

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
21 March 2002 (21.03.2002)

PCT

(10) International Publication Number
WO 02/22022 A1

(51) International Patent Classification⁷: **A61B 8/00**,
G01S 15/89

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(21) International Application Number: PCT/EP01/10117

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(22) International Filing Date: 30 August 2001 (30.08.2001)

(25) Filing Language:

English

(81) Designated State (*national*): JP.

(26) Publication Language:

English

(84) Designated States (*regional*): European patent (AT, BE,
CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC,
NL, PT, SE, TR).

(30) Priority Data:

60/232,450 13 September 2000 (13.09.2000) US
09/695,191 24 October 2000 (24.10.2000) US

Published:

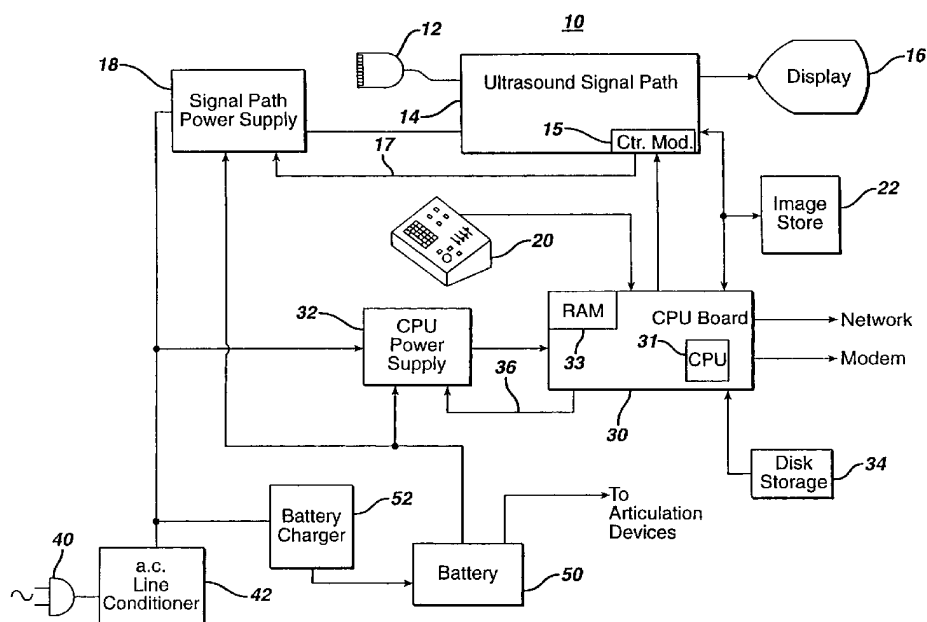
- with international search report
- before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments

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

(54) Title: PORTABLE ULTRASOUND SYSTEM WITH BATTERY BACKUP FOR EFFICIENT SHUTDOWN AND RESTART



(57) Abstract: An ultrasound system is described which can be turned off quickly by an operator command or in response to an interruption of a.c. power to the system. When a.c. power is cut off, the system switches to battery backup while a processor executes an orderly shutdown sequence. The system can completely shut down, or the state of the system can be minimally preserved by battery backup in either volatile or nonvolatile memory so that the system can restart without having to sequence through an entire bootup procedure. This enables the system to remain active even when the ultrasound system is unplugged and being moved.



WO 02/22022 A1

Portable ultrasound system with battery backup for efficient shutdown and restart

This invention relates to ultrasonic diagnostic imaging systems and, in particular, to portable ultrasound systems with battery backup.

In today's efficiently run hospitals, the portability of an ultrasound system enables the system to be used in more than one lab or department. An ultrasound system can
5 be used in radiology for most of the time and wheeled into the obstetrics department or delivery room when needed for an obstetrical exam, for instance. Portability also enables an ultrasound system to be used at the patient's bedside so that, instead of moving a patient to the ultrasound lab, the ultrasound system is moved to the patient, which is important in diagnosing many critically ill patients. Frequently, medical emergencies will necessitate that
10 the ultrasound system be moved quickly and the examination commenced at once at the new location. An impediment to such speed and convenience is the necessity to turn off the conventional ultrasound system through a time-consuming shutdown sequence before it can be unplugged and moved. This delay is repeated at the new location when it is necessary to power up the ultrasound system through a complex and time-consuming boot-up procedure.
15 Accordingly it would be desirable to avoid these time-consuming steps so that the ultrasound system can be relocated immediately and be ready to scan instantly at the new location.

In accordance with the principles of the present invention, an ultrasonic diagnostic imaging system is described which can be turned off quickly and restarted and be ready for scanning in a matter of seconds. This is accomplished by allowing a processor
20 and/or memory within the system to remain active even when the system is "turned off." When the system is turned off the state of the system is minimally preserved in either volatile or nonvolatile memory so that the system can restart without having to sequence through an entire bootup procedure. In a preferred embodiment the processor has a battery backup, enabling the processor to remain active even when the ultrasound system is unplugged and
25 being moved. When the ultrasound system arrives at its destination, diagnosis can begin at once.

In the drawings:

FIGURE 1 illustrates in block diagram form an ultrasonic diagnostic imaging system constructed in accordance with the principles of the present invention;

FIGURE 1a illustrates a method for initializing the ultrasound system of
FIGURE 1;

FIGURES 2a-2d illustrate different methods for efficiently turning off an
ultrasound system so that it can be restarted quickly;

5 FIGURES 3a-3d illustrate different methods for rapidly restarting an
ultrasound system;

FIGURE 4 illustrates a method by which an inactive ultrasound system can
respond to a remote inquiry;

10 FIGURE 5 illustrates a method by which an inactive ultrasound system
automatically prepares for scanning at a predetermined time; and

FIGURE 6 illustrates a method by which an ultrasound system assumes a state
of lower power consumption during periods of inactivity.

Referring first to FIGURE 1, an ultrasonic diagnostic imaging system 10
constructed in accordance with the principles of the present invention is shown in block
15 diagram form. The components of a typical ultrasound system are shown at the top of the
drawing, including a scanhead or transducer 12, an image display 16, and the ultrasound
signal path 14 which connects the transducer and the display. The ultrasound signal path will
typically include a beamformer which controls the transmission of ultrasonic waves by the
transducer 12 and forms received echo signals into steered and focused beams, a signal
20 processor which processes coherent echo signals in the desired mode of display, *e.g.*, B
mode, Doppler mode, harmonic or fundamental mode, and an image processor which
produces image signals of the desired format from the processed echo signals, such as a 2D
or 3D image or spectral Doppler display. The ultrasound signal path is controlled in a
coordinated manner by a system controller which responds to user commands and dictates
25 the overall scheme of functionality of the ultrasound signal path. For instance, the system
operator may enter a command on the user control panel 20 to request two dimensional
colorflow imaging using a certain scanhead. The system controller would respond to this
command by conditioning the beamformer to operate and control the desired scanhead,
initializing the signal processor to Doppler process the received echo signals, and setting up
30 the image processor to produce a grayscale B mode image with flow shown as a color
overlay.

The source of energy for a cart-borne or tabletop ultrasound system is
generally a.c. line voltage accessed by a plug 40. The a.c. power is filtered and rectified by
an a.c. line conditioner 42, which produces a DC supply voltage such as 48 volts. This

voltage is supplied to a signal path power supply 18, which supplies power to the scanhead 12 and ultrasound signal path 14. The a.c. line conditioner provides two other functions, which are to sense and respond to different a.c. power sources and to provide power factor correction which matches current and voltage phases to prevent instantaneous current spikes during cycles of the a.c. power. The a.c. line conditioner will sense whether the plug 40 is connected to 110 volt, 60 Hz power or 220 volt 50 Hz power, for instance, and will respond to configure the line conditioner to produce the required 48 VDC from either a.c. source. Power factor correction will cause the ultrasound system to use power more efficiently by appearing as a more resistive rather than reactive load to the a.c. power system. The power supply 18 is a DC to DC converter, which supplies a number of DC voltages for different components and modules of the ultrasound system. For instance, a high voltage is supplied as a drive voltage for the ultrasonic transducer, and lower level voltages are supplied to the digital processing circuitry of the system. The signal path power supply 18 is generally capable of providing 1000 watts or more of power to a cart-borne ultrasound system.

In accordance with the principles of the present invention a CPU board 30 is coupled to the ultrasound signal path 14 which controls the powering up and powering down of the ultrasound signal path. The functions of the CPU board discussed below may, in a particular embodiment, be integrated into the system controller of the ultrasound signal path and be performed there. In FIGURE 1 a separate CPU board is shown for ease of illustration and understanding. The CPU board 30 may comprise an off-the-shelf motherboard such as an ATX form factor motherboard with a system core chipset and basic input/output (BIOS) software. BIOS is code that runs from some sort of non-volatile memory such as a PROM or flash storage device and stays resident on the CPU board. The BIOS software boots the CPU from a cold power-up and launches the operating system. The BIOS software performs such functions as checking basic hardware operability and hardware resources available. Vendors of BIOS software include Phoenix, Award, and American Megatrends. The CPU board includes a CPU processor 31 (sometimes referred to herein as the CPU) which may be a microprocessor such as the microprocessors available from Intel, Advanced Micro Devices, or Motorola, or a processor of more limited capability such as a reduced instruction set (RISC) processor. The CPU board includes a random access memory (RAM) 33 which enables the CPU to run an operating system software program (OS) resident on nonvolatile disk storage 34. The OS is operated to control various operating aspects of the ultrasound signal path 14, display 16 and peripheral devices connected to the ultrasound system such as printers and recorders, as described below. The OS refers to the platform software that tends

to housekeeping functions and provides an interface to launch application software.

Operating system software includes DOS, Windows95-2000, Windows CE and NT, Solaris, and OS2. Any software that is not an OS and performs a given task is referred to as application software. Examples of application software includes word processor software, spreadsheet software, communication or analysis software, and the custom software that runs an ultrasound machine. In the illustrated embodiment the CPU board is coupled to the ultrasound signal path 14 by way of a control interface shown as control module 15 of the ultrasound signal path 14. When the functionality of the CPU board is integrated into the ultrasound signal path, the need for this interface may be partially or wholly eliminated.

The CPU board may be powered by the signal path power supply 18, however, in the illustrated embodiment the CPU board 30 is powered by its own CPU power supply 32. The CPU power supply has a lower capacity than that of the power supply 18, and may for instance be a 250 watt power supply. The CPU power supply 32, like the power supply 18, is a DC to DC converter which converts the voltage level supplied by the a.c. line conditioner to the DC voltages required by the CPU board 30 and, preferably, also the disk storage 34. The CPU power supply is coupled to the a.c. line conditioner and is energized in the same manner as the power supply 18.

In accordance with another aspect of the present invention, the ultrasound system includes an optional battery 50 which provides a backup source of power to the signal path power supply 18 and the CPU power supply 32. The battery is charged by a battery charger 52 coupled to the a.c. line conditioner 42 so that the battery can be fully charged whenever the plug 40 is connected to a source of a.c. line voltage. The battery 50 is also coupled to the drive motors of articulation devices, when present, by which movable parts of the ultrasound system such as the display 16 and control panel 20 can be raised, lowered, and tilted for the convenience of the operator. This enables the ultrasound system's articulated components to be moved and adjusted even when the system is not plugged into a wall outlet.

