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(54) METHOD AND SYSTEM FOR LATERAL GAIN CONTROL IN AN ULTRASOUND IMAGING SYSTEM

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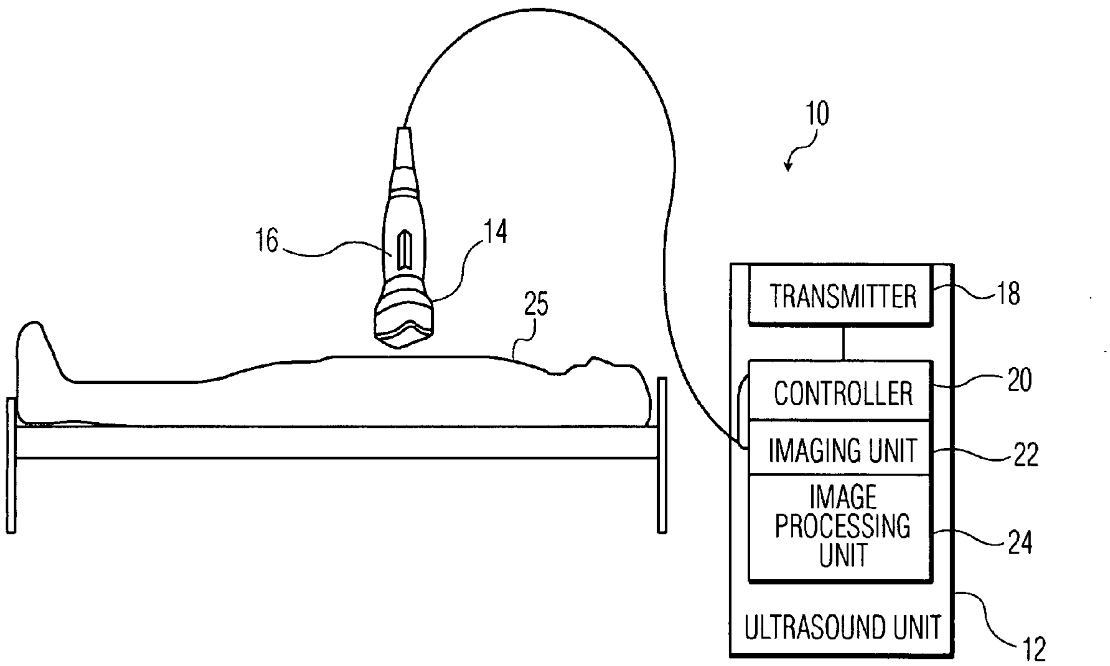
(57) **ABSTRACT**

An ultrasound imaging system lateral gain control circuit operates in conjunction with an ultrasound imaging system for generating an ultrasound image of an ultrasound analysis object using an ultrasound sensing circuit for sensing an ultrasound signal returning from an ultrasound analysis object to an ultrasound transducer. The ultrasound image is defined by a first region and a second region. The first region and second region together form the complete ultrasound image. The first region associates with a region proximate to the ultrasound transducer, while the second region associates with a region distal from the ultrasound transducer. The lateral gain control circuit controls the two-dimensional ultrasound image brightness between the two regions by controlling the ultrasound signal amplification by separately controlling the first region signal amplification and the second region signal amplification.



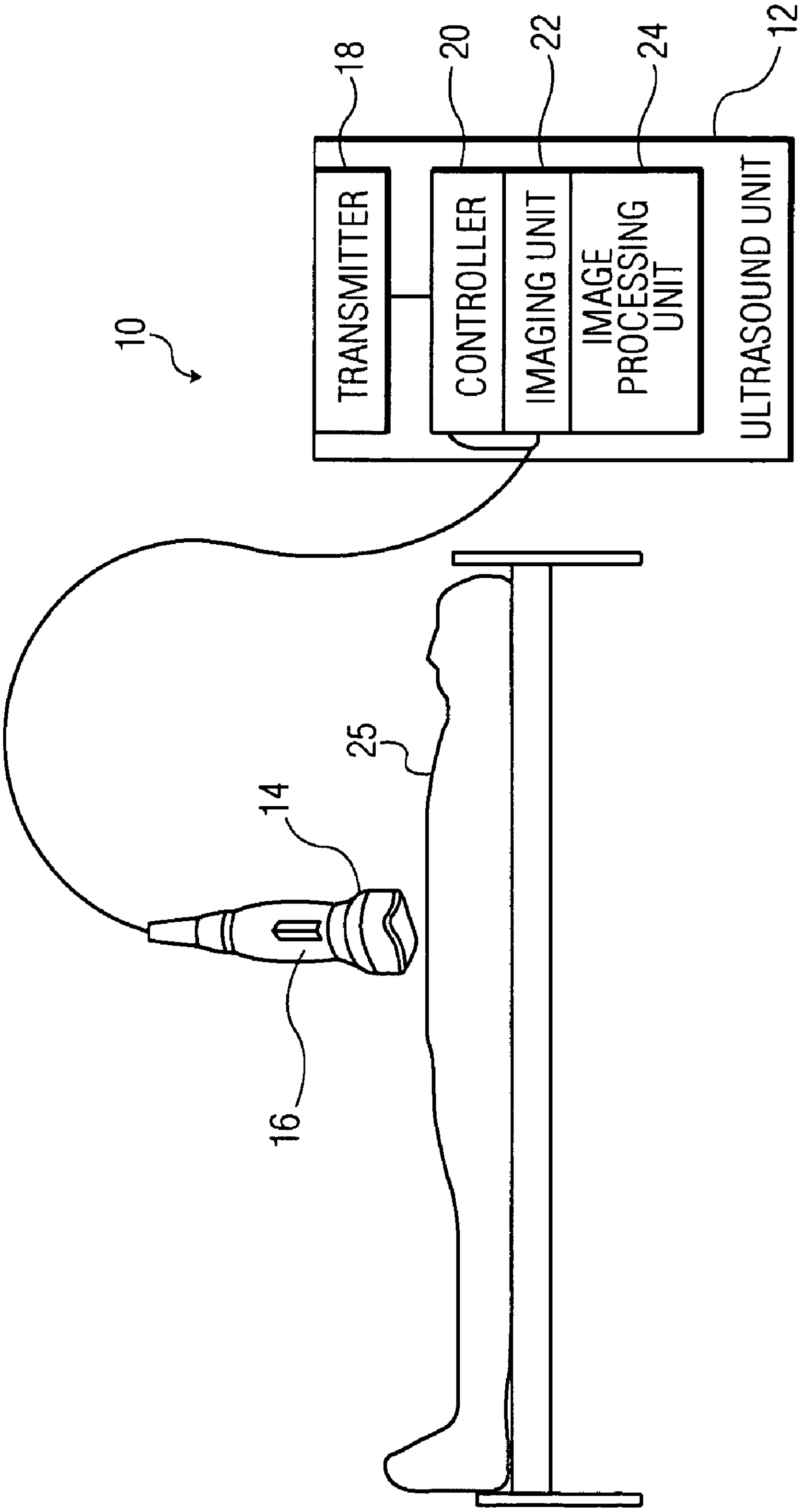
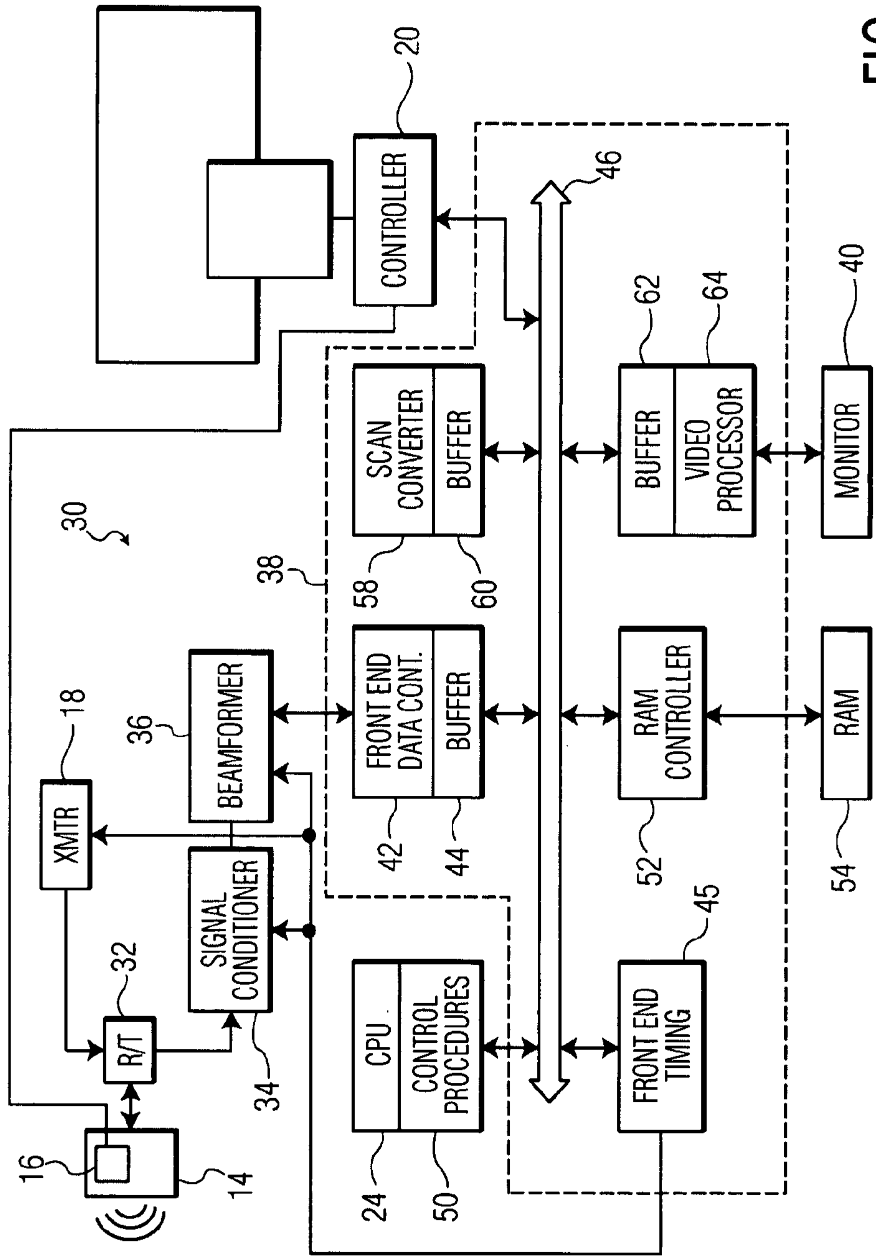
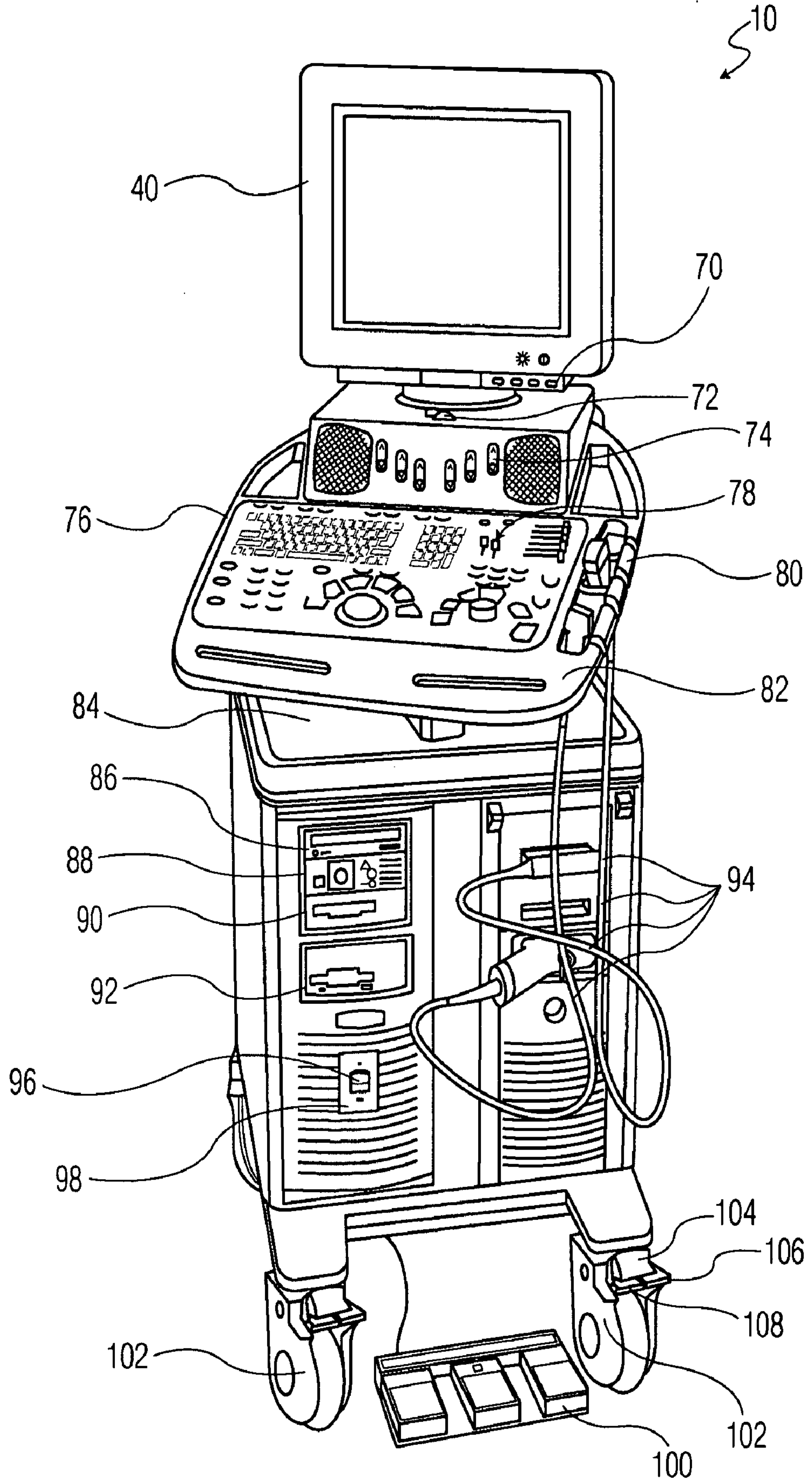

