(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 June 2005 (16.06.2005)

PCT

(10) International Publication Number
WO 2005/053664 A2

(51) International Patent Classification[7]: A61K 31/00

(21) International Application Number: PCT/US2004/039660

(22) International Filing Date: 24 November 2004 (24.11.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/525,208 26 November 2003 (26.11.2003) US

(71) Applicant: **TERATECH CORPORATION** [US/US]; 77-79 Terrace Hall Avenue, Burlington, MA 01803 (US).

(72) Inventors: **WONG, William**; 1041 Randolph Avenue, Milton, MA 02186 (US). **MAURER, David**; 19 Forest Street, Stoneham, MA 02180 (US). **BRODSKY, Michael**; 56 Regent Circle, Brookline, MA 02445 (US). **CHIANG, Alice, M.**; 4 Glenfeld East, Weston, MA 02493 (US).

(74) Agents: **HOOVER, Thomas, O.** et al.; Weingarten, Schurgin, Gagnebin & Lebovici, LLP, Ten Post Office Square, Boston, MA 02109 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

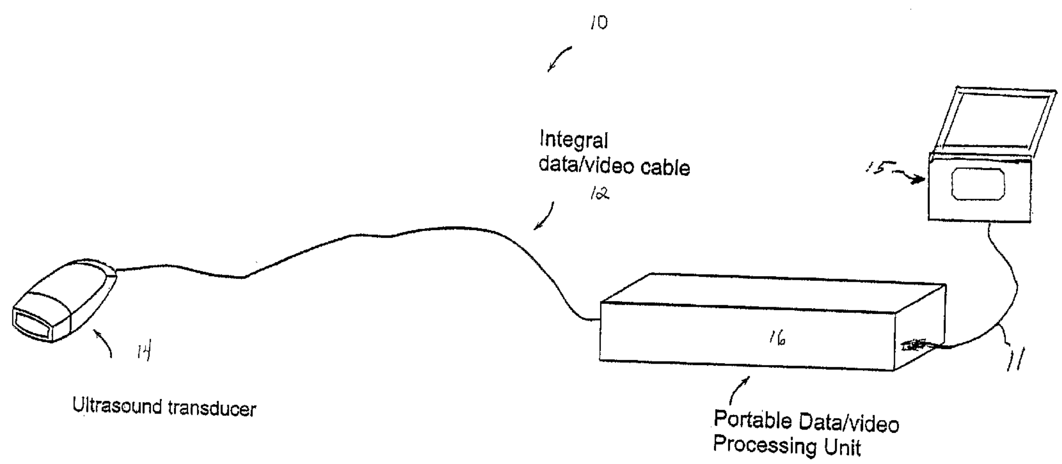
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*

[Continued on next page]

(54) Title: MODULAR PORTABLE ULTRASOUND SYSTEMS



(57) Abstract: The present invention relates to a lightweight, high resolution portable ultrasound system using components and methods to improve connectivity and ease of use. A preferred embodiment includes an integrated system in which the beamformer control circuitry can be inserted into the host computer as a peripheral or within the processor housing. The modular system can include a docking assembly for a cart system having a console to operate the system and house additional communications and peripheral systems.

WO 2005/053664 A2

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

Published:

— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

MODULAR PORTABLE ULTRASOUND SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority of Provisional Application number 60/525,208 filed November 26, 2003 entitled: MODULAR PORTABLE ULTRASOUND SYSTEM. The above application is incorporated entirely herein by reference.

BACKGROUND OF THE INVENTION

Conventional ultrasound imaging systems typically include a hand-held probe coupled by cables to a large rack-mounted console processing and display unit. The probe typically includes an array of ultrasonic transducers which transmit ultrasonic energy into a region being examined and receive reflected ultrasonic energy returning from the region. The transducers convert the received ultrasonic energy into low-level electrical signals which are transferred over the cable to the processing unit. The processing unit applies appropriate beam forming techniques to combine the signals from the transducers to generate an image of the region of interest.

Typical conventional ultrasound systems include a transducer array each transducer being associated with its own processing circuitry located in the console processing unit. The processing circuitry typically includes driver circuits which, in the transmit mode, send precisely timed drive pulses to the transducer to initiate transmission of the ultrasonic signal. These transmit timing pulses are forwarded from the console processing unit along the cable to the scan head. In the receive mode, beamforming circuits of the processing circuitry introduce the appropriate delay into each low-level electrical signal from the transducers to dynamically focus the signals such that an accurate image can subsequently be generated.

There still remains a need to provide stand-alone processing ultrasound units with the necessary hardware, for example, connectors to enable truly portable ultrasound systems that can function on an independent platform. There is a need for an ultrasound transducer connector assembly with an electrical connector of minimal mechanical complexity, size and cost.

SUMMARY OF THE INVENTION

The system and method of the present invention includes a hand held transducer probe that is connected by wire or wireless connection to a lightweight processing unit including a housing and internal circuitry for processing signals received from the probe. In a preferred embodiment the processing unit housing includes a display and manual and/or virtual controls that can control the display and processor operation, and a battery providing power to the processor housing and the transducer array. A preferred embodiment includes a console of a cart system to provide control features of the modular system.

In a preferred embodiment of the invention, the processor housing includes a transmit/receive (T/R) chip that communicates with the transducer array. A system controller communicates with the T/R chip, a local memory, a preamplifier/TGC chip, a charge domain beamformer circuit and a standard high speed communication interface such as IEEE 1394 USB connection to a system processor.

A preferred embodiment of the invention includes a connector system to secure the cable from the transducer probe to the processor housing. The connector system preferably uses a smaller lightweight connector than prior art systems yet meeting the standard shielding and mechanical strength and integrity requirements for medical ultrasound imaging systems.

A preferred embodiment of the invention includes a circuit that identifies the type of transducer array that has been connected to the housing. The circuit can be a single integrated circuit contained in the housing connector module that communicates with the processor and can include a memory storing calibration data for each probe. The display screen will display probe type information for the user. The connector system can include a connector actuator or lock that can be manually actuated by the user to secure the male and female connector elements. In a preferred embodiment a lever is rotated from a first position to a second position such that a cam element attached to the lever mates with a catch element on the cable connector element attached to the probe cable. The lever pulls the connector in and also operates to push the connector element out when actuated in the reverse direction thereby reducing the strain often caused by the user in pulling the cable connector element out of the housing connector element.

In accordance with a preferred embodiment, the method for performing an ultrasound scan on a region of interest of a patient includes connecting a probe to a portable processing unit with a connector system, locking the connector in place, employing the onboard identification circuit to identify the probe and display probe information on the display prior to the scan, entering patient information and performing the scan. Another preferred embodiment of the invention includes a cart system in which the processor housing and display can be connected or docked with a mobile station or cart having a control panel and a port assembly for receiving one or more transducer probes.

The foregoing and other features and advantages of the system and method for ultrasound imaging will be apparent from the following more particular description of preferred embodiments of the system and method as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a portable ultrasound imaging system including a hand-held probe in accordance with a preferred embodiment of the present invention.

FIG. 2 illustrates a modular portable system having a hand-held ultrasound transducer connected to a processing and display unit in accordance with the present invention.

FIG. 3 illustrates a single board computer and beamformer circuits that form the processing unit in accordance with a preferred embodiment of the present invention.

FIGS. 4A and 4B illustrate block diagrams of preferred embodiments of a modular, portable ultrasound system including a hand-held transducer assembly interfacing with a processing unit having the beamformer electronics in accordance with the present invention.

FIG. 4C illustrates a single chip, N-channel, time-multiplexed multiple beamforming processor with on-chip apodization and bandpass filter.

FIG. 5A illustrates a view of a stand alone portable ultrasound processing and display unit in accordance with a preferred embodiment of the present invention.

FIG. 5B illustrates an exploded view of the ultrasound processing and display unit shown in FIG. 5A in accordance with a preferred embodiment of the present invention.

FIGS. 6A and 6B illustrate a 10-inch and 12-inch display, respectively, that can be included in an ultrasound stand-alone unit in accordance with a preferred embodiment of the present invention.

FIG. 7 is a side view of an ultrasound processing and display unit in accordance with a preferred embodiment of the present invention.

FIGS. 8A-8B illustrate views of a single board computer included in the ultrasound stand alone unit in accordance with a preferred embodiment of the present invention.

FIG. 9 illustrates a view of the configuration of the computer boards in a stand alone ultrasound unit in accordance with a preferred embodiment of the present invention.

FIGS. 10A-10F illustrate views of the ultrasound processing unit configured for different applications such as different processing unit configured in different applications such as different original engineering manufacture (OEM) configurations and stand alone configurations in accordance with a preferred embodiment of the present invention.

FIG. 11 illustrates a schematic drawing of an analog board included in an ultrasound processing unit in accordance with a preferred embodiment of the present invention.

FIG. 12 illustrates a schematic view of a digital board and a power supply daughter board included in an ultrasound processing unit in accordance with a preferred embodiment of the present invention.

FIGS. 13A-13B illustrate the pin assignment of an electrically erasable programmable read only memory (EEPROM) and an electrically programmable read only memory integrated circuits, respectively, that can be included in the ultrasound processing unit in accordance with a preferred embodiment of the present invention.

FIG. 14 illustrates a semiconductor one-wire identification integrated circuit chip installed in transducer assemblies in accordance with a preferred embodiment of the present invention.

FIG. 15A illustrates a view of a graphical user interface display screen showing the appropriate transducer parameters upon connection of a transducer probe with the ultrasound processing unit in accordance with a preferred embodiment of the present invention.

FIG. 15B illustrates in tabular from characteristics of the ID chip system.

FIG. 15C illustrates a process sequence using the ID chip system..

FIG. 15D shows a schematic circuit diagram for a multiple connector assembly in accordance with the invention.

FIG. 15E illustrates a schematic circuit diagram for a multiplexed multiconnector system for transducer arrays.

FIG. 15F illustrates another preferred schematic circuit diagram for a multiconnector system for transducer arrays.

FIG. 16 illustrates an ultrasound processing unit and an ultrasound transducer connector in accordance with a preferred embodiment of the present invention.

FIGS. 17A and 17B illustrate views of an ultrasound transducer connector assembly in accordance with a preferred embodiment of the present invention.

FIG. 18 is an exploded view of the ultrasound transducer connector assembly illustrated in FIGS. 17A and 17B in accordance with a preferred embodiment of the present invention.

FIGS. 19A, 19B and 19C illustrate detailed views of the ultrasound transducer connector assembly including sectional views in accordance with a preferred embodiment of the present invention.

FIG. 20 illustrates a view of an ultrasound processing unit with an ultrasound transducer connector assembly having a lock in accordance with a preferred embodiment of the present invention.

FIGS. 21A and 21B illustrate a close-up view of an ultrasound transducer connector assembly inserted into a ultrasound processing unit and a cut-away view of the inserted ultrasound transducer connector assembly, respectively, showing a sliding lever in accordance with a preferred embodiment of the present invention.

FIGS. 22A and 22B illustrate views of an ultrasound transducer connector assembly inserted into an ultrasound processing unit having a lever to secure the connector assembly in accordance with a preferred embodiment of the present invention.

FIGS. 23A and 23B illustrate further details of the lever and an exploded view of the lever assembly of an ultrasound processing unit in accordance with a preferred embodiment of the present invention.

FIGS. 24A-24D illustrate different views of the ultrasound processing unit showing the ultrasound transducer connector assembly in accordance with a preferred embodiment of the present invention.

FIG. 25 illustrates a view of the ultrasound processing unit showing a partial view of the lever for the transducer connector assembly in accordance with a preferred embodiment of the present invention.

FIGS. 26A and 26B illustrate further views of the ultrasound processing unit showing the ultrasound transducer connector assembly in accordance with a preferred embodiment of the present invention.

FIGS. 27A-27C illustrate views of an ultrasound transducer connector in accordance with a preferred embodiment of the present invention.

FIGS. 28A-28C illustrate views of an alternate embodiment of an ultrasound transducer connector in accordance with the present invention.

FIG. 29 illustrates a schematic view of an ultrasound system including an ultrasound console having a remote hardware keypad in accordance with a preferred embodiment of the present invention.

FIG. 30 illustrates a schematic diagram of an ultrasound console in accordance with a preferred embodiment of the present invention.

FIGS. 31A-31F illustrate preferred embodiments of a modular ultrasound imaging system in accordance with the invention.

FIGS. 32A - 32D illustrate a preferred cart system for use in embodiment of a conjunction with a modular ultrasound imaging system in accordance with the inventors.

FIG. 33 illustrates a modular system having a plurality of transducer connectors.

FIG. 34 is a schematic circuit diagram of a modular cart system in accordance with a preferred embodiment of the invention

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Preferred embodiments of the present invention include modular, portable ultrasound systems that can be used as a stand-alone system. The preferred embodiments integrate the display with the processing unit which is then connected to different ultrasound transducer probes. Preferred embodiments as described in U.S. Patent Application No. 10/386,360, filed on March 11, 2003, the entire teachings of which are incorporated herein by reference, include a display integrated on the ultrasound transducer. The operator can easily view the image and operate the probe or scan head, as well as perform operations in the same local area with the other hand. The data/video processing unit is also compact and portable, and may be placed close to the operator or alternatively at a remote location. Optionally, in another embodiment, a display is also integrated into the data/video processing unit. The processing unit also provides an external monitor port for use with traditional display monitors.

FIG. 1 illustrates a preferred embodiment of a portable ultrasound imaging system 10 including a hand-held ultrasound transducer with integrated display and a portable processing unit. The ultrasound transducer 14 comprises any of the standard ultrasound transducer arrays. The interface 12 delivers signals from the array 14 to an interface processor housing 16 that can include a system controller and beamformer as described in detail below. A second cable interface 11 can include a Firewire (IEEE 1394) connection delivering a beamformed representation for further processing to a personal computer 15.

FIG. 2 illustrates a modular portable system having an ultrasound transducer connected to a processing and display unit in accordance with the present invention. In this preferred embodiment, the video and power wires for the display are integrated with the transducer data wires for the transducer to form a single cable assembly 24 that connects the ultrasound transducer to the portable data/video processing unit 26.

The data/video processing unit 16 is compact and portable. In a preferred embodiment, the beamformer electronics is an integral part of the processing unit and communicating with a single board computer 110 using a Firewire (IEEE 1394) cable as illustrated in FIG. 4A.

FIG. 3 illustrates the single board computer and beamformer circuits that form the processing unit in accordance with a preferred embodiment of the present invention. FIGS. 4A and 4B illustrate block diagrams of preferred embodiments of a modular, portable ultrasound system including a hand-held transducer assembly interfacing with a processing unit in accordance with the present invention.

In a preferred embodiment, the beamformer electronics is moved inside the processing unit to further reduce the size and weight of the hand-held transducer as illustrated in FIG. 4B. The processing unit 138 can comprise a compact single board 44 computer and the beamformer electronics as illustrated in FIG. 3. The beamformer electronics includes a digital processing printed circuit board and an analog processing printed circuit board 48. The beamforming electronics communicates with the single board computer via a Firewire (IEEE 1394) chip.

An operating environment for the system includes a processing system with at least one high speed processing unit and a memory system. In accordance with the practices of persons skilled in the art of computer programming, the present invention is described with reference to acts and symbolic representations of operations or instructions that are performed by the processing system, unless indicated otherwise. Such acts and operations or instructions are sometimes referred to as being "computer-executed", or "processing unit executed."

It will be appreciated that the acts and symbolically represented operations or instructions include the manipulation of electrical signals by the processing unit. An electrical system with data bits causes a resulting transformation or reduction of the electrical signal representation, and the maintenance of data bits at memory locations in the memory system to thereby reconfigure or otherwise alter the processing unit's operation, as well as other processing of signals. The memory locations where data bits are maintained are physical locations that have particular electrical, magnetic, optical, or organic properties corresponding to the data bits.

The data bits may also be maintained on a computer readable medium including magnetic disks, optical disks, organic disks, and any other volatile or non-volatile mass storage system readable by the processing unit. The computer readable medium includes cooperating or interconnected computer readable media, which exist exclusively on the processing system or is distributed among multiple interconnected processing systems that may be local or remote to the processing system.

In an embodiment, the compact single board computer has a printed circuit board size of a 5 ¼ inch disk drive or a 3 ½ inch disk drive. One embodiment of the present invention uses a NOVA-7800-P800 single board computer in a 5 ¼ inch form factor, with a low power Mobile Pentium-III 800 MHz processor, 512 Mbytes of memory, and has on board interface ports for Firewire (IEEE 1394), local area network (LAN), Audio, integrated device electronics (IDE), personal computer memory card international association (PCMCIA) and Flash memories.

For some dedicated applications, the entire ultrasound system includes the hand-held ultrasound transducer with an integrated display and the portable data/video processing unit. The system can be operated without any controls other than power on/off. For other applications, the system is equipped with an optional operator interface such as buttons and knobs, either on the processing unit, or integrated in the transducer assembly, or both. The processing unit can provide an additional video output to drive an external monitor, or optionally an integrated display on the processing unit itself.

The microprocessor in FIG. 4B provides the functionality for down conversion, scan conversion, M-mode, Doppler processing, color flow imaging, power Doppler, spectral Doppler and post signal processing.

FIG. 4C illustrates a single chip, N-channel time-multiplexed beamforming processor with on-chip apodization and bandpass filter in accordance with a preferred embodiment of the present invention. Beamforming circuits in accordance with preferred embodiments are described in U.S. Patent No. 6,379,304, issued on April 30, 2002, the entire teachings of which are incorporated herein by reference.

FIG. 5A illustrates a view of a stand alone portable ultrasound processing and display unit in accordance with a preferred embodiment of the present invention. The processing unit includes a motherboard single board computer. In a preferred embodiment, the motherboard has the following requirements that are fulfilled by a Pentium M, 512 MB of RAM or more, 10 GB hard drive, hard drive-free configuration. It includes a flash memory (approximately 1 GB) with a larger RAM (approximately 1 GB). The display that can be integrated into the processing unit may include a 10-inch or 12-inch display, having 1024 x 768 resolution, 200 Nits brightness as a minimum (after touch screen), 250 desirable, 400:1 contrast ratio, and have a large viewing angle. The ultrasound module can be connected using a 6 pin Firewire connection. The ultrasound module operates with 12 watt as maximum power.

The graphical user interface includes a touch screen having no drift, and providing for finger operation (no RF pens). The ports for the processing unit include at least 2 universal serial bus (USB) ports to connect an external keyboard, mouse, CDW, and an Ethernet port. The processing unit provides for battery operation, two hours minimum at peak processing power of 7 watt required for ultrasound.

A preferred embodiment of the processing unit provides for modularity with a removable processing unit 208 residing inside the ultrasound system. An ultrasound control pad module 212 and custom keyboard 204 can be made removable or configurable. The module 200 itself can also be used as an outside remote control module (USB or wireless) or as an OEM building block. The display module 202 can be made configurable (10-inch or 12-inch), Sun readable or configurable with different platforms. The module has a stand, as illustrated in FIG. 7. There is a protective cover for the display and controls in accordance with a preferred embodiment of the present invention. The unit may be re-used as a stand. A probe holder may be located on the side or on the top of the unit. In alternate preferred embodiments, the probe holder may also be engaged from the side when needed. The probe holder is easy to clean. A handle is provided for ease of carrying the unit. A universal mount that accommodates different holders, for example, tripods, arms, stands, is provided in accordance with a preferred embodiment of the present invention. The ultrasound unit can be docked and is rugged.

FIG. 5B illustrates an exploded view of the ultrasound processing and display unit shown in FIG. 5A in accordance with a preferred embodiment of the present invention. The unit 200 includes the modular display 202, the ultrasound processing unit 208 that includes the beamforming circuitry, a keyboard 204, a control pad module 204, a battery module 206 and the single board computer 214.

FIGS. 6A and 6B illustrate a 10-inch and 12-inch display, respectively, that can be included in an ultrasound stand-alone unit in accordance with a preferred embodiment of the present invention. As described hereinbefore, the display in accordance with a preferred embodiment of the present invention provides a resolution of 1024 x 768 and a large viewing angle.

FIG. 7 is a side view of an ultrasound processing and display unit having a stand in accordance with a preferred embodiment of the present invention.

FIGS. 8A-8B illustrates views of a single board computer included in the ultrasound stand alone unit in accordance with a preferred embodiment of the present invention. FIG. 8A illustrates a view of a single board computer 270 used in the ultrasound portable unit including the interface ports. . The interfaces include video graphics adapter (VGA) 281, a local area network (LAN) interface 282, a IEEE 1394 interface 283 and a PS/2 bus interface 284 which has a microchannel architecture. Further, the interfaces include a universal serial bus (USB) interface 285, a COM1 interface 286 which is a serial communications port, a Personal Computer Memory Card International Association (PCMCIA) interface 297 for PC-cards and a CFII interface 288. FIG. 8B illustrates a view 300 of an embedded mobile Pentium III processor single board computer with interfaces for VGA, LAN, audio, IEEE and video capture.

FIG. 9 illustrates a view of the configuration 310 of the computer boards in a stand alone ultrasound unit in accordance with a preferred embodiment of the present invention. An analog board 312 is spaced from a digital board 322. A transducer socket 314 having a at least a 160 pin socket is provided. A power supply daughter board 320 is provided and spaced from the analog and digital boards by a separator 316. A plurality of interfaces are also provided, for example, IEEE 1394 interface 318, and a Deutsch Industrie Norm (DIN) connector 324 which is a multipin connector conforming to the specifications of the German National Standards Organization.

FIGS. 10A-10F illustrate views of the ultrasound processing unit configured for different applications such as different processing unit configured in different applications such as different original engineering manufacture (OEM) configurations and stand alone configurations in accordance with a preferred embodiment of the present invention. A preferred embodiment includes the motherboard, display driver and ultrasound interface in the housing with the provisions for plug-in transducer arrays. An alternate embodiment includes stand-alone unit with a plug-in transducer array.

FIG. 10A illustrates an OEM configuration having a basic aluminum box with mounting holes. FIG. 10B illustrates the ultrasound processor inside a housing. FIG. 10C illustrates the ultrasound processing unit inside a PC drive bay. FIG. 10D illustrates an OEM configuration with FIG. 10E is a view of a stand-alone configuration three transducer connectors. A mutiplexor can be used to select which connector signals are being processed. having an OEM housing, a single board computer, a LCD, and a battery module. FIG. 10F illustrates the processing unit that can be connected in an OEM configuration or be a stand-alone unit.

An interlock is included to sense if a probe is present and to determine the calibration coefficient in accordance with a preferred embodiment of the present invention. A one wire identification (ID) chip for identifying the transducer is included in accordance with a preferred embodiment of the present invention. The computer can be pre-programmed with signal conditioning for each probe in accordance with a preferred embodiment of the present invention. By effectively connecting the probe, the circuit identifies the probe and accesses the pre-programmed conditions for that probe. Calibration coefficients are stored for each probe in the memory of the processing unit. The system can include multiple connection ports that allows for the connection of two or three probes to one system using a multiplexed interface.

FIG. 11 illustrates a schematic drawing of an analog board included in an ultrasound processing unit in accordance with a preferred embodiment of the present invention. A transducer connector is accommodated in region 452.

FIG. 12 illustrates a schematic view of a digital board 470 and a power supply daughter board 472 included in an ultrasound processing unit in accordance with a preferred embodiment of the present invention. Also provided is a mini-DIN interface 474, and IEEE 1394 interfaces 476, 484.

FIGS. 13A-13B illustrate the pin assignment of an electrically erasable programmable read only memory (EEPROM) and an electrically programmable read only memory integrated circuits, respectively, that can be included in the ultrasound processing unit in accordance with a preferred embodiment of the present invention.

FIG. 13A illustrates a 4096 bits, one-wire EEPROM that assures absolute identity as no two parts are alike. The memory is partitioned into sixteen 256-bit pages for packetizing data. This EEPROM identifies and stores relevant information about each ultrasound transducer to which it is associated. It is easily interfaced with using a single port pin of a microcontroller. The 4 Kb, one-wire EEPROM can be, for example, but not limited to a DS2433 circuit provided by Dallas Semiconductor.

FIG. 13B illustrates, for example, a DS2502/5/6 UNW UniqueWare™ add only memory chip provided by Dallas Semiconductor. The EPROM can be a 1024 bits, 16 kbits or 65 kbits memory and can communicate with the economy of one signal plus ground.

Preferred embodiment of the medical ultrasound systems use many transducers depending upon the application. These systems also identify which transducer is attached at any given time in accordance with a preferred embodiment of the present invention.

In addition to identifying the transducer type, preferred embodiments also identify the individual probe of the same type, such that calibration information can be associated with a particular probe. The one-wire ID circuits described with respect to FIGS. 13A and 13B provide identification of each transducer and corresponding calibration information by installing the semiconductor one-wire identification chips in each transducer assembly as shown in FIG. 14. FIG. 14 illustrates a semiconductor one-wire identification integrated circuit chip installed in transducer assemblies in accordance with a preferred embodiment of the present invention.

Each ID chip has a unique serial number, plus a writable/readable memory for storage of calibration or additional identification data. In an ultrasound application of a preferred embodiment, the serial number and probe type information are accessed from memory upon probe insertion. The information is used to call up the appropriate transducer parameters and the new probe is then made available to the user on the display screen, as shown in FIG. 15A. FIG. 15A illustrates a view of a graphical user interface display screen showing the appropriate transducer parameters upon connection of a transducer probe with the ultrasound processing unit in accordance with a preferred embodiment of the present invention.

In addition to the identification, each transducer is unique and it is desirable to calibrate out these differences in accordance with a preferred embodiment of the present invention. Therefore, software executable instructions are provided by the ultrasound applications control for storing and retrieving individual calibration data to the ID chip. Examples of calibration differences can include electrical, acoustic and mechanical differences. These may be used, but are not limited to, procedures such as mounting of needle guides for biopsy, three-dimensional positioning sensing devices and transducer element variation calibration.

A method of probe type identification is usually provided by using multiple connector pins which are tied to logic zero or one. To differentiate between 32 probe types, 5 connector wires are required. In the one-wire method, only a single wire is required, and the data is passed between the probe and the host system serially.

The invention incorporates a read/writable non-volatile memory chip (ID chip) in the transducer termination board, as shown in FIG. 14. An example of the memory chip is the Dallas Semiconductor DS2433 One-wire Idenfication chip with 4096 bits of non-volatile storage. Other non-volatile read/writable memory can be used, but the One-wire chip has the advantage of using only one signal wire and one ground wire, and does not require additional pins for power supply. The identification circuit can also include a radio frequenge wireless link that connects to the probe housing to identify the type of probe sending data to the ultrasound system.

The memory of the ID chip is organized as 128 words of 32 bits wide, divided into four segments: The IDENTIFICATION segment, the USAGE segment, the FACTORY segment and the USER segment shown in FIG. 15B.

The IDENTIFICATION segment holds the information which identifies the transducer type and hardware revision and serial number. The Ultrasound Application reads these information when a transducer is attached to a system and performs the appropriate set up based on the transducer type and hardware revisions. This segment is written at the factory and is not modifiable by the user.