The ultrasound system has connections for a network and/or modem by which diagnostic information obtained by use of the ultrasound system can be remotely stored or shared with others. The network and modem connections also enable information from remote sources to be provided to the ultrasound system, such as electronic mail and reference image libraries as described in U.S. patents 5,897,498 and 5,938,607. In the embodiment shown in FIGURE 1 these connections are made from the CPU board 30, although in a particular embodiment they may also be made from the ultrasound signal path 14.

When a conventional ultrasound system is turned on, it must initialize all of its functionality from a cold start, which can take many minutes to accomplish. Likewise, when the system is turned off, the ultrasound system goes through a lengthy process to power down its various modules and subsystems in an orderly but time consuming sequence. In an embodiment of the present invention, the CPU board is rarely, if ever, completely powered down. The CPU board controls the other components and subsystems of the ultrasound system to be in various suspended states or entirely powered down, and may even itself go into a suspend or low power state, but is selectively available to be restored and to restore the rest of the ultrasound system to full operation in a short or almost instantaneous period of time.

In concept, the CPU board 30 and its OS and associated software act as a central processor with the other elements of the ultrasound system, including the ultrasound signal path 14, in essence viewed as peripheral devices to this central processor. The CPU board OS and, if desired, application software control the states of operation of these peripheral devices, within the constraints dictated by the user, so that the entire system is run efficiently and effectively. This can entail directing other elements of the ultrasound system to be in a high state of readiness, or to be in various suspend states with different time periods to return to full operation and different levels of power consumption, or to be partially or completely powered down. Not only does the CPU board OS control other elements of the system in this way; in a preferred embodiment it can impose these same controls on itself, even to a state in which the entire system is in a suspend state where it is consuming only 5-10 watts or less of power and can thus be maintained by battery power for a substantial period of time.

Several examples will illustrate the degrees of control which are possible. If the OS detects a lengthy period of inactivity by the ultrasound system, it may progressively power down or suspend operation of certain system components. The display for instance, might first be set to standby, then later powered down completely. Similar action might be taken with peripheral devices such as printers and recorders. The periods of inactivity after which these actions are automatically performed can be set by the system operator. Selected elements and even major portions of the ultrasound system which take little or virtually no time to reactivate can be powered down even for short periods of time such as a few seconds. For instance, when the operator freezes an image on the display screen, major portions of the ultrasound signal path can be placed in a low power suspend state until realtime scanning is resumed. This suspend state would be unnoticed by the operator, to whom the system would

always appear fully active. Such a suspend state might only last for a period of seconds, but the accumulation of such periods over time can result in a significant reduction in power consumption and component heat exposure and dissipation. Other elements of the system might always be maintained in a high degree of readiness, such as a network connection or modem, which would thus respond to queries at any time of the day or night.

The ultrasound signal path may be set to different inactive state levels from which it can return to full operation in a timeframe desired by the system operator. For instance, processors in the ultrasound signal path can be set to an idle state in which peripheral devices controlled or accessed by the processors including the nonvolatile disk drives servicing the processors are powered down. The processors and their volatile memory (RAM) continue to operate normally so that full operation can be restored almost immediately. In a lower inactive state, in addition to powering down the peripheral devices, the clock rate of the processors is reduced to a lower rate during inactive periods. The processors continue to be energized, as does the volatile memory used by the processors, which enables their resumption to full operability in fractions of a second. In an even lower inactive state the processors themselves are powered down, and the context, or variable data, of the processors such as register values, stacks and index values of the processors are stored in RAM, which remains energized. When power is restored to the processors a pointer restores the context of the processor to its state prior to shutdown, and full operability resumes fairly rapidly. In yet an even lower inactive state, the processor context is stored in RAM, and the RAM data is stored in nonvolatile (disk or semiconductor, *e.g.*, flash) storage. The nonvolatile storage, RAM and processor are then shut down. When operation is resumed the RAM data is retrieved from the nonvolatile storage, the context of the processor restored, and operation resumes from the point at which it was interrupted. In a machine as complex as an ultrasound system, different processors may have different inactive state levels, chosen as a function of the roles played by the various processors and the speed with which the operator wants the system to return to full operation. If the operator wants the system to return to full operation in fractions of a second, for instance, the CPU board OS may set the lowest inactive state for key processors to be that in which processor clock speed is reduced, but the processors and their volatile memory continue to be energized. If a longer time to resume operation is acceptable, a lower inactive state would be used. The sizes of data blocks used by the system is also a consideration. If large blocks of data are needed to configure the beamformer for scanhead operation and the time needed to restore the beamformer data from disk is unacceptable, the OS can cause the RAM memory of the

beamformer in which the data is stored to be continuously energized, obviating to restore the data from disk.

The following drawings illustrate flowcharts for operating an ultrasound system in accordance with some of the foregoing considerations and options. These

5 embodiments describe implementations of the present invention by an OS for ease of illustration; however, it will be appreciated that in a constructed embodiment the invention may be implemented in whole or in part by the OS, application software, BIOS software, or a combination thereof. The present invention can also be implemented in hardware such as by FPGA (field programmable gate array) control in lieu of OS control. As used herein the term

10 OS refers to any of these approaches. FIGURE 1a illustrates the flowchart of a process for initializing a default operating state for the ultrasound system. The default operating state is typically one which an operator uses most often. If the ultrasound system operator is an obstetrician, for instance, the default operating state may be an obstetrical exam with a particular curved array scanhead. If the ultrasound system operator is a cardiologist, the

15 default operating state may be a cardiac echo exam with a particular phased array scanhead. The default operating state would typically be initialized the first time the operator uses the ultrasound system, although it can be set or altered at a later point in time. In the process illustrated in FIGURE 1a, the ultrasound system is turned on (101) and the CPU board and its OS boot up (102). The OS in turn causes the ultrasound signal path to boot up (103). When

20 the ultrasound signal path is fully operational its functionality is tested (104) to verify that the system is fully functional, a step which may be selectively bypassed by the operator. The operator then uses the user interface to select the default exam type (105). If the operator is an obstetrician, for example, an obstetrical exam may be selected. The operator also selects the scanhead to be used for the preferred exam (106). When all of the necessary parameters

25 of the default operating state have been selected by the operator, the ultrasound system, preferably the OS, creates a file which defines the default operating state, referred to herein as the "DQuickStart" file (107). The OS then stores the DQuickStart file at a storage location from which it can be retrieved when needed, preferably on nonvolatile storage media such as disk storage 34. When the ultrasound system is restarted under several of the conditions

30 discussed below, the OS retrieves the DQuickStart file and initializes the ultrasound system for operation in the predetermined default operating state.

When a conventional ultrasound system is turned off, it proceeds through a lengthy process of terminating operations and shutting down modules and processors. When the power-down process is completed, generally the only circuit which is active is the

battery-supported chip which maintains the system clock and calendar. All other circuitry is completely turned off. FIGURE 2a illustrates a power-down state of the present invention from which full operability of the ultrasound system may be resumed fairly rapidly. Unlike the conventional power-down sequence, key system circuits continue to be energized. In

5 FIGURE 2a the OFF button is actuated (201) and the ultrasound system queries the operator as to whether the current ultrasound exam is to be continued when the system is restarted (202). In this example the operator responds that the current examination is to be continued. The application data for the current exam is saved to RAM (203) and the OS powers down the ultrasound signal path (204). The OS also powers down the ultrasound system's
10 peripheral devices or puts them in a suspend state, including the hard drive (HD) disk storage 34 (205). The register and stack values (context) of the CPU are saved to RAM (206) and a flag is set instructing the CPU to use the saved values when it is restarted (207). The CPU is then clocked at a low clock speed (208) to conserve energy.

The ultrasound system may be restarted from this state by following the
15 process charted in FIGURE 3a. When the ultrasound system ON button is actuated (301) the CPU is clocked at its normal clock rate (302). The peripheral devices including the hard drive are turned on (303) and power is restored to the ultrasound signal path (304). The OS checks the restart flag (305) and finds that it is set to restart from RAM. The register and stack values of the CPU are restored from RAM (306) and checked for corrupted data (307).
20 Since the ultrasound system may have been left in its inactive state for a considerable period of time, such as overnight or for several days or longer, it is prudent to check for data corruption since the ultrasound system is being relied upon to provide patient diagnostic information. If corrupted data is found, a full recovery bootup is performed (308). If no data corruption is found the data previously stored for the examination, the application data, and
25 the scanhead data are restored to the ultrasound signal path (315). The system is now ready to continue the same exam that was underway when it was turned off.

In this and the other quick start sequences described below, it is seen that the step (104) of testing full functionality of the ultrasound signal path is not performed during the rapid restoration of system operability. That is because such self-testing can be very
30 time-consuming, detracting from the desired quick system restart. However, such functionality testing should be performed to continually assure accurate system functionality.

In an embodiment of the present invention such functionality testing is performed at run-time, either as part of mode transitions, in the background, or when periodic idle or partially inactive states are encountered such as when an image is frozen on the screen. Uninterrupted

full functionality testing of the ultrasound signal path is performed automatically on a cold start reboot. At other times such functionality testing is intermittently conducted by the OS when such scheduling can be conducted without interruption of operations commanded by the operator, such as during the night when the system is not in use. Thus, safety hazards and risk concerns are abated on a periodic but continual basis.

Variations of these processes are possible. Instead of powering down the entire ultrasound signal path (204) the OS may leave some or all of the processors of the ultrasound signal path in one or more idle states or low clock speeds, or turn off some of the components and modules of the ultrasound signal path processors while leaving others energized. For instance, the volatile memory holding data for the beamformer may be left in an energized condition. The OS can do this by commanding the signal path power supply 18 by way of the control module 15 and the command line 17 to switch power off to all elements of the ultrasound signal path except the beamformer RAM. As another alternative, rather than switching the CPU to a low clock speed, the OS may issue a command to the CPU power supply 32 over command line 36 to switch power off to all CPU board components except the board's RAM. While this action would increase the time required by the system to return to full operability, it would enable the CPU power supply to operate at an output level of approximately 5 watts or less, which may be sustained by battery power for an appreciable amount of time.

FIGURE 2b illustrates a procedure by which the ultrasound system is "turned off" to a lower state of readiness, requiring more time to be restored to full operability but exhibiting lower power consumption when "turned off." After the operator actuates the OFF button (201) and elects to continue the current examination when the system is restarted (202), the application data for the current exam is save to RAM (203), the ultrasound signal path is powered down (204), the peripheral devices are powered down (211), and the register and stack values of the CPU are saved to RAM (206). The data stored in RAM is saved to nonvolatile disk or semiconductor storage (209) and a flag is set to notify the CPU to start from the data in nonvolatile storage when operation is resumed. The disk drive and RAM is powered down and the CPU is switched to a low clock speed. Alternatively, the CPU may also be powered down as the data needed on restart is retained in nonvolatile storage. This will require the CPU to reboot on restart, but will not require power to be maintained to the CPU while the system is off.

