 microseconds which equates to 57.14 kHz. A loop that generates the 57 kHz IR signal is run 34 times, thereby giving a total time of 595 microseconds.

The detector 490 is configured to look for the pulse signal 560 including a pulsed portion or an IR signal burst 561 at a specific frequency. When the signal 560 is detected with the appropriate frequency component, the output of the detector 490 becomes active, effectively demodulating the transmitted signal. The detector 490 includes a built-in frequency filter having a range of 53.6 kHz to 60 kHz (56.8±3.2 kHz).

In addition to a band-pass filter, the IR detector 490 adjusts its sensitivity level proportionately to the strength of the inci-

dent light signal. This helps further filter noise signals that may be present in the 56.8 kHz range.

The IR detector 490 filters the incident light to allow only the wave length associated with IR to come into contact with the internal photo diode or sensor 491. This helps filter out the effects of sunlight, incandescent lighting, and fluorescent lights.

Upon detecting the appropriate wave length or frequency pulse signal 560, the detector 490 provides an essentially demodulated signal 562 such as that illustrated in FIG. 23. The signal illustratively has a high value of approximately 5 volts.

The demodulated signal 562 from the detector 490 is then transmitted to a Resistor-Capacitor (RC) filter 564 comprising part of the power supply module 489. The RC filter 564 converts the signal 562 of FIG. 23 to a waveform 566 such as that illustrated in FIG. 24. The waveform of FIG. 24 has a nominal value of approximately 3.8 volts±0.5 volts. Illustratively, the RC filter 564 is of conventional design and includes a 100 kohm resistor and a 0.1 µF capacitor. The output from the RC filter 564 passes through a conventional analog to digital (A/D) converter (not shown) on its way to the microprocessor 558.

If the RC filter output drops below 3.3 volts, then the microprocessor knows that an obstacle has blocked the IR light path between the emitter 482 and the detector 490, or that a fault condition exists, such as the emitter 482 or detector 490 not functioning properly. In either case, the microprocessor 558 functions by activating an indicator 100 and disabling the lifting device 66 from further lowering of the patient support as detailed herein.

It should be appreciated that each emitter 482 and detector 490 could be configured to send and receive signal waveforms having different bit or pulse patterns, including different pulse frequencies and pulse durations, in order to further limit the possibility of cross talk between different emitters and detectors. As may be appreciated, since the detectors 490 are configured to detect a frequency rather than an intensity, interference from external light sources is reduced. Furthermore, by looking for frequency, similar emitters 482 and detectors 490 may be used for obstacle detection for a wide range of distances between the respective emitters 482 and detectors 490.

Referring now to FIGS. 25-30, a further illustrative embodiment obstacle or interference detection device 612 is shown coupled to the base frame 28 of the patient support 410. The interference detection device 612 illustratively includes first and second sensors 614 and 616 which are coupled to upper surfaces 618 and 620 of the longitudinally extending first (right) and second (left) side members 25 and 27 of the base frame 24, respectively. While in the following description, first and second sensors 614 and 616 are illustrated as being associated with the side members 25 and 27 of the patient support 410, it should be appreciated that additional sensors could be positioned adjacent the head end 18 and the foot end 20 of the patient support 410.

Each sensor 614 and 616 is configured to provide an interference detection signal to a control system 622 in the event that it detects an obstacle or determines that a fault condition exists. More particularly, each sensor 614 and 616 is configured to provide the interference detection signal to control system 622 upon detecting that an object, such as an individual's foot, is supported on one of the upper surfaces 618 and 620 of the base frame 24. As described in greater detail below, the sensors 614 and 616 are configured to generate an interference detection signal only when a predetermined sufficient force is applied thereto or when a fault condition occurs. As

15

such, the sensors 614 and 616 avoid generating false interference detection signals which could impact the normal operation of the patient support 410.

Referring further to FIGS. 28 and 29, each sensor 614 and 616 illustratively includes a force sensing tape switch 624 including upper and lower contacts 626 and 628 which extend in substantially parallel relation in a longitudinal direction above the side members 25 and 27 of the base frame 24. Each contact 626 and 628 is electrically conductive and is in electrical communication with control system 622 through conventional wires 630 and 632, respectively. Further, the upper contact 626 is resilient so that a downwardly acting vertical force 634 will cause it to deflect into electrical contact with the lower contact 628, and upon removal of the force 634 the upper contact 626 will return to its original position in spaced relation to the lower contact 628. Illustratively, each contact 626 and 628 is formed from a thin sheet or layer of stainless steel. A pair of isolation spacers 636 and 638 are positioned intermediate the upper and lower contacts 626 and 628 along opposing longitudinally extending side edges 640 and 642 thereof. As such, the isolation spacers 636 and 638 define a central void 644 through which the upper contact 626 may be deflected into electrical contact with the lower contact 628. The isolation spacers 636 and 638 may be formed of any electrically insulative material, and are illustratively formed from either a Mylar® film or conventional adhesive.