The USAGE segment holds the statistical information about the usage of the transducer. The first entry logs the serial number and date when the transducer is first used outside of the factory (the Inauguration System Serial # and Date code). The second and third entries in this segment logs the serial number and the date of the two systems most recently the transducer was attached to. The Date Code values are Julian date of the conection date minus the Julian date of January 1, 2000. The 16 bit date code field can sotre dates of more than a century starting from the year 2000. The 16 but date code filed can store dates of more than a century starting from the year 2000. The fourth word of the USAGE segment is a counter which increments once per 5 minutes when a transducer is attached and activated in a system. These statistical information are updated in the field by the Ultrasound Application software, and is not modifiable by the user. The values are set to zeros before the transducer leaves the factory. These statistical information are read and recorded when a transducer is returned to the factory for service.

The FACTORY segement holds the factory calibration information for the transducer. Examples of factory calibration data are the per element gain and propagation delay fine adjustments. When a transducer is attached and activated by the Ultrasound Application, the application first reads the transducer ID information from the IDENTIFICATION segment and loads up the appropriate set ups for that particular transducer type. The application then reads the FACTORY segement and applies the fine adjustments to the transducer set up. This segment is written at the factory and is not modifiable by the user.

The USER segment is reserved for the end user to store post-factory calibration data. Example of post-factory calibration data are position information of needle guide brackets and 3-D position sensing mechanism. The USER segment is the only segment which the user application software can modify.

FIG. 15C shows the software flow-chart of a typical transducer management module within the ultrasound application program.

When a TRANSDUCER ATTACHE event is detected, the Transducer Management Software Module first reads the Transducer Type ID and hardware revision information from the IDENTIFICATION Segment. The information is used to fetch the particular set of transducer profile data from the hard disk and load it into the memory of the application program. The software then reads the adjustment data from the FACTORY Segment and aplies the adjustments to the profile data just loaded into memory. The software module then sends a TRANSDUCER ATTACHE Message to the main ultrasound application program, which uses the transducer profile already loaded and perform ultrasound imaging. The Transducer Management Software Module then waits for either a TRANSDUCER DETACH event, or the elapse of 5 minutes. If a TRANSDUCER DETACH is detected, the transducer profile data set is removed from memory and the module goes back to wait for another TRANSDUCER ATTACHE event. If a 5 minutes time period expires without TRANSDUCER DETACH, the software module increments the Cumulative Usage Counter in the USAGE Segment, and waits for another 5 minutes period or a TRANSDUCER DETACH event.

There are many types of ultrasound transducers. They differ by geometry, number of elements, and frequency response. For example, a linear array with center frequency of 10 to 15 MHz is better suited for breast imaging, and a curved array with center frequency of 3 to 5MHz is better suited for abdominal imaging.

It is often necessary to use different types of transducers for the same or different ultrasound scanning sessions. For ultrasound systems with only one transducer connection, the operator will change the transducer prior to the start of a new scanning session.

In some applications, it is necessary to switch among different types of transducers during one ultrasound scanning session. In this case, it is more convenient to have multiple transducers connected to the same ultrasound system, and the operator can quickly switch among these connected transducers by hitting a button on the operator console, without having to physically detach and re-attach the transducers, which takes a longer time.

The switching among different connected transducers can be implemented either by arrays of relays 554 as seen in FIG. 15E, or by arrays of high voltage Multiplexer integrated circuits 556, as seen in FIG. 15F (switching between two 128-

elements transducers). These relays or MUXVIC's form an additional layer of circuits between the ultrasound transmitter/receiver circuits and the transducer connectors.

The present invention utilizes a system that performed a method of multi-transducer switching using multiple Transmit/Receive integrated circuits 562, 564 as seen in FIG. 15D, without the use of relays or commercial multiplexer integrated circuits. A typical two transducer switching circuit using an integrated circuits in accordance with the invention deliver signals to the amplifier and beamformer circuit 565.

The Transmit/Receive integrated circuit includes multiple channel devices with a programmable waveform generator and high voltage driver for each transducer element, and a receive routing circuit for each element pair. The receive output is programmable to receive from transducer element 566 or 568 of the element pair, or turned off. The outputs of multiple integrated circuits are wired together. Connection to diferent transducers in the same system is achieved by programming the On/Off states of individual receive channels amoung the multiple integrated circuits, and by programming the transmit sequence of each of the transmit channels on all of the integrated circuits.

One advantage of this approach is the higher intergration over the use of commercial available relays and multiplexer chips, especially when compared to a relay switching approach, because relays are mechanical devices and are generally larger. There are two versions of these, Transmit/Receive integrated circuits, one version has 64 transducer element channels and another version has 32 transducer channels. This high channel count integration of at least 32 channels combined with the small high pin density transducer connector, allows implementation of a multiple transducer configuration in a very compact size.

Another advantage is the elimination of an extra circuit layer, when compared to the multiplexer chips approach. Typical commercial multiplexer chips suitable for ultrasound channel switching typically have an ON resistance of greater than 20 ohms (example, Supertex HV20220), and therefore have measureable attenuation of both the transmit and receive signals compared with a direct connection in a single transducer system. The present approach has identical transmit/receive circuit for single transducer system, or multiple transducers system, with no additional signal attenuation resulting from adding the multiple transducers switching function.

Yet another advantage of the present approach is the added ability to operate a very large element count transducer with a true full transmit aperture. For example, a 128 channel ultrasound engine can operate a 768 element linear array by adding a one to six multiplexer array. A traditional implementation using relays of multiplexers can switch among six segements of 128 elements each across the entire 768 elements at any one time. The present approach will have 768 programmable transmitter, and therefore can use any size of transmit aperture anywhere on transducer array, including using the entire 768 element at the same time. The ability to use larger than 128 element transmit aperture allows the ultrasound system to have better penetration and resolution, compared to systems that are limited to 128.

FIG. 16 illustrates an ultrasound processing unit and an ultrasound transducer connector in accordance with a preferred embodiment of the present invention. An ultrasound transducer is coupled to its associated ultrasound processing unit 572 via a cable, which is routed into an ultrasound transducer connector assembly 574 and, mates with a corresponding terminal located on ultrasound console. A sliding lever is included to secure the connector to the processing unit.

FIGS. 17A and 17B illustrate views of an ultrasound transducer connector assembly in accordance with a preferred embodiment of the present invention. The ultrasound transducer connector assembly 18 shows a connector housing. FIG. 18 is an exploded view of the ultrasound transducer connector assembly illustrated in FIGS. 17A and 17B in accordance with a preferred embodiment of the present invention. An electrical connector 606 may have 160 contacts or more. The connector assembly housing 604, 610 interfaces with a cable 602 which in turn is coupled to an ultrasound transducer.

FIGS. 19A, 19B and 19C illustrate detailed views of the ultrasound transducer connector assembly including sectional views in accordance with a preferred embodiment of the present invention. A cable 640 is attached to a first end of connector housing element 630. A close-up view 620 of connector assembly element 620 is seen in FIG. 19A. A side view 650 is shown in FIG. 19C.

The movable connector component has electrical contacts that mate with the stationary connector component having stationary electrical contacts on the processing unit. For mating, the movable connector component is brought towards the stationary connector component. Initially, there is a gap separating the movable electrical contacts from stationary electrical contacts, so that the contacts are not subjected to any friction or insertion force. A locking mechanism draws in the movable connector component which is received in a recess of the stationary connector component. The lever slides from right to left causing the movable connector component to close into the recess and contact the corresponding stationary electrical contacts to make an electrical connection. The ultrasound transducer connectors minimize the physical stress exerted upon their electrical contacts, thus avoiding wear and potential damage to the contacts.

FIG. 20 illustrates a view of an ultrasound processing unit with an ultrasound transducer connector assembly 674 having a lock 672 in accordance with a preferred embodiment of the present invention. FIGS. 21A and 21B illustrate a close-up view of an ultrasound transducer connector assembly inserted into a ultrasound processing unit and a cut-away view of the inserted ultrasound transducer connector assembly, respectively, showing a sliding lever in accordance with a preferred embodiment of the present invention. The connector is drawn in the end of the housing when inserted and locked and is ejected when detached. The connector assembly in accordance with a preferred embodiment of the present invention allows for a one-hand operation. A preferred embodiment of the present invention includes a sash lock similar to a window lock. The lever includes a lever action which also yields a significant mechanical advantage as it translates insertion force to a lateral action of the lock. The lever for the connector assembly is resistant to abusive use as it has rails which act with the lever to eliminate twists applied to the connector. A rotating catch is used to eject the connector after use.

FIGS. 22A and 22B illustrate views of an ultrasound transducer connector assembly inserted into an ultrasound processing unit 700 having a lever 732 shown in the detailed portion 720, to secure the connector assembly in accordance with a preferred embodiment of the present invention.

FIGS. 23A and 23B illustrate further details 730 of the lever 732 and an exploded view 740 of the lever assembly of an ultrasound processing unit in accordance with a preferred embodiment of the present invention. The lever assembly includes a spring 742 which being a resilient member, assists in drawing the lever 744 into the locked position.

FIGS. 24A-24D illustrate several views of the ultrasound processing unit showing the ultrasound transducer connector assembly in accordance with a preferred embodiment of the present invention. Circuit boards are mounted in FIGS. 24B and 24C along with the connector assembly in accordance with the invention.

FIG. 25 illustrates a view of the ultrasound processing unit 800 showing a partial view of the lever for the transducer connector assembly in accordance with a preferred embodiment of the present invention.

FIGS. 26A and 26B illustrate further views 810, 820 of the ultrasound processing unit showing the ultrasound transducer connector assembly in accordance with a preferred embodiment of the present invention.

FIGS. 27A-27C illustrate views of an ultrasound transducer connector in accordance with a preferred embodiment of the present invention. In a preferred embodiment the maximum voltage of the ultrasound transducer connector can be 100 volts. The connector can include 160 or 240 pins or more. The base plate protects the pins and rises up into position during printed circuit board insertion. In one embodiment the connector assembly includes, but is not limited to, a Molex® 53941 right angle docking station board-to-board shielded plug.

FIGS. 28A-28C illustrate views of an alternate embodiment of an ultrasound transducer connector in accordance with the present invention. In this preferred embodiment the connector assembly includes, but is not limited to, a Molex® 54145 right angle docking station board-to-board shielded receptacle. Alternatively, a molex®3441 connector can be used. The specification of these connectors being incorporated herein by reference. These a small high density pin connectors having a pin pitch of less than 1mm, and preferably 0.8mm or less. The connectors can have 160 pins, 192 pins, 250pins or more. When this system is used in connection with the insertion and release mechanism described in connection with FIGS. 20-26, this provides a secure and reliable connection assembly that fits within a smaller and lighter assembly for portable applications. Note that there is a probe present pin is an interlock to indicate that a probe has been inserted correctly.

FIG. 31 illustrates a schematic view of an ultrasound system including an ultrasound console having a remote hardware keypad in accordance with a preferred embodiment of the present invention. The system includes a console 950 connected with a USB/PS/2 interface to a host computer 960.

FIG. 32 illustrates a schematic diagram of an ultrasound console in accordance with a preferred embodiment of the present invention. A universal serial bus (USB) console is used for a remote hardware keypad. This hardware user interface in accordance with a preferred embodiment of the present invention displaces a software graphical user interface and allows any ultrasound imaging control function to be accessed via a control keypad. The controls are communicated with a host computer through a USB port.

In a preferred embodiment, the ultrasound console includes a USB device and USB Driver which is implemented with a FTDI USB245M controller chip, for example. This integrated chip is simple as it can be integrated into the console without requiring a custom device driver. The USB Console uses the FTDI supplied dynamic link library (DLL) device driver in accordance with a preferred embodiment of the present invention.

The console in accordance with a preferred embodiment of the present invention is made up of at least four types of hardware functions: buttons, potentiometers, trackball, and LEDs. The buttons are momentary switches. The architecture in accordance with a preferred embodiment of the present invention allows for 128 buttons. The potentiometers are either linear slide potentiometers for time gain control (TGC), or rotary dials for GAINs. Each potentiometer can have a position reading between 0 and 255. A digital potentiometer with clickers is considered to be a button, not a potentiometer in the preferred embodiments. One embodiment includes 11 potentiometers: 8 slide switches numbered from 0 to 7, for TGC and three rotary dial potentiometers numbered 8 to 10.

In a preferred embodiment, a trackball is a stand-alone unit which communicates with the host system via a PS/2 interface or USB interface. The trackball may go to the host system directly, or combined with the console the USB interface via a USB hub.

In a preferred embodiment, light emitting diodes (LEDs) are provided on the console and can be individually addressed to turn on or off. A preferred embodiment has 8 LEDs, numbered from 0 to 7, and the LEDs are located at the buttons #0 to 7 respectively.

A preferred embodiment includes a software interface protocol from the console to a host system. When a button is pressed or a potentiometer position is changed, a three byte message is sent from the console to the host. Tables 1 and 2 illustrate, respectively, the message sent by using a button and a potentiometer in accordance with a preferred embodiment of the present invention.

Table 1

Button Message

	Bit 7	6	5	4	3	2	1	0
Byte #0	1	1	1	1	1	1	1	1
Byte #1	0	Button number						
Byte #2	X	X	X	X	X	X	X	X

Table 2

Potentiometer Message

	Bit 7	6	5	4	3	2	1	0
Byte #0	1	1	1	1	1	1	1	1
Byte #1	0	Potentiometer number						
Byte #2	Potentiometer position value							

The host may send a "Query" command to the console, and the console responds by sending Potentiometer Messages for every potentiometer on the console in accordance with a preferred embodiment of the present invention. Messages can be sent back-to-back in a preferred embodiment.

A preferred embodiment also includes a software interface protocol from a host system to a console. The host can send messages to the console to turn LEDs on/off, or to query the current readings of every potentiometer. Tables 3, 4 and 5 provide the LED-On message, LED-Off message and a query message, respectively, in accordance with a preferred embodiment of the present invention.

Table 3

LED-ON Message

	Bit 7	6	5	4	3	2	1	0
Byte #0	1	1	1	1	1	1	1	1
Byte #1	0	0	0	0	0	0	0	1
Byte #2	0	LED number						

Table 4

LED-OFF Message

	Bit 7	6	5	4	3	2	1	0
Byte #0	1	1	1	1	1	1	1	1
Byte #1	0	0	0	0	0	0	1	0
Byte #2	0	LED number						

Table 5

Query Message

	Bit 7	6	5	4	3	2	1	0
Byte #0	1	1	1	1	1	1	1	1
Byte #1	1	0	0	0	0	0	0	0
Byte #2	0	X	X	X	X	X	X	X

FIG. 30 illustrates the USB console for remote key pad in accordance with a preferred embodiment of the present invention. It is a hardware user interface and allows any ultrasound imaging control function to be accessed via a "traditional" control key pad. The control keys include, trackball with right and left enter keys, dedicated Freeze/live key, dedicated Save key, 8 Slide potentiometers each with a lateral movement to control the TGC gain, dedicated overall B-mode gain control pot, dedicated overall Color Flow Imaging gain control potentiometer, dedicated overall Pulsed Wave Spectral Doppler gain control pot, dedicated B-mode selection key, dedicated Power Doppler-mode selection key, dedicated Color Flowing Imaging-mode selection key, dedicated Pulsed Wave Spectral Doppler selection key, dedicated M-mode selection key, and dedicated Triplex selection key.

An LED is provided on each mode selection key. Once a mode is selected by a user, the selected mode-control key lights up.

The basic module system of the present invention is an external peripheral 16, 26 to a personal computer as shown generally in FIG's 1-3 or a basic system configuration of the system pairs it with an off-the-shelf notebook computer with a firewire port. An important advantage of this configuration is that the system gets its power from the notebook computer via the single Firewire cable. No additional power supply is needed. The combination of the peripheral 16,26 and the notebook computer can both run on the battery of the computer, making the system very portable.

The modular system can be structured as a transformable system: a fully portable ultrasound system consisting of the ultrasound module and a notebook computer in a single portable suitcase, and which can be converted into a full feature cart system for stationary use.

The suitcase configuration shown in FIG.'s 31A-31F integrates the ultrasound module and the notebook computer into a single suitcase package. An off-the-shelf consumer notebook computer 1004 with control panel or keyboard 1008 and display 1006 is secured to the suitcase using a low cost molded bracket 1005 shaped for the particular notebook model. Alternate notebook computer models can be used with a different molded bracket.

As seen in FIG 31F, the ultrasound module 1018 is situated in the base 1016 and base cover 1015 and top 1012. A handle 1002 can be extended from the housing base 1010 so that a user can carry the system with one hand. The system can be connected to, or dock with a console of a cart system seen in FIG.'s 32A-32D this embodiment of the invention utilizes a mobile cart system for use in connection with a portable ultrasound imaging system. Shown in FIG. 33 is a system having a plurality of transducer cable connectors 1144, 1146.

This system can use the switching systems described in connection with FIGS. 15D-15F, for example.

The cart system 1100 uses a base assembly 1108 and a USB hub 1220. The base assembly can be connected to a docking bay 1222 that receives the processor housing 1000. A preferred embodiment of the docking bay system as seen in FIG. 34 provides electrical interface connections between the base assembly and the processor housing at docking connector 1205. The base assembly can further include a control panel 1150 such that the user can control certain operations of the ultrasound system using control elements on the control panel 1150.

The cart configuration docks the suitcase module 1000 to a cart 1100 with a full operator console 1118. Once docked, the cart and the suitcase together forms a full feature roll-about system 1200 shown in the schematic control circuit diagram of FIG. 34. that may have other peripherals added, such as printers and video recorders. The docking mechanism is a simple, cable-less mating connection, very much like the desk top docking station for a notebook computer. This easy docking scheme allows the user to quickly attach or detach the suitcase to convert the system between stationary use(cart), and portable use.

The user console 1118 on the cart is designed with a USB interface. The electronics on the console gets its power from the USB bus from the battery in housing 100, eliminating the need for an additional power source. However, parts 1211 and 1362 with transformer 1360 and outlets 1324, 1326 can also be used for power distribution and access. The user console is attached to the notebook computer via the USB port of the notebook computer, routed through the docking connector of the suitcase.

An alternate design of the user console 1118 duplicates the cart base console design in a smaller portable console with the same USB interface. This portable console can be plugged into the suitcase without the cart.

With a USB powered console, the cart system can operate solely on the notebook computer battery without the need for being connected to the wall AC power outlet, or, when the cart system is running on wall AC power, it can continue to operate during power outage.

The cart system duplicates many of the notebook computer peripheral ports so that the cart system has as much features as a full blown computer, such as network connection 1203and printer ports second USB hub 1320 to printer 1340. A VOR, 1350 can receive S Video through docking connections 1205, 1222 from processor 1004. There is also an Svideo port 1207. The first USB hub 1220 is connected via docking parts with the computer USB port and with the second hub 1320. Control elements 1150 can be used to operate the cart system 1200 through hub 1220. The portable system 1000 has one or more connector and beamformer system 1014 with 1394 interface an EKG port 1208, a microphane port 1204, ethernet port 1203, USB port 1202, Svideo port 1207 and power access 1201. The console 1118 has power access 1211, ethernet 1212, USB port 1213, microphane 1216 and EKG port 1214. DC 1302 and USB 1306 connections run from the console to the lower base unit6 1300.

In view of the wide variety of embodiments to which the principles of the present invention can be applied, it should be understood that the illustrated embodiments are exemplary only, and should not be taken as limiting the scope of the present invention. For example, the steps of the flow diagrams may be taken in sequences other than those described, and more or fewer elements may be used in the block diagrams. While various elements of the preferred embodiments have been described as being implemented in software, other embodiments in hardware or firmware implementations may alternatively be used, and vice-versa.

It will be apparent to those of ordinary skill in the art that methods involved in the system and method for determining and controlling contamination may be embodied in a computer program product that includes a computer usable medium. For example, such a computer usable medium can include a readable memory device, such as, a hard drive device, a CD-ROM, a DVD-ROM, or a computer diskette, having computer readable program code segments stored thereon. The computer readable medium can also include a communications or transmission medium, such as, a bus or a communications link, either optical, wired, or wireless having program code segments carried thereon as digital or analog data signals.

The claims should not be read as limited to the described order or elements unless stated to that effect. Therefore, all embodiments that come within the scope and spirit of the following claims and equivalents thereto are claimed as the invention.

CLAIMS

What is claimed:

1. An ultrasound imaging system comprising: an ultrasound image processor housing having a display and a first docking connector; a base assembly that receives the processor housing, the base assembly having a second docking connector; and a control element on the base assembly that controls an operation of an image processor in the processor housing such that ultrasound image data are displayed on the display.

2. The system of claim 1 further comprising a transducer probe connector on the processor housing.

3. The system of claim 2 wherein the processor further comprises an outer housing having the first docking connector, a computer, the display and beamformer housing.

4. The system of claim 3 wherein the beamformer housing further comprises a plurality of transducer connectors.

5. The system of claim 4 wherein each transducer connector is connected to a transmit and receive circuit.

6. The system of claim 5 wherein each transmit and receive circuit is connected to a digital control circuit and a beamforming circuit.

7. The system of claim 2 wherein the transducer connector includes a housing connector element having a lock assembly.

8. The system of claim 7 wherein the lock assembly comprises a manually activated lever that mates with a catch on a transducer probe connector element.

9. The system of claim 1 further comprising a transducer identification circuit.

10. The system of claim 1 wherein the base assembly further comprises a console, the control element being mounted to the console.

11. The system of claim 1 wherein the base assembly further comprises a first universal serial bus (USB) hub.

12. The system of claim 11 wherein the first USB hub is connect to a printer mounted on the base assembly.

13. The system of claim 10 wherein the console further comprises a second USB hub that is connected to the second docking connector.

14. The system of claim 1 wherein the control element compromises a plurality of controls that control operations of the image processor.

15. The system of claim 3 wherein the beamformer housing includes a beamformer device and a Firewire interface connected to the computer.

16. The system of claim 1 wherein the image processor housing further comprises an ethernet port, a USB port, as video port, a microphone port, an EKG port, and a power source connector.

17. The system of claim 1 wherein the base assembly further comprises a VCR.

18. The system of claim 13 wherein the second USB hub is connected to the control element, a second ethernet port, a second USB port and the first USB hub.

19. The system of claim 2 wherein the transducer probe connector comprises a probe identification circuit.

20. The system of claim 19 wherein the probe identification circuit comprises a radio frequency link to a transducer probe to identify the type of probe transmitting signals to the processor housing.

21. The system of claim 2 wherein the connector has at least 160 pins and a pitch between pins of less than 1 mm.

22. The system of claim 21 wherein the connector has at least 250 pins.

23. The system of claim 21 wherein the pitch between pins is 0.8mm or less.

24. The system of claim 21 wherein the probe connector comprises an insertion device.

25. The system of claim 24 wherein the insertion device comprises a lever that engages the probe connector.

26. The system of claim 24 wherein the insertion device comprises a lock assembly.

27. The system of claim 25 wherein the lever has a mating surface that mates with a catch on the probe cable connector.

28. The system of claim 1 further comprising a beamformer housing comprising a beamformer, a system controller, a memory, a standard communication interface and a connector that connects the beamformer housing to a transducer probe cable.

29. The system of claim 1 further comprising a plurality of computer programs stored on a computer in the processor housing, the programs including a scan conversion program, a doppler processing program and a transducer identification program.

30. A portable ultrasound imaging system comprising:

a probe housing including a transducer array;

a processor housing including a port for receiving ultrasound image data from the probe housing; and

a probe identification circuit in the housing, the probe identification circuit identifying each of a plurality of probes that can communicate image data to the processor housing.

31. The system of Claim 30 further comprising a cable that connects the probe housing to the processor housing with a connector system.

32. The system of Claim 31 further comprising a cable connector element and a housing connector element that can be attached with a lock assembly.

33. The system of Claim 32 wherein the lock assembly includes a manually actuated lever that is attached to the housing and having a mating surface that mates with a catch on the cable connector element.

34. The system of Claim 30 wherein the probe identification circuit comprises an integrated circuit mounted on a connector system assembly in the processor housing.

35. The system of Claim 34 wherein the probe identification circuit comprises a one-wire identification circuit.

36. The system of Claim 34 wherein the probe identification circuit comprises a programmable, writable and readable memory to store calibration information.

37. The system of Claim 30 wherein the processor housing further comprises a display and a control panel.

38. The system of Claim 30 wherein the processor housing includes a beamforming circuit, a system controller and an image processor.

39. The system of Claim 38 further comprising an analog to digital converter that receives beamformed data and a

Firewire interface that delivers converted beamformed data to the image processor.

40. A method of imaging a region of interest with ultrasound energy comprising:

providing a portable ultrasound imaging system including a transducer array within a handheld probe, a cable interface that is connected to a data processor housing having a data processing system, and a peripheral device inserted into a port of the processor housing, the peripheral device including a connector for the cable interface, a beamforming device and a system controller connected to the beamforming device,

providing output signals from the data processor to the handheld probe to actuate the transducer array;

delivering ultrasound energy to the region of interest;

collecting ultrasound energy returning to the transducer array from the region of interest;

transmitting data from the handheld probe to the processor housing with the cable interface; and

performing a beamforming operation with the beamforming device in the peripheral device such that the data processing system receives a beamformed electronic representation of the region of interest from the beamforming device.

41. The method of Claim 40 further comprising providing a peripheral device including a Firewire interface.

42. The method of Claim 40 further comprising providing a probe identification circuit in the peripheral device.

43. A portable ultrasound system for imaging a region of interest comprising:

a handheld probe in which a transducer array is mounted; and

a data processing system within a data processor housing the housing including an electronic device that is connected to the handheld probe with a cable interface, such that the data processing system receives a representation of the region of interest, from the electronic device using a communication interface the electronic device including a programmable beamforming device and a system controller connected to the beamforming device.

44. The system of Claim 43 further comprising a Firewire connection between the electronic device and the data processing system.

45. The system of claim 43 further comprising a probe identification circuit.

46. A connector device for a Transducer probe of an ultrasound imaging system comprising: A transducer probe having a cable and a first connector; a circuit housing having a second connector that receives ultrasound image signals from the transducer probe; the second connector having an actuator that engages the first connector.

47. The connector of claim 46 wherein the actuator comprises a lever that moves from a release position to an engage position.

48. The method of claim 43 wherein said gas sampling unit is communicatively coupled to a communications network.

49. The connector of claim 46 wherein the first connector has feature that is engaged by the actuator to move the second connector into the first connector as the actuator moves from a first position to a second position.

50. The connector of claim 46 wherein the connector has at least 160 pins and a pin pitch of less than 1mm.

51. The connector of claim 50 wherein the connector has at least 250 pins and a pin pitch of 0.8mm or less.

52. The connector of claim 46 wherein the actuator has a cam element.

53. The connector of claim 46 wherein movement of the actuator from an engage position to a release position disengages the second connector from the first connector.

54. A method of using a connector assembly for an ultrasound system comprising:

moving a connector actuator from a first position to a second position to engage a housing connector of an ultrasound imaging device with a transducer probe connector.

55. The method of claim 54 further comprising identifying the transducer probe with a probe identification circuit.

56. The method of claim 55 further comprising storing probe identification data in a memory.

57. The method of claim 54 further comprising providing an identification circuit mounted on the housing connector.

58. The method of claim 54 further comprising actuating a computer program that accesses transducer data from a database in accordance with an identified transducer.