10
TRANSMITTER
18
CONTROLLER
20
IMAGING UNIT
22
IMAGE PROCESSING UNIT
24
ULTRASOUND UNIT
12
14
16
25

FIG. 1



CONTROLLER
20
46
SCAN CONVERTER
BUFFER
BUFFER
VIDEO PROCESSOR
MONITOR
62
64
40
30
38
58
60
XMTR
18
BEAMFORMER
36
FRONT END DATA CONT.
BUFFER
RAM CONTROLLER
RAM
SIGNAL CONDITIONER
42
44
52
54
32
R/T
34
CPU
CONTROL PROCEDURES
FRONT END TIMING
45
16
14
24
50

FIG. 2


10
40
70
72
74
76
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108
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102
100

FIG. 3

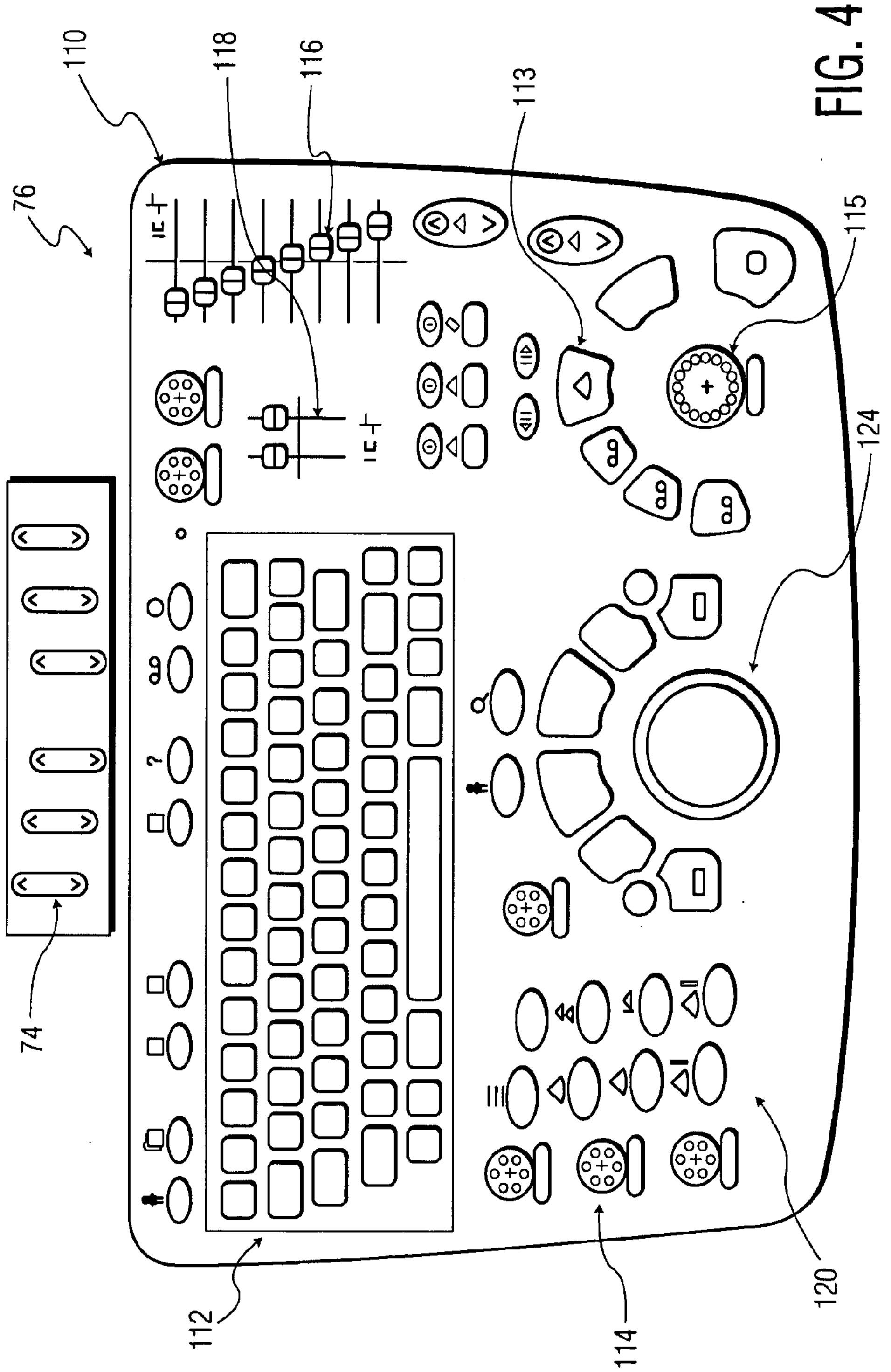


FIG. 4

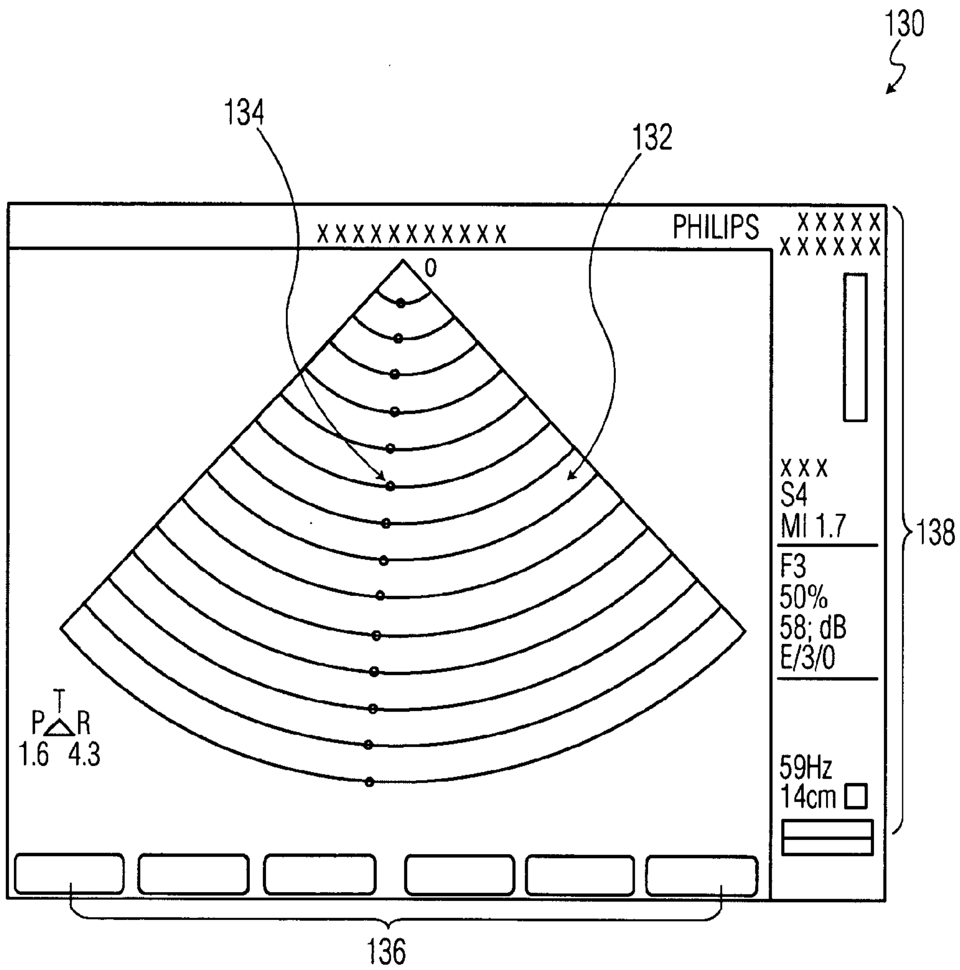

130
134
132
XXXXXXXXXXX
PHILIPS
XXXXX
XXXXXX
0
XXX
S4
MI 1.7
F3
50%
58; dB
E/3/0
59Hz
14cm
138
T
P R
1.6 4.3
136

FIG. 5

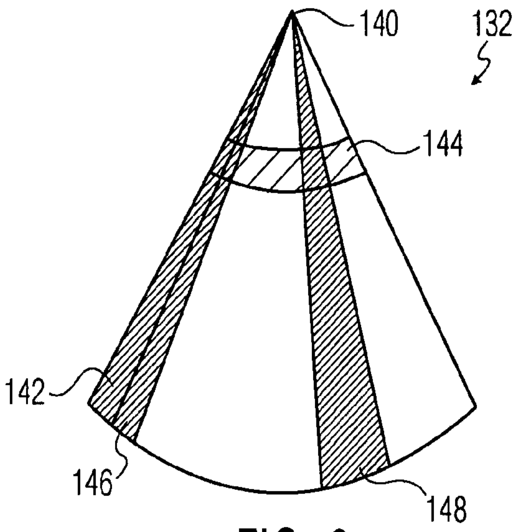


FIG. 6

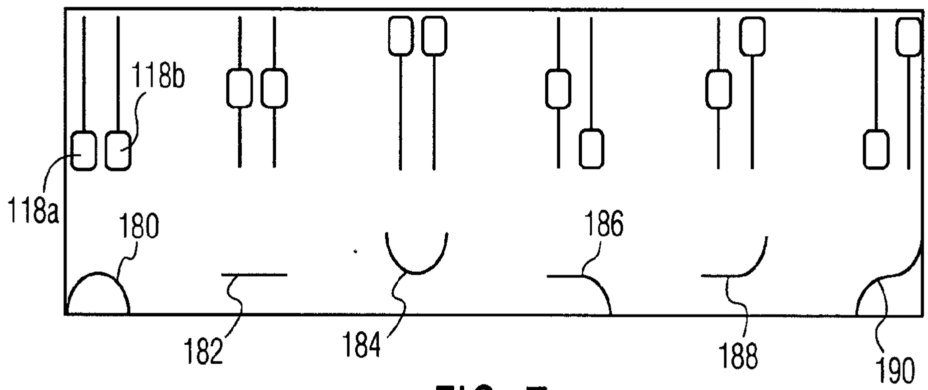


FIG. 7

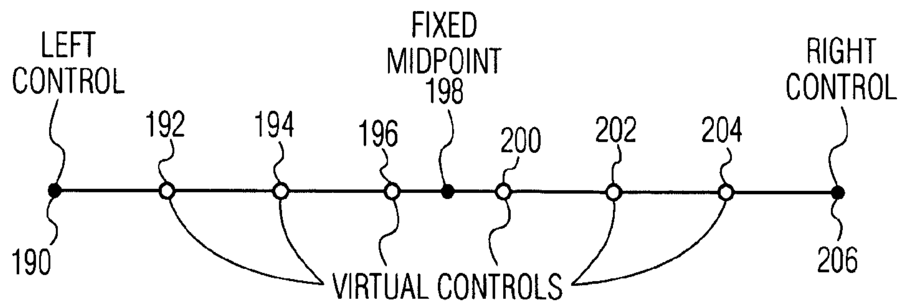
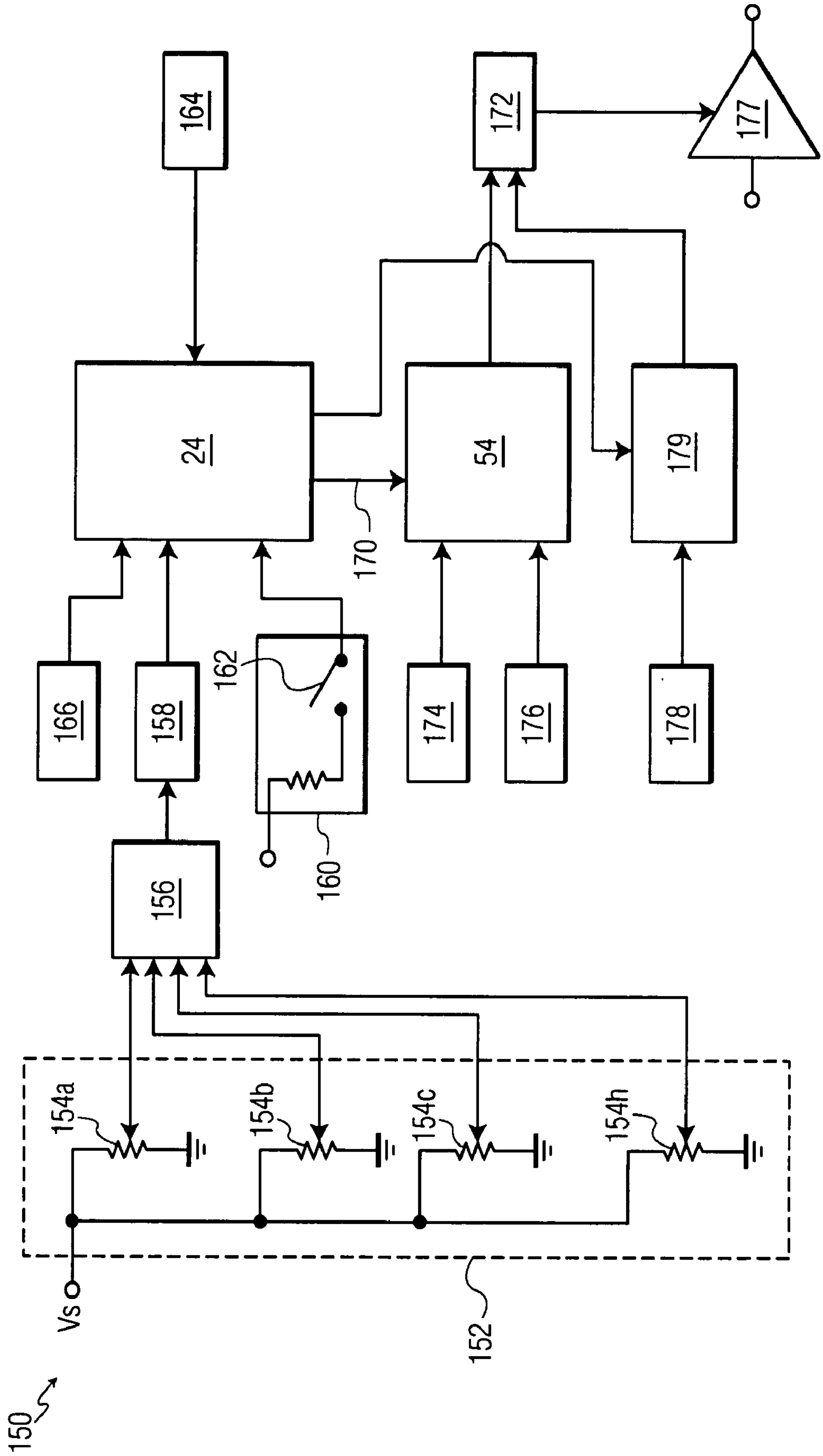