The ultrasound system may be restarted from this off state by following the sequence shown in FIGURE 3b. When the ON button is actuated (301) the process follows

the same procedure diagrammed in FIGURE 3a up to the point where the restart flag is checked (305). Here the OS sees that the "Start From Disk" flag has been set, and consequently the data stored on the hard drive is restored to RAM (316). The register and stack values of the CPU are restored (306), and a data corruption check is performed (307).

- 5 If no data corruption is found the examination application data and the scanhead data are restored (315), and the system is once again ready to continue the previous exam. As before, variations are possible such as leaving portions of the ultrasound signal path energized and/or operating at selected idle levels to enable a quicker restart.

In the previous scenarios the operator has elected to have the system continue
10 the current ultrasound exam when the ultrasound system is restarted. FIGURE 2c shows one possible scenario when the operator has elected not to continue the same exam on restart. When the operator makes this election (202, the system queries whether the same type of examination as the most recent one is to be used on restart (212). If the operator routinely uses the ultrasound system for a particular type of cardiac exam, for instance, the choice
15 might be made to restart the system for the same type of cardiac exam as that which has just been completed. But if the operator wants a different exam the next time the system is used or is not sure what type of exam will be performed next by the system, the operator answers "No", as shown in the drawing. The OS responds by setting a flag for the DQuickStart file (213), powering down the ultrasound signal path (204), powering down the peripherals
20 including the hard drive (205), and setting the CPU to a low clock speed (208). When the system is restarted the ultrasound system follows the sequence shown in FIGURE 3c. When the ON button is actuated (301) the CPU is returned to its normal clock speed (302) and the hard drive and peripheral devices are turned on (303). The ultrasound signal path is turned on (304) and the OS checks the restart flag (305). Upon finding the DQuickStart flag set, the
25 DQuickStart file is selected from nonvolatile storage (309) and the previously set default operating parameters are implemented. The ultrasound signal path is conditioned for starting the default exam application (310) and the beamformer is set up to operate the default scanhead (311) or, if it is unavailable, a scanhead presently connected to the ultrasound system. The ultrasound system is now ready to perform the default exam.

- 30 As in the previous examples, variations of this scenario may be employed. Instead of switching the CPU to a low clock speed, the CPU board can be turned off, as the DQuickStart file is stored in nonvolatile storage; only the restart flag needs to be maintained. This would take more time to restart, as the CPU board would have to be rebooted. As another alternative which would result in an even faster restart, instead of setting the

DQuickStart flag during the power-down sequence, the parameters of the DQuickStart file could be loaded into RAM and power to the RAM maintained so that the OS could immediately implement the DQuickStart application without having to recall the DQuickStart file from storage upon restart.

5 FIGURE 2d shows a sequence of events that occur when the operator elects to begin the same type of exam as that which was just completed when the ultrasound system is restarted. When the operator makes this election (212), the OS builds a file called CQuickStart, which contains parameters of the type of exam just completed, including the scanhead used (214). The CQuickStart file is saved to disk (or, in one of the alternatives
10 described above, is stored in RAM), and a flag is set for the CQuickStart file (215). The ultrasound signal path is powered down (204), the peripherals and hard drive powered down (205), and the CPU is set to a low clock speed (208). When the ultrasound system is turned on (301) as illustrated in FIGURE 3d, the normal CPU clock speed is resumed (302), the hard drive and peripherals turned on (303), and the ultrasound signal path is turned on (304). The
15 OS checks the restart flag and finds that the CQuickStart flag is set (305). The OS retrieves the CQuickStart file from disk (or implements it immediately if it was stored in RAM) (312), and starts the exam application identified by the CQuickStart file (313), including setting up the beamformer for the scanhead identified by the file (314). The alternatives applicable to the previous scenario of FIGURES 2c and 3c are also applicable to this one.

20 As mentioned above, when the OS powers down different elements of the ultrasound system it will power them to an idle level which allows them to be returned to full operability in the timeframe required by the user. Different elements of the ultrasound system may be set to different idle levels, and these levels may vary for different users as different users may have different demands for the time in which the ultrasound system must
25 restart. The OS will also power down different elements of the system in consideration of the type of functions they perform, as previously illustrated by the example of maintaining power to the beamformer memory. FIGURE 4 illustrates another example of this. An ultrasound system which is externally accessible over a network or modem may need to be available for remote querying at any time. For example, remote diagnostics may be performed at night
30 when the ultrasound system is not otherwise in use, as described for instance in U.S. patent [application serial number 09/534,143, filed 3/23/00]. As another example, the diagnosing physician may want to review images stored on the ultrasound system from his home after the ultrasound lab has closed for the day. Such a scenario is described in U.S. Pat. 5,851,186. In these cases, the ultrasound system is essentially "on call" 24 hours a day. In this mode,

when the ultrasound system is turned off at the end of the day, the network interface or modem may be in a suspend or power-down state, but still aware of network or phone activity such that it can be fully active if called. The CPU can be put in a low power state, or even turned off, so long as it continues to be responsive to an interrupt from the network or
5 modem to handle external queries. The CPU itself can be responsive to such an interrupt in an idle (e.g., low clock speed) state, or the chipset on the CPU board can be responsive to such an interrupt and restart the CPU accordingly. In some cases the BIOS software on the CPU board can be programmed to handle these interrupts.

As an example, a physician desires to use his home computer to view an image
10 acquired the previous business day by the ultrasound system. The physician connects to the ultrasound system either through the network connection or modem as shown in FIGURE 4, which sends an interrupt to the CPU board (401). In the case where the CPU was powered down to a low clock speed, the CPU responds to the interrupt by resuming its normal clock speed (402). In the case where the CPU was turned off, the CPU board chipset responds to
15 the interrupt by restarting the CPU. The hard drive and other peripherals may be turned on (403) if needed to respond to the request, as they may be required to run Web applications to respond to an Internet browser. The OS turns on the memory device where the ultrasound images are stored (404). In the example of FIGURE 1 the ultrasound images are stored on an image store 22 connected to the ultrasound signal path and the CPU board. The OS then runs
20 the communications software needed to respond to the request, such as Web applications software (405). As described in the aforementioned patent, a Web server can transmit an image file index to the physician who selects the image desired. The desired image is then retrieved from the image memory or disk and transmitted over the network, modem, or Internet to the physician, who then views it on the screen of his home computer. After the
25 communication has ended, the hard drive, image memory, peripherals and CPU can be powered down again to await the next query in a low power state.

With the ultrasound system having the ability to power up and power down the system selectively, a procedure such as that shown in FIGURE 5 can be employed to automatically restart the ultrasound system at a predetermined time. This allows the
30 ultrasound system to be shut down when it is not used overnight, but to be ready for scanning when the ultrasound lab is opened the next day. At the time the ultrasound system is turned off, the operator enters a command for the ultrasound system to restart at a designated time and date. If the ultrasound lab opens at 8 a.m. the next day, it may be desirable to have the ultrasound system turn on at 7:45 a.m. and to perform a self-diagnosis at the time so that the

system is fully ready for scanning at 8 a.m. When the operator turns the ultrasound system off, the selection is made to restart the system for the default exam or a custom exam (including the most recently performed exam as explained above), and the appropriate QuickStart file is flagged. The system is then shut down to the desired idle level; in this

5 example, the CPU is switched to a low clock speed. A timer in the ultrasound system, which may be implemented on the CPU board, keeps track of the time and when the appointed start time occurs the timer sends an interrupt to the CPU board (501). In response to the interrupt the CPU returns to the normal clock speed (502), and the OS turns on the hard drive and peripherals (503). The OS then checks to see whether the a flag is set for the default exam or
10 a custom exam (504). If the default exam has been flagged, the ultrasound signal path is turned on (505) and the DQuickStart file is retrieved. The beamformer is programmed for the scanhead used in the default examination (508) and the default exam application is set up on the ultrasound system (510). A full self-test of system functionality may be performed. The ultrasound system is then fully ready for scanning when the operator arrives to use it.

15 When the OS finds that the custom exam flag has been set, the ultrasound signal path is turned on (505) and the CQuickStart file is retrieved (507) which contains the parameters of the exam which the operator wants to perform first. The beamformer is programmed for the scanhead of the custom exam (509) and the custom exam application is set up on the ultrasound system (511). A full self-test of system functionality may be
20 performed. Thus, the ultrasound system is ready to use immediately when the ultrasound lab is opened in the morning without having to leave the system fully powered up overnight.

As discussed above, a high performance ultrasound system can consume approximately 1000 watts of power, even when sitting unused. This power consumption will produce a heating effect which must be dissipated by the lab or hospital's air conditioning
25 system, which costs money. Furthermore, the heating of components in the system can reduce component life, leading to degraded system reliability. FIGURE 6 illustrates an approach to reducing this cost and unnecessary component heat dissipation, which is for the ultrasound system to progressively turn off its modules and subsystems when it is sitting unused for a period of time. In a preferred implementation the user is given the opportunity
30 to activate or deactivate such a progressive shutdown, select the time which passes before the progressive shutdown commences, and select the time passages between the successive steps of the shutdown. The order in which the various components of the system shut down can also be changed. In the progressive sequence of FIGURE 6 the first element to be shut down is the display device, which may first be put on standby (601) and, after a further passage of

time, completely powered down. After further time the OS powers down the ultrasound system peripheral devices such as printers and recorders (602). After further time, any unsaved exam data and the register and stack values of the CPU (context) are stored to RAM (603) and the RAM data saved to disk (604). The ultrasound signal path is powered down (605) and the CPU board's peripherals and hard drive are powered down (606). Finally the CPU is set to an idle state, in this example a low clock speed (607). The ultrasound system is now consuming only a small amount of power, perhaps 5 watts or less, but the CPU, still being energized, can restart the ultrasound system in a relatively short amount of time.

In a variation of the sequence of FIGURE 6, the OS is continually monitoring the use of the ultrasound system and turning modules and components off and on where the situation permits to effect a lower overall power consumption and component heating. Modules and subsystems may be placed into low power states for seconds and even fractions of seconds where possible to achieve this. For example, the operator may interrupt real time imaging to freeze an image on the display screen. Sensing this state, the OS can maintain power to the display 16, the image store 22 where the frozen image is stored, and that portion of the ultrasound signal path which applies image display signals to the display such as the video driver of the system. The transmit and receive beamformers can be set to an inactive, low power state at this time, as can the signal and image processing portions of the ultrasound signal path 14, since real time imaging has been suspended. To the operator, this suspense state is transparent, as the frozen image is maintained on the display as the operator has commanded. This reduces the power consumption and heating of those subsystems of the ultrasound signal path 14 which have been placed in the low power state. The 1200 watt consumption of an ultrasound signal path can be momentarily reduced to 200 watts, for example. When the operator unfreezes the image to resume real time imaging, the low power subsystems are restored to full operability immediately, without any interruption in system operability apparent to the operator. Over time, such periodic reductions in power consumption can reduce the heating and hence prolong the life of components of the ultrasound signal path, as well as reduce the air conditioning load imposed by the ultrasound system.