59. The method of claim 58 further comprising modifying the transducer data or sending a transducer attach signal to an application program or update a usage history or increment a transducer usage counter or record a transducer detach signal.

60. A method of using a modular ultrasound imaging system comprising;

Connecting an image processor housing to a base assembly;

and operating a control element on the base assembly to actuate an ultrasound imaging operation using the image processor housing.

61. The method of claim 60 further comprising providing a base assembly including a cart having a console with a docking port a plurality of control elements to activate display of image data on a display attached to the processor housing.

62. The method of claim 60 further comprising providing a processor housing having a laptop personal computer having a standard graphical user interface having a

Windows® format, the computer being connected to a beamformer housing within the processor housing using a firewire interface.

63. The method of claim 61 further comprising providing a console having a first USB hub connected to USB port of the processor housing and connected to a second USB hub in the base assembly.

64. The method of claim 60 further comprising providing a plurality of transducer connectors on the processor housing.

65. The method of claim 60 further comprising providing an ethernet port, and Sviseo port, an EKG port and a microphone port

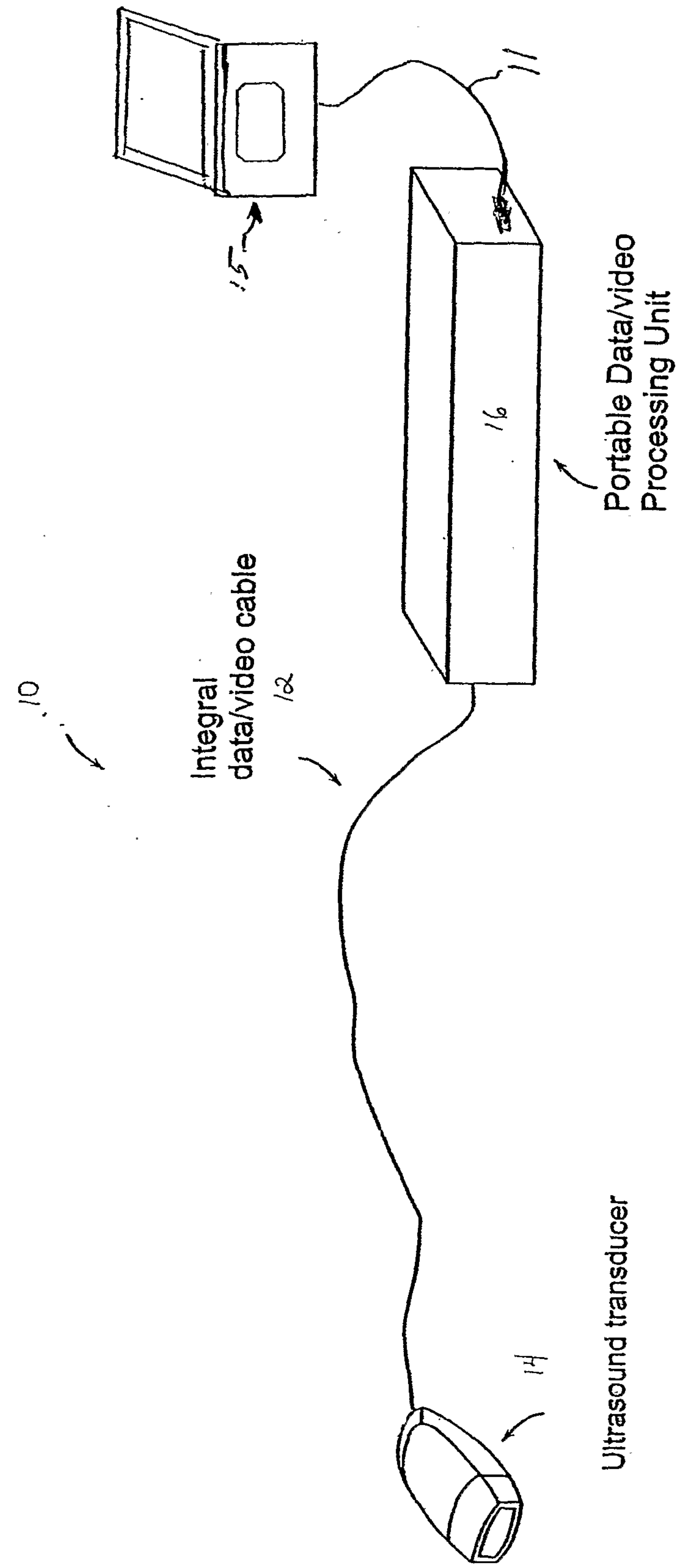

11
15
Portable Data/video
Processing Unit
16
Integral
data/video cable
12
10
Ultrasound transducer
14

FIG. 1

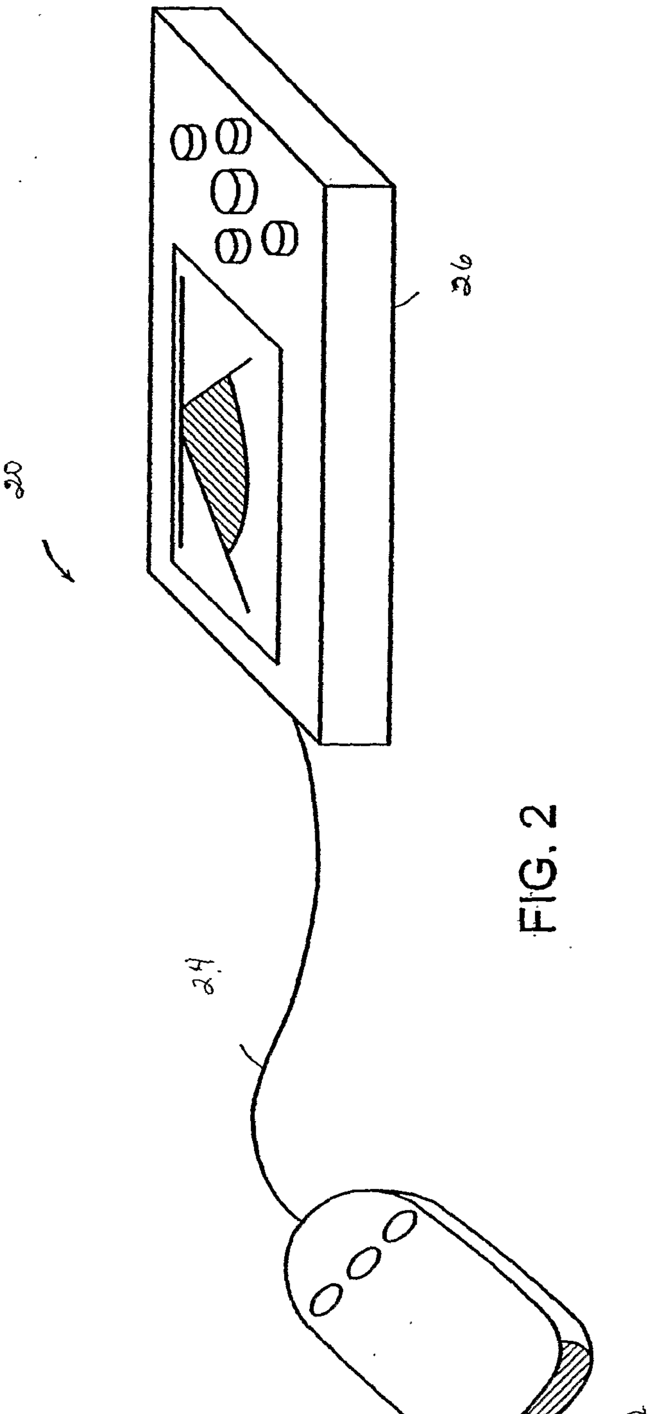


FIG. 2

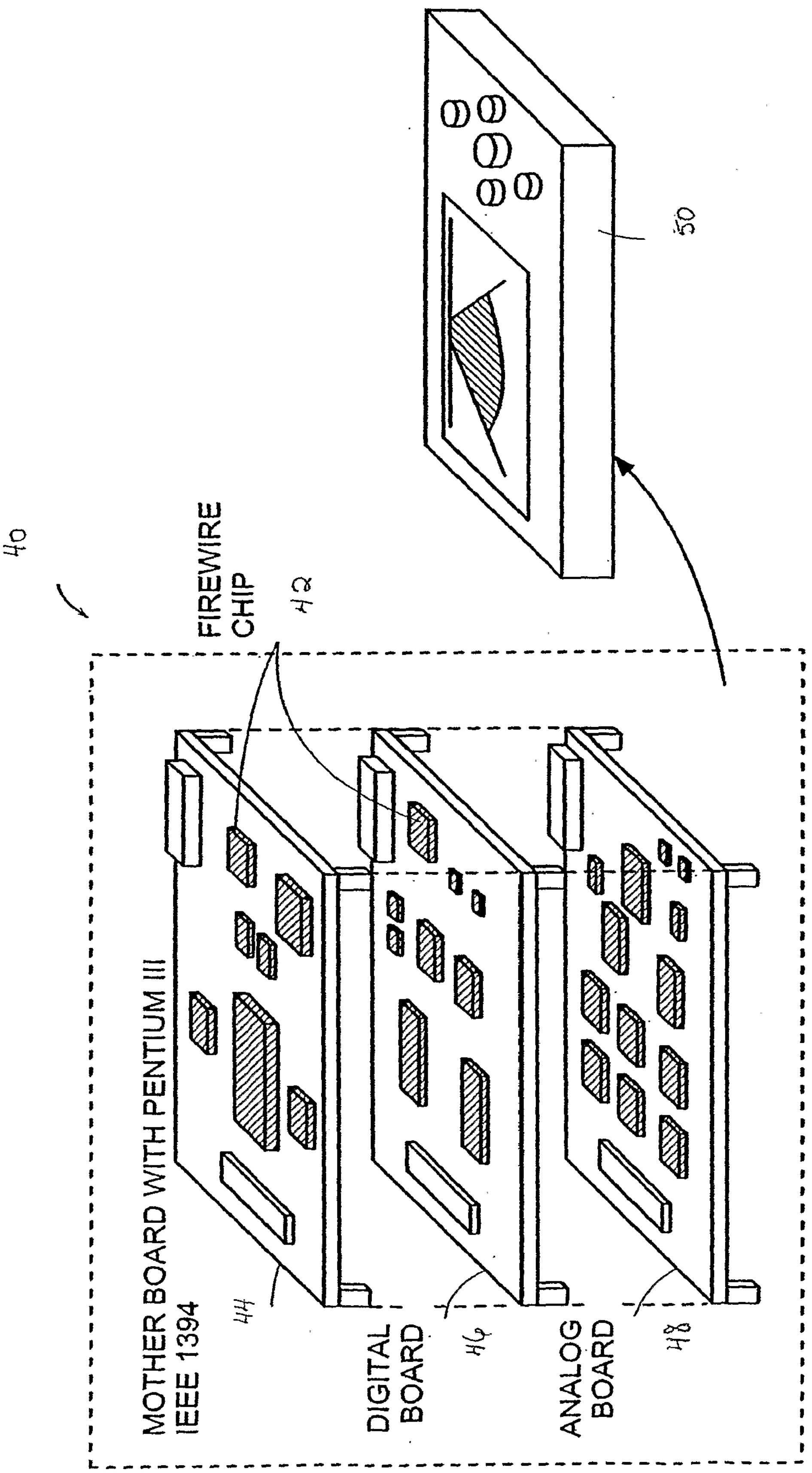

40
FIREWIRE CHIP
42
50
MOTHER BOARD WITH PENTIUM III IEEE 1394
44
DIGITAL BOARD
46
ANALOG BOARD
48

FIG. 3

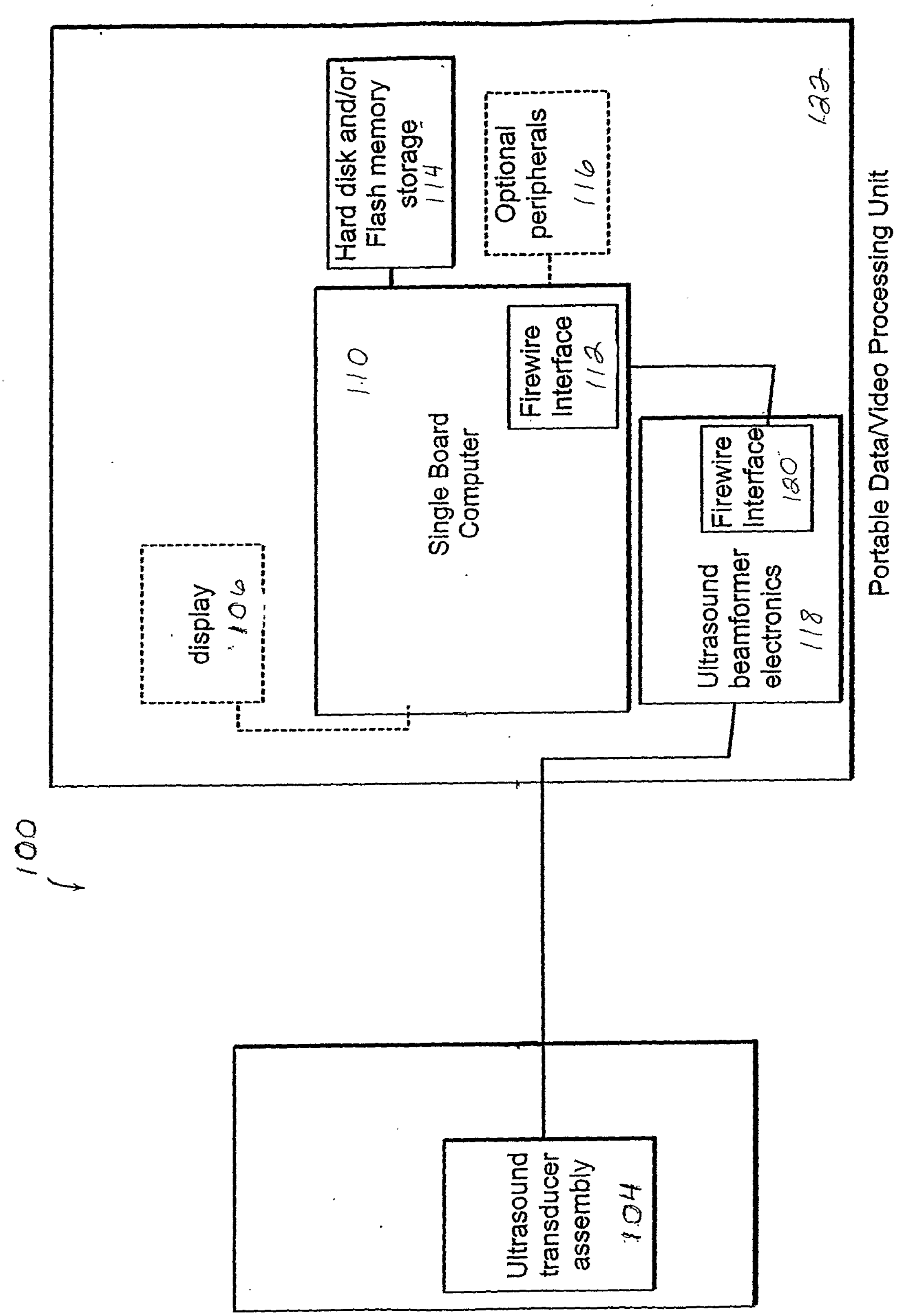

Hard disk and/or Flash memory storage 114
Optional peripherals 116
122
Firewire Interface 112
110
Single Board Computer
Firewire Interface 180
Ultrasound beamformer electronics 118
display 106
Portable Data/Video Processing Unit
100
Ultrasound transducer assembly 104

FIG. 4A

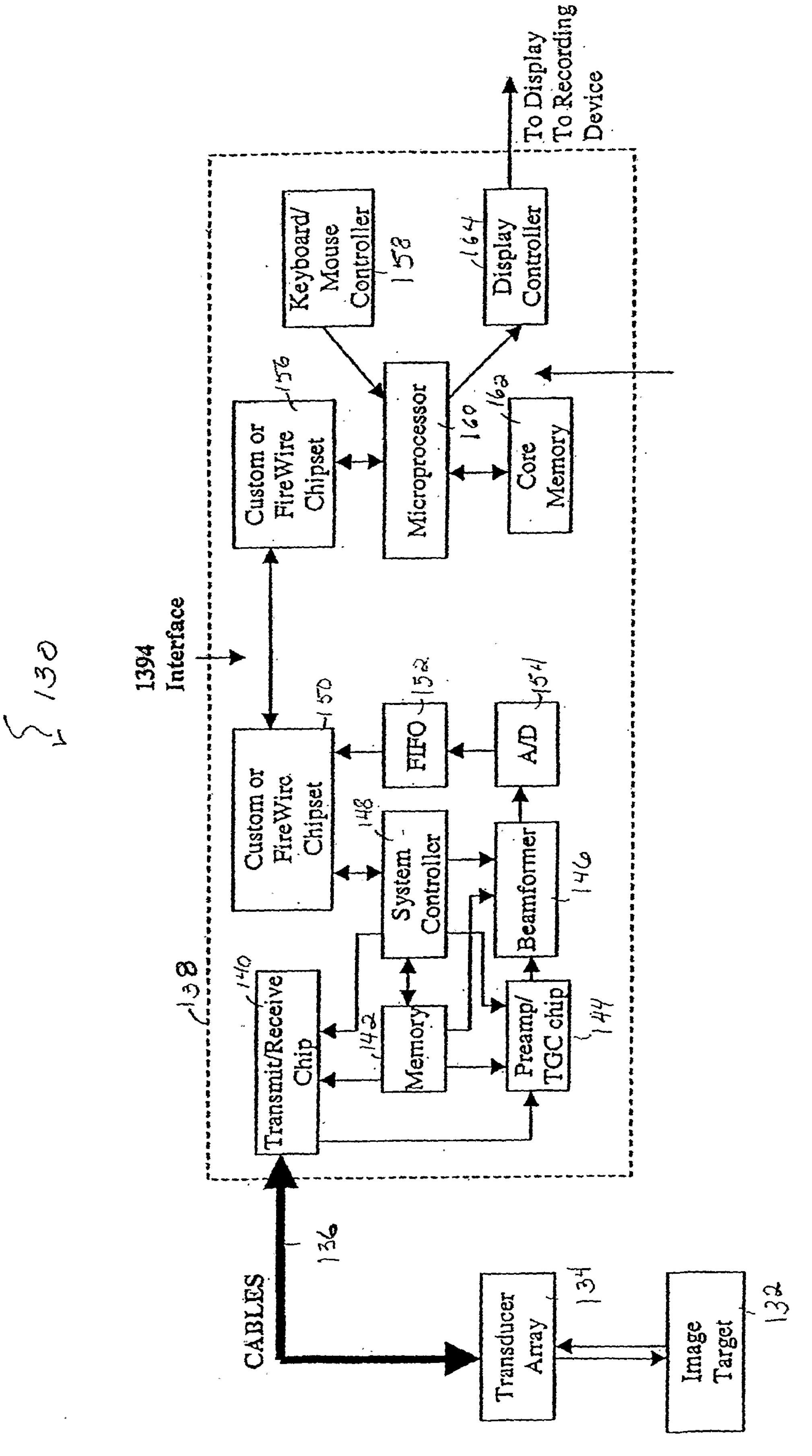

130
1394 Interface
To Display
To Recording
Device
138
Transmit/Receive Chip
140
Memory
142
Preamp/ TGC chip
144
Beamformer
146
System Controller
148
Custom or FireWire Chipset
150
FIFO
152
A/D
154
Custom or FireWire Chipset
156
Keyboard/ Mouse Controller
158
Microprocessor
160
Core Memory
162
Display Controller
164
CABLES
136
Transducer Array
134
Image Target
132

FIG. 4B

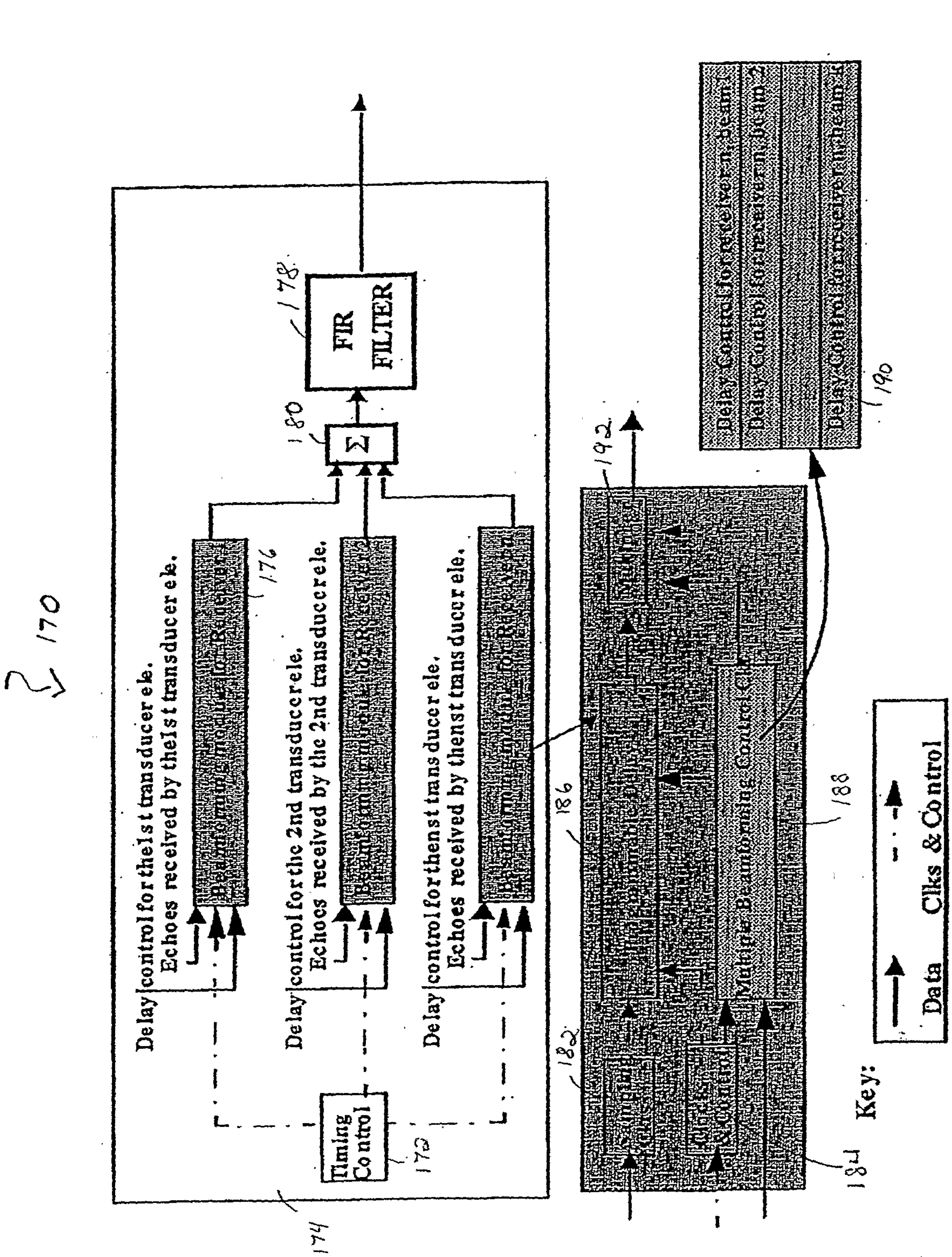

170
Delay control for the 1st transducer ele.
Echoes received by the 1st transducer ele.
Delay control for the 2nd transducer ele.
Echoes received by the 2nd transducer ele.
Delay control for the nst transducer ele.
Echoes received by the nst transducer ele.
176
180
Σ
178
FIR FILTER
Timing Control
172
174
182
184
186
188
190
192
Key:
Data
Clks & Control