FIG. 8



164
172
177
24
54
179
170
166
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162
174
176
178
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156
154a
154b
154c
154h
Vs
152
150

FIG. 9

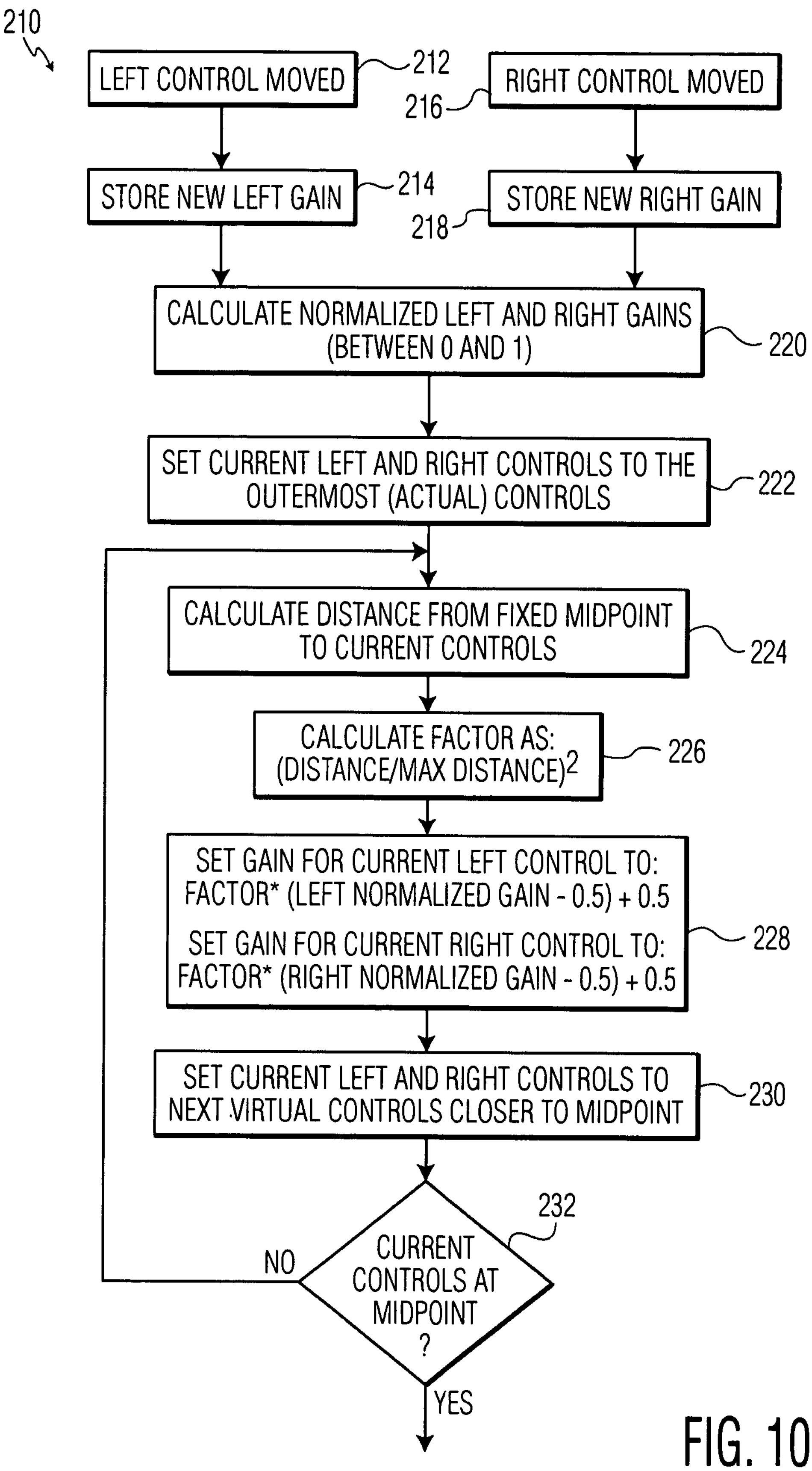
210
LEFT CONTROL MOVED
212
RIGHT CONTROL MOVED
216
STORE NEW LEFT GAIN
214
STORE NEW RIGHT GAIN
218
CALCULATE NORMALIZED LEFT AND RIGHT GAINS (BETWEEN 0 AND 1)
220
SET CURRENT LEFT AND RIGHT CONTROLS TO THE OUTERMOST (ACTUAL) CONTROLS
222
CALCULATE DISTANCE FROM FIXED MIDPOINT TO CURRENT CONTROLS
224
CALCULATE FACTOR AS: (DISTANCE/MAX DISTANCE)2
226
SET GAIN FOR CURRENT LEFT CONTROL TO: FACTOR* (LEFT NORMALIZED GAIN - 0.5) + 0.5
SET GAIN FOR CURRENT RIGHT CONTROL TO: FACTOR* (RIGHT NORMALIZED GAIN - 0.5) + 0.5
228
SET CURRENT LEFT AND RIGHT CONTROLS TO NEXT VIRTUAL CONTROLS CLOSER TO MIDPOINT
230
CURRENT CONTROLS AT MIDPOINT ?
232
NO
YES

FIG. 10

METHOD AND SYSTEM FOR LATERAL GAIN CONTROL IN AN ULTRASOUND IMAGING SYSTEM

CROSS REFERENCE TO RELATED CASES

[0001] Applicants claim the benefit of Provisional Application Ser. No. 60/503,847, filed Sep. 17, 2003.

[0002] The present invention relates to ultrasound systems and their methods of operation and, in particular, to an ultrasound imaging system lateral gain control circuit and method of operation for controlling the lateral gain in an ultrasound image.

[0003] Diagnostic ultrasound imaging systems transmit sound energy into the human body and receive signals reflecting from tissue and organs such as the heart, liver, and kidney. In general, these systems convert echoes received from objects on the plurality of paths into electrical signals from which they generate and display an ultrasound image in a two-dimensional format known as color flow imaging or color velocity imaging. The amplitudes of reflected components for structures such as the heart or vessel walls have lower absolute velocities and are 20 dB to 40 dB (10-100 times) larger than reflected components due to blood cells.

[0004] One important aspect of ultrasound imaging system includes operator adjustable gain control for controlling the gain of an ultrasonic scanning system as a function of the scanning angle of a received beam. Existing ultrasonic scanning systems employ several techniques for controlling transmit or receive channel gains. At least some of these gains are operator adjustable to help present the desired image on the display screen. For example, the SONOS line of ultrasound systems, which is manufactured by PHILIPS MEDICAL SYSTEMS, incorporates an operator adjustable transmit gain control mechanism. Varying this control affects the intensity of the entire signal that the ultrasound image monitor displays. In addition, the time gain compensation (known as "TGC") function allows an operator to adjust the receive channel gain in discrete steps as a function of distance from the origin of the beam. TGC control permits the adjustment of gain to compensate for the attenuation occurring as the ultrasound signal as it propagates through the scanned medium.