While such periodic reductions in system power consumption will reduce thermal emission by the ultrasound system, this capability may also be used to reduce audible emission as well. The noise made by an operating ultrasound system is the humming of fans used to cool the electronic components and power supplies. When the overall power consumption of the ultrasound system and component heating are reduced, the need for fan

cooling is reduced as well. When individual components, modules, or subsystems are powered down or turned off even for short intervals, the fans used to cool them can be operated at a reduced fan speed or even periodically turned off. Thus, thermal levels in the ultrasound system can be monitored by the CPU board OS and the speed of the cooling fans adjusted when possible. It may be appreciated that during a 30 minute ultrasound exam, the system operator may spend half the time changing operating states, making measurements on frozen images, talking to the patient, and other non-real-time scanning activities. Advantage can be taken of these circumstances by the OS to control the ultrasound system so that it is fully operational only when required. This can lead to a reduction in thermal and noise pollution by an equivalent amount.

The embodiment of FIGURE 1 is seen to include a battery backup, an interim power source which can sustain key elements of the ultrasound system for periods when a.c. power is not available. This ability to sustain key elements such as the CPU and RAM even when the system is not plugged in to its a.c. power source enables the ultrasound system to be moved and restarted very quickly to meet the needs of a modern hospital. As explained at the outset of this patent, it is often necessary to quickly move an ultrasound system from one area of a hospital to another to perform a diagnosis in another department of the hospital as soon as possible. But this cannot be done when an ultrasound system has to sequence through a lengthy shutdown procedure before it can be turned off and unplugged, and must go through a lengthy boot-up sequence when restarted at the new location. The ultrasound system shown in FIGURE 1 by use of the processes shown in the preceding flowcharts can be quickly moved without these delays. For example suppose that the ultrasound system is called to be moved from the ultrasound lab to the delivery room in obstetrics for an immediate scan. The operator can touch the OFF button, pull the ultrasound system plug from the wall, and begin to move the ultrasound system to the obstetrics ward without waiting for any of the shutdown procedure to occur. When the plug is pulled the ultrasound system switches to its backup battery power source, and as it is being moved the ultrasound system will shut itself down using one of the sequences described above. The ultrasound system can shut itself down for a restart to the default exam (which may in this example be an obstetrical exam) or to the most recently used exam for instance. Preferably the ultrasound system under these conditions will not shut the CPU down completely, but will leave the CPU and its RAM energized so that the system can be restarted quickly when it arrives at the obstetrics ward for the emergency exam. If desired, the OS can be programmed to respond to a loss of a.c. power during a shutdown sequence by powering down to a high

state of readiness from which it can be returned to full operability almost instantly. For example, by sensing the loss of a.c. power, or sensing the switchover to battery power, or detecting the lack of operator responses to the queries posed during shutdown (*e.g.*, restart the same exam?) the OS would continue to maintain power to all processors and volatile storage devices (RAM) in the ultrasound system for as long as sufficient battery power was available to do so. As another example the ultrasound system may experience an inadvertent loss of a.c. power, for instance, if the a.c. power cord is accidentally pulled from the wall or the circuit breaker for the a.c. line powering the system trips. In such instances the OS automatically performs a shutdown such that the current exam is resumed on restart (FIGURES 2a and 3a). Alternatively, if battery capacity is sufficient, the ultrasound system can be powered in a fully active state by the battery until the battery is substantially discharged, at which point a shutdown is automatically performed. Devices which consume relatively large amounts of energy and do not retain critical data in volatile storage, such as the display and the scanhead's transducer drivers, could be shut down to conserve battery power while still affording the ability to restart almost instantly. When the ultrasound system arrives in the obstetrics ward in the first example, is plugged in, and the ON button depressed, it is ready for scanning virtually immediately.

In an embodiment where the ultrasound system does not contain battery backup power, some of the aforementioned delays can still be avoided. For instance, sufficiently sized capacitors in the power supply system can retain sufficient energy to sustain an OS shutdown sequence even in the absence of battery backup. Such capacitively stored energy could power the CPU board for the time required to complete an orderly shutdown. The operator could thus press the OFF button, pull the a.c. plug from the wall and

CLAIMS:

1. An ultrasound system comprising:

- an ultrasound signal path and controller;
- an a.c. power supply having an input and an output;
- a power supply path having an input coupled to the output of the a.c. power supply and an output coupled to provide a DC energizing potential for the ultrasound signal path and controller; and
- a battery coupled to the power supply path to provide a DC energizing potential to at least one of the ultrasound signal path and controller when the a.c. power supply is inoperable.

2. The a.c. powered ultrasound system of Claim 1, which can be rapidly shut down in the absence of a.c. power comprising:

- an ultrasound signal path;
- an a.c. power supply coupled to provide an energizing potential for the ultrasound signal path;
- a processor which controls a shutdown sequence to power down the ultrasound signal path in response to an OFF command; and
- an energy storage device coupled to the processor, wherein the energy storage device provides power to the processor during the shutdown sequence when the a.c. power supply is inoperative.

3. The a.c. powered ultrasound system of Claim 2, wherein the capacity of the energy storage device is chosen in relation to the time and energy required to execute the shutdown sequence.

4. The a.c. powered ultrasound system of Claim 3, wherein the energy storage device provides power to the processor when energizing potential for the a.c. power supply is inadvertently disconnected from the a.c. power supply.

5. The a.c. powered ultrasound system of one of Claims 2 to 4, wherein the energy storage device is a capacitive device.

6. The a.c. powered ultrasound system of one of Claim 2 to 4, wherein the energy
5 storage device is a battery.

7. The ultrasound system of Claim 6, wherein the battery provides power to at least a portion of the ultrasound signal path when the a.c. power supply is inoperative.

10 8. A method for powering down an a.c. powered ultrasound system comprising:
- turning off at least a portion of an ultrasound signal path;
- disabling a source of a.c. power; and
- maintaining battery backup power to a processor which is responsive to a
command to restore the ultrasound signal path to an operational state.

15

9. The method of Claim 8, wherein maintaining further comprises maintaining the operability of operating system software on the processor.