FIG. 4C

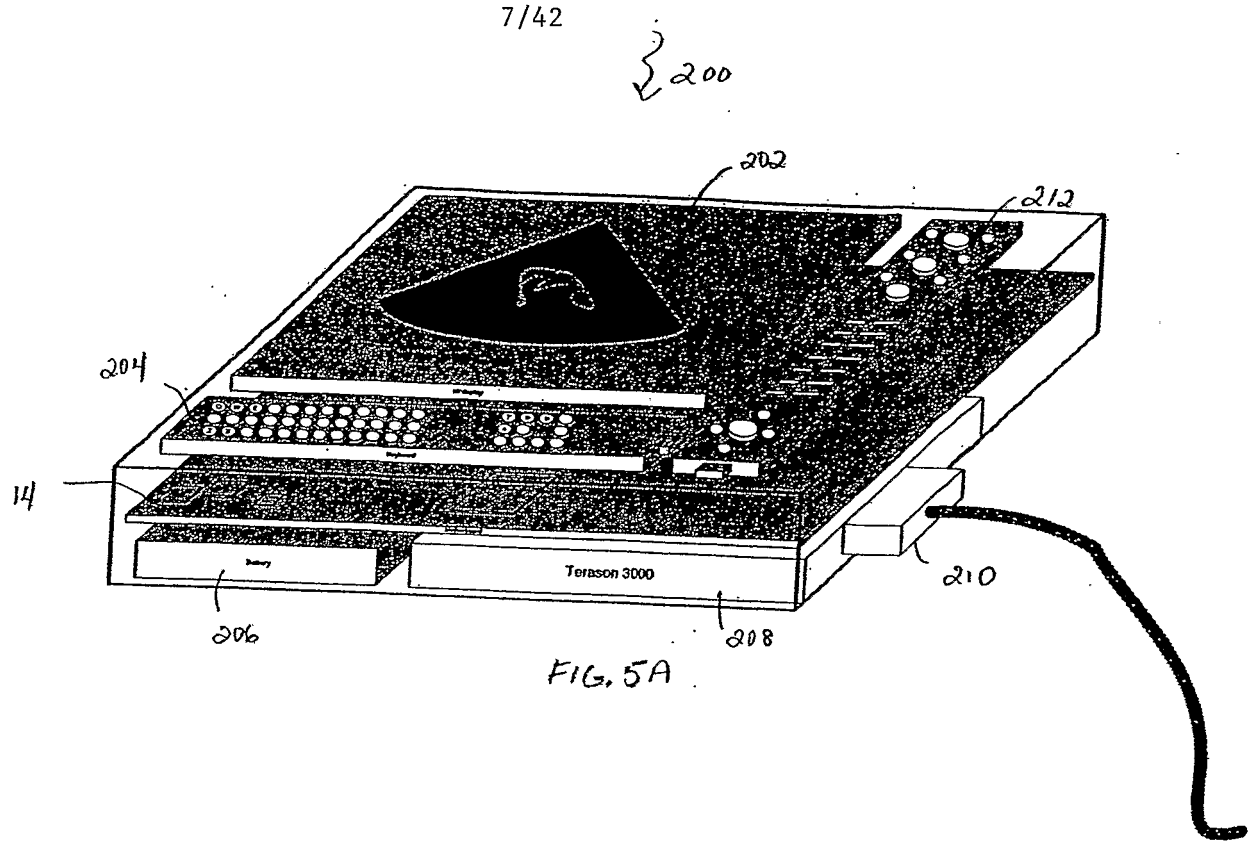

200
202
212
204
14
Terason 3000
210
206
208

FIG. 5A

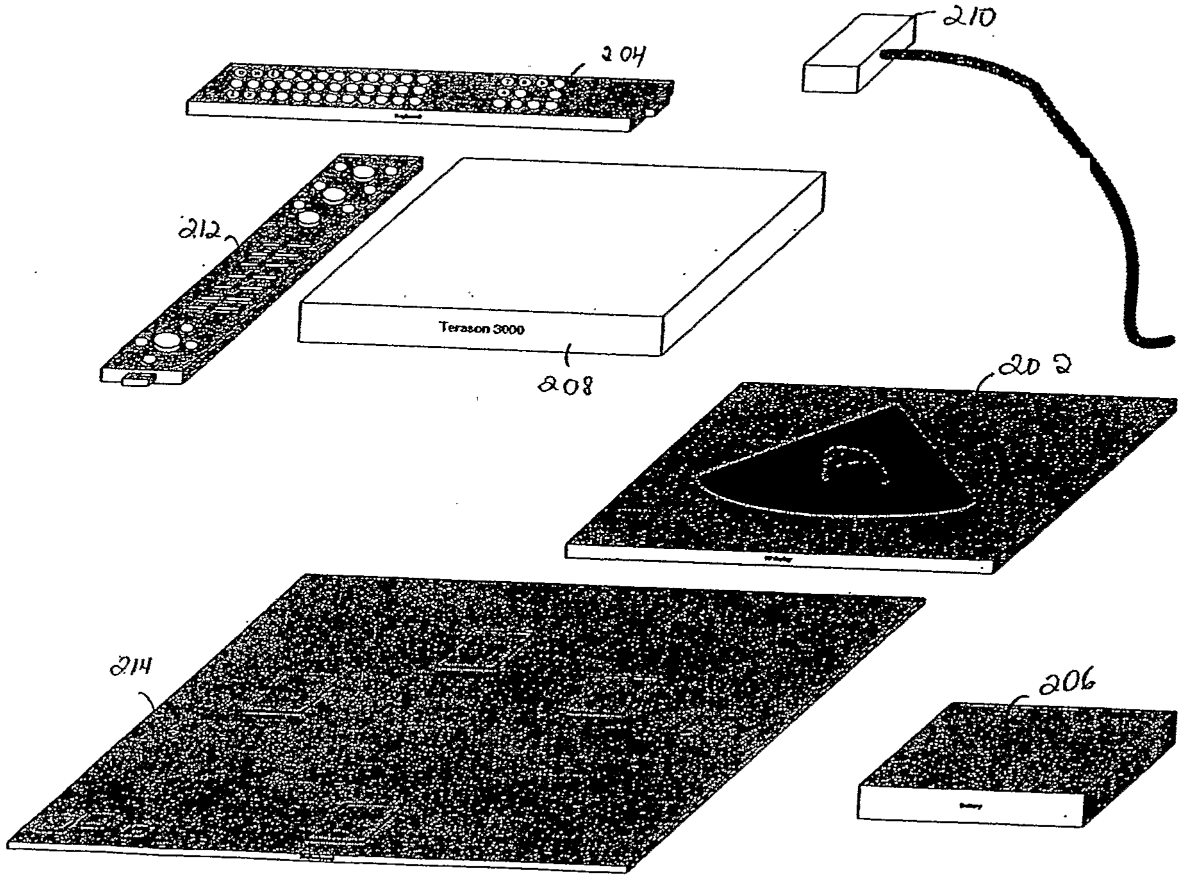

210
204
212
Terason 3000
208
202
214
206

FIG. 5B

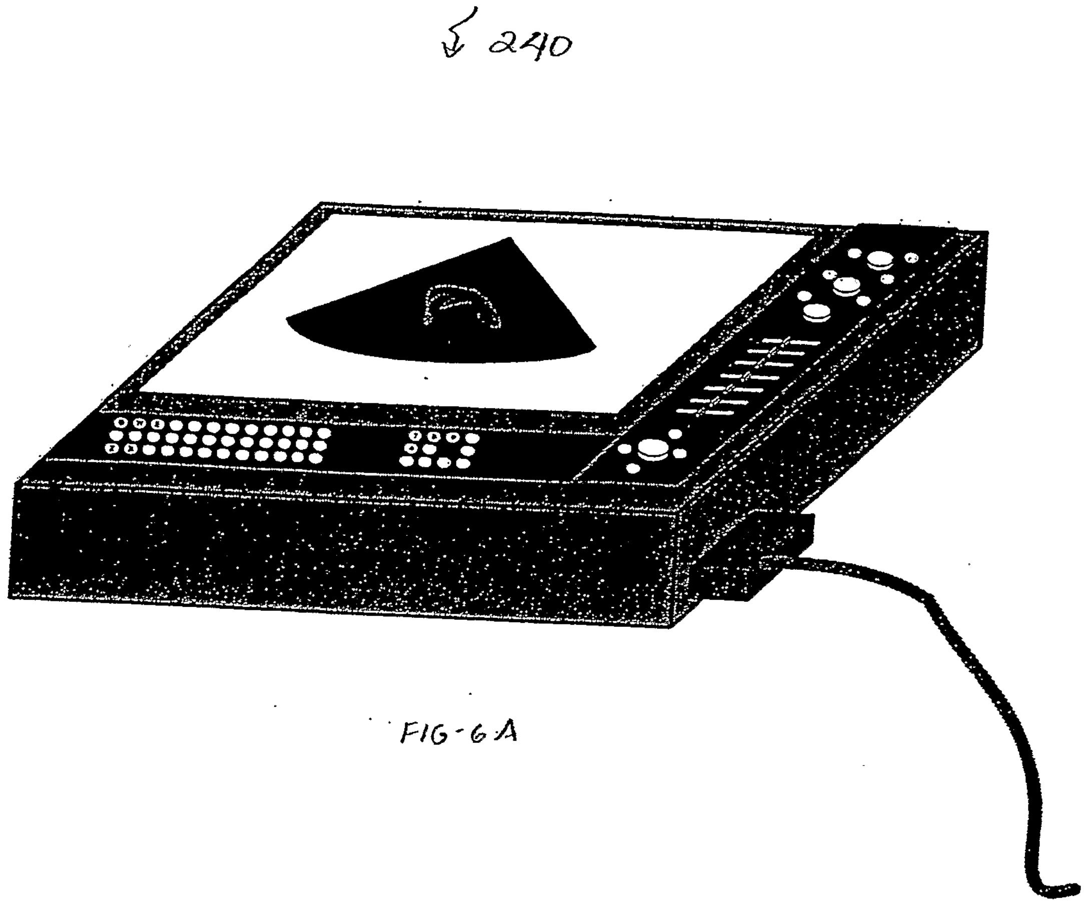


FIG-6A

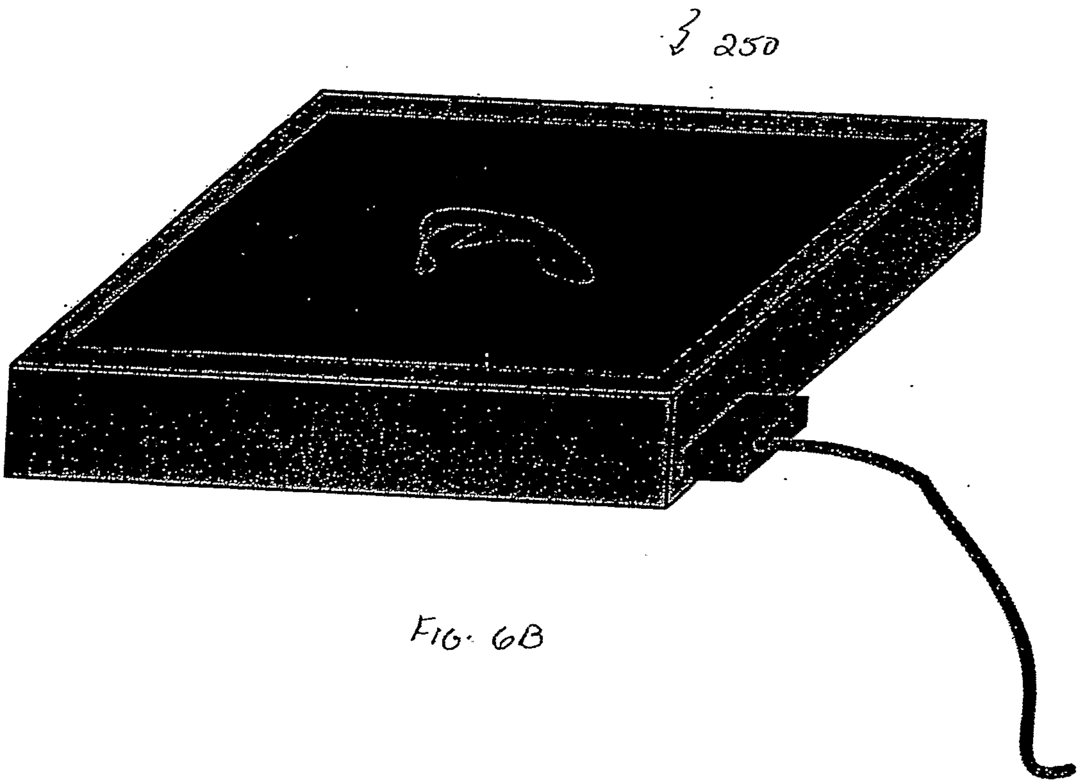


FIG. 6B

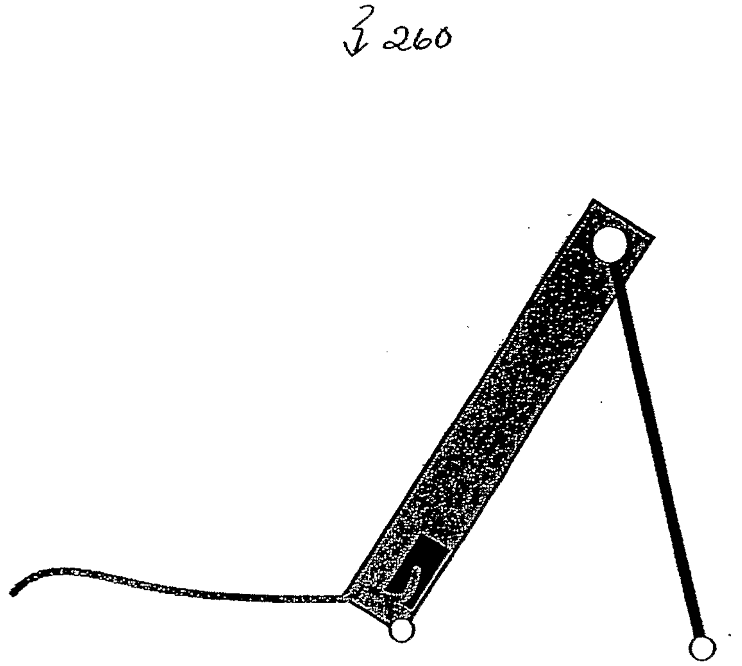


FIG. 7.

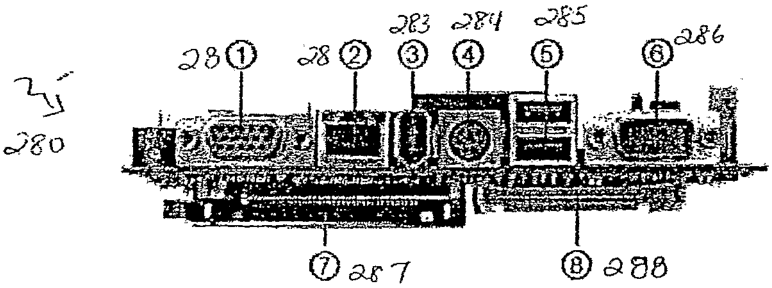


FIG. 8A

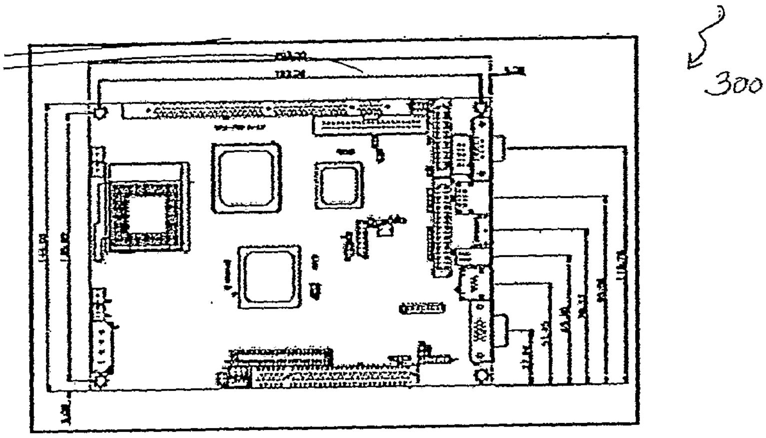


FIG. 8B

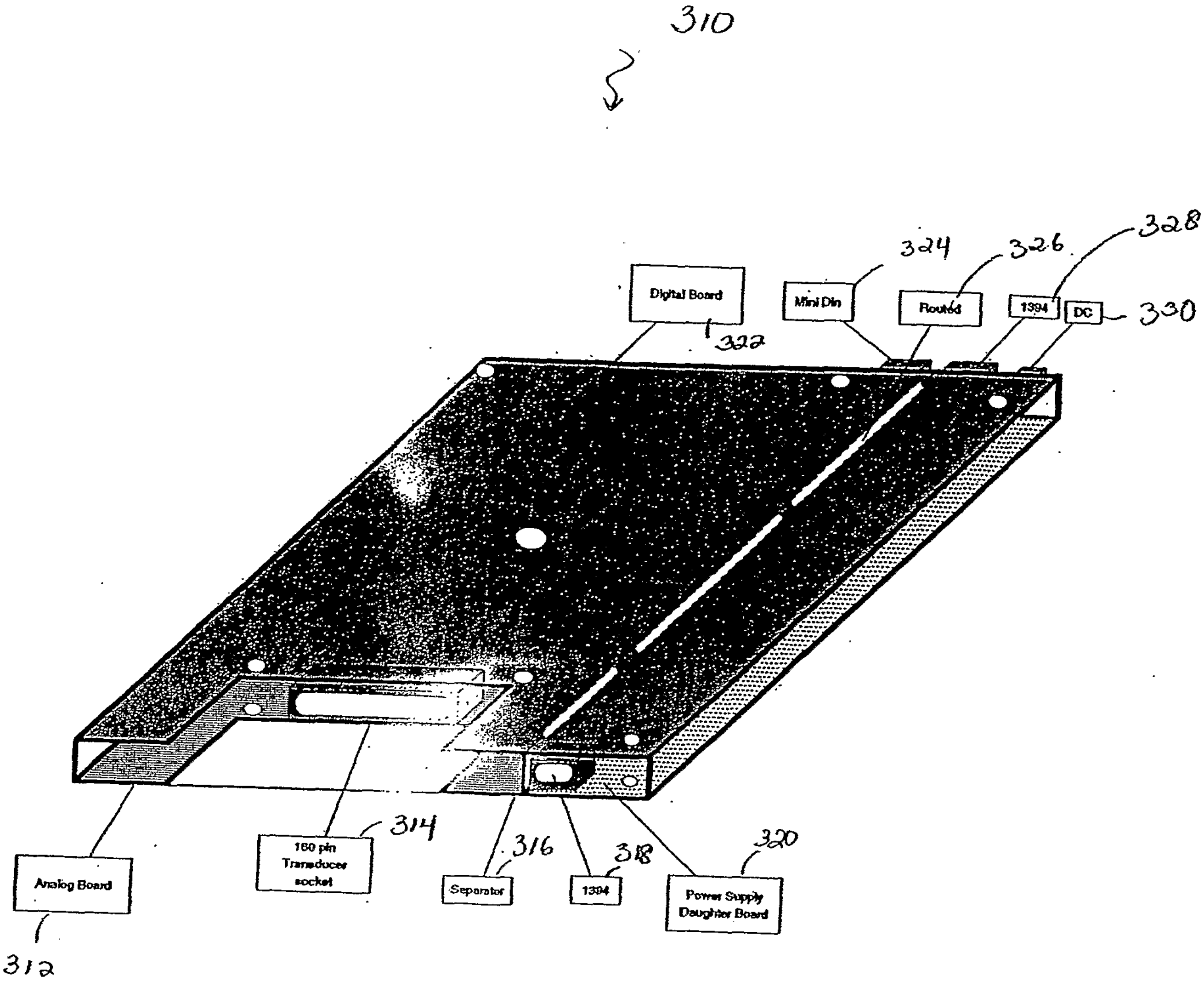

310
Digital Board
322
Mini Din
324
Routed
326
1394
328
DC
330
Analog Board
312
160 pin Transducer socket
314
Separator
316
1394
318
Power Supply Daughter Board
320

FIG. 9

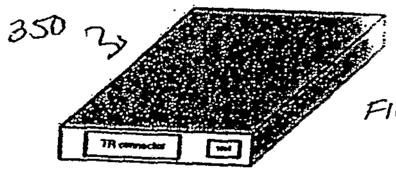


FIG. 10A

OEM configuration. Basic aluminum with mounting holes

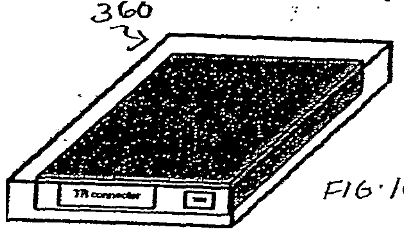


FIG. 10B

skin

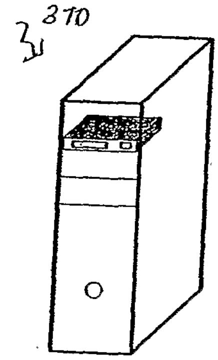


FIG. 10C

OEM box inside drive bay

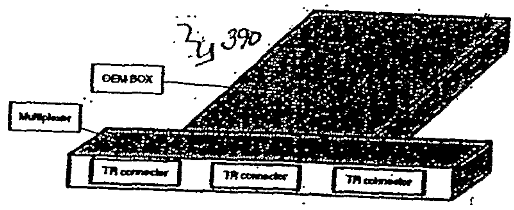


FIG. 10D

OEM with Multiplexor

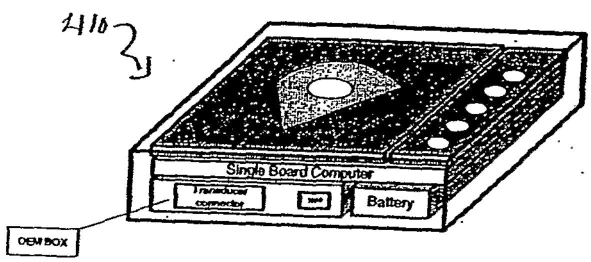


FIG. 10E

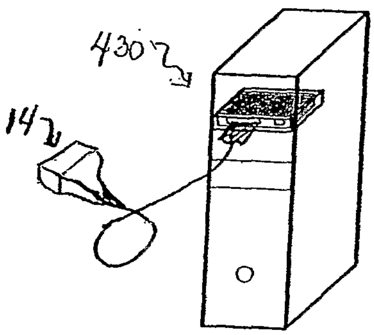


FIG. 10F

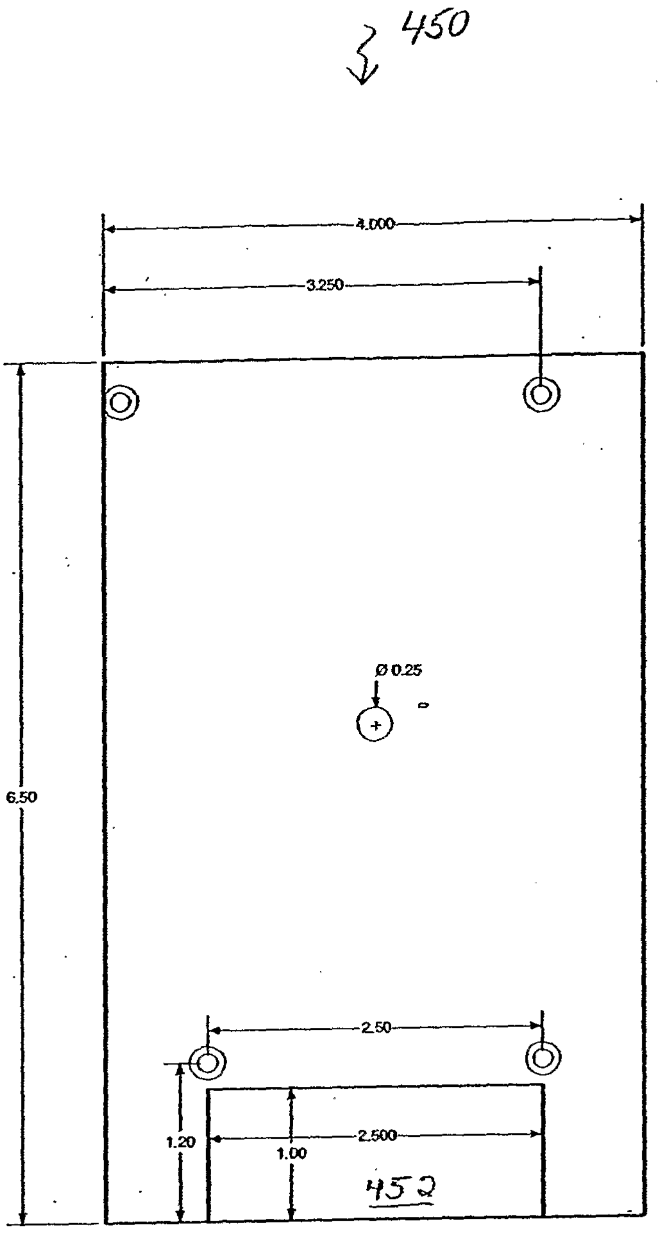


FIG. 11

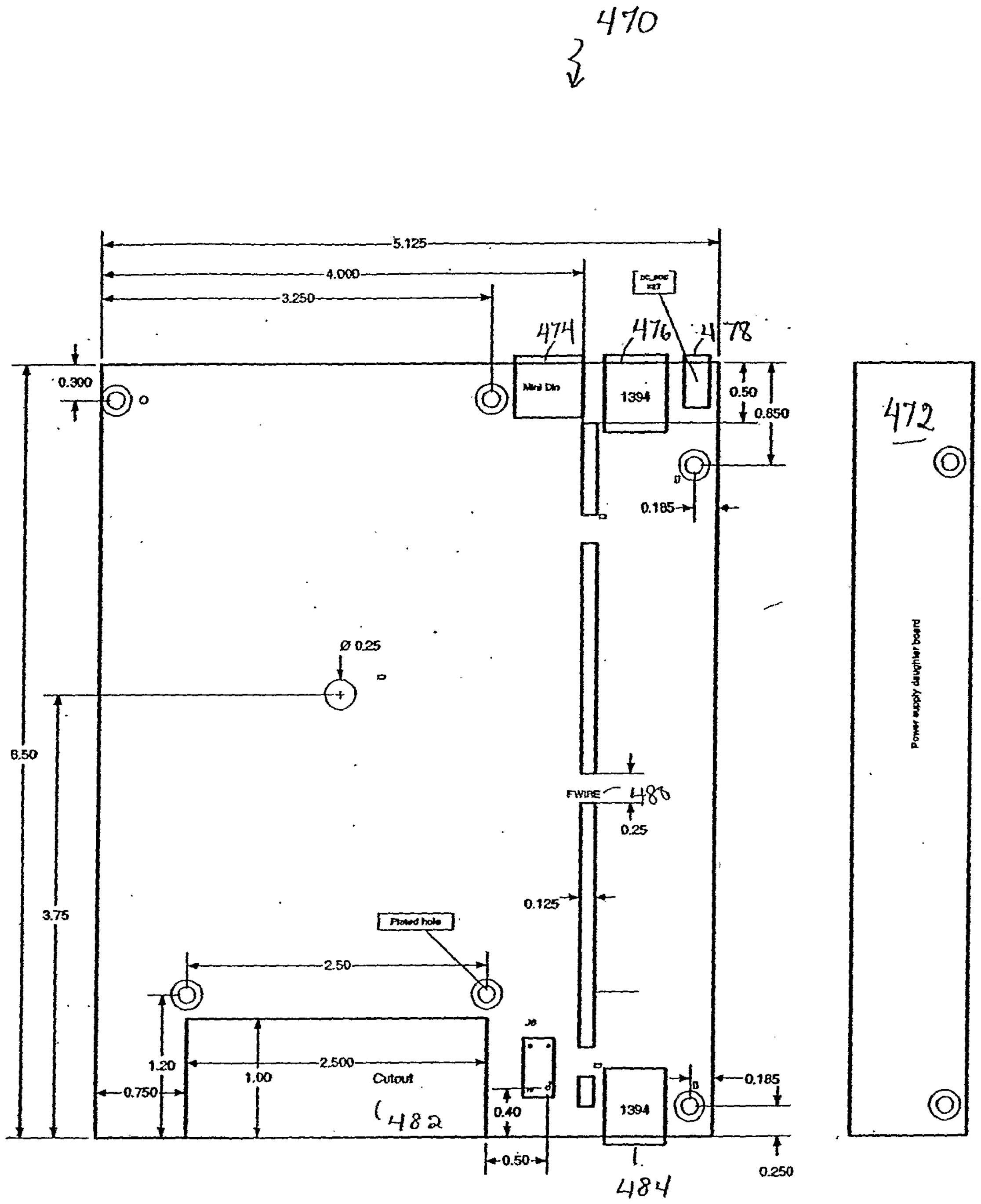

470
5.125
4.000
3.250
474
476
478
Mini Din
1394
0.300
0.50
0.850
0.185
472
Power supply daughter board
Ø 0.25
6.50
3.75
FWIRE
488
0.25
0.125
Plated hole
2.50
1.20
2.500
1.00
Cutout
482
0.750
J6
0.40
0.50
1394
0.185
0.250
484