[0005] At times, it also may be desirable to modify the gain, and hence the intensity of the displayed signal, as a function of the scan angle. This may enable the clinician to better analyze a particular region of a subject's anatomy, such as the motion of a wall of the heart. Such a gain adjustment, oriented along scan lines or within a range of scan angles, also may be desirable if the ultrasound signal is decreased in a particular region by shadowing, caused by anatomical structures such as the ribs or lungs of the subject being scanned, or where tissue fiber orientation of the subject results in displayed signals having unacceptable brightness. Finally, such an adjustment may be desirable in a system utilizing techniques for automatically detecting and highlighting such border regions as the interface between the wall and a chamber of the subject's heart. Absent such an adjustment, in regions where shadowing appears, there may not be sufficient signal for such automatic detection circuits to effectively function. U.S. Pat. No. 5,195,521, which is assigned to the assignee of the present application, describes such the operation of such a detection circuit.

[0006] Currently only cardiac ultrasound systems use LGC controls that allow the user to control the relative gain applied to various lateral sections of the image. LGC control typically reduces the echo intensity of the cardiac walls to get a more uniform image. While the LGC controls could be highly useful for non-cardiac applications in allowing the clinician to optimize image presentation, no current specialty or general imaging system provides LGC. For example, refraction from the baby's head or stomach sidewalls can make the image too dim at the sides to be viewed easily. In abdominal studies, a rib may cause shadowing and make one side of the image too dim. Similarly, a gas pocket may make one side of the image too bright. Large disparities in image brightness across an image can make it difficult or impossible to get accurate measurements of anatomy.

[0007] In prior gain adjustment systems oriented along scan lines or within a range of scan angles, the individual controls have been either unduly complex or adapted from the earlier TGC type of controls. For example, the SONOS line of gain adjustment controls use an 8-slider system called lateral gain control (LGC) to adjust different aspects of scan line or scan angles. Unfortunately, this creates significant problems relating to the complexity of understanding how to adjust these controls, the effect of different controls, and the general expense of the hardware and circuitry in manufacturing these controls. The 8-slider system presents to the clinician many choices and may ultimately result in inferior performance, due to these controls being improperly positioned. Accordingly, a need exists for a simpler way to control the image display gain for scan line and scan angle images.

[0008] In accordance with the present invention, a method and system for controlling the lateral gain of an ultrasound image is provided that substantially eliminates or reduces the disadvantages and problems associated with prior ultrasound image system display gain control methods and systems.

[0009] According to one aspect of the present invention, the present invention provides a LGC circuit and method of operation for laterally controlling the gain of an ultrasound image generated by an ultrasound imaging system. The present invention generates an ultrasound image of an ultrasound analysis object using an ultrasound sensing circuit for sensing an ultrasound signal returning from an ultrasound analysis object to an ultrasound transducer. The ultrasound image includes a first region and a second region. The first region and the second region together form the ultrasound image with the first region associating with a region of the ultrasound analysis object proximate to the ultrasound transducer and the second region associating with a region of the ultrasound analysis object distal from the ultrasound transducer. The invention further laterally controls the two-dimensional brightness of the ultrasound image between the first region and the second region by controlling the amplification of the ultrasound signal using a first gain control circuit for controlling the signal amplification of the first region and a second gain control for controlling the signal amplification of the second region.

[0010] By allowing lateral gain control, the user has the ability to control more carefully the image on the ultrasound display. Therefore, variations caused by local gas bubbles or other object features can be viewed more precisely.

[0011] A further technical advantage of the present invention is that of providing lateral gain control in ultrasound analysis methods and systems beyond the known areas of cardiac analysis. The simplicity of the present invention makes its use practical in a wide variety of applications beyond cardiac analysis.

[0012] The present invention permits the system operator to vary laterally the gain of the received signal as a function of the position of the beam. The invention provides, moreover, at least one operator adjustable LGC command for varying system gain as a function of the displacement of a particular scan line from a reference point, the gain along the scan line as a function of its distance from the system's transducer being substantially constant.

[0013] Other technical advantages are readily apparent to one skilled in the art from the following figures, description, and claims.

[0014] For a more complete understanding of the present invention and advantages thereof, reference is now made to the following description which is to be taken in conjunction with the accompanying drawings in which like reference numbers indicate like features and wherein:

[0015] **FIG. 1** is a diagram illustrating the use of an ultrasound diagnostic system that may use the present invention;

[0016] **FIG. 2** is a block diagram of an ultrasound system in accordance with the preferred embodiment of the present invention;

[0017] **FIG. 3** shows an ultrasound imaging system that may employ the lateral gain control method and system of the present invention;

[0018] **FIG. 4** portrays in more detail the control panel of the ultrasound imaging system of the present invention including the lateral gain controls of the present invention;

[0019] **FIGS. 5 and 6** provide views of an ultrasound image including the lateral gain control display of the present invention;

[0020] **FIG. 7** depicts the variable positions that the sliding lateral gain control of an embodiment of the present invention;

[0021] **FIG. 8** shows diagrammatically the control response from the variable positioning the sliding lateral gain controls of **FIG. 7**;

[0022] **FIG. 9** depicts a lateral gain control circuit that the present invention may employ; and

[0023] **FIG. 10** provides a flow diagram for the general use lateral gain control process and circuitry of the present invention.

[0024] The preferred embodiment of the present invention and its advantages are best understood by referring to **FIGS. 1 through 10** of the drawings, like numerals being used for like and corresponding parts of the various drawings.

[0025] **FIG. 1** shows a simplified block diagram of an ultrasound imaging system **10** that may use the concepts presented in the preferred embodiment of the present invention. It will be appreciated by those of ordinary skill in the relevant arts that ultrasound imaging system **10**, as illustrated in **FIG. 1**, and the operation thereof as described hereinafter is intended to be generally representative of such systems and that any particular system may differ significantly from that shown in **FIG. 1**, particularly in the details of construction and operation of such system. As such, ultrasound imaging system **10** is to be regarded as illustrative, exemplary, and not limiting as regards the invention described herein or the claims attached hereto.

[0026] In certain circumstances, when it is desirable that a piece of hardware possess certain characteristics, these characteristics are described more fully in the following text. The required structures for a variety of these machines may appear in the description given below. Machines that may be modified in accordance with the teachings of the present invention include those manufactured by such companies as AGILENT TECHNOLOGIES, PHILIPS MEDICAL SYSTEMS INTERNATIONAL, GE MEDICAL SYSTEMS, and SIEMANS MEDICAL SYSTEMS, as well as other manufacturers of ultrasound equipment.

[0027] Ultrasound imaging system **10** generally includes ultrasound unit **12** and connected transducer **14**. Transducer **14** includes spatial locator receiver (or simply "receiver") **16**. Ultrasound unit **12** has integrated therein spatial locator transmitter (or simply "transmitter") **18** and associated controller **20**. Controller **20** provides overall control of the system by providing timing and control functions. As will be discussed in detail below, the control routines include a variety of routines that modify the operation of receiver **16** so as to produce an ultrasound image as a live real-time image, a previously recorded image, or a paused or frozen image for viewing and analysis. The differing functions and uses of the ultrasound imaging system that may employ the present invention are described more fully below.

[0028] Ultrasound unit **12** is also provided with imaging unit **22** for controlling the transmission and receipt of ultrasound, and image processing unit **24** for producing a display on a monitor (See **FIG. 3**). Image processing unit **24** contains routines for rendering an ultrasound image which may include, for example, a three-dimensional ultrasound image. Transmitter **18** should be located in an upper portion of ultrasound unit **12** so as to obtain a clear transmission to receiver **16**. As modern ultrasound units are often configured in a cart format, such mounting should not be a problem, such that the details thereof are omitted.

[0029] During freehand imaging, a user moves transducer **14** over subject **25** in a controlled motion. Ultrasound unit **12** combines image data produced by imaging unit **22** with location data produced by the controller **20** to produce a matrix of data suitable for rendering onto a monitor. Ultrasound imaging system **10** integrates image rendering processes with image processing functions using general purpose processors and PC-like architectures. On the other hand, use of ASICs to perform the stitching and rendering is possible.

[0030] **FIG. 2** is a block diagram **30** of an ultrasound system in accordance with the preferred embodiment of the present invention. The ultrasound imaging system shown in **FIG. 2** is configured for the use of pulse generator circuits, but could be equally configured for arbitrary waveform operation. Ultrasound imaging system **10** uses a centralized architecture suitable for the incorporation of standard personal computer ("PC") type components and includes transducer **14** which, in a known manner, scans an ultrasound beam, based on a signal from a transmitter **18**, through an angle. Backscattered signals, i.e., echoes, are sensed by transducer **14** and fed, through receive/transmit switch **32**, to signal conditioner **34** and, in turn, to beamformer **36**. Transducer **14** includes elements, preferably configured as a steerable two-dimensional array. Signal conditioner **34** receives backscattered ultrasound signals and conditions those signals by amplification and forming circuitry prior to their being fed to beamformer **36**. Within beamformer **36**, ultrasound signals are converted to digital values and are configured into "lines" of digital data values in accordance with amplitudes of the backscattered signals from points along an azimuth of the ultrasound beam.