10. The method of one of Claims 8 or 9, further comprising storing context
20 information.

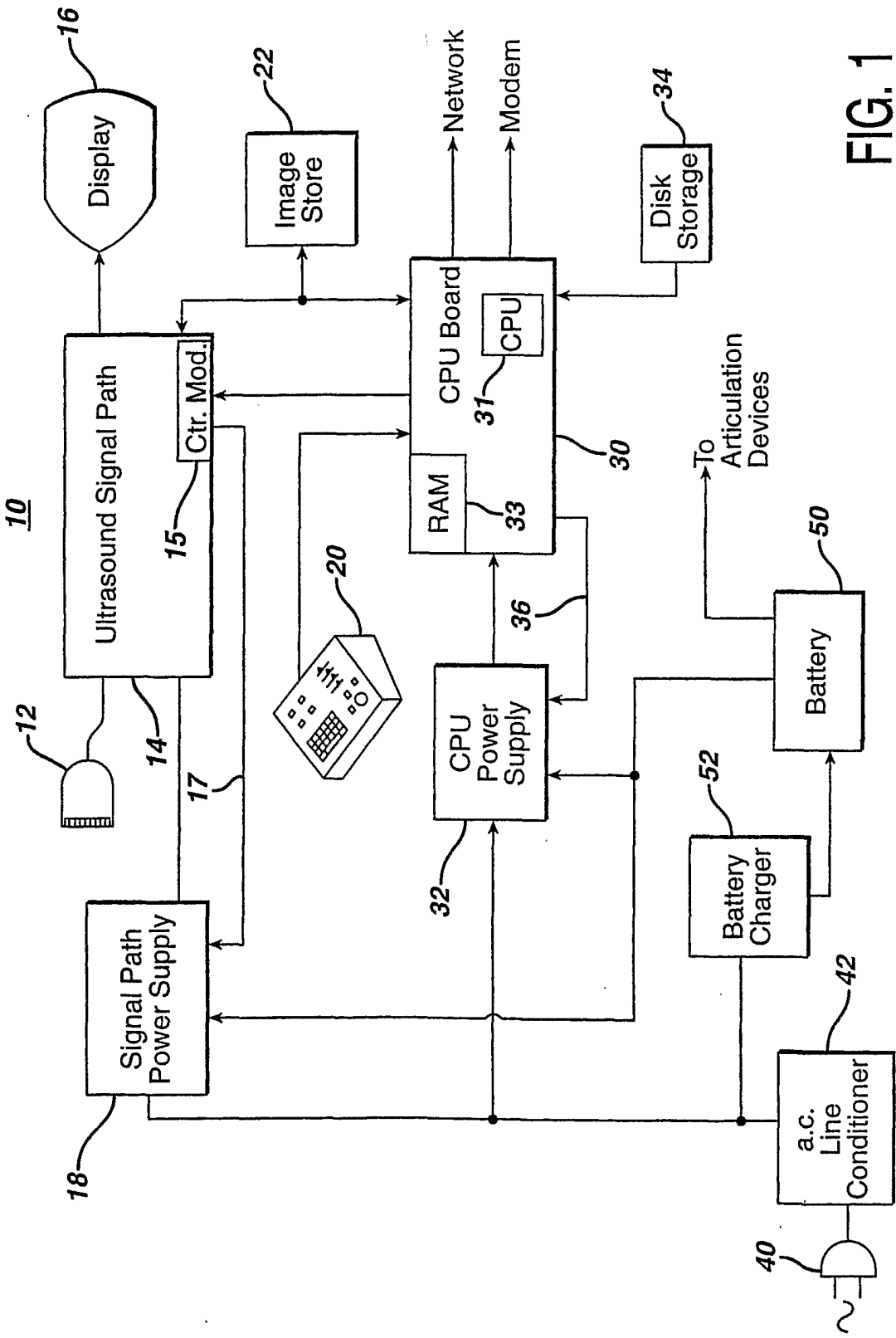


FIG. 1

2/13

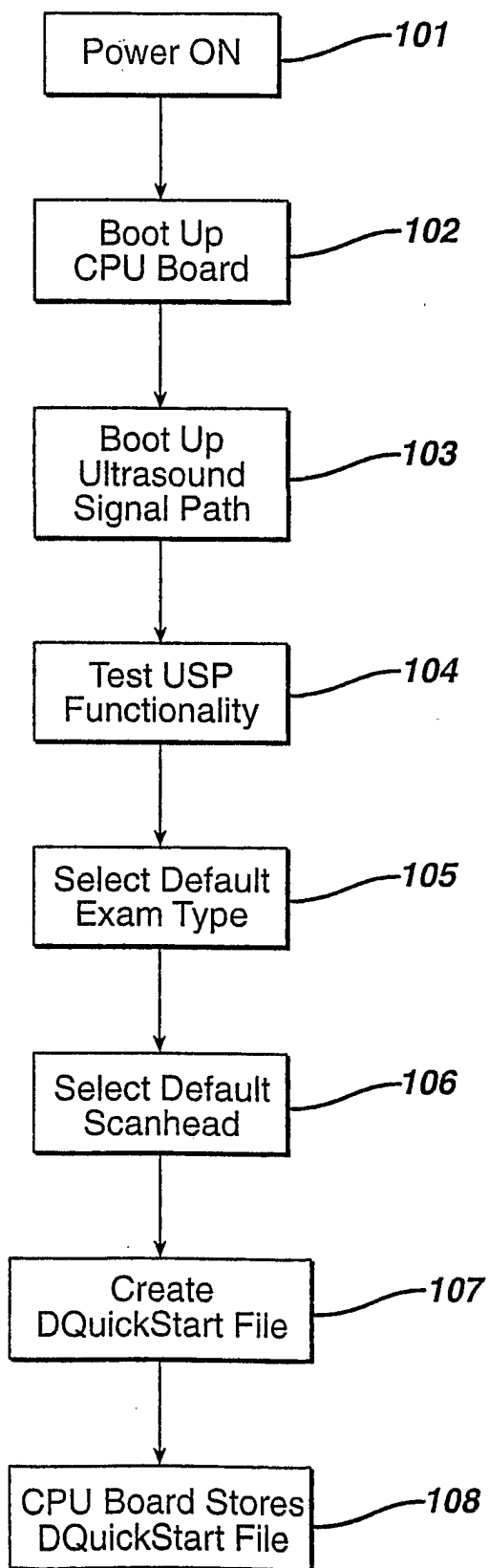


FIG. 1a

3/13

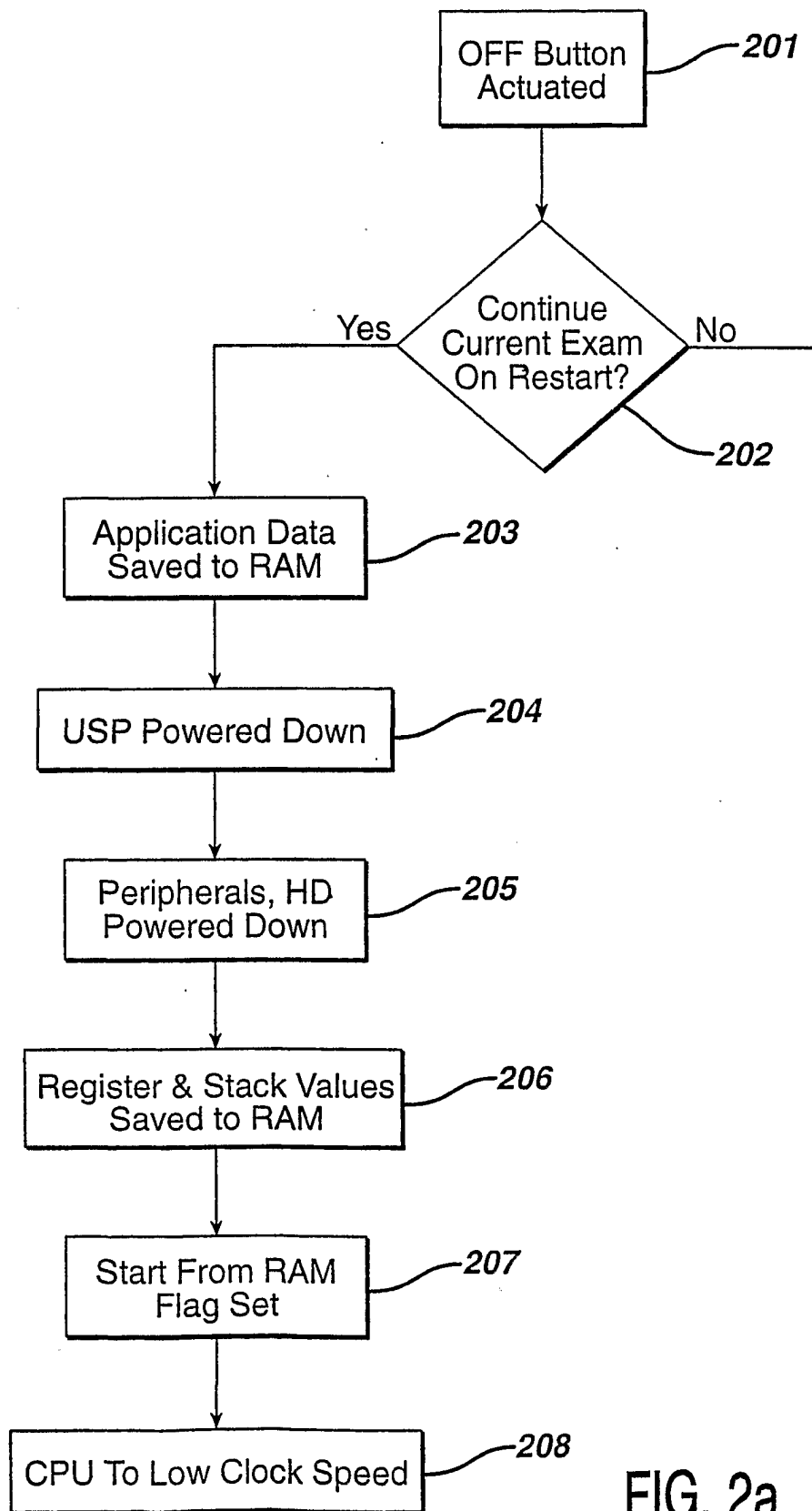


FIG. 2a

4/13

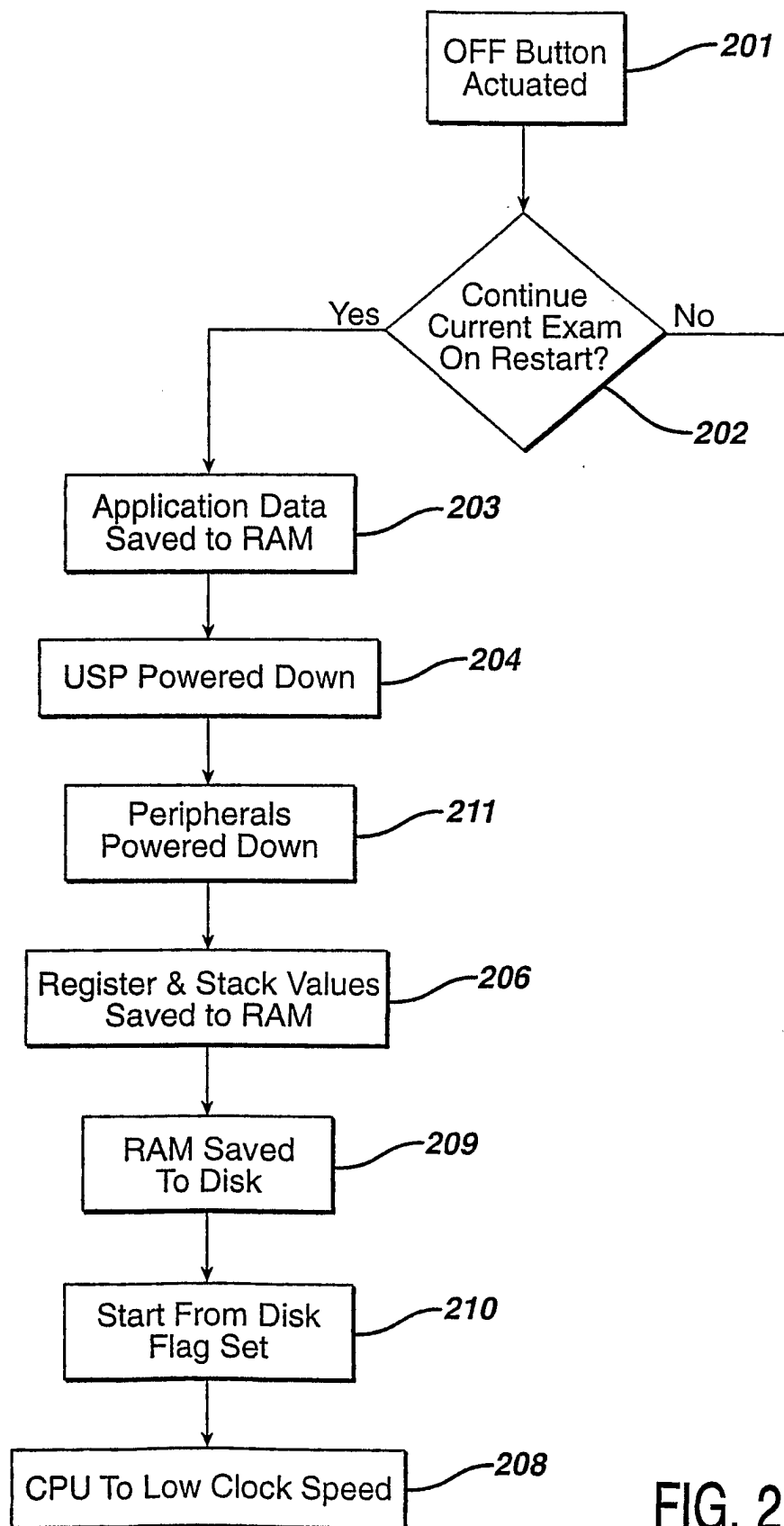


FIG. 2b

5/13

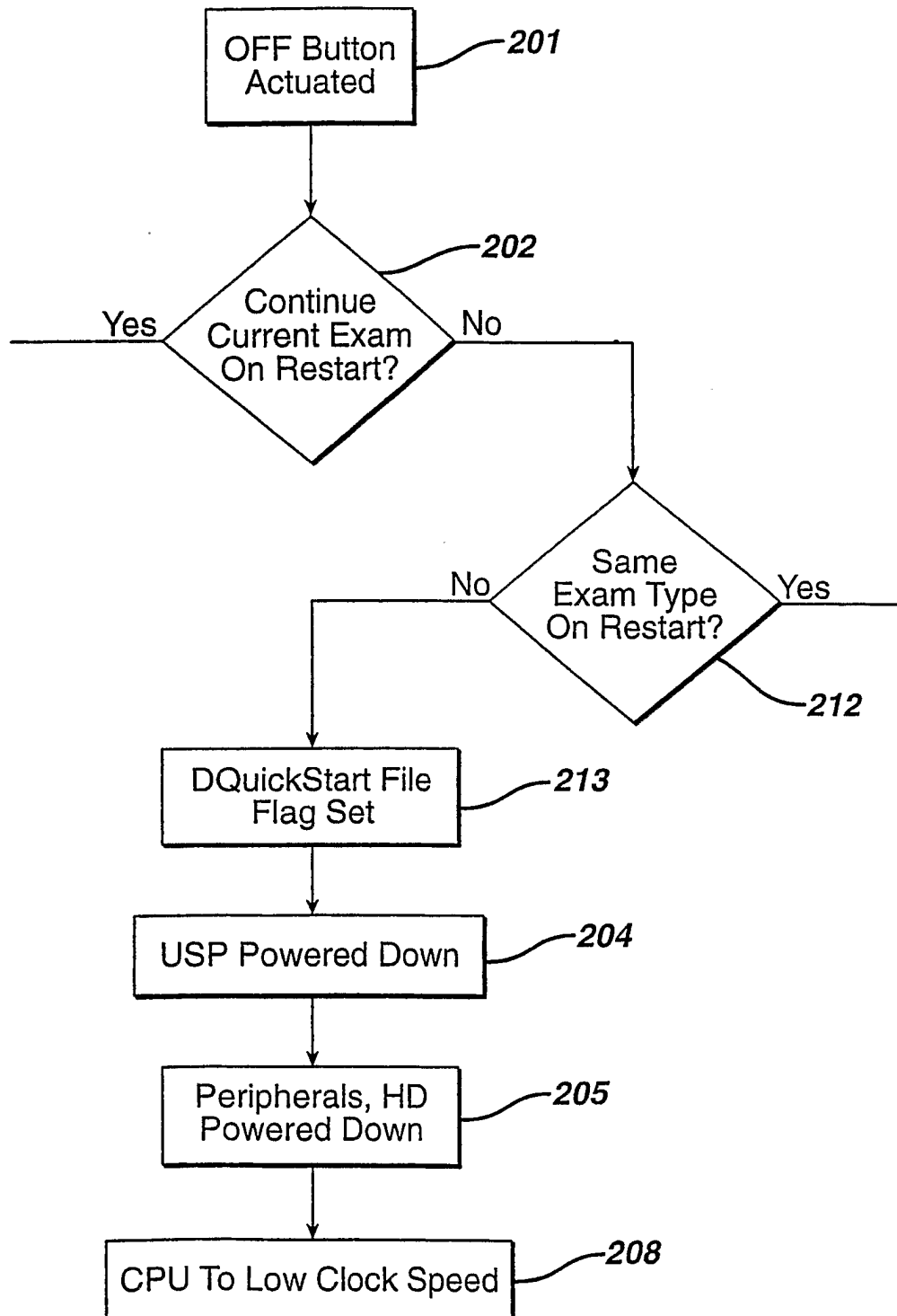


FIG. 2c

6/13

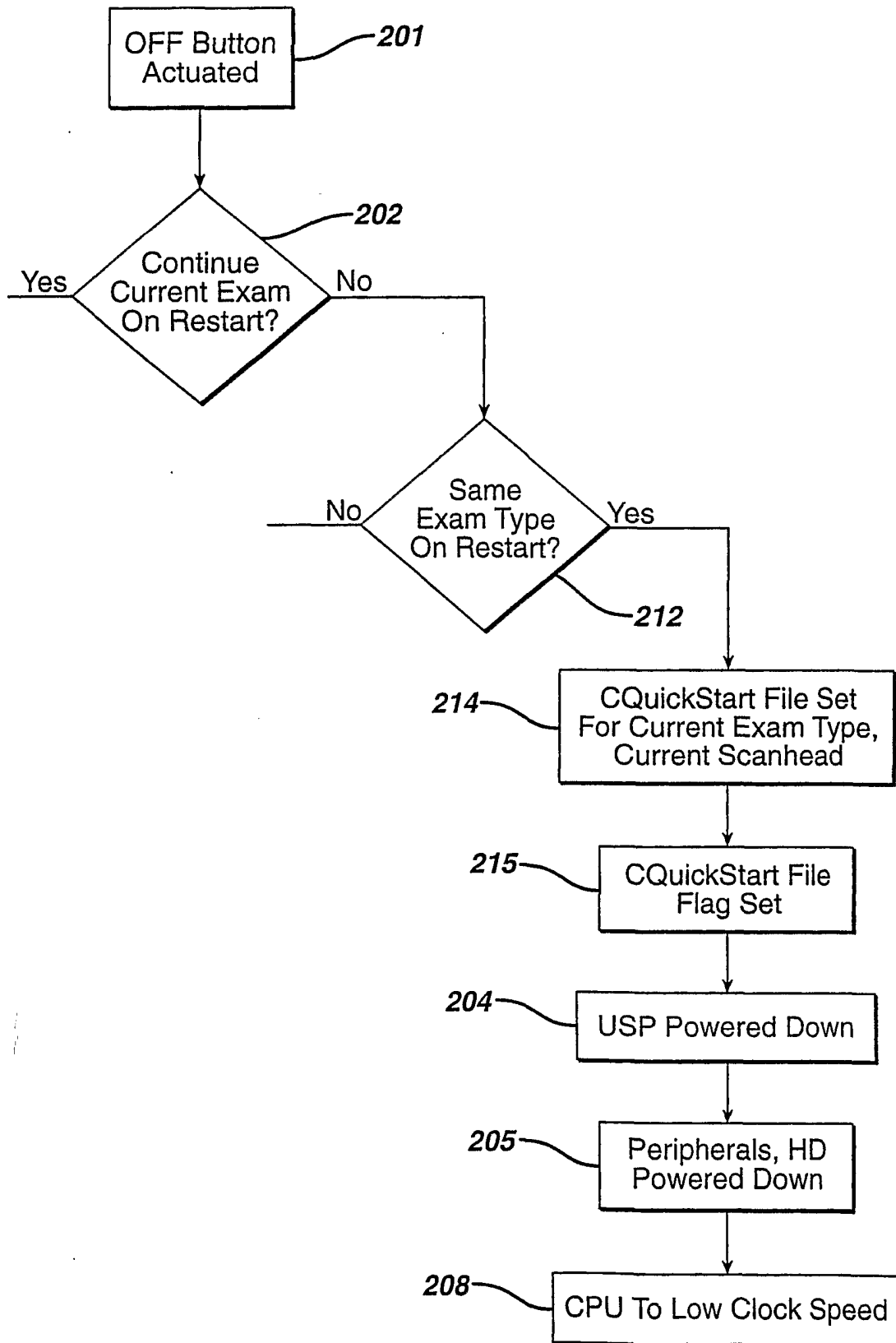


FIG. 2d

7/13

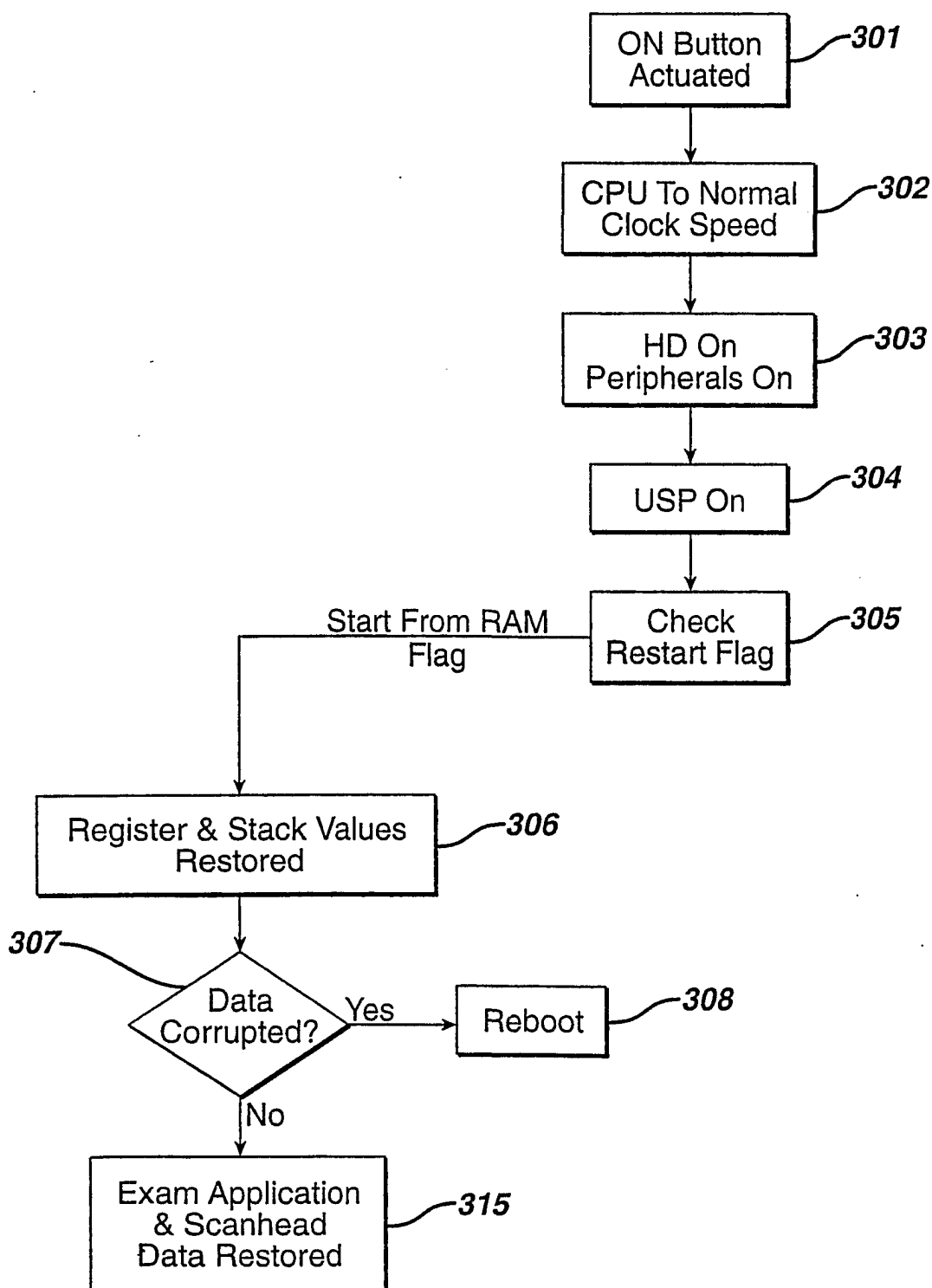


FIG. 3a

8/13

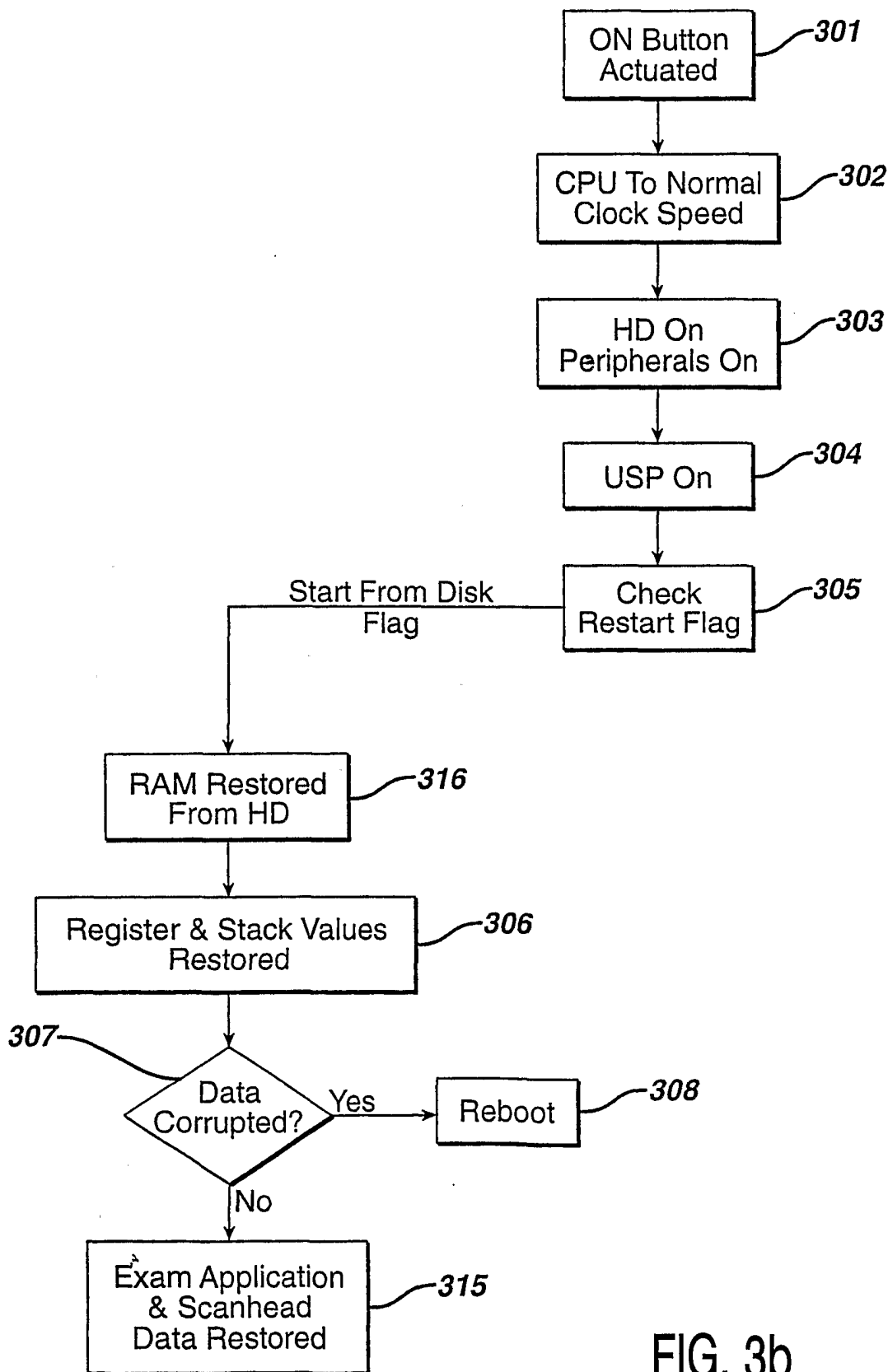


FIG. 3b

9/13

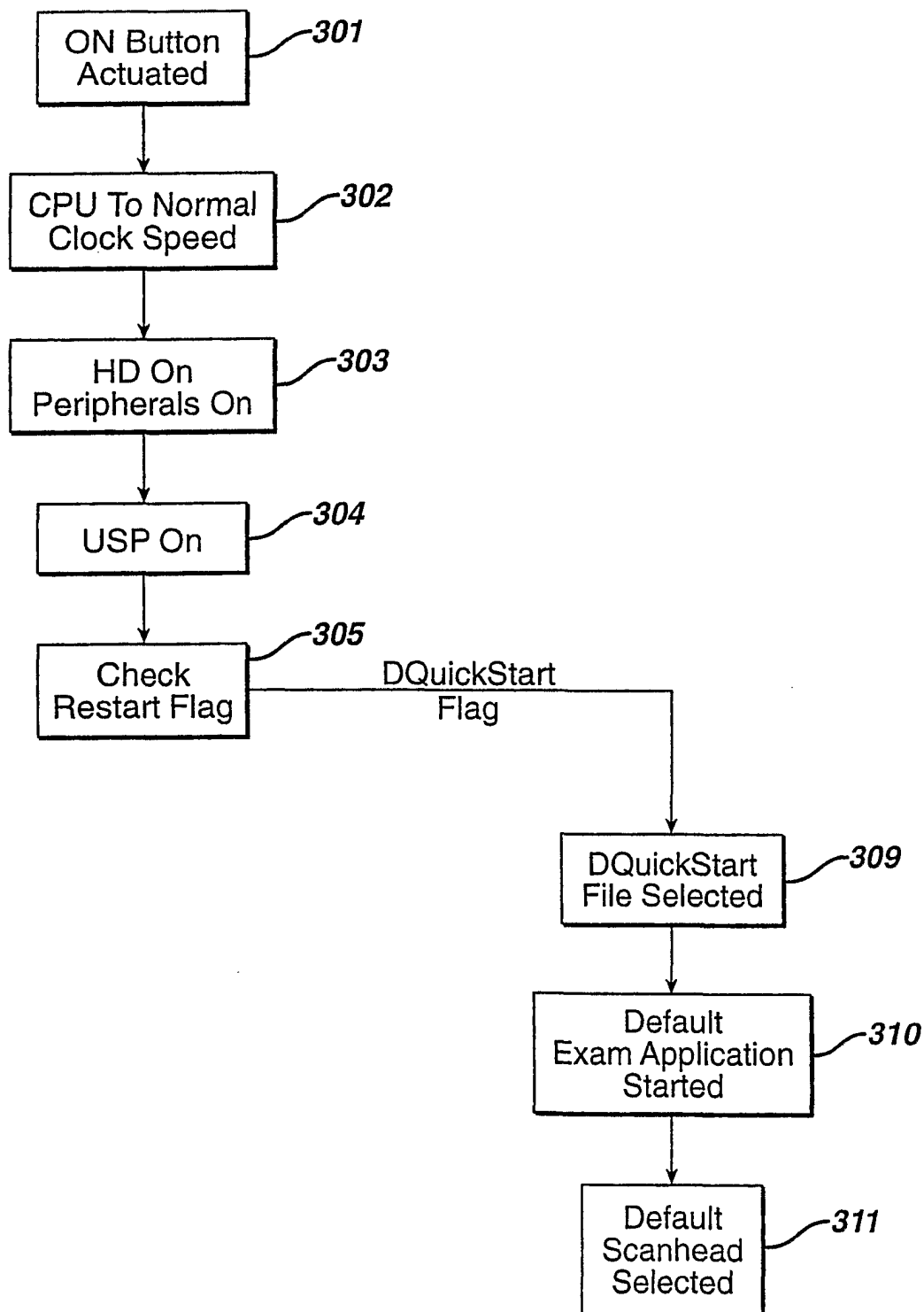


FIG. 3c

10/13

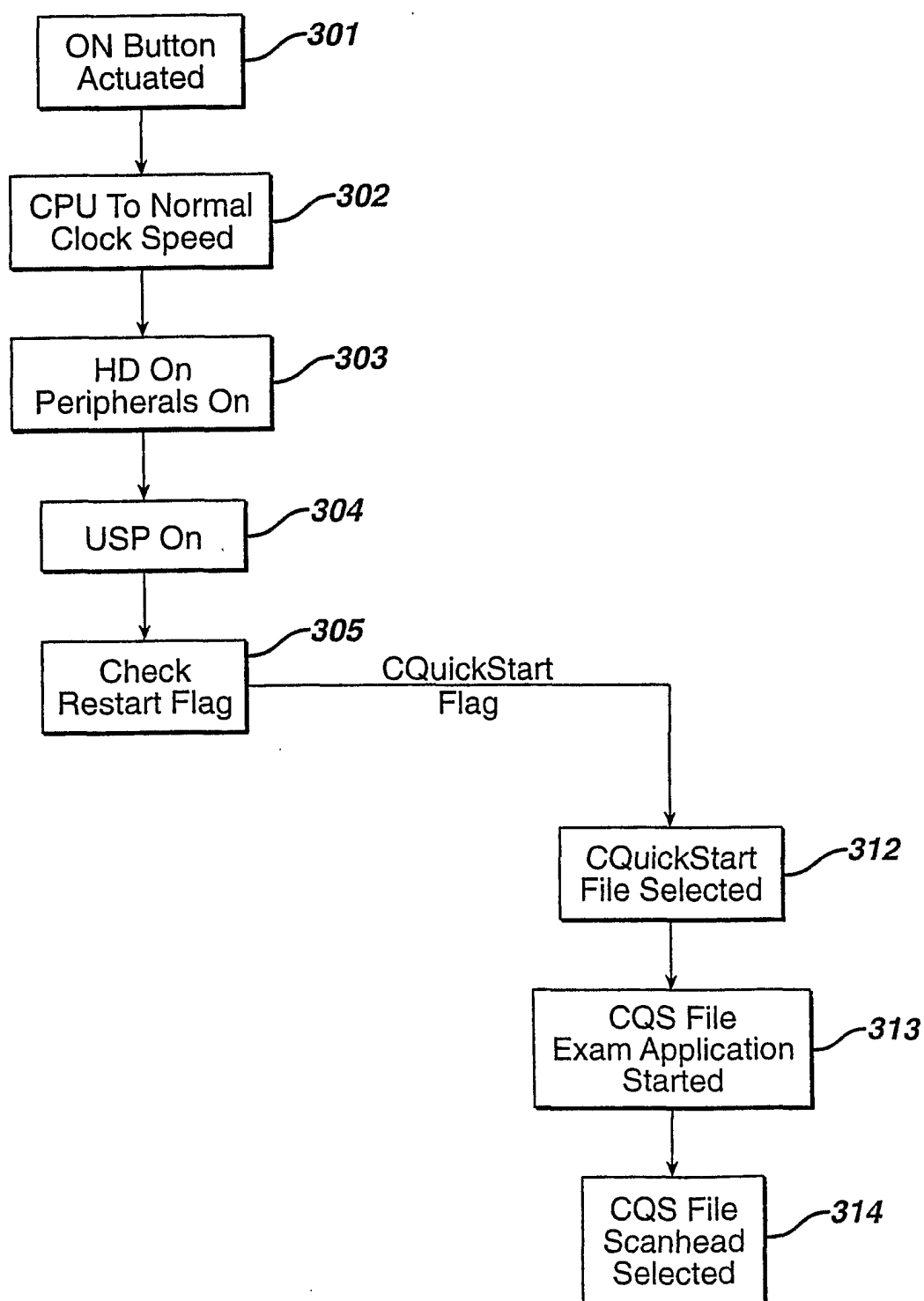


FIG. 3d

11/13

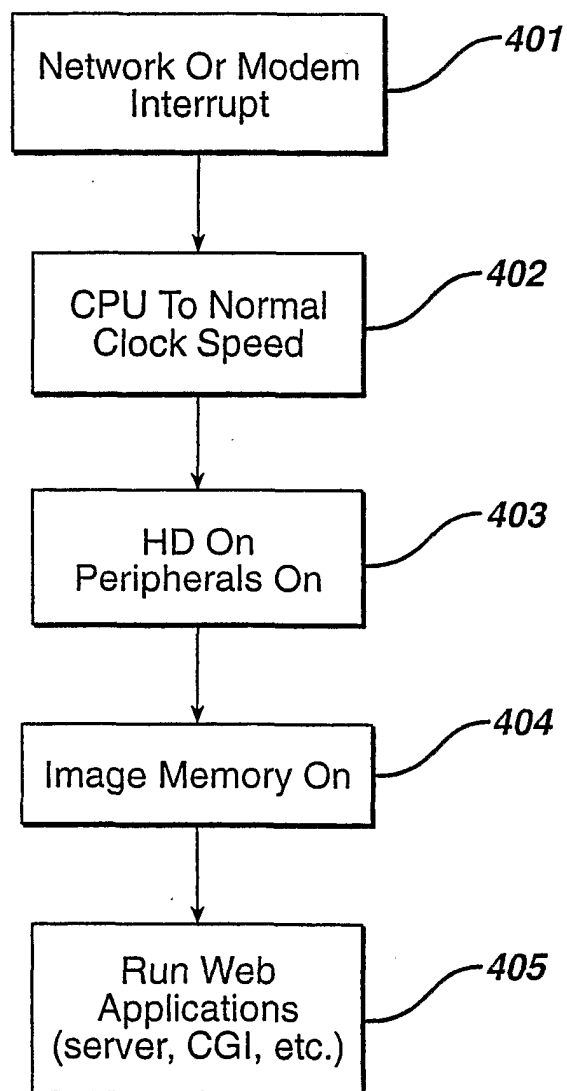


FIG. 4

12/13

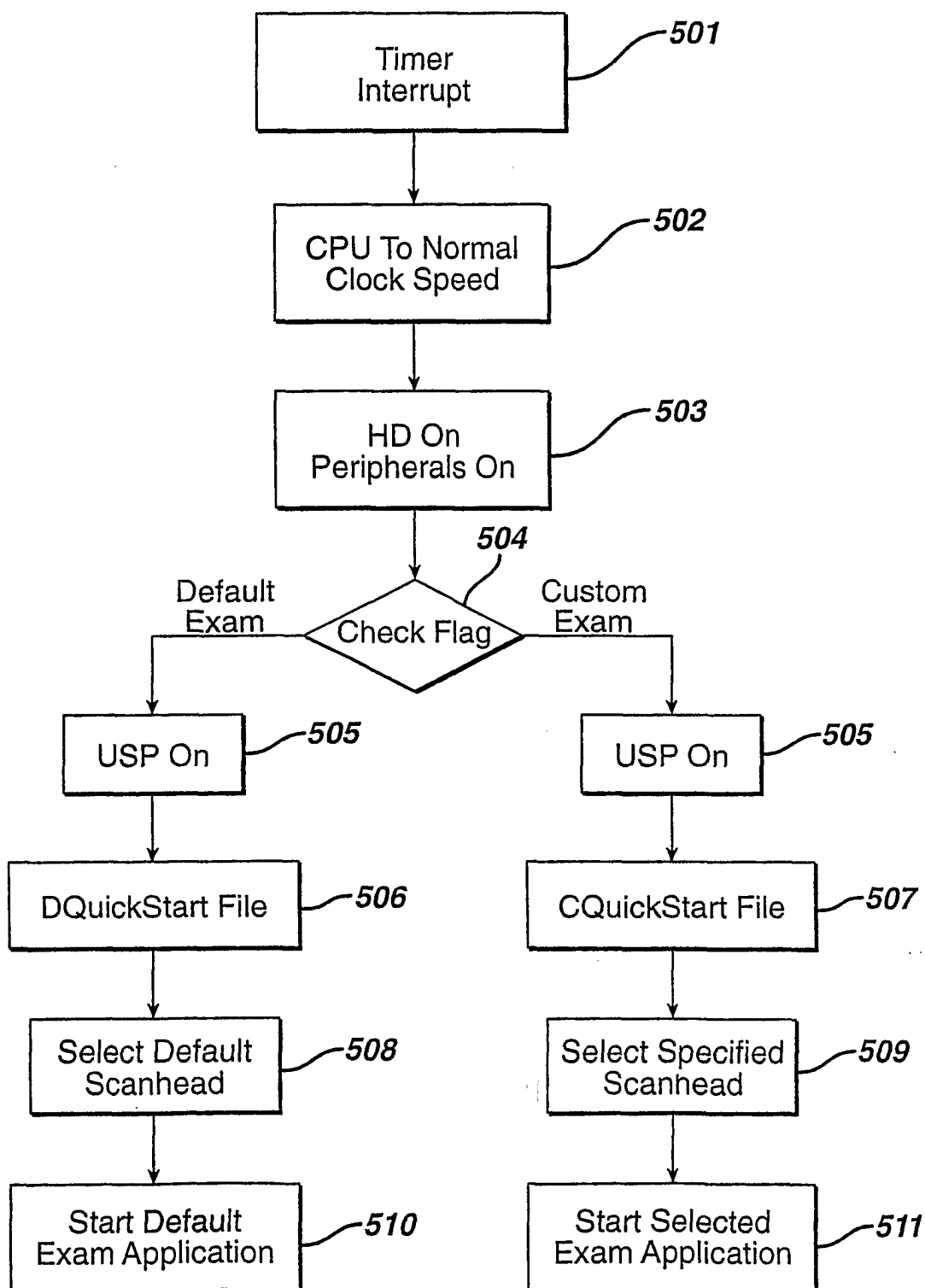


FIG. 5

13/13

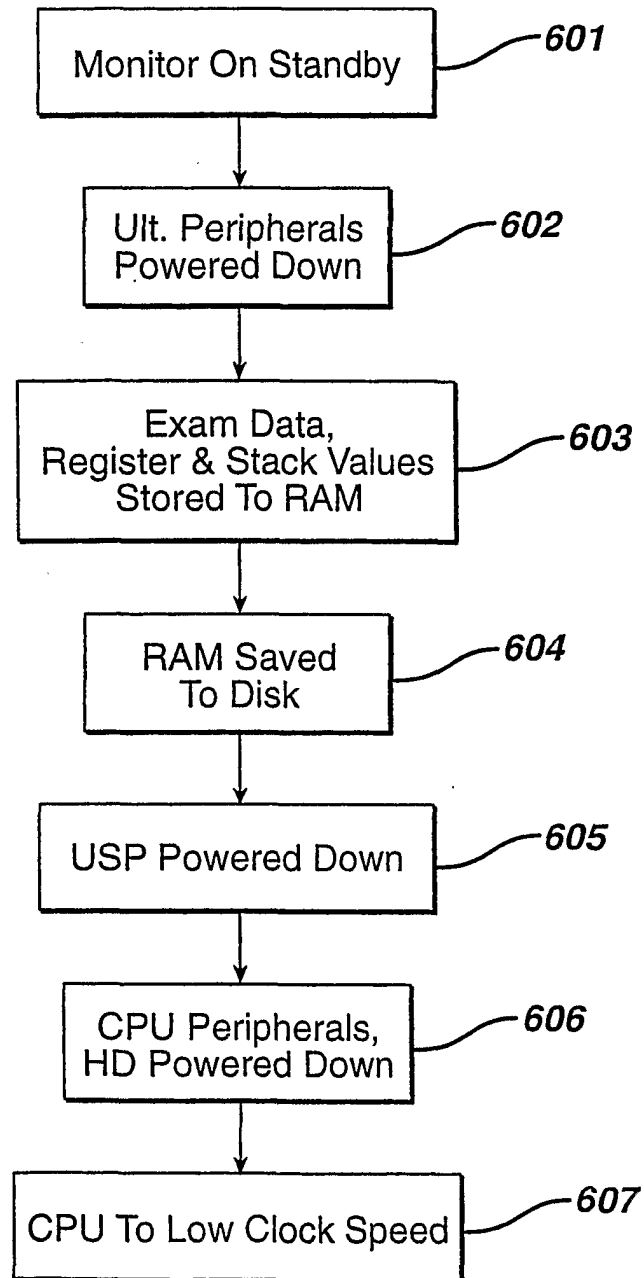


FIG. 6