FIG. 12

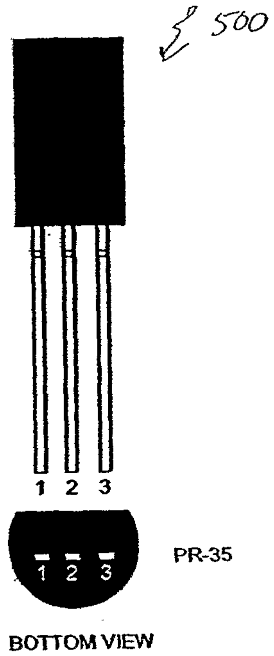


FIG-13A

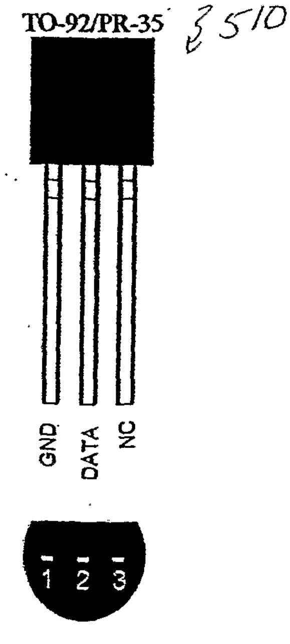


FIG-13B

BOTTOM VIEW
See Mech.
Drawings Section

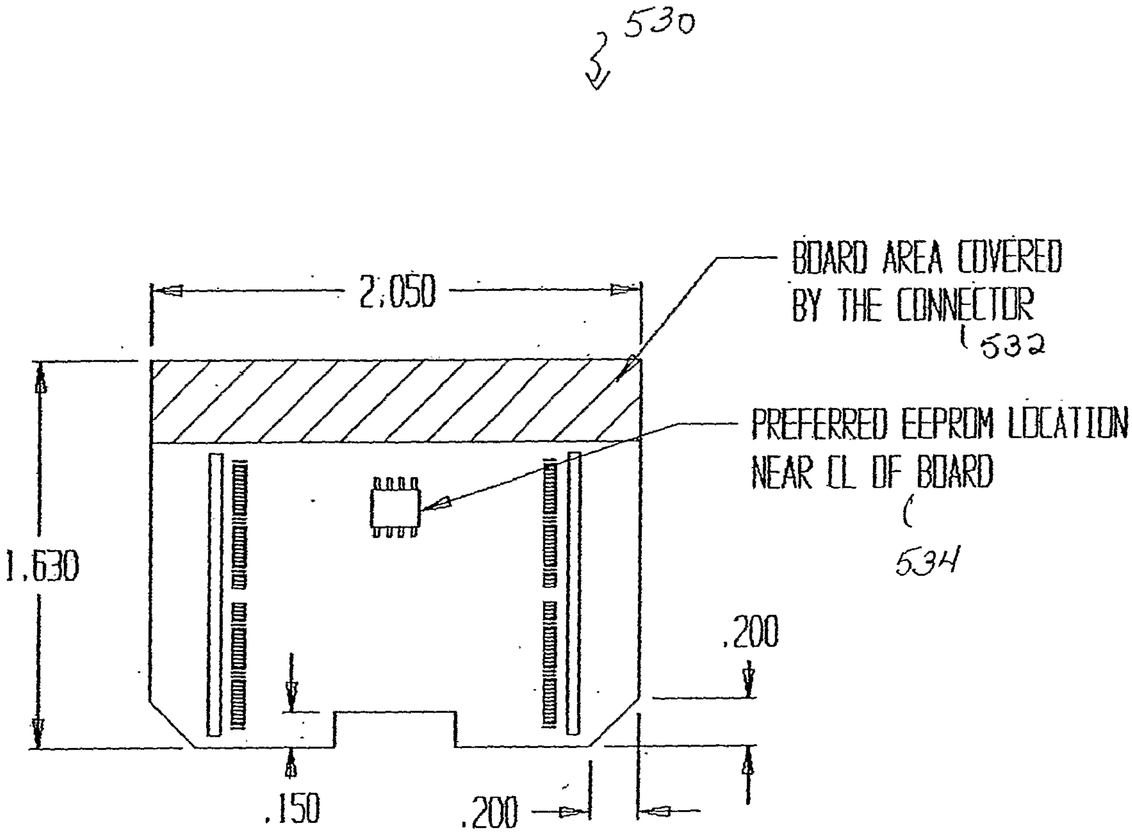
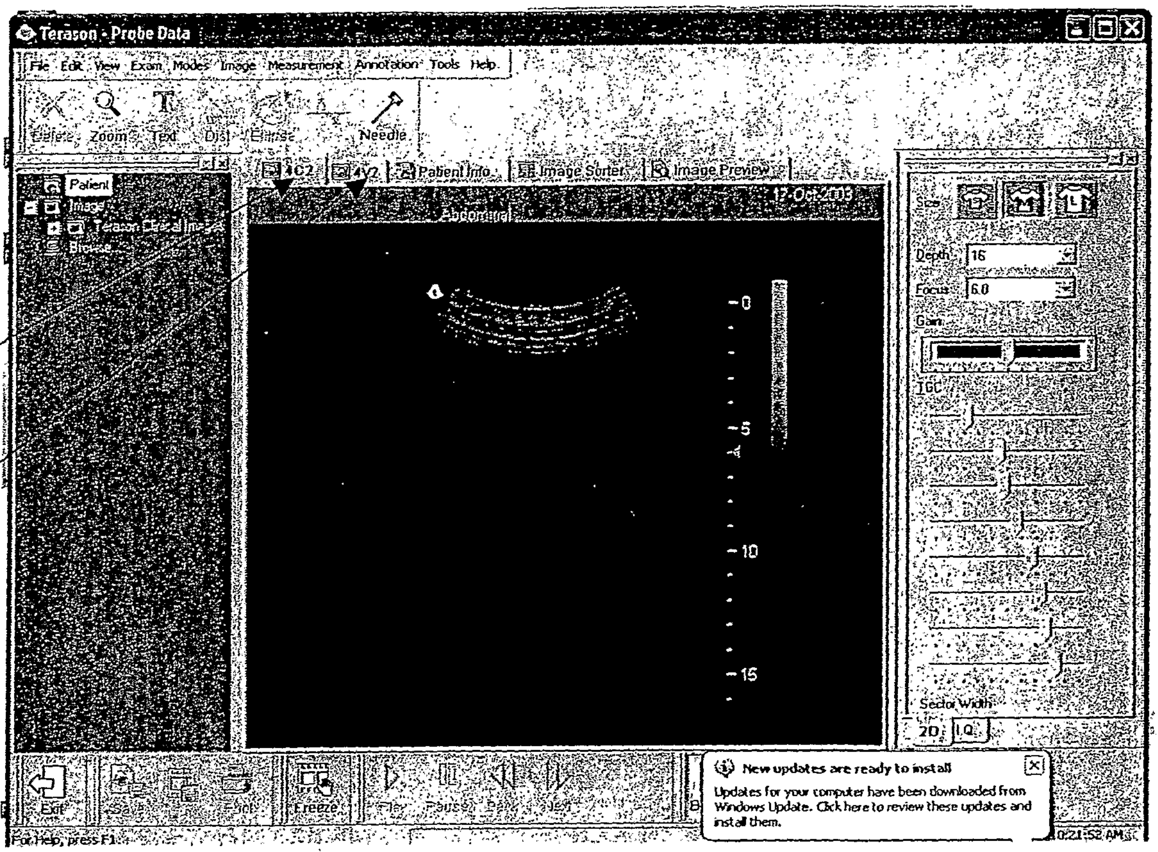

530
2.050
BOARD AREA COVERED
BY THE CONNECTOR
532
PREFERRED EEPROM LOCATION
NEAR CL OF BOARD
534
1.630
.200
.150
.200

FIG. 14

550



probe types

552

FIG. 15A

Typical Transducer ID chip Memory Map:

Word Address	Bits 31-24	Bits 23-16	Bits 15-8	Bits 7-0
IDENTIFICATION segment				
0	Major revision #	Minor revision #	Transducer type ID #	
1	Transducer Serial #			
2 to 7	reserved	reserved	reserved	reserved
USAGE Segment				
8	Inauguration System Serial #		Inauguration Date Code	
9	Recent System Serial #		Recent System Date Code	
10	Previous System Serial #		Previous System Date Code	
11	Cumulative Usage Counter			
12 to 31	reserved	reserved	reserved	Reserved
FACTORY Segment				
32 to 63	Per element gain adjustments: 256 entries of 4 bits each.			
64 to 95	Per element propagation delay adjustments: 256 entries of 4 bits			
USER Segment				
96 to 127	Reserved for user defined calibration data			

FIG 15B

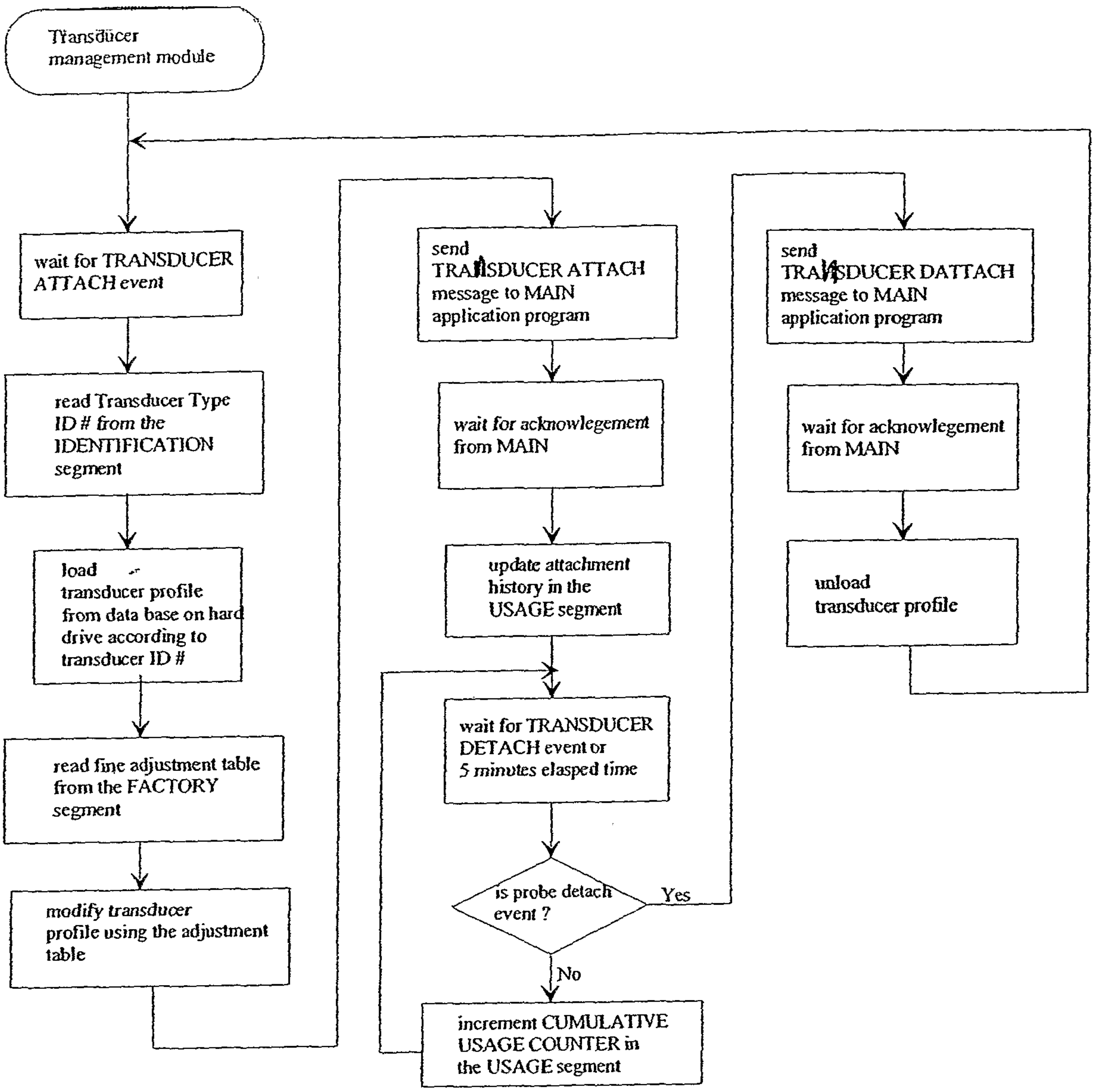

Transducer management module
wait for TRANSDUCER ATTACH event
read Transducer Type ID # from the IDENTIFICATION segment
load transducer profile from data base on hard drive according to transducer ID #
read fine adjustment table from the FACTORY segment
modify transducer profile using the adjustment table
send TRANSDUCER ATTACH message to MAIN application program
wait for acknowlegement from MAIN
update attachment history in the USAGE segment
wait for TRANSDUCER DETACH event or 5 minutes elasped time
is probe detach event ?
Yes
No
increment CUMULATIVE USAGE COUNTER in the USAGE segment
send TRANSDUCER DATTACH message to MAIN application program
wait for acknowlegement from MAIN
unload transducer profile

FIG 15C

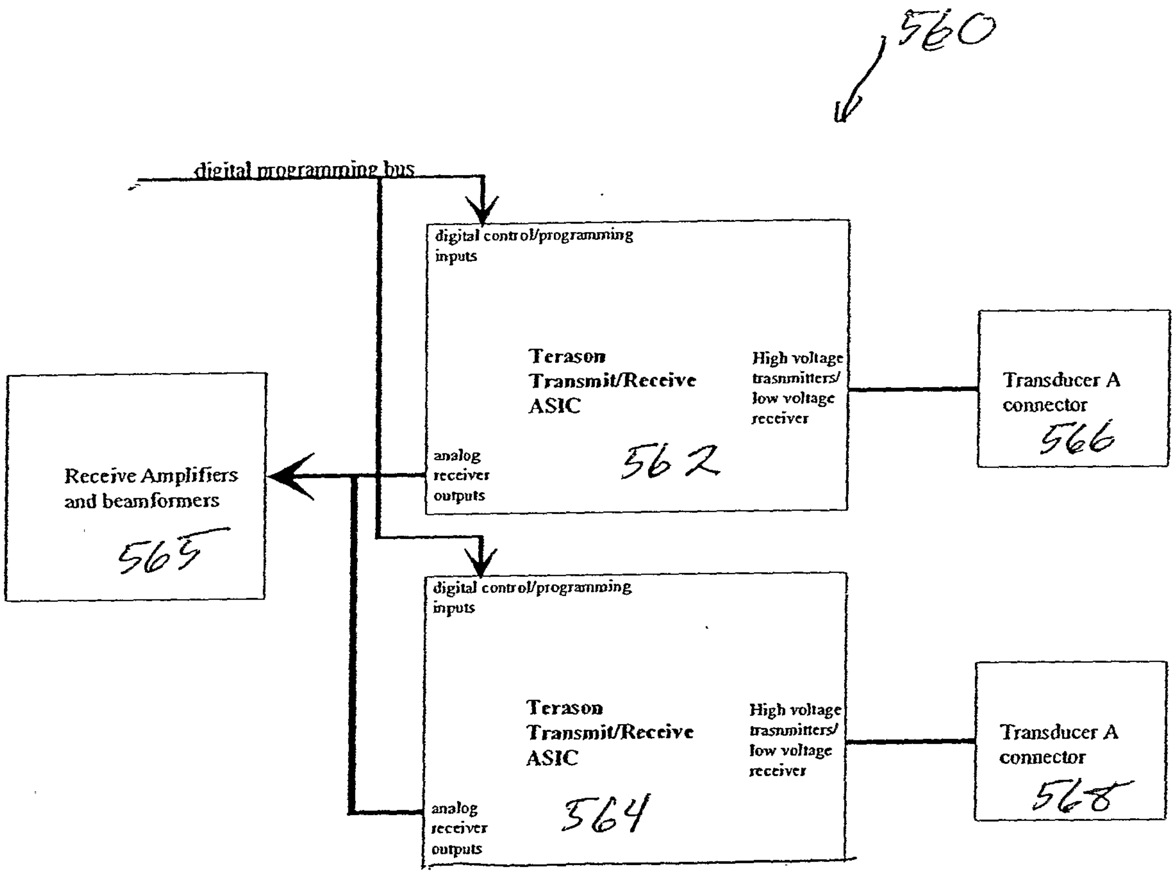

560
digital programming bus
digital control/programming inputs
Terason Transmit/Receive ASIC
562
High voltage trasnmitters/ low voltage receiver
analog receiver outputs
Transducer A connector
566
Receive Amplifiers and beamformers
565
digital control/programming inputs
Terason Transmit/Receive ASIC
564
High voltage trasnmitters/ low voltage receiver
analog receiver outputs
Transducer A connector
568