[0031] Beamformer **36** feeds digital values to application specific integrated circuit (ASIC) **38** which incorporates the principal processing modules required to convert digital values into a form more conducive to video display that feeds to monitor **40**. Front end data controller **42** receives lines of digital data values from beamformer **36** and buffers each line, as received, in an area of buffer **44**. After accumulating a line of digital data values, front end data controller **42** dispatches an interrupt signal, via bus **46**, to shared central processing unit (CPU) **48**, which may be a MOTOROLA PowerPC. CPU **48** executes control procedures **50** including, for example, procedures that are operative to enable individual, asynchronous operation of each of the processing modules within ASIC **38**. More particularly, upon receiving an interrupt signal, CPU **48** feeds a line of digital data values residing in buffer **42** to random access memory (RAM) controller **52** for storage in random access memory (RAM) **54** which constitutes a unified, shared memory. RAM **54** also stores instructions and data for CPU **48** including lines of digital data values and data being transferred between individual modules in ASIC **38**, all under control of RAM controller **52**.

[0032] Transducer **14**, as mentioned above, incorporates receiver **16** that operates in connection with transmitter **28** to generate location information. The location information is supplied to (or created by) controller **20** which outputs location data in a known manner. Location data is stored (under the control of the CPU **48**) in RAM **54** in conjunction with the storage of the digital data value.

[0033] Control procedures **50** control front end timing controller **45** to output timing signals to transmitter **18**, signal conditioner **34**, beamformer **36**, and controller **20** so as to synchronize their operations with the operations of modules within ASIC **38**. Front end timing controller **45** further issues timing signals which control the operation of the bus **46** and various other functions within the ASIC **38**.

[0034] As aforesaid, control procedures **50** configure CPU **48** to enable front end data controller **44** to move the lines of digital data values and location information into RAM controller **52** where they are then stored in RAM **54**. Since CPU **48** controls the transfer of lines of digital data values, it senses when an entire image frame has been stored in RAM **54**. At this point, CPU **48** is configured by control procedures **50** and recognizes that data is available for operation by scan converter **58**. At this point, therefore, CPU **48** notifies scan converter **58** that it can access the frame of data from RAM **54** for processing.

[0035] To access the data in RAM **54** (via RAM controller **52**), scan converter **58** interrupts CPU **48** to request a line of the data frame from RAM **54**. Such data is then transferred to buffer **60** of scan converter **58** and is transformed into data that is based on an X-Y coordinate system. When this data is coupled with the location data from controller **20**, a matrix of data in an X-Y-Z coordinate system results. A four-(4-) dimensional matrix may be used for 4-D (X-Y-Z-time) data. This process is repeated for subsequent digital data values of the image frame from RAM **54**. The resulting processed data is returned, via RAM controller **52**, into RAM **54** as display data. The display data is stored separately from the data produced by beamformer **36**. CPU **48** and control procedures **50**, via the interrupt procedure described above, sense the completion of the operation of scan converter **58**. Video processor **64**, such as the MITSUBISHI VOLUMEPRO series of cards, interrupts CPU **48** which responds by feeding lines of video data from RAM **54** into buffer **62**, which is associated with the video processor **64**. Video processor **64** uses video data to render an ultrasound image on monitor **40**.

[0036] One such system that embodies the techniques of the present invention is the EnVisor Series Ultrasound System manufactured by Philips Medical Systems. The EnVisor series is a powerful ultrasound imaging and image review tool capable of imaging in a variety of modes, including a three-dimensional mode and a panoramic imaging mode. Storing, managing, and reviewing images, as well as performing measurements and calculations using a comprehensive analysis package is possible using a system such as the EnVisor Ultrasound System. Intended uses of such a system include a variety of diagnostic ultrasound applications. These are outlined in the following Table 1.

TABLE 1

Ultrasound System Lateral Gain Control Uses

Imaging Application	2D Mode	M-Mode	PW Doppler	CW Doppler	Color Flow	Color Power Anglo	Calcs Analysis
Abdominal	X		X		X	X	X
Cardiac	X	X	X	X	X	X	X
Gynecological	X		X		X	X	X
Intra-operative	X		X		X	X	X
Musculoskeletal	X						
Neonatal Head	X		X		X	X	X
Obstetrical	X	X	X		X	X	X
Pediatric	X	X	X	X	X	X	X
Small Parts	X		X		X	X	X
Transcranial	X		X		X	X	X
Trans-esophageal	X	X	X	X	X		X
Vascular	X		X		X	X	X

[0037] Thus, the ultrasound imaging system in which the lateral gain control method and system of the present invention may be employed may provide two-dimensional analysis, M-mode analysis, pulsed wave analysis, continuous wave analysis, and support color flow studies. Moreover, color power angio and calcs analysis may be achieved with a system that employs the teachings of the present invention. With such a system, abdominal studies may be performed with fundamental or tissue harmonic imaging to obtain images that can be used for detecting abdominal organ abnormalities, evaluating organ size and texture, determining size, contour, and potency of vessels, characterizing obstructions, determining blood flow patterns and velocities, and guiding a biopsy needle, for example, may all be improved with the lateral gain control provided by the present invention. Cardiac studies may be performed with fundamental or tissue harmonic imaging to obtain images that can be used for detecting abnormalities in heart anatomy and blood flow, determining the blood flow patterns and velocities in the heart and associated, vessels, and imaging and measuring anatomic parameters of the heart and associated vessels.

[0038] Gynecological studies are performed with fundamental or harmonic tissue imaging to obtain images that can be used for visualizing female reproductive organs, determining blood flow patterns and velocities, guiding a biopsy needle, and detecting structural abnormalities.

[0039] Intraoperative studies are performed during surgery to obtain images that can be used to help the surgeon locate and visualize anatomical structures, visualize blood flow patterns and quantify velocities, and image and measure anatomical and physiological parameters of interest. Musculoskeletal studies may be performed to obtain images that can be used for evaluating tendon, ligament, and muscle size and contour, detecting pathology and other abnormalities, and evaluating integrity of tendons and ligaments.

[0040] Neonatal head studies are performed to obtain an image of brain structures that can be used to detect abnormalities, such as abnormal ventricle size or a shift in the midline or flow abnormalities. In addition, neonatal head studies are often performed to detect bleeding. Moreover, obstetrical studies may be performed with fundamental or harmonic tissue imaging to obtain images of the fetus that can be used for detecting maternal or fetal structural abnormalities, imaging and measuring anatomic parameters of the fetus, and determining blood flow patterns and velocities. Vascular studies may be performed to obtain images that can be used for detecting vessel size, contour, characterizing obstructions and abnormalities, determining blood flow patterns and velocities, imaging and measuring anatomic parameters of vessels, and detecting structural irregularities.

[0041] **FIG. 3** shows ultrasound imaging system **10** for using the LGC features of the present invention. As **FIG. 3** shows, monitor **40** is controlled by monitor controls **70** and may be positioned using rotation lock lever **72**. Monitor **40** presents ultrasound images and related data to the user. Soft keys **74** are programmable according to the particular function which ultrasound imaging system **10** performs such as those which have been already been described. System control panel **76**, which is described in more detail below, contains variable controls, including lateral gain controls **78**, as well as transducer holder **80** for holding transducer **14** and handles **82** for permitting easy movement of ultrasound imaging system **10**. Height release handle **84** permits adjustable positions system control panel **76** and monitor controls **70** according to the user's height.

[0042] Ultrasound imaging system **10** further includes drive **86** and physic panel **88**, as well as optical disk drive **50** and floppy disk drive **52** for receiving recordable media. Transfer conductors **94** supply data and power to transducer **14**. On/off button **96** and reset button **98** control power to ultrasound imaging system **10**. Using foot switch **100**, a user can control operation of ultrasound unit **12** through foot control. Movement of ultrasound imaging system **10** occurs through the use of wheels **102**, which wheel release **104**, wheel lock **106** and swivel lock **108** control.

[0043] Foot switch **100** allows three of the most commonly used functions to be operated with the user's foot. This keeps the users hands free to manipulate the transducer and the other system controls. The footswitch has three pedals that are configurable during 2D. Footswitch **100** behaves differently while the stress function is active.

[0044] **FIG. 4** shows system control panel **76** providing horizontal surface **110** that contains keyboard **112** a user may press, rotary controls **114** a user may turn, and TGC **116** slide controls that move left and right. The two LGC slide controls **118** of the present invention move up and down. Notice that keyboard **112**, rotary controls **114**, and slide controls **116** and **118** are grouped along with other controls with related functions. For example, Doppler controls **120** are grouped in the lower left corner.

[0045] Soft keys **74** are oval keys above system control panel **76** and below monitor **40**. The functions of the soft keys **74** change depending on the mode, the application, the preset, and the transducer. The function of each soft key **74** is described above the soft key on the bottom of the imaging screen. To use a soft key **74**, a user presses the up or the down arrow on the key to choose or change the selection that corresponds to the key on the imaging screen.