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference PHUS009238W0	FOR FURTHER ACTION see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/EP 01/ 10117	International filing date (day/month/year) 30/08/2001	(Earliest) Priority Date (day/month/year) 13/09/2000
Applicant KONINKLIJKE PHILIPS ELECTRONICS N.V.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

- a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No.

☐ as suggested by the applicant.

☒ because the applicant failed to suggest a figure.

☐ because this figure better characterizes the invention.

1
☐ None of the figures.

INTERNATIONAL SEARCH REPORT

Int ☐ National Application No

PCT/EP 01/10117

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61B8/00 G01S15/89

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61B G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 96 32888 A (IMEX MEDICAL SYSTEMS INC) 24 October 1996 (1996-10-24) abstract	1,6,7 4,8
A	page 7, line 7 - line 14 page 14, line 26 -page 16, line 16; tables 1-10	
X	WO 00 31563 A (KONINKL PHILIPS ELECTRONICS NV) 2 June 2000 (2000-06-02) page 11, line 17 - line 27 page 13, line 1 -page 14, line 11; tables 1,6-10	1,6,7
P,Y	WO 00 66001 A (SONOSITE INC) 9 November 2000 (2000-11-09) page 2, line 20 -page 3, line 21 page 4, line 2 -page 8, line 23; tables 1-3	1,2,4,6, 7 8-10
A		
	--- -/--	



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

G document member of the same patent family

Date of the actual completion of the international search

14 February 2002

Date of mailing of the international search report

20/02/2002

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Weihs, J

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 01/10117

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 603 323 A (SOUQUET JACQUES ET AL) 18 February 1997 (1997-02-18) page 3, line 62 -page 4, line 57; table 2 ---	1,2,4,6, 7
A	US 3 959 732 A (SCHAEFER LOUIS F) 25 May 1976 (1976-05-25) column 8, line 26 - line 62 ---	5