FIG 15D

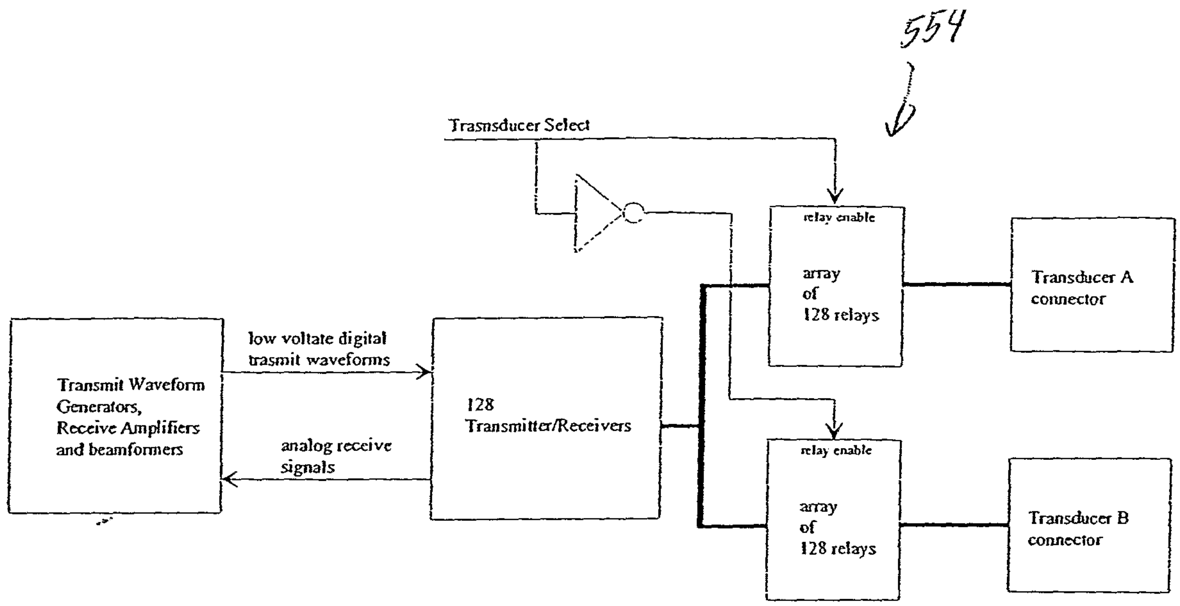


FIG 15E

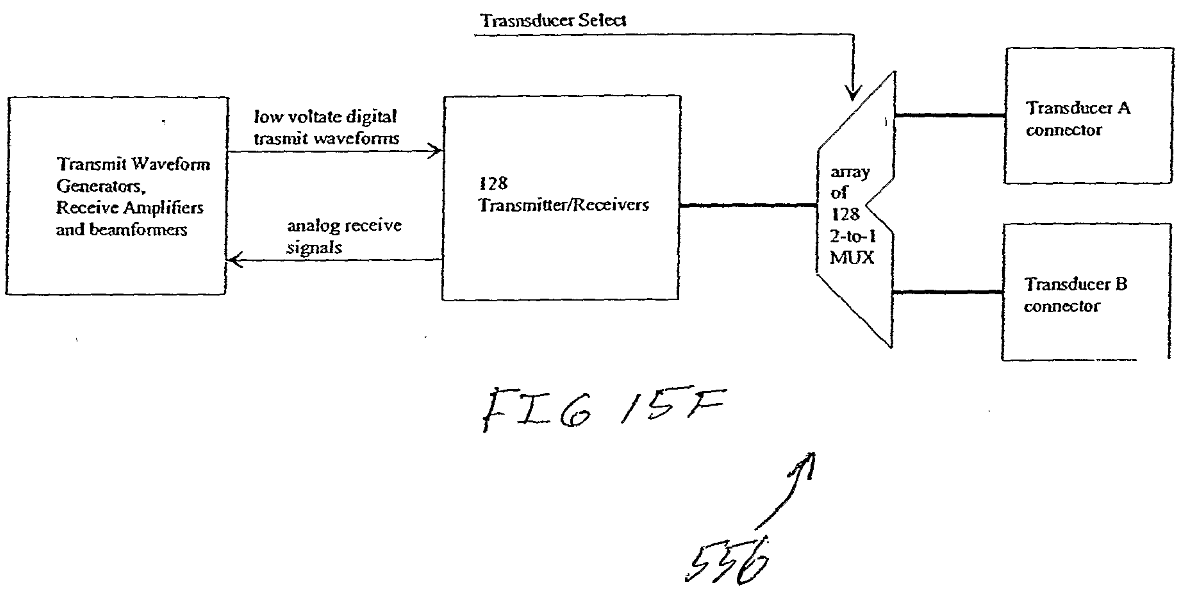


FIG 15F

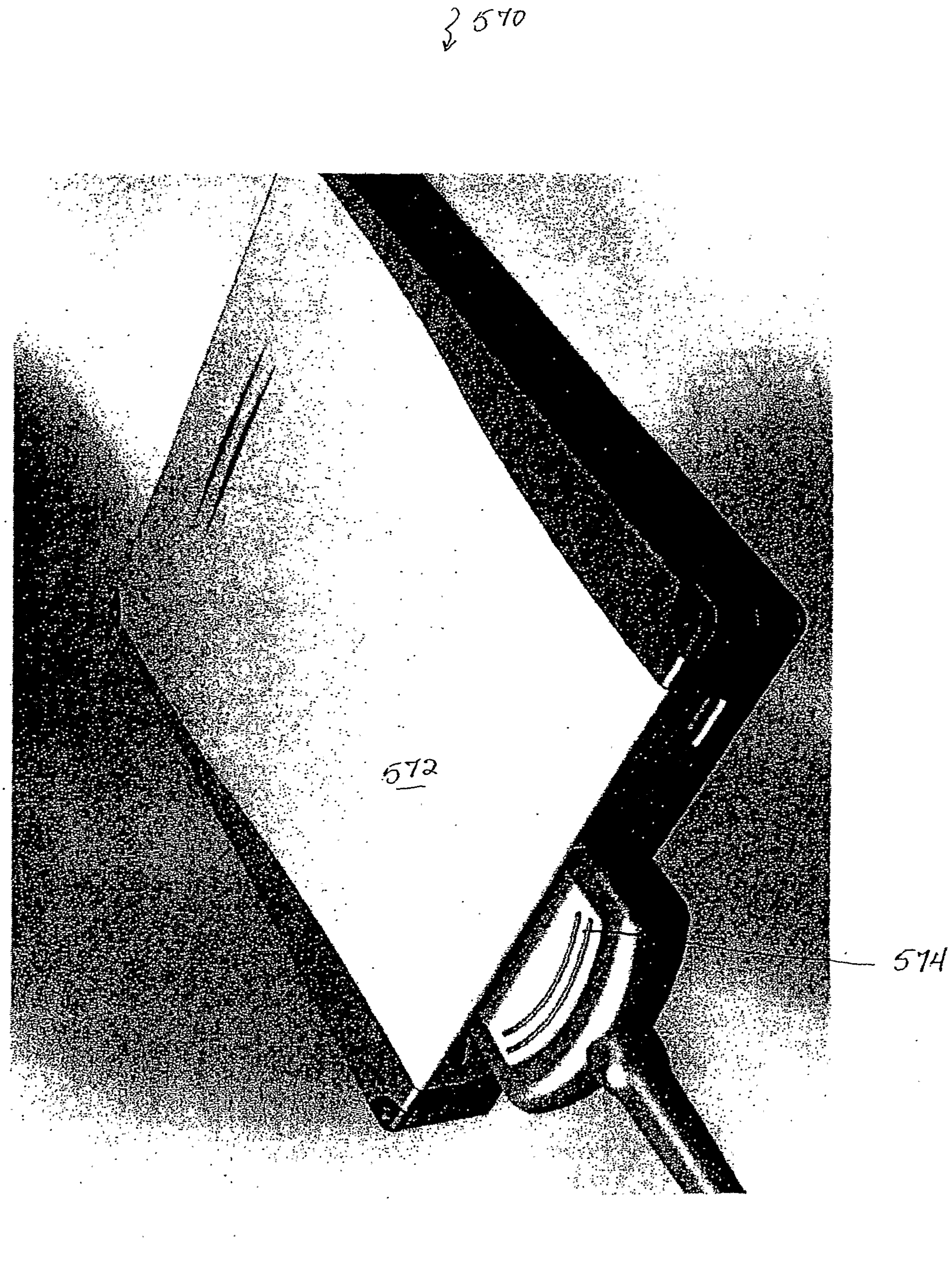


FIG. 16

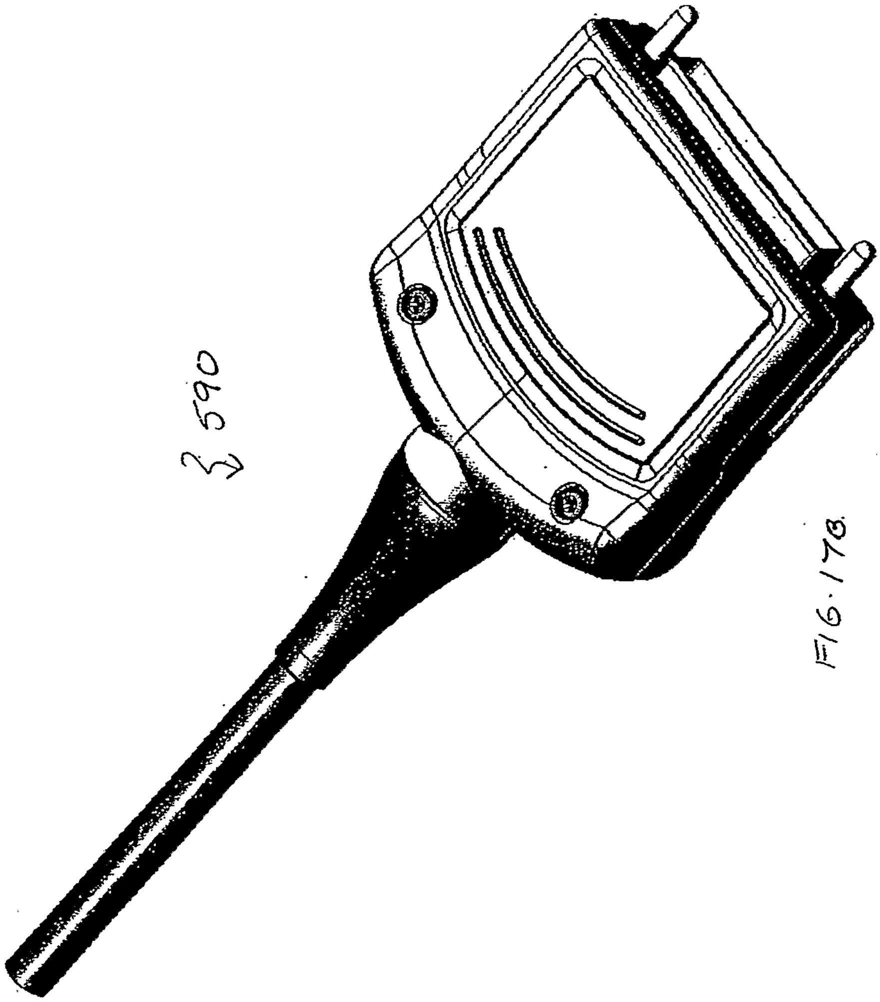


FIG. 17B

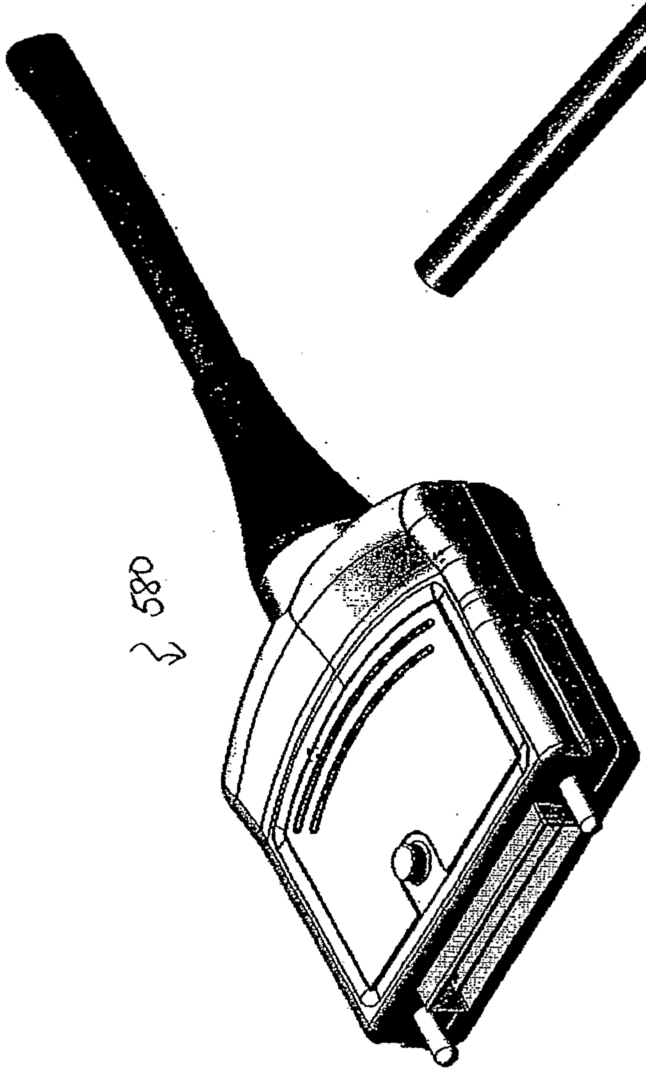


FIG. 17A

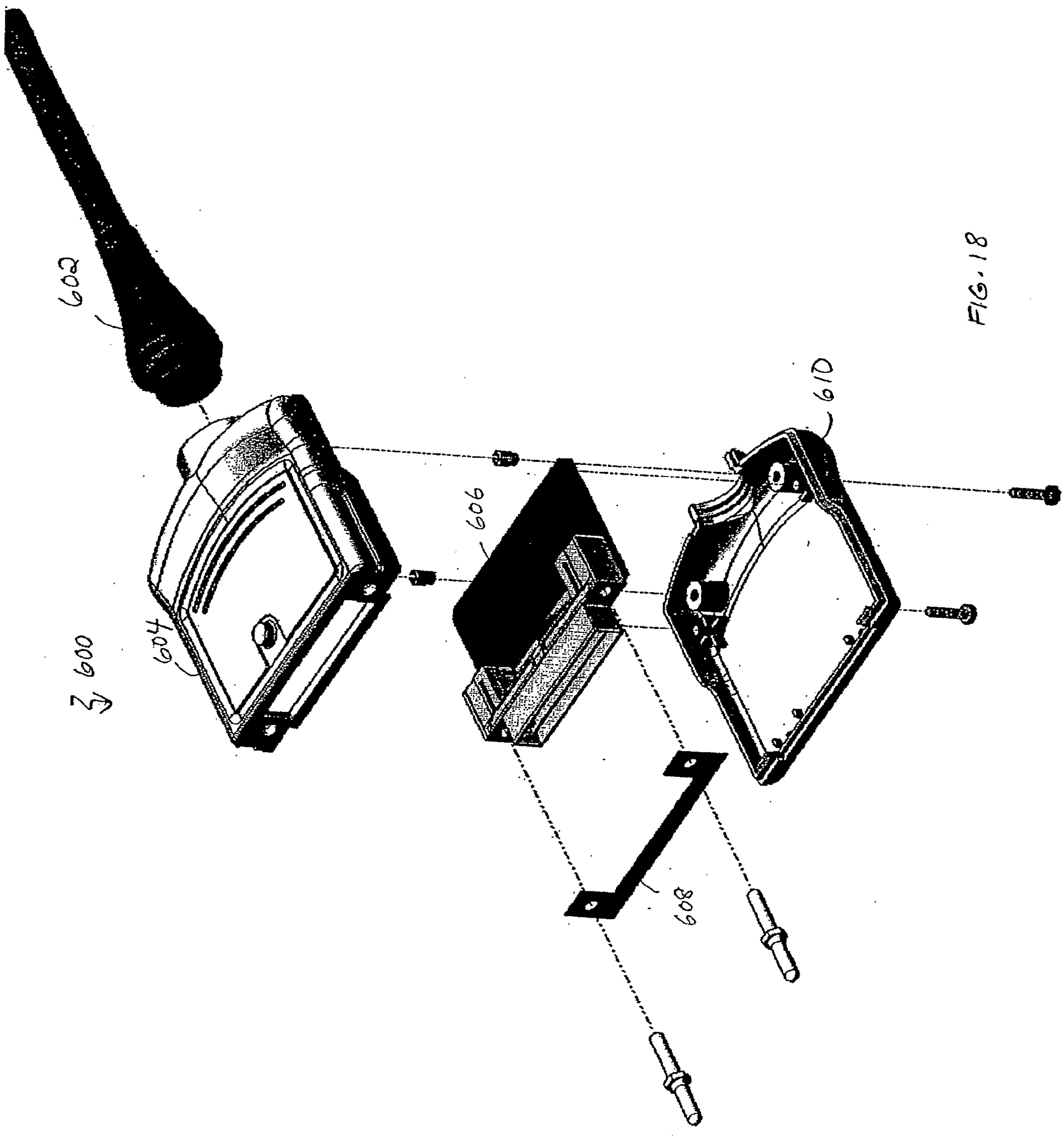


FIG. 18

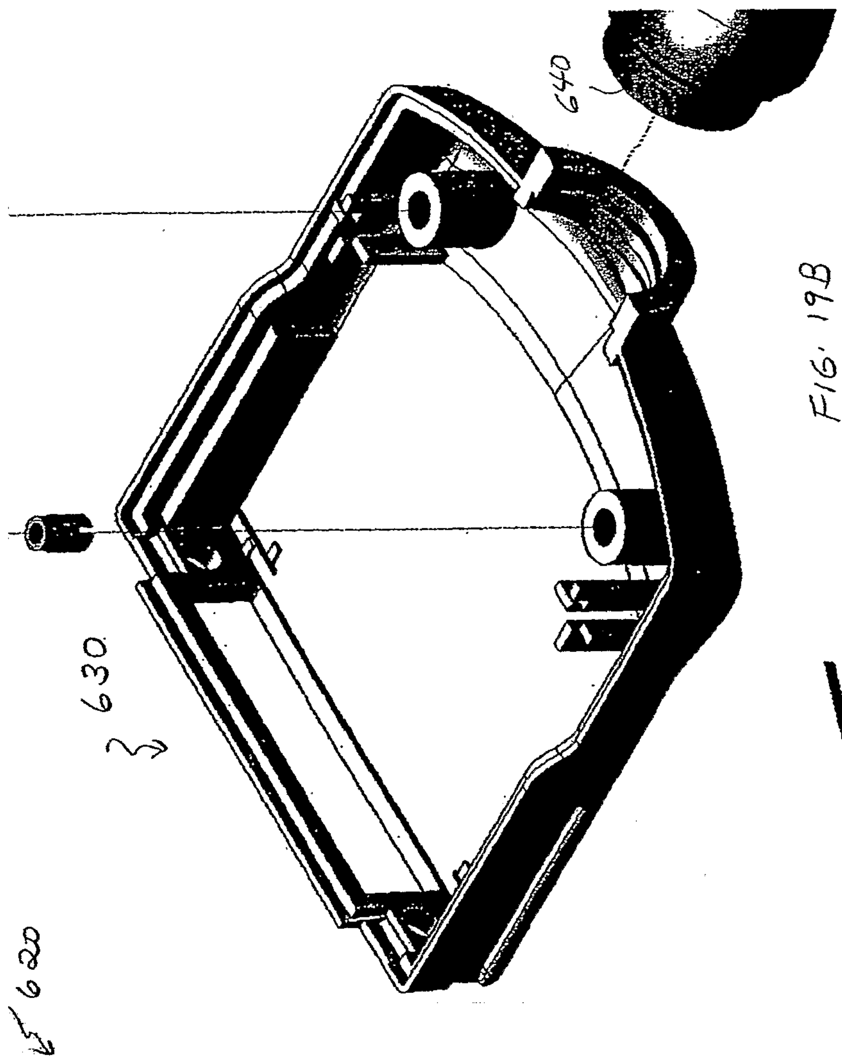


FIG 19B

FIG 19A

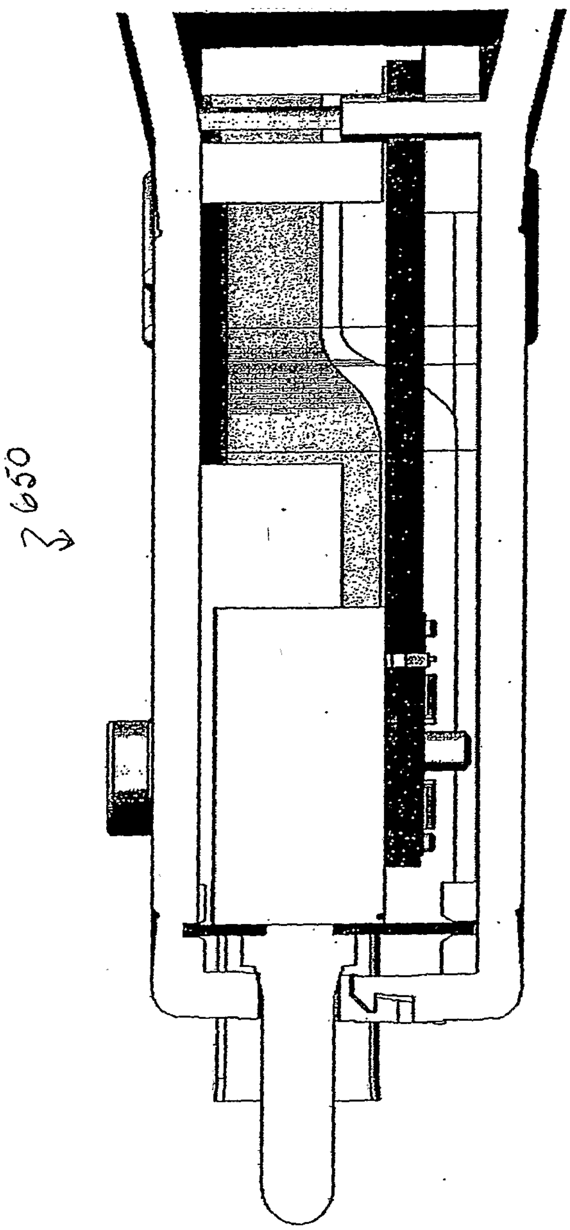


FIG 19C

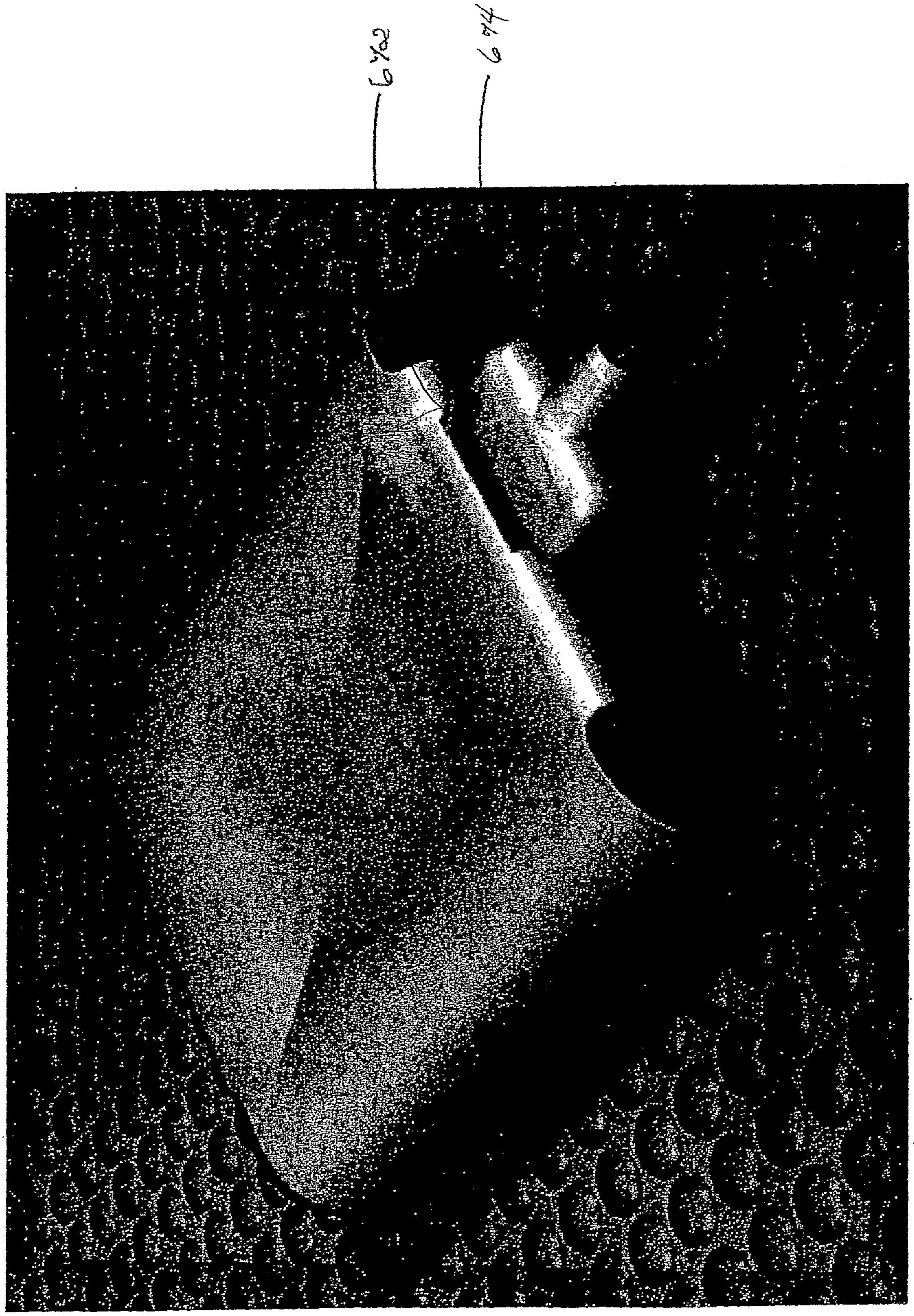


FIG. 20

680

FIG. 21A

690

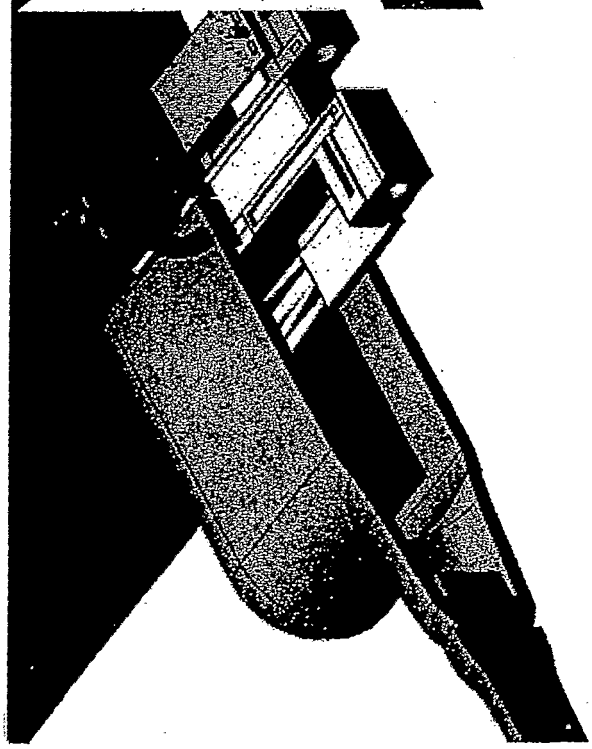