[0046] Trackball **124**, enter key **126**, and select key **128** work together somewhat like a computer mouse. Moving trackball **124** is like moving the mouse. Pressing enter key **126** is like pressing the left button on a mouse. In reviewing an image, pressing select key **128** is like pressing the right button on a mouse. To click an item on monitor **40** or to choose an option, the user moves trackball **124** to place the cursor over the item or the option and then presses enter key **126**.

[0047] **FIG. 5** shows imaging screen **130** that monitor **40** may display. Imaging screen includes scan sector **132**, along which lateral gain line **134** sweeps. Also appearing on screen **130** are soft key displays **136**, which display the functions to be performed by soft keys **74** of control panel **76**. Imaging screen **130** also includes settings and patient display region **138**. While scan sector **132** may vary, such as when multiple scan sectors **132** are displayed, instead of a single scan sector, soft keys functions **136**, settings and patient information **138**, however, always remain in the same location.

[0048] The various components of scan sector **132** appear diagrammatically at **FIG. 6**, which illustrates the scan format and some of the terminology to be used in the discussion of the present invention. Scan sector **132** is typically in the form of a wedge having a point of origin **140**. Scan lines, such as **142**, represent a transmitted and received signal at a particular angle, as measured with respect to a reference, such as one extremity of the scan region. These scan lines generally are not directly displayed, but are processed through the well-known technique of scan conversion, which forms no part of the instant invention, and will not be discussed herein. Region **144** is an example of TGC gain modification and may be varied by an operator in a band as a function of its radial distance from origin **140**. Region **146** is an example of gain modification in accordance with the principles of the present invention. An operator may vary the gain in subsector **146**, which may be a region having a predetermined angular size. Lateral gain control is constant as a function of its radial distance from origin **140**. It may also be constant within the subsector **146**. Subsector **148** is another example of where lateral gain may be used. It should be appreciated that the entire scan sector **132** may be subdivided into a predetermined number of subsectors, not illustrated, with each subsector having an associated LGC function.

[0049] The real time functions of ultrasound imaging system **10** and their associated controls can be classified as imaging modes, applications, and other functions. Imaging modes functions that change (or potentially change) the screen format. Applications functions that do not change the screen format, but take control of system resources, and possibly display dialog boxes, to accomplish a given task.

[0050] The LGC functions of the present invention have application in a wide variety of imaging modes, a few of which are here described. For example, the lateral gain control of the present invention may be used with gray scale real time two-dimensional imaging. LGC may also have application in the Color Flow mode, which provides in real time, two-dimensional imaging showing color overlaying a gray scale image in which the color is determined from the amount and direction of moving blood. The Color Angio mode of operation, which provides in real time two-dimensional imaging showing color overlaying a gray scale image in which the color is determined from the amplitude of moving blood. Moreover, the MMode, which is a gray scale time motion display having a selectable scroll rate may use the present invention. Other operational modes which may make use of the lateral gain control of the present invention include the Color MMode, which is a time motion display showing color overlaying gray scale in which the color is determined from the amount and direction of moving blood. Finally, the Doppler preview function, which presents a real time two-dimensional imaging (gray scale with optional color flow overlay) allowing prepositioning of the Doppler cursor, may also use the simplified lateral gain control of the present invention.

[0051] Once an imaging modality has been chosen, there are additional modes, controls, and system features that can be used to enhance, format, or annotate the image display. This is the point at which the LGC functions of the present invention come into play. Lateral gain controls are controls that give the user the ability to adjust the relative brightness laterally across an ultrasound image. These controls have not previously been used on specialty or general imaging ultrasound systems. Lateral gain controls on specialty ultrasound systems allow users to balance laterally image brightness in non-cardiac applications which would contribute to overall image quality. The LGCs work in conjunction with overall gain, TGCs and power to adjust the image brightness. In addition, LGCs enable certain measurements such as fetal head diameter to be taken in situations where they could not otherwise be reliably taken due to too much variability in brightness across the image. Although LGC sliders **118** are slider switches, other possible embodiments include paddle switches, rocker switches, and knobs.

[0052] As for the present embodiment, LGC sliders **118** adjust the amplification of returning ultrasound signals within the left and right halves of the image area. Referring to **FIG. 7**, moving an LGC slide potentiometer **118***a* up increase the amplification within its respective half of the image, while moving an LGC slide potentiometer **118***a* down will decrease the amplification within its respective half of the image. The left LGC slide potentiometer **118***a* controls the amplification on the side of the image nearest the transducer dot. The right LGC slide potentiometer **118***b* controls the amplification on the side of the image farthest from the transducer dot. For each control, the amplification increases with the distance from the center line of the image.

[0053] The algorithm for calculating LGC profile from two controls allows two continuously-variable gain adjustment controls to generate an entire LGC gain profile normally requiring many more controls. The profiles **180** through **190** of **FIG. 7** are limited to compound parabolic curves comprised of left hand half-parabolas joined at a fixed midpoint to independent right hand half-parabolas, which half-parabolas may take on different positive, zero, or negative curve angles. The left and right gain controls **118***a* and **118***b* govern the gain at the left and right ends of the compound curve respectively. The gain set by each control may range both below and above the fixed midpoint gain. Some examples of control positions and the resulting gain profiles are shown in **FIG. 7** as profiles **180** through **190**.

[0054] To calculate the gain profile, a larger number of virtual gain controls are assigned along the distance of the profile. The gain profile is then represented by the gain value at each virtual gain control. The concept of virtual gain controls is illustrated in **FIG. 8**. In particular, the various points of control values that may exist from left control point **190**, through midpoint control **198**, and on to right control point **206** include the other virtual control points **192**, **194**, **196**, **200**, **202**, and **204**. These points more of less correspond to the various positions of left gain control **118***a* and right gain control **118***b*. Calculation of a new gain profile is started when either the left or the right gain control is moved. This calculation is implemented through an LGC circuit, such as that of **FIG. 9**, to follow the logic described in **FIG. 10**. Note that the normalized gain of the midpoint is fixed at 0.5.

[0055] Although a variety of circuit configurations may achieve the LGC functions of the present invention, one such LGC circuit **150** appears in **FIG. 9**. In **FIG. 9**, box **152** represents a user interface, by which an operator may select LGC gain values for each subsector where LGC is desired. The use of operator adjustable potentiometers **154***a* through **154***h* is shown, however, with the present invention either a set of such potentiometers or other electrical configurations may be employed to achieve the various control setpoints of **FIGS. 7 and 8**. These potentiometers may be of the linear, as opposed to a rotary type, such as the potentiometers used to control the TGC gain profile on such systems. The analog control voltages generated by elements **154***a* through **154***h* are converted to digital format by analog multiplexer **156** and analog-to-digital converter **158**. This digital signal is applied to CPU **24**. While CPU **24** may be a dedicated processor, in the preferred embodiment, this processing function is implemented through the use of multiple processors, which are also used to control other system functions, such as beam formation. Also supplied to CPU **24** is an LGC enable command **160**, which may take the form of off/on switch **162**, or otherwise implemented in software instructions. An additional input to CPU **24** is the output of TGC generator **164**, which provides a TGC identification and value, and which may be implemented using structure similar to that used to generate the LGC commands. Also supplied to CPU **24** is the output of transducer identification generator **166** which provides information regarding the type of transducer being used.

[0056] When the LGC controls are enabled, CPU **24** will generate an LGC gain value for each scan line, which corresponds to the control signals selected by an operator via LGC control **118**. The LGC profile may be generated by retrieving precalculated values entered in internal memory of CPU **24** or it may be calculated as needed. **FIG. 8**, below illustrates in more detail how the present invention makes of use of only two LGC slider controls **118** to achieve the differing LGC control effects.

[0057] The LGC profile data is read into line gain RAM **54** via Data Line **170**. Although it does not form part of the present invention, in the preferred embodiment, Line **170** also contains gain information related to the earlier mentioned compensation for transducer gain variations. This transducer gain compensation is stored in memory and retrieved in response to a command (not shown) related to the transducer type or its operating frequency. Thus, for a given scan line, the data stored in RAM **54** represents the sum of the LGC signal, and the probe compensation signal. Data is retrieved from RAM **54** and applied to adder **172** in response to information regarding the particular scan line being generated, which is provided by line counter **174**, and the line type, (e.g., Doppler, Color Flow, 2-D Imaging) as indicated by line type counter **176**.

[0058] In the preferred embodiment, also applied to adder **172** is information related to the TGC gain profile. Data is retrieved from RAM **54** in response to depth (as measured with respect to origin **140** of **FIG. 6**) information provided by depth counter **178**.

[0059] The combined output signal of adder **172** is supplied via data line **180** to variable gain amplifier **68**. Depending on the nature of amplifier **68**, the signal contained on line **65** may remain in digital form, or if an analog control signal is required, Adder **64** may include a digital-to-analog converter. Any change to the settings of potentiometers **154***a*-**154***h* will result in new data being generated by processor **52**, and supplied via data line **53** to RAM **54**, which in turn updates the data stored in **54**. If the LGC control **48** is not enabled, then the data contained in data line **53** will only relate to the transducers probe configuration.