The lower contact 628 is secured to a base 646, illustratively formed from an electrically insulative material to prevent electrical communication between the lower contact 628 and the base frame 24. An adhesive 648 may be utilized to secure the lower contact 628 to the base 646. In one illustrative embodiment, the base 646 is made from a thermoplastic material and formed as a unshaped channel. The base 646 is secured to a respective upper surface 618, 620 of the base frame 24, illustratively through the use of an adhesive, although other conventional fastening means, such as screw or bolts, may likewise be used. A potting compound 650,

16

Referring to FIG. 30, a schematic representation of the first sensor 614 of the obstacle detection device 612 is shown. It should be appreciated that the second sensor 616 is substantially identical. The upper and lower contacts 626 and 628 are shown as embodied within the switch 624. As stated previously, the upper and lower contacts 626 and 628 are made of an electrically conductive material and are spaced apart at their sides edges 640 and 642 by isolation spacers 636 and 638. However, the upper and lower contacts 626 and 628 are capable of contacting each other within the central void 644 positioned between the contacts 626 and 628. As detailed above, the upper contact 626 is configured to contact the lower contact 628 when an obstacle exerts a sufficient force against the upper surface 652 of the potting compound 650. As such, the switch 624 is open when the upper and lower contacts 626 and 628 remain spaced apart, and the switch 624 is closed when the upper contact 626 is brought into contact with the lower contact 628 by the application of a sufficient downward force against the upper surface 652.

As shown in FIG. 30, the lower contact 628 is electrically connected to a ground 654. The upper contact 626 is connected to a voltage supply 656 through a first resistor 658, illustratively having a value of 270 ohms. The voltage supply 656 may form part of the control system 622. Further, the upper and lower contacts 626 and 628 are connected together by a second resistor 660, illustratively having a value of 1 kohm. A voltage output signal 662 is taken at the upper contact 626 and then sent to an Analog to Digital (A/D) converter 664 to generate a logic signal for control system 622. The A/D converter 664 may be incorporated within the control system 622.

When the force exerted by an obstacle does not bring the upper contact 626 into contact with the lower contact 628, the switch 624 is open and the circuit shown in FIG. 30 is a voltage divider. In an illustrative embodiment, the voltage supply 656 is a five volt supply and the values of first and second resistors 658 and 660 are selected such that a voltage value corresponding to a high logic value is measured at the

17

illustratively 2 seconds, while preventing operation of the lifting device 66 to lower the elevating frame 26. Raising the elevating frame 26 for a time period after an obstacle has been detected, provides for the immediate and automatic movement of the frame 26 in a direction away from the detected obstacle. 5

While the sensors 614 and 616 of the interference detection device 612 are illustratively positioned on the base frame 24, it should be appreciated that the sensors 614 and 616 could likewise be positioned on a lower surface of the elevating frame 26. Further, the interference detection device 612 may be utilized to detect obstacles between any two portions of a patient support apparatus which move relative to each other. For example, the interference detection device 612 may be used between the foot end and head end siderails 46 and 47, between the head end siderails 47 and the headboard 42, and between the foot end siderails 46 and the footboard 44. 10

In a further alternative embodiment of the obstacle detection device 12 of the present invention, the detectors 90, 92, 94 may comprise cameras utilizing vision technology to detect obstructions. More particularly, the camera captures images as the elevating frame 26 moves along its path of travel. The images captured by the camera are compared by the control unit 98 to predefined images of the elevating frame 26 moving along the path of travel with no obstructions present. If each captured image fails to substantially match a corresponding predefined image, then the control unit 98 generates the stop signal 108 to prevent movement of the elevating frame 26 in the manner detailed above. 15

In yet another illustrative embodiment of the obstacle detection device 12 of the present invention, the detectors 90, 92, 94 may comprise conductors, such as fiber optic cables, each having a property that changes between a first state and a second state upon movement of bed frame components. Additional details of such a conductor are disclosed in U.S. patent application Ser. No. 09/791,936, filed Feb. 23, 2001, which is assigned to the assignee of the present invention and which is expressly incorporated by reference herein. 20

While the foregoing illustrative description details application of the obstacle detection device 12 of the present invention for detecting an obstacle between an elevating frame 26 and a base frame 24, this in no way is intended to limit the scope of the invention. Moreover, the obstacle detection device 12 may be utilized to detect obstacles between any two portions of a patient support apparatus which move relative to each other. For example, the obstacle detection device 12 may be used between the first and second siderails 46 and 47, between the first siderail 46 and the footboard 44, and between the second siderail 47 and the headboard 42. 25