FIG. 21B

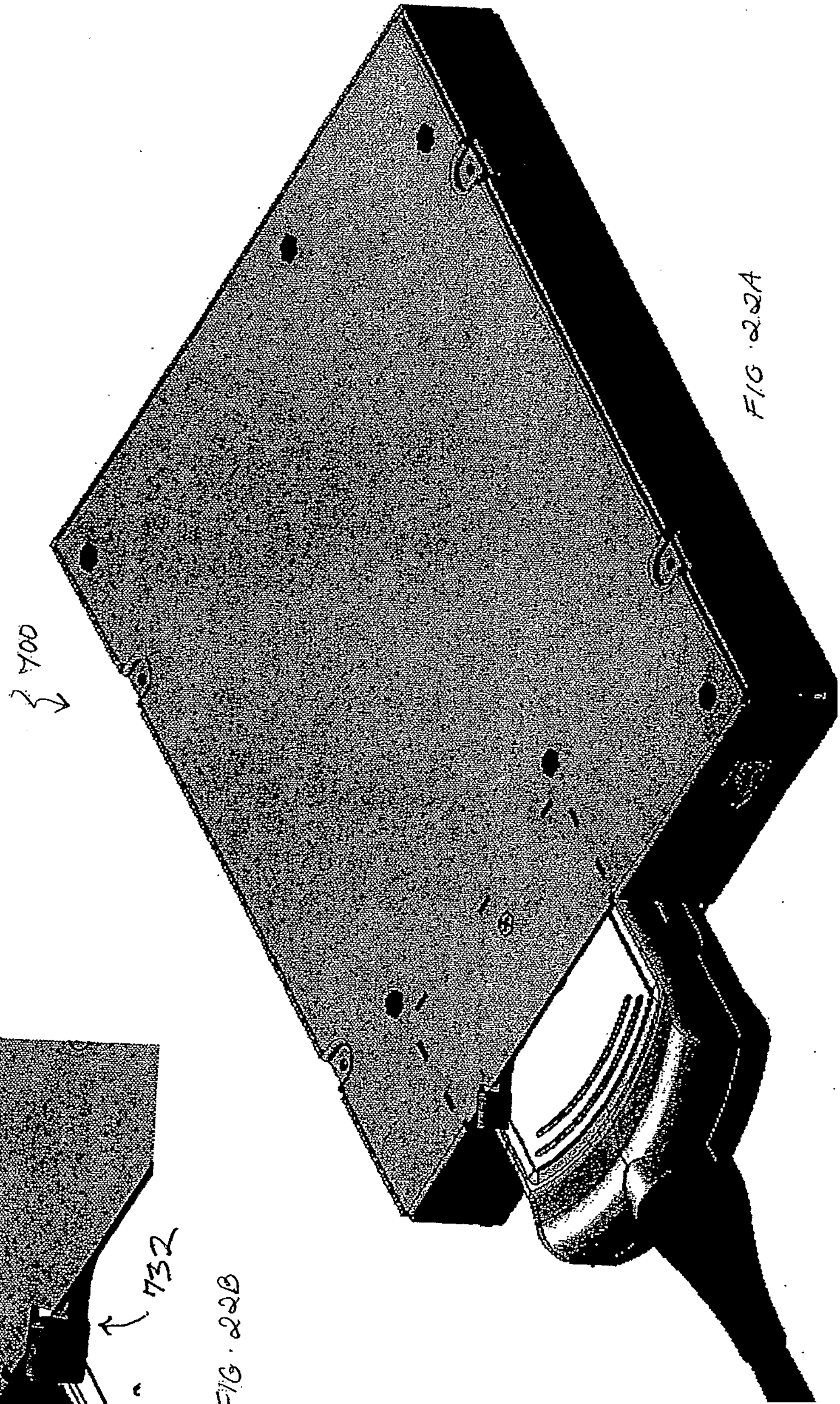


FIG. 22A

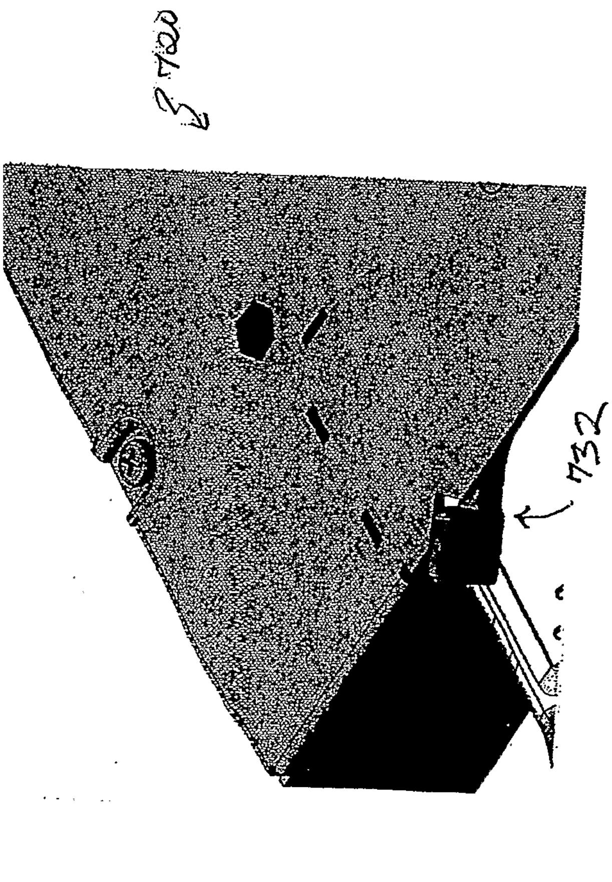


FIG. 22B

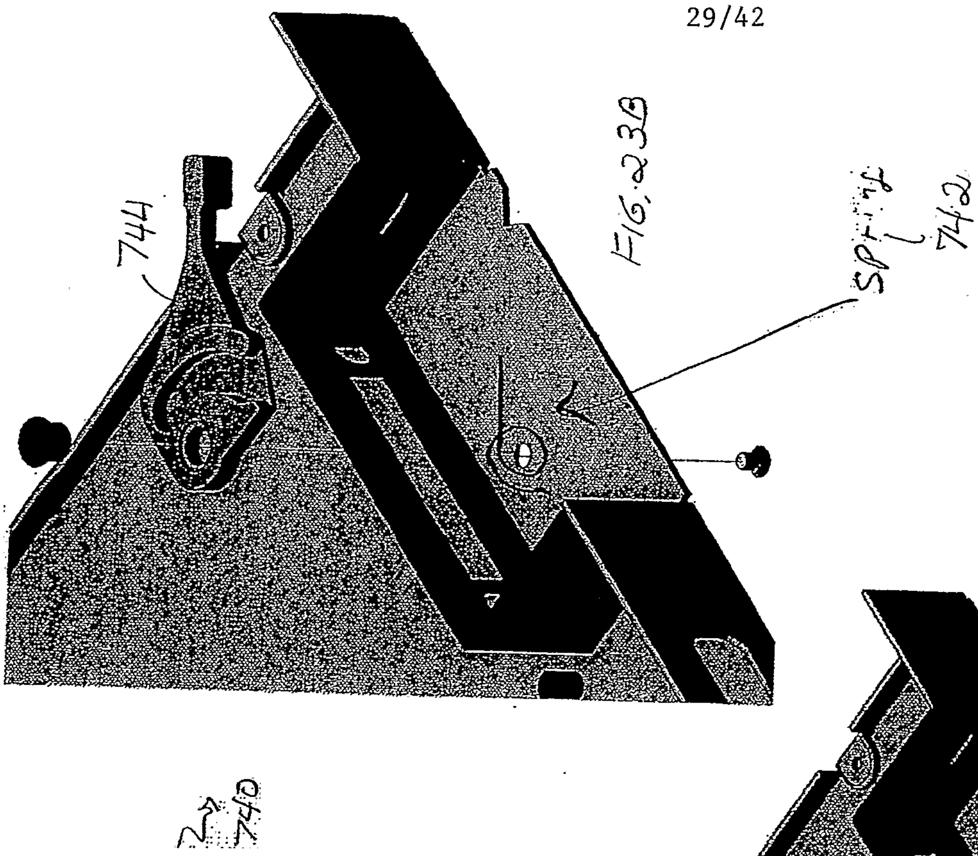


FIG. 23B

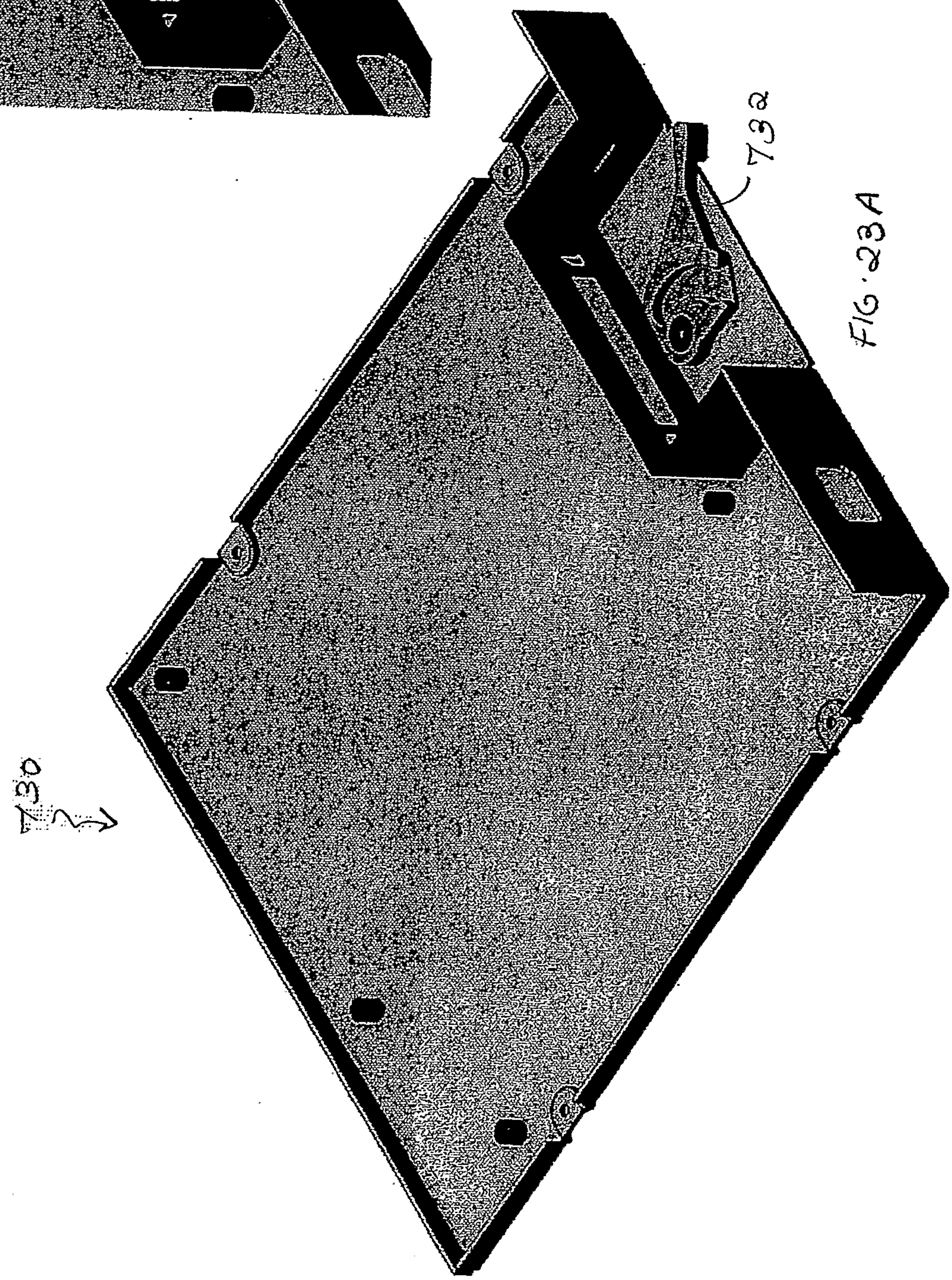


FIG. 23A

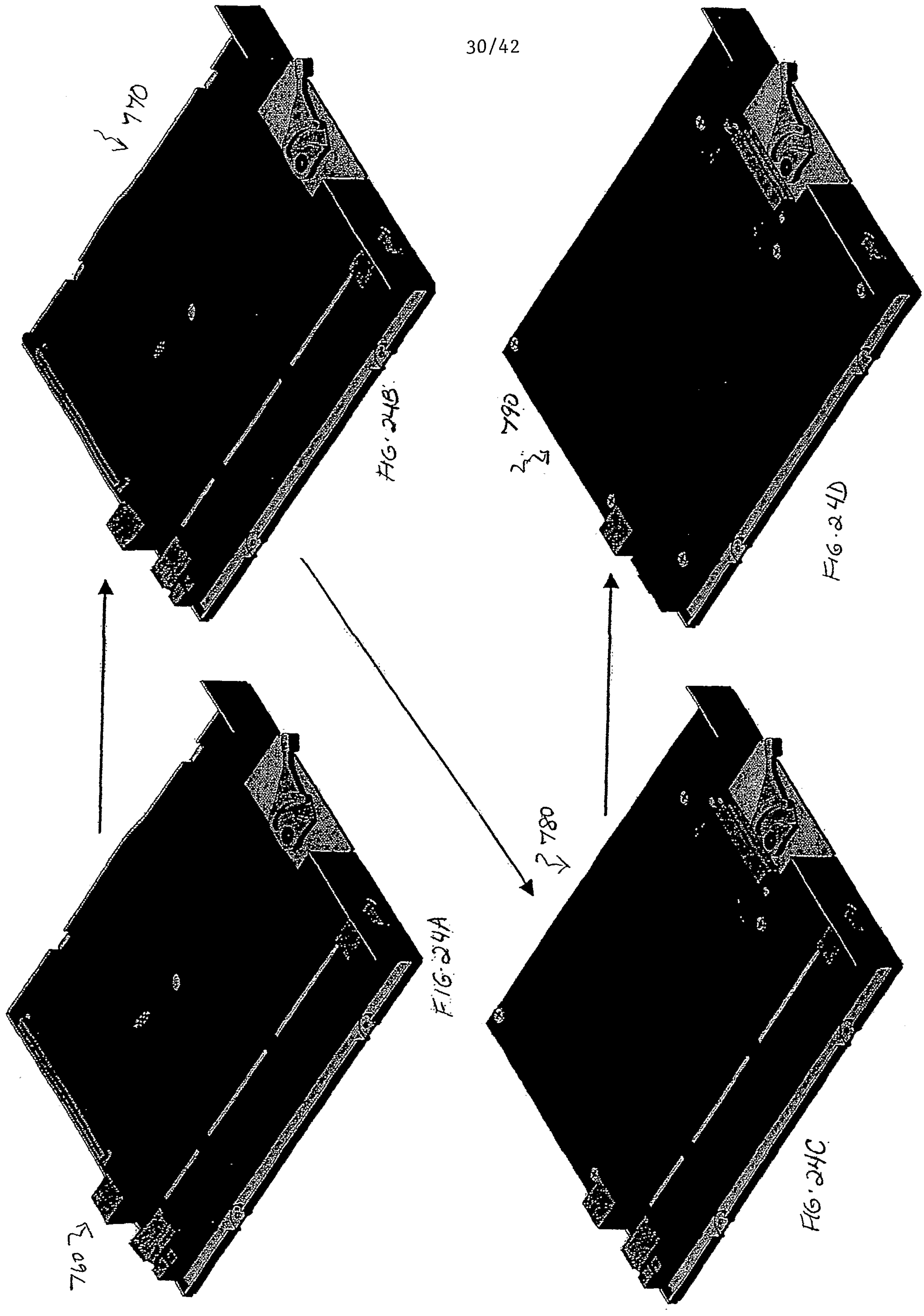


FIG. 24A

FIG. 24B

FIG. 24C

FIG. 24D

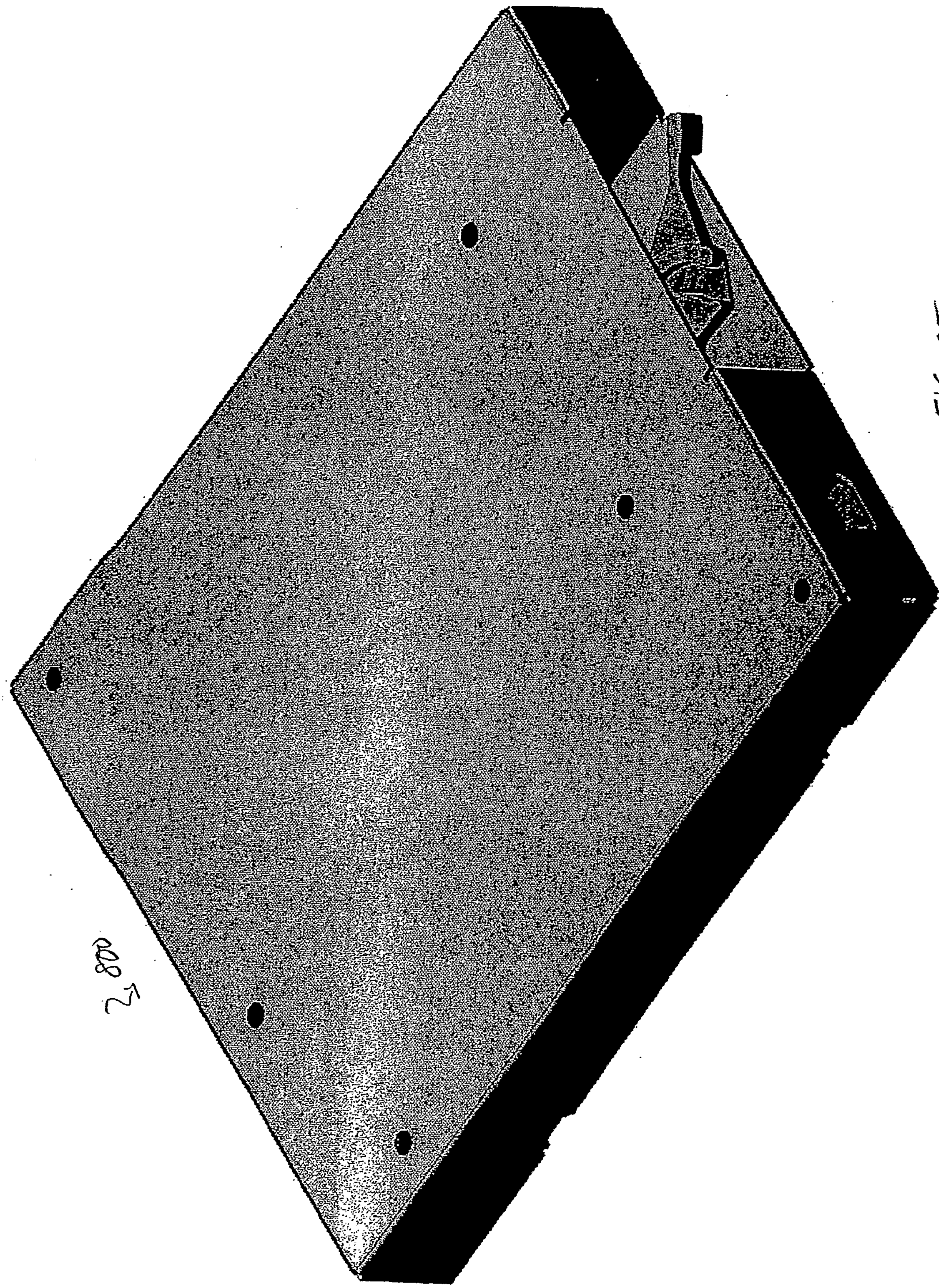


FIG. 25

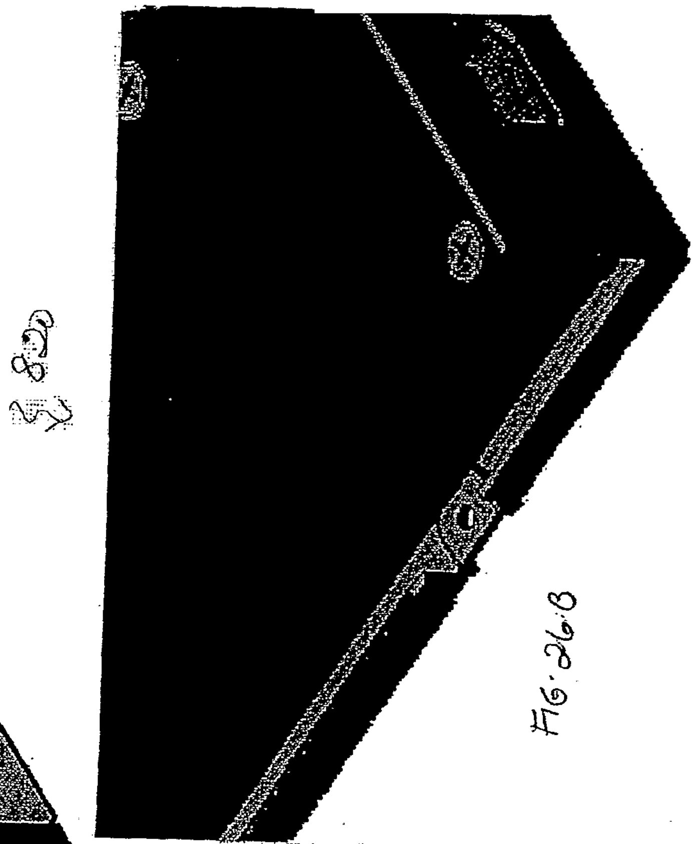


FIG. 26B

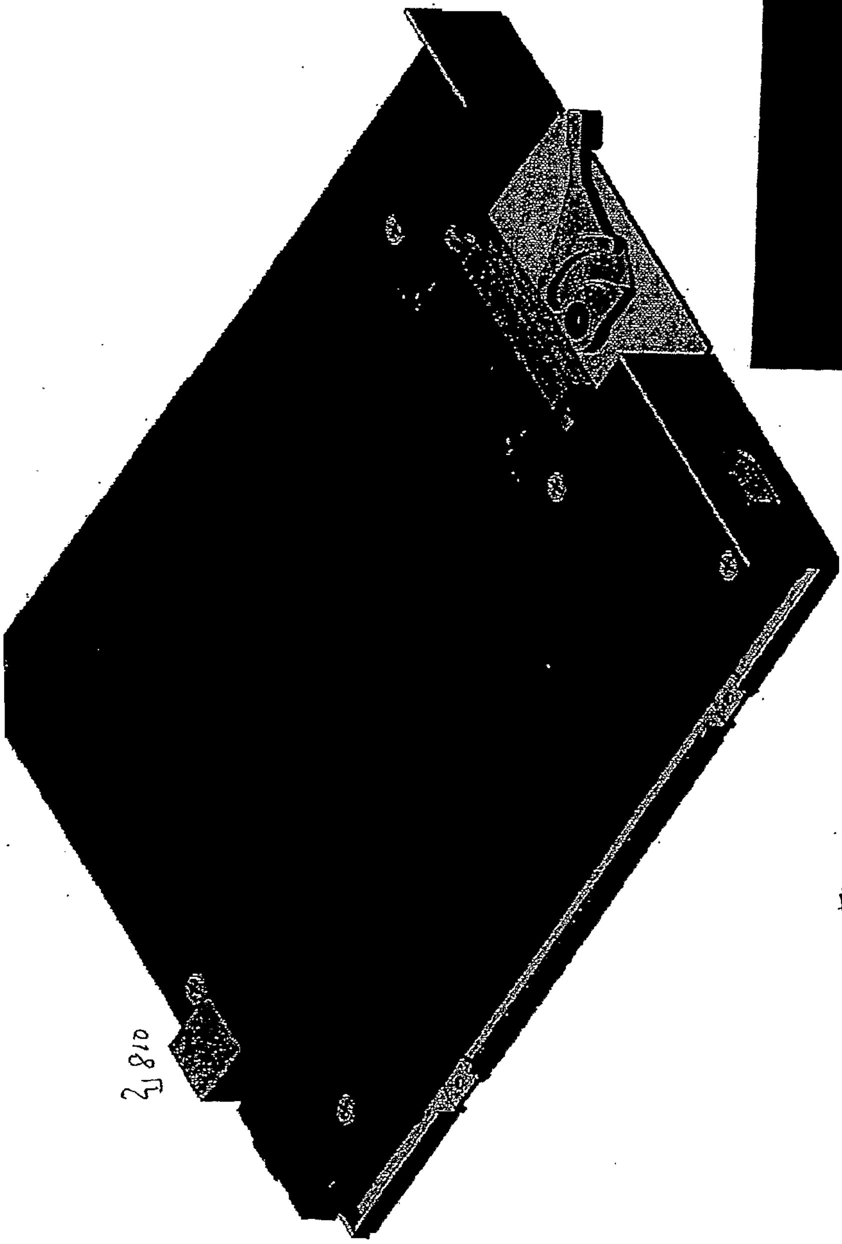


FIG. 26A

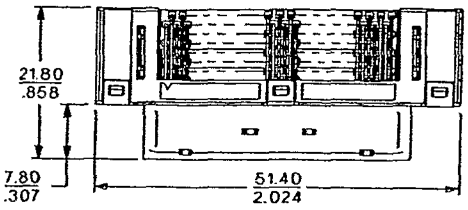
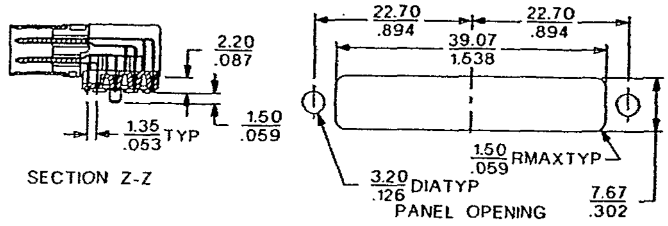