[0060] The present invention may also implement a gain save function for storing the current system gain settings as the system acquires each view for subsequently automatically restoring them. With this feature, the first time the ultrasound system acquires a view, the current gain settings (as defined by the current system control settings) are adjusted to control the way the image display appears to the user. These settings are stored with the view when the view is acquired. Each subsequent time the view is selected for acquisition, the gain settings that were stored the previous time the view was acquired are used. If the user manipulates the gain settings, then the new settings are stored with the view when the view is acquired. If the gain settings are not changed, then the original settings are preserved.

[0061] **FIG. 10** provides flow chart **210** for describing the process of the present invention for using a dual LGC control switch. Beginning at step **212**, the process senses the movement of left LGC control **118***a* (**FIG. 7**) and stores, at step **214**, the new left gain value. Then, if right LGC control **118***b* is sensed to have moved, at step **216**, the process stores the new right gain value at step **218**. Next, at step **220**, the process calculates normalized left and right gain values to have a range between 0 and 1. At step **222**, the process sets the current left and right controls to the outermost or actual controls. Then, at step **224**, the distance from a fixed midpoint to the current control position is calculated. At step **226**, a factor is calculated as the square of the distance measured relative to the maximum distance for the sensed signals. Step **228** sets the gain for the current left and right controls to equal the calculated factor times the left normalized value minus 0.5 (i.e., normalized left[or right] gain minus 0.5). The value 0.5 is then subtracted from the resulting product. At step **230**, the process sets the current left and right controls to the next virtual controls closer to the midpoint. Then, at query **232**, the test occurs of whether the current controls are at the midpoint. If so, then the value is used for the LGC signal that a circuit such as that of **FIG. 9** uses to control the lateral gain of the ultrasound image display.

[0062] In summary, the present invention provides a method and system for laterally controlling the gain of an ultrasound image for use in a general ultrasound imaging system. The method includes steps of generating an ultrasound image of an ultrasound analysis object using an ultrasound sensing circuit for sensing an ultrasound signal returning from an ultrasound analysis object to an ultrasound transducer. The ultrasound image includes a first region and a second region. The first region and the second region together form the ultrasound image, with the first region associating with a region of the ultrasound analysis object proximate to said ultrasound transducer. The second region associates with a region of said ultrasound analysis object distal from said ultrasound transducer. The method further includes the steps of laterally controlling in two-dimensions the brightness of the ultrasound image between the first region and the second region by controlling the amplification of the ultrasound signal using a first gain control circuit for controlling the signal amplification of the first region and a second gain control for controlling the signal amplification of the second region.

[0063] Accordingly, it is to be understood that the embodiments of the invention herein described are merely illustrative of the application of the principles of the invention. Reference herein to details of the illustrated embodiments is not intended to limit the scope of the claims, which themselves recite those features regarded as essential to the invention.

1. A method for laterally controlling the gain of an ultrasound image for use in a general ultrasound imaging system, the method comprising the steps of:

generating an ultrasound image of an ultrasound analysis object using an ultrasound sensing circuit for sensing an ultrasound signal returning from an ultrasound analysis object to an ultrasound transducer, said ultrasound image comprising a first region and a second region, said first region and said second region together forming completely said ultrasound image with said first region associating with a region of said ultrasound analysis object proximate to said ultrasound transducer and said second region associating with a region of said ultrasound analysis object distal from said ultrasound transducer;

laterally controlling in two dimensions the brightness of said ultrasound image between said first region and said second region by controlling the amplification of said ultrasound signal using a first gain control circuit for controlling the signal amplification of said first region and a second gain control for controlling the signal amplification of said second region.

2. The method of claim 1, further comprising the step of laterally controlling in two dimensions the brightness of said ultrasound image using a first slider switch for controlling the signal amplification of said ultrasound signal using said first region and a second slider switch for controlling the signal amplification of said second region.

3. The method of claim 1, further comprising the step of laterally controlling in two dimensions the brightness of said ultrasound image using a first rocker switch for controlling the signal amplification of said ultrasound signal using said first region and a second rocker switch for controlling the signal amplification of said second region.

4. The method of claim 1, further comprising the step of generating said ultrasound image of an ultrasound analysis object, wherein said ultrasound analysis comprises a gynecological analysis object.

5. The method of claim 1, further comprising the step of generating said ultrasound image of an ultrasound analysis object, wherein said ultrasound analysis comprises an abdominal analysis object.

6. The method of claim 1, further comprising the step of generating said ultrasound image of an ultrasound analysis object using a pulsed wave ultrasound signal.

7. The method of claim 1, further comprising the step of generating said ultrasound image of an ultrasound analysis object using a continuous wave ultrasound signal.

8. A general ultrasound imaging system providing lateral gain control for laterally controlling the gain of an ultrasound image, the system comprising:

ultrasound image forming circuitry for generating an ultrasound image of an ultrasound analysis object using an ultrasound sensing circuit for sensing an ultrasound signal returning from an ultrasound analysis object to an ultrasound transducer, said ultrasound image comprising a first region and a second region, said first region and said second region together forming said ultrasound image with said first region associating with a region of said ultrasound analysis object proximate to said ultrasound transducer and said second region associating with a region of said ultrasound analysis object distal from said ultrasound transducer; and

a lateral gain control circuit for laterally controlling in two-dimensions the brightness of said ultrasound image between said first region and said second region by controlling the amplification of said ultrasound signal using a first gain control circuit for controlling the signal amplification of said first region and a second gain control for controlling the signal amplification of said second region.

9. The system of claim 8, further comprising a first slider switch for controlling the signal amplification of said ultrasound signal using said first region and a second slider switch for controlling the signal amplification of said second region.

10. The system of claim 8, further comprising a first rocker switch for controlling the signal amplification of said ultrasound signal using said first region and a second rocker switch for controlling the signal amplification of said second region.

11. The system of claim 8, further comprising a first paddle switch for controlling the signal amplification of said ultrasound signal using said first region and a second paddle switch for controlling the signal amplification of said second region.

12. The system of claim 8, further comprising the step of generating said ultrasound image of an ultrasound analysis object using a pulsed wave ultrasound signal.

13. The system of claim 8, further comprising the step of generating said ultrasound image of an ultrasound analysis object using a continuous wave ultrasound signal.

14. The system of claim 8, further comprising the step of generating said ultrasound image of an ultrasound analysis object using an M-mode ultrasound signal.

15. A storage medium for storing instructions for use in a general ultrasound imaging system, said instructions for providing lateral gain control for laterally controlling the gain of an ultrasound image, the storage medium comprising:

ultrasound image forming instructions for generating an ultrasound image of an ultrasound analysis object using an ultrasound sensing circuit for sensing an ultrasound signal returning from an ultrasound analysis object to an ultrasound transducer, said ultrasound image comprising a first region and a second region, said first region and said second region together forming said ultrasound image with said first region associating with a region of said ultrasound analysis object proximate to said ultrasound transducer and said second region associating with a region of said ultrasound analysis object distal from said ultrasound transducer; and

lateral gain control instructions for laterally controlling in two-dimensions the brightness of said ultrasound image between said first region and said second region by controlling the amplification of said ultrasound signal using a first gain control circuit for controlling the signal amplification of said first region and a second gain control for controlling the signal amplification of said second region.

16. The storage medium of claim 15, further comprising instructions for laterally controlling in two dimensions the brightness of said ultrasound image using a first slider switch for controlling the signal amplification of said ultrasound signal using said first region and a second slider switch for controlling the signal amplification of said second region.

17. The storage medium of claim 15, further comprising instructions for laterally controlling in two dimensions the brightness of said ultrasound image using a first rocker switch for controlling the signal amplification of said ultrasound signal using said first region and a second rocker switch for controlling the signal amplification of said second region.

18. The storage medium of claim 15, further comprising instructions for generating said ultrasound image of an ultrasound analysis object, wherein said ultrasound analysis comprises a gynecological analysis object.

19. The storage medium of claim 15, further comprising instructions for generating said ultrasound image of an ultrasound analysis object, wherein said ultrasound analysis comprises an abdominal analysis object.

20. The storage medium of claim 15, further comprising instructions for generating said ultrasound image of an ultrasound analysis object using a pulsed wave ultrasound signal.

21. The storage medium of claim 15, further comprising instructions for generating said ultrasound image of an ultrasound analysis object using a continuous wave ultrasound signal.

* * * * *

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摘要(译)

超声成像系统横向增益控制电路与超声成像系统一起操作，用于使用超声感测电路产生超声分析对象的超声图像，用于感测从超声分析对象返回到超声换能器的超声信号。超声图像由第一区域和第二区域限定。第一区域和第二区域一起形成完整的超声图像。第一区域与靠近超声换能器的区域相关联，而第二区域与远离超声换能器的区域相关联。横向增益控制电路通过分别控制第一区域信号放大和第二区域信号放大来控制超声信号放大，从而控制两个区域之间的二维超声图像亮度。