Although the invention has been described in detail with reference to certain illustrated embodiments, variations and modifications exist within the scope and spirit of the invention as described and as defined in the following claims. 30

The invention claimed is:

1. A patient support apparatus comprising:
  - a first component;
  - a second component configured to move relative to said first component along a path of travel;
  - a detection unit comprising:
    - a single emitter supported by one of said first and second components and
    - a plurality of detectors supported by the other of said first and second components, said detectors configured to provide a control signal in response to an obstacle within said path of travel between the emitter and any one of the plurality of detectors; and

18

a control unit in communication with said detector; and a lifting device configured to move said second component vertically relative to said first component and wherein said control unit deactivates said lifting device if any one of said plurality of detectors fails to detect a signal emitted by said single emitter. 35

2. The patient support apparatus of claim 1, wherein said emitter generates an obstacle detection signal.

3. The patient support apparatus of claim 2, wherein said obstacle detection signal includes a pulsed portion having a predefined frequency, and said detector is configured to detect said predefined frequency.

4. The patient support apparatus of claim 3, wherein said predefined frequency is approximately 57 kHz.

5. The patient support apparatus of claim 3, wherein said pulsed portion has a duration of approximately 600 microseconds followed by a delay of approximately 2 milliseconds.

6. The patient support apparatus of claim 2 wherein the obstacle detection signal is a wireless signal.

7. The patient support apparatus of claim 6 wherein the wireless signal is an electromagnetic curtain.

8. The patient support apparatus of claim 1, wherein said emitter comprises an infrared source.

9. The patient support apparatus of claim 1, further comprising an indicator configured to indicate failure of any one of said plurality of detectors to detect an obstacle detection signal emitted by said single emitter.

10. A method of preventing movement of a movable component of a bed upon detection of an obstacle within a path of travel of the component, said method comprising the steps of: providing the bed having the movable component; providing a detection unit comprising a single emitter and a plurality of detectors; causing the emitter to emit an obstruction detection signal for detecting an obstacle within the path of travel between the emitter and any one of the detectors; moving said component; generating a stop signal if at least one of said detectors fails to detect said obstacle detection signal; and preventing movement of said movable component in response to said stop signal wherein said movable component includes an elevating frame movable vertically relative to a base frame, and the moving step includes moving said elevating frame vertically relative to said base frame. 40

11. The method of claim 10, wherein said step of generating a signal comprises the steps of providing a light source and emitting infrared light from said light source.

12. The method of claim 10 wherein the obstruction detection signal is a wireless signal.

13. The method of claim 10 wherein the obstruction detection signal is an infrared signal.

14. The method of claim 10 wherein the obstruction detection signal forms a curtain.

15. A patient support apparatus comprising:
 

- a base frame;
- an elevating frame configured to move relative to said base frame along a path of travel above said base frame;
- a detection unit comprising:
  - a single emitter supported by one of said frames and
  - a plurality of detectors supported by the other of said frames, said detectors configured to provide a control signal in response to an obstacle within said path of travel between the emitter and any one of the plurality of detectors; and

**19**

a control unit in communication with said detector and configured to prevent relative movement of the frames in response to said control signal.

16. The patient support apparatus of claim 15 wherein the emitter is supported by the base frame and the detectors are supported by the elevating frame.

17. The patient support apparatus of claim 15, wherein the prevented movement is movement of the elevating frame toward the base frame.

18. The patient support apparatus of claim 17 wherein the prevented movement is lowering of the elevating frame relative to the base frame.

19. A patient support apparatus, comprising:

first and second sides extending substantially parallel to each other;

third and fourth sides extending substantially parallel to each other and substantially perpendicular to the first and second sides, the first and second sides cooperating with the third and fourth sides to define corners,

first and second detection units associated respectively with the first and second sides, the first detection unit oriented to emit an obstacle detection signal away from

**20**

the third side and toward the fourth side, the second detection unit oriented to emit a signal away from the fourth side and toward the third side.

20. The bed of claim 19, comprising a third detection unit associated with the third side and an optional fourth detection unit associated with the fourth side, the first, second and third detection units and the fourth detection unit, if present, each comprising an emitter proximate one corner and a detector proximate another corner, the emitter of the third detection unit and the emitter of the fourth detection unit, if present, being oriented to not emit a signal toward a detector of the first or second detection unit.

21. The bed of claim 19 wherein the first side is a left side, the second side is a right side, the third side is a foot side and the fourth side is a head side.

22. The patient support apparatus of claim 19 wherein each of the detection units comprises a single emitter and a plurality of detectors.

23. The patient support apparatus of claim 20 wherein each of the detection units comprises a single emitter and a plurality of detectors.

\* \* \* \* \*