FIG 27B



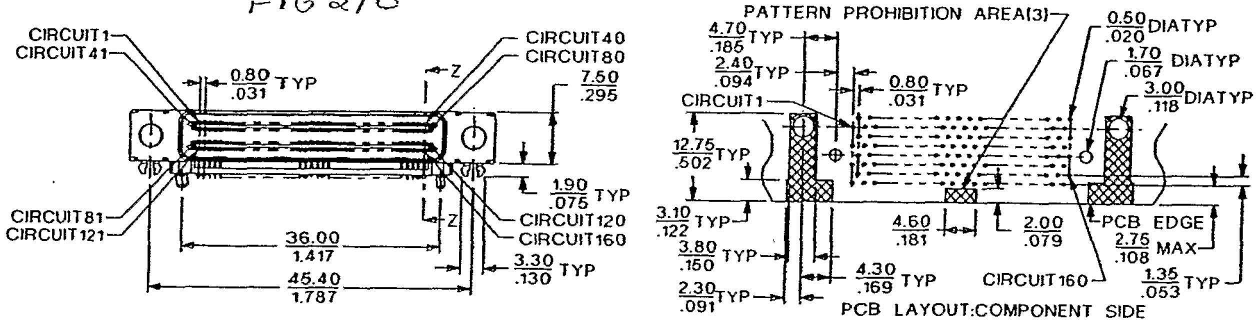


FIG. 27C

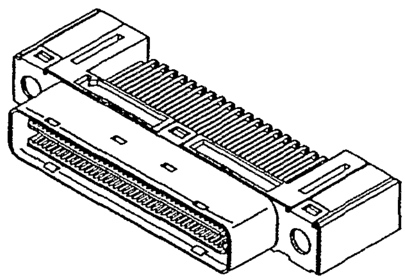


FIG 27A

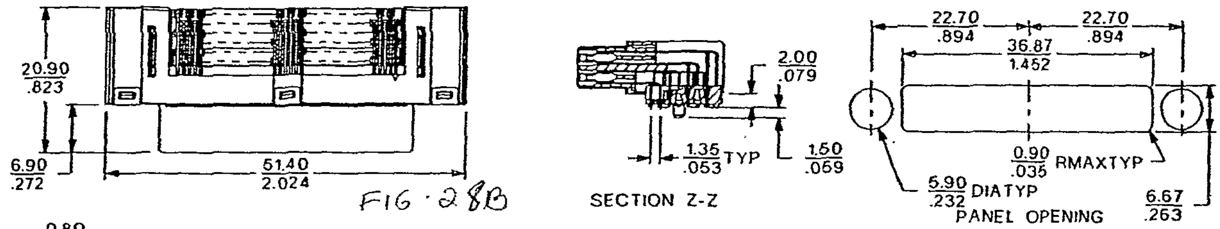


FIG. 28B

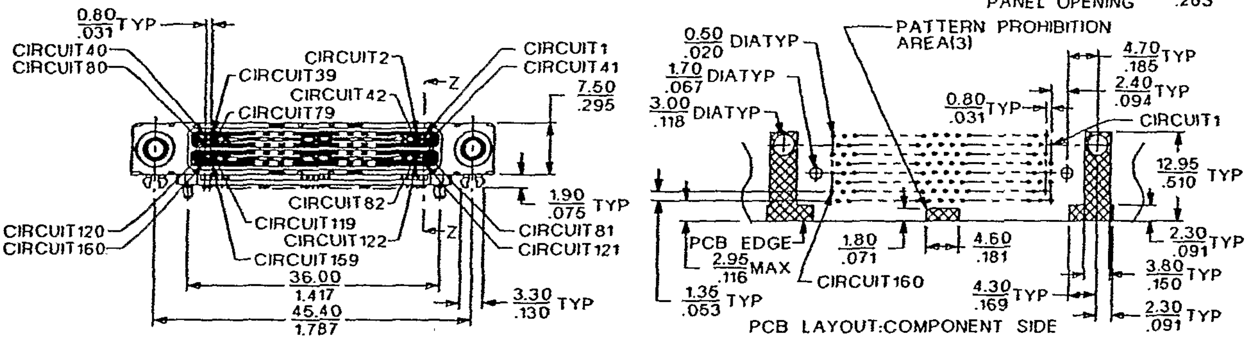


FIG. 28C

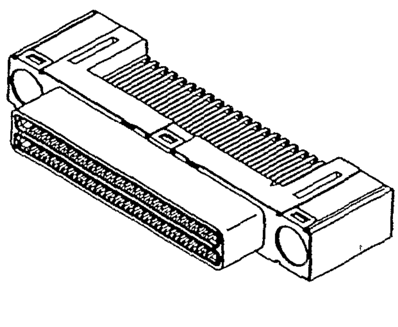


FIG 28A

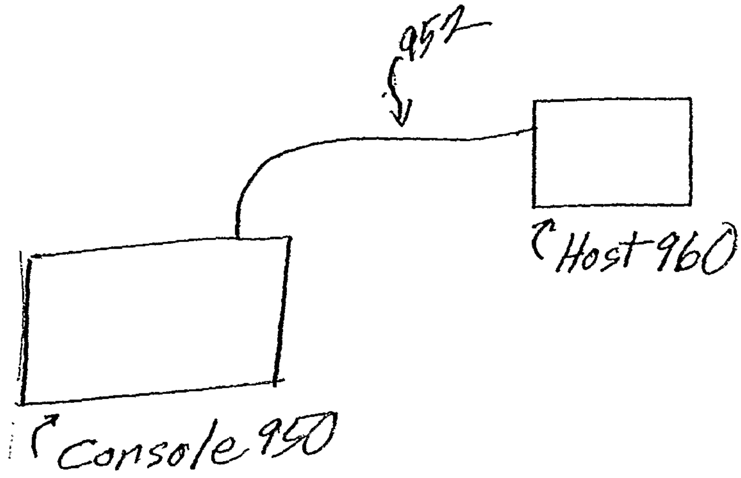

952
Host 960
Console 950

Fig. 29

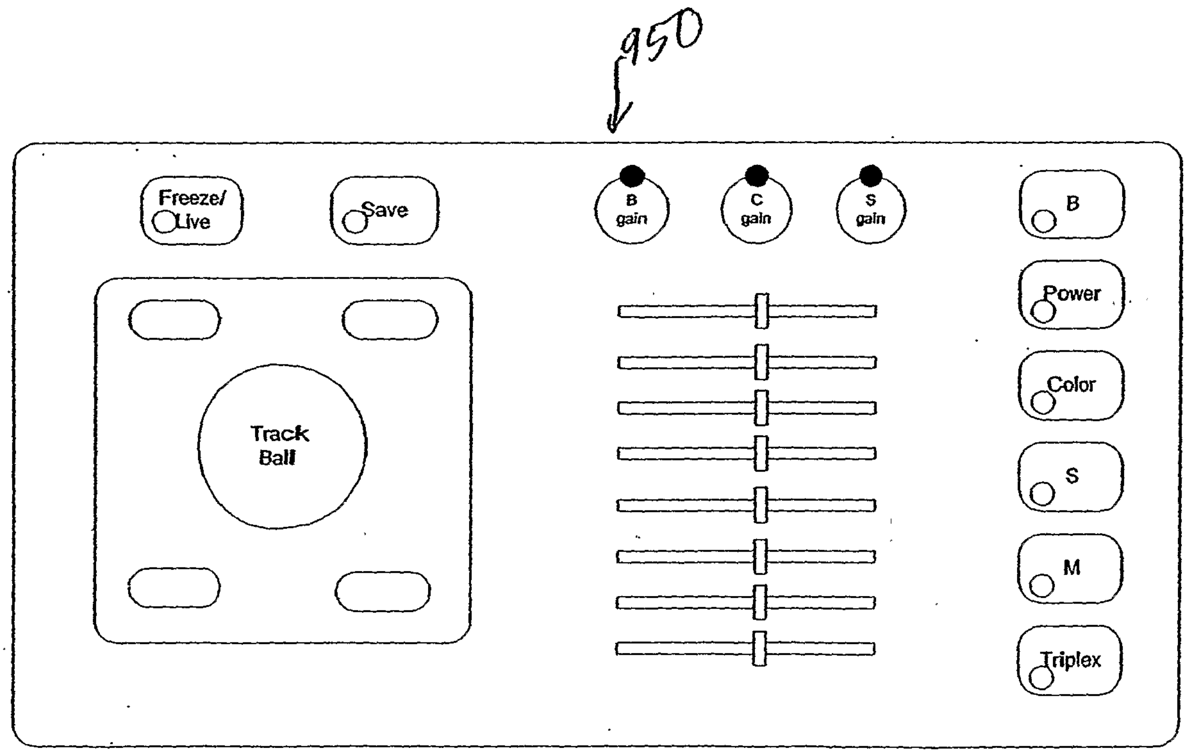

950
Freeze/ Live
Save
B gain
C gain
S gain
B
Power
Color
S
M
Triplex
Track Ball

FIG. 30

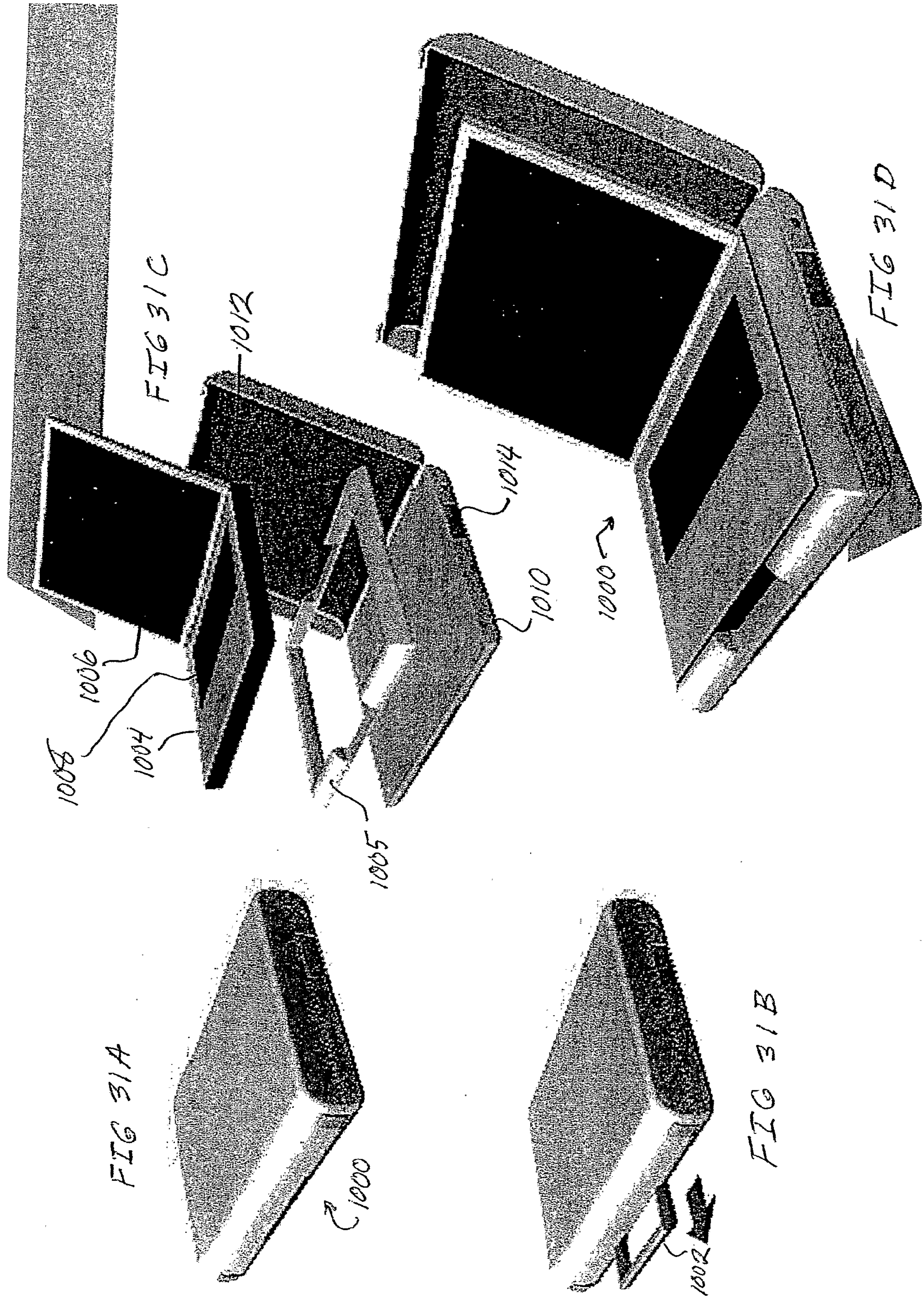


FIG 31C
1012
1014
1006
1008
1004
1005
1010
1000
FIG 31D
FIG 31A
1000
FIG 31B
1002

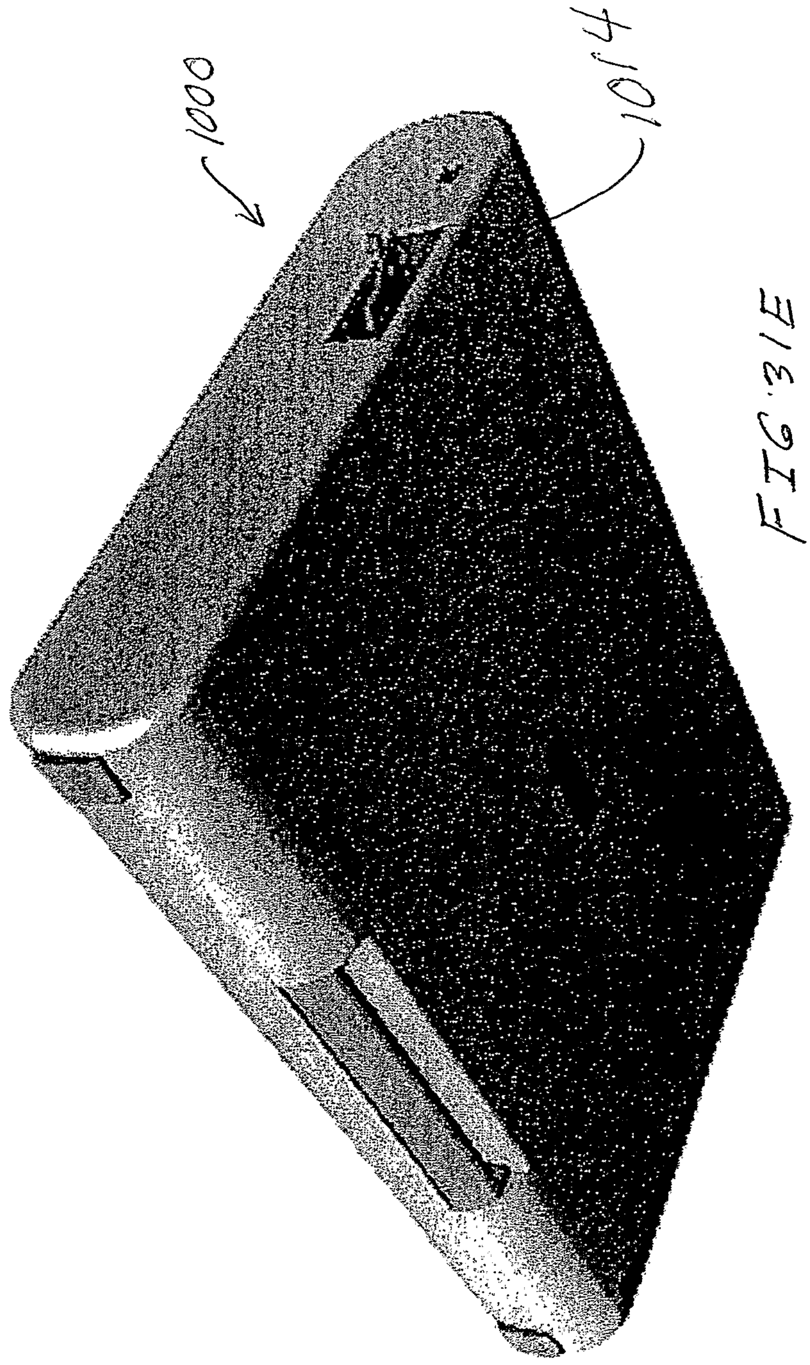


FIG. 31E

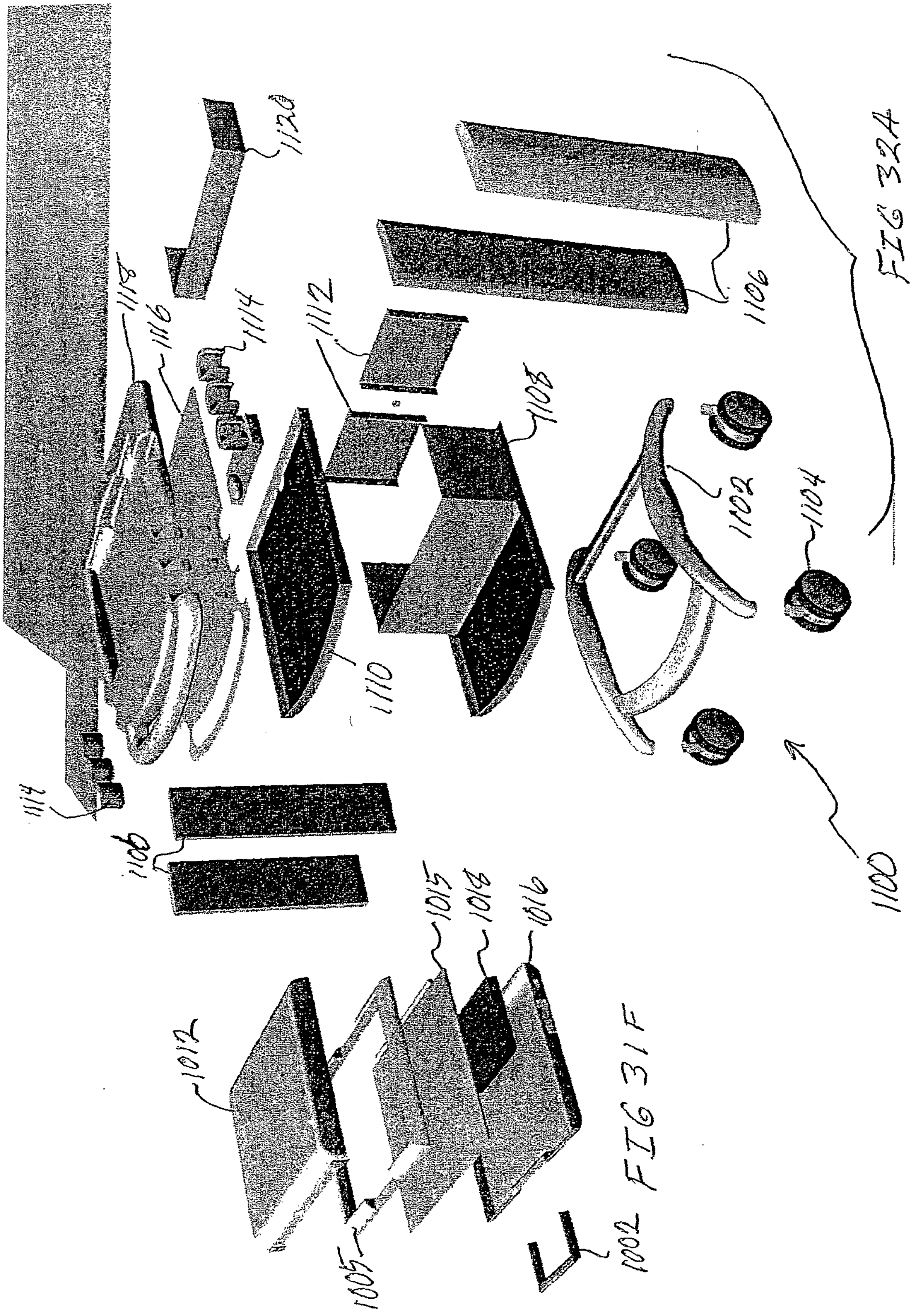


FIG 32A

FIG 31F

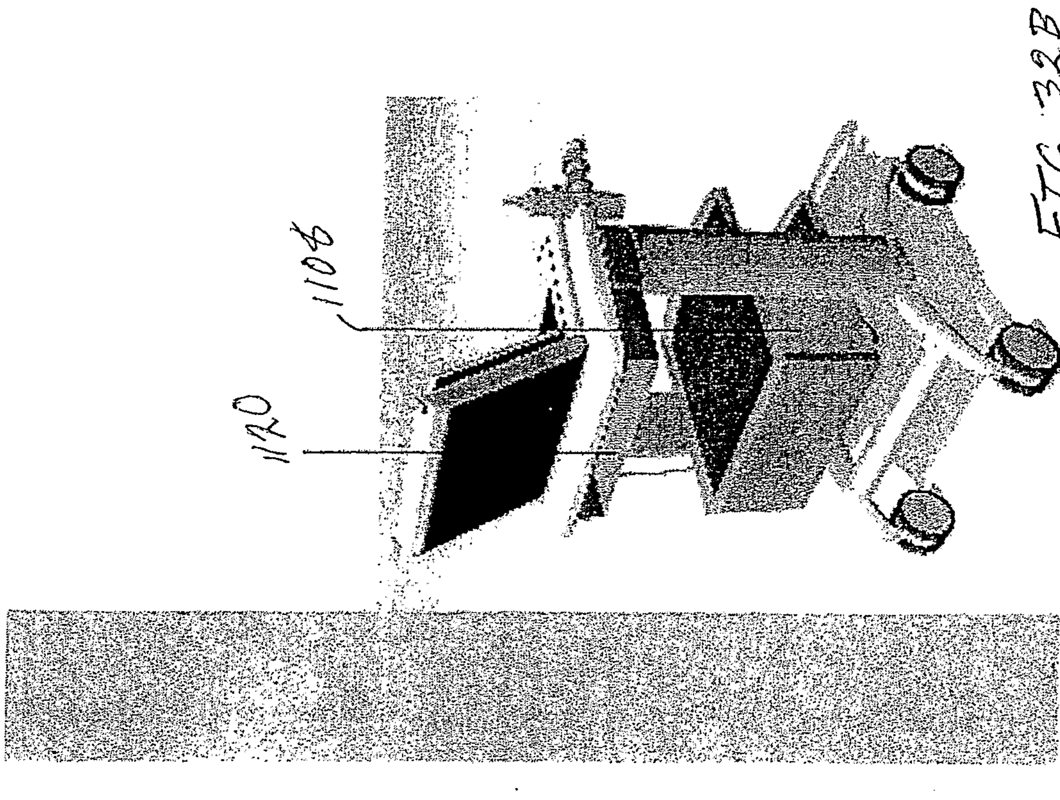


FIG 32B

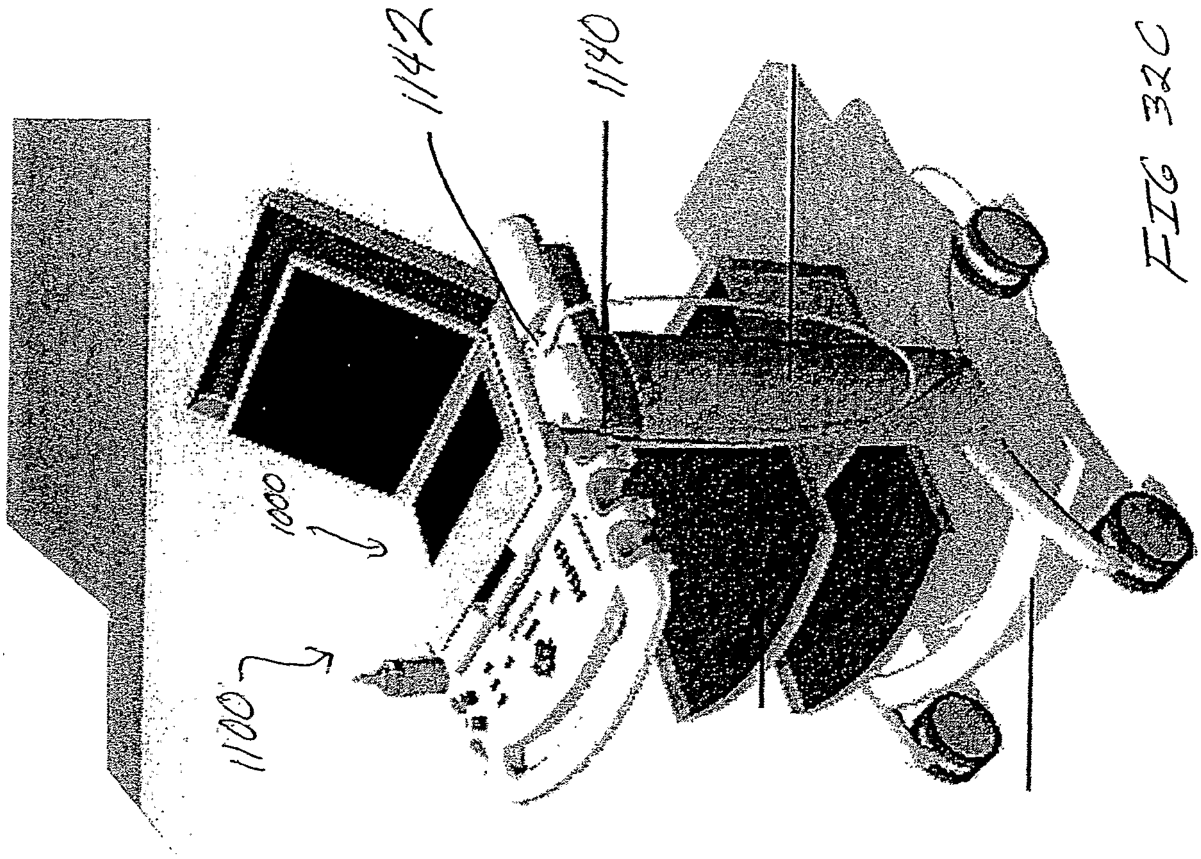


FIG 32C

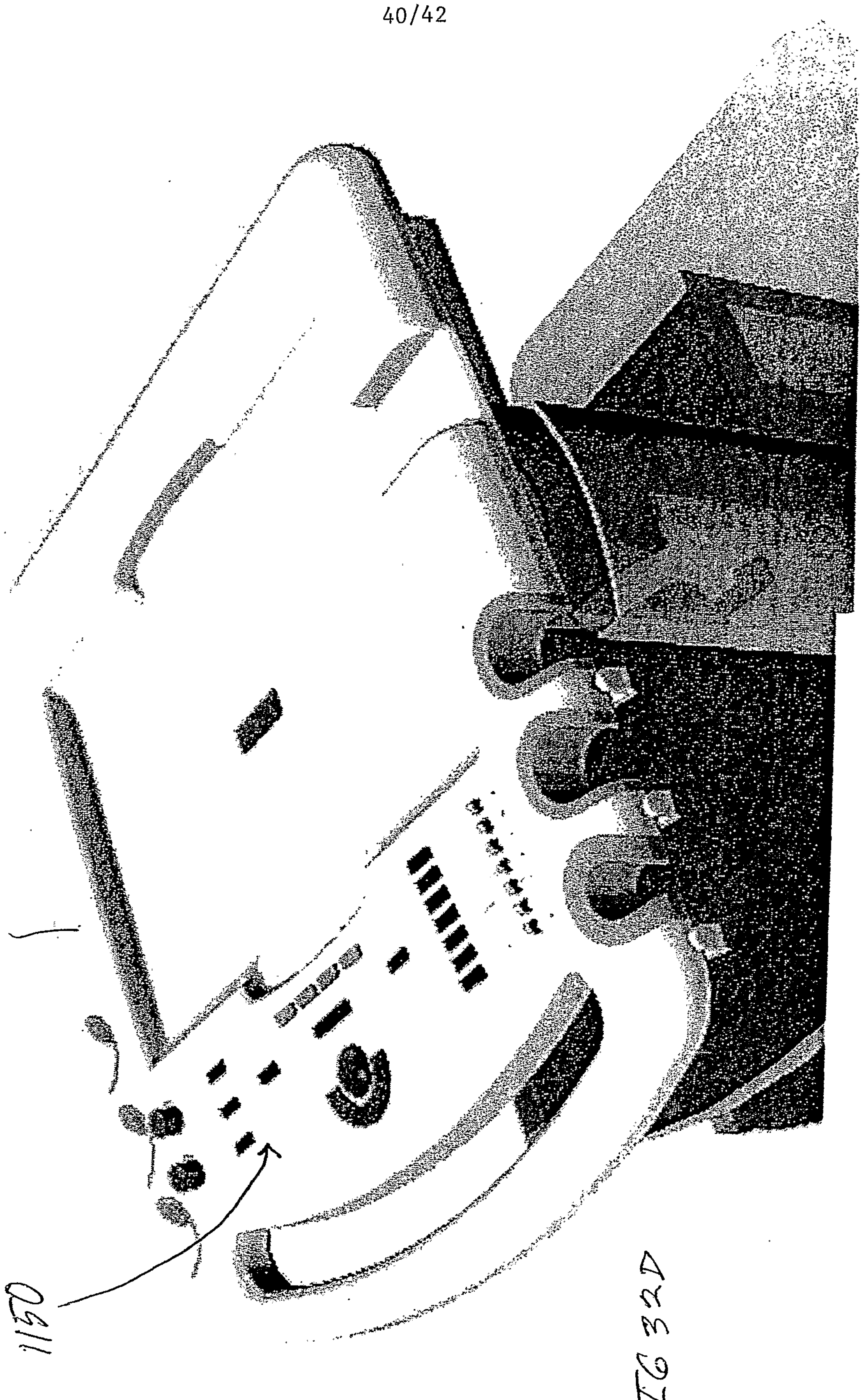


FIG 32D

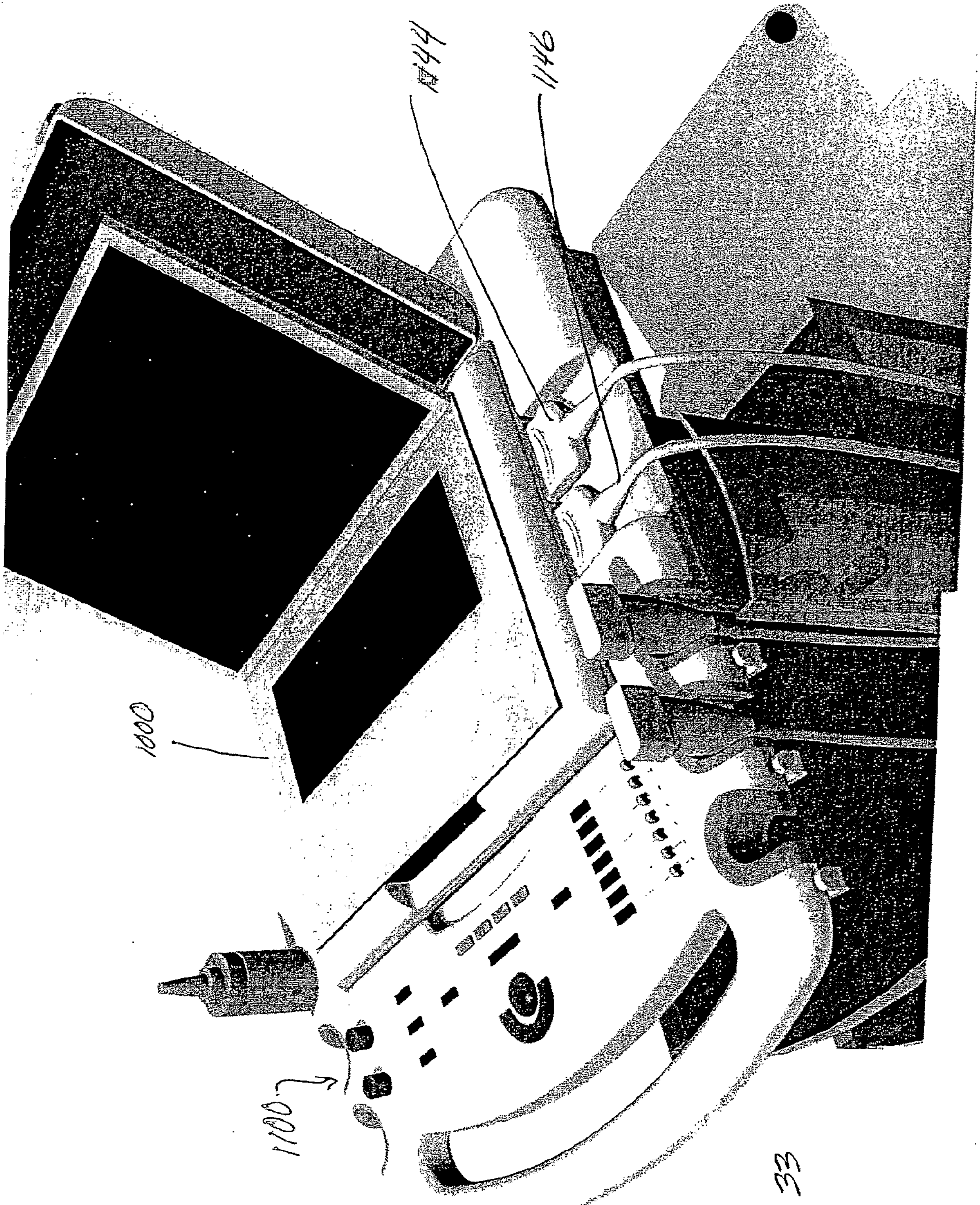


FIG 33

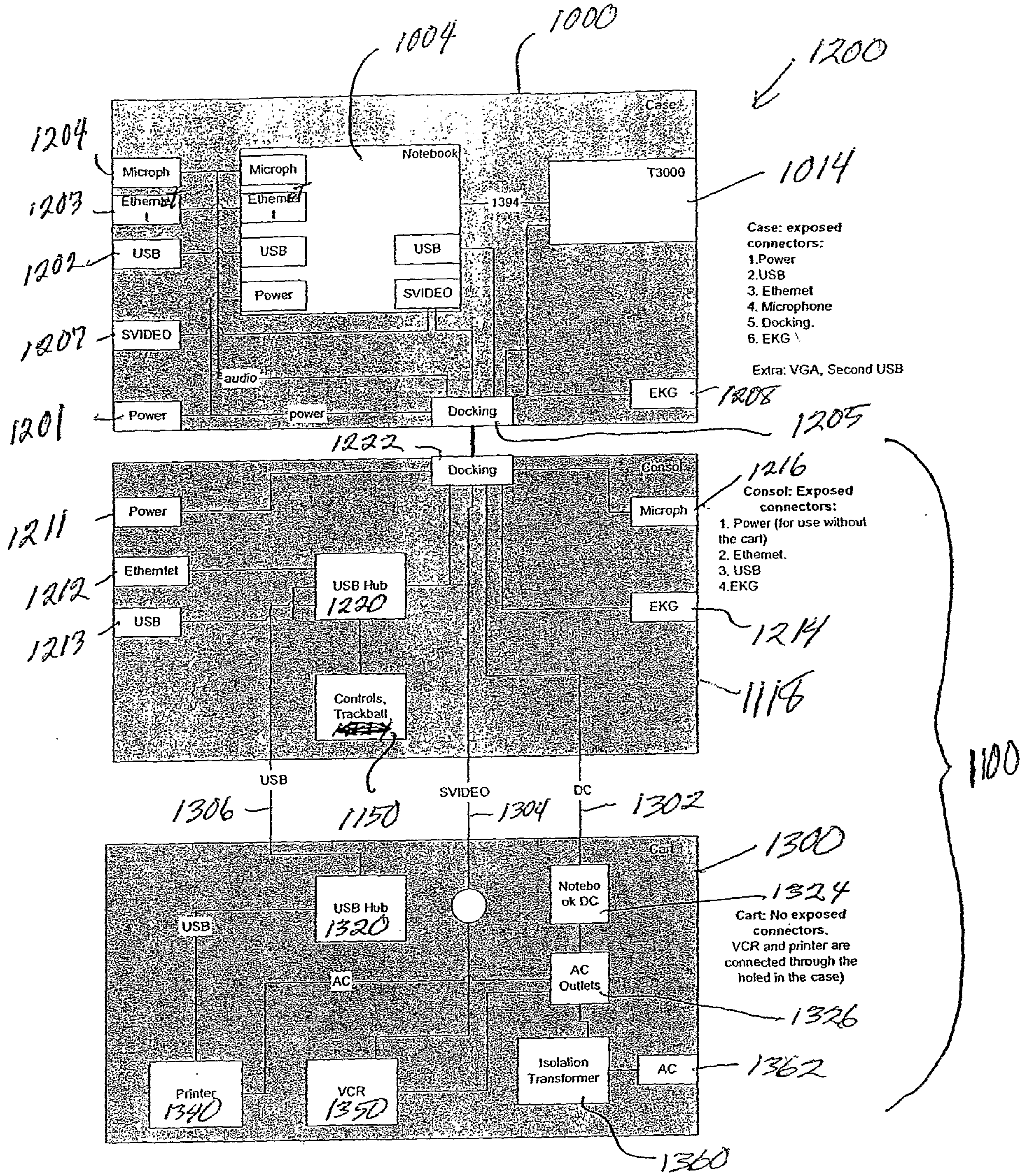

1000
1004
1200
Case
Notebook
T3000
1014
1204
Microph
1203
Ethernet
1202
USB
Power
SVIDEO
1207
1394
audio
power
1201
Docking
EKG
1208
1205
Case: exposed connectors:
1.Power
2.USB
3. Ethernet
4. Microphone
5. Docking.
6. EKG
Extra: VGA, Second USB
1222
Consol
1216
1211
Ethernet
1212
USB Hub
1220
1213
Consol: Exposed connectors:
1. Power (for use without the cart)
2. Ethernet.
3. USB
4.EKG
1214
Controls, Trackball
1118
1100
USB
SVIDEO
DC
1306
1150
1304
1302
Cart
1300
USB Hub
1320
Notebook DC
1324
Cart: No exposed connectors.
VCR and printer are connected through the holed in the case)
AC
AC Outlets
1326
Printer
1340
VCR
1350
Isolation Transformer
1362
1360

FIG 34

patsnap

专利名称(译)	模块化便携式超声系统		
公开(公告)号	EP1695113A2	公开(公告)日	2006-08-30
申请号	EP2004812223	申请日	2004-11-24
[标]申请(专利权)人(译)	泰拉科技公司		
申请(专利权)人(译)	TERATECH CORPORATION		
当前申请(专利权)人(译)	TERATECH CORPORATION		
[标]发明人	WONG WILLIAM MAURER DAVID BRODSKY MICHAEL CHIANG ALICE M		
发明人	WONG, WILLIAM MAURER, DAVID BRODSKY, MICHAEL CHIANG, ALICE, M.		
IPC分类号	G01S15/89 A61B8/00		
CPC分类号	A61B8/00 A61B8/4427 A61B8/4438 A61B8/4472 A61B8/58 A61B2560/0456 G01S7/5208 G01S7/52082 G01S15/899 G01S15/89		
优先权	60/525208 2003-11-26 US		
外部链接	Espacenet		

摘要(译)

本发明涉及一种轻型高分辨率便携式超声系统，其使用组件和方法来改善连接性和易用性。优选实施例包括集成系统，其中波束形成器控制电路可作为外围设备或在处理器外壳内插入主计算机中。模块化系统可以包括用于推车系统的对接组件，该推车系统具有控制台以操作系统并容纳附加的通信和外围系统。