P,X	US 6 203 498 B1 (BUNCE STEVEN ET AL) 20 March 2001 (2001-03-20) column 4, line 50 -column 6, line 32 column 13, line 47 -column 14, line 37; tables 1,2,9 -----	1-4,6,7 8-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

Intel. Application No

PCT/EP 01/10117

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 9632888	A	24-10-1996	US 5640960 A WO 9632888 A1	24-06-1997 24-10-1996
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专利名称(译)	带备用电池的便携式超声系统，可高效关闭和重启		
公开(公告)号	EP1318753A1	公开(公告)日	2003-06-18
申请号	EP2001960719	申请日	2001-08-30
[标]申请(专利权)人(译)	皇家飞利浦电子股份有限公司		
申请(专利权)人(译)	皇家飞利浦电子N.V.		
当前申请(专利权)人(译)	皇家飞利浦电子N.V.		
[标]发明人	WITTROCK PAUL LINKHART KENNETH R ROBINSON ANDREW L OLSSON LARS J		
发明人	WITTROCK, PAUL LINKHART, KENNETH, R. ROBINSON, ANDREW, L. OLSSON, LARS, J.		
IPC分类号	A61B8/00 G01S7/52 G01S15/89		
CPC分类号	G01S7/52096 A61B8/00 A61B8/4427 A61B8/56 A61B8/565 A61B2560/0214 A61B2560/0431 G01S7/52017		
代理机构(译)	LOTTIN , CLAUDINE		
优先权	60/232450 2000-09-13 US 09/695191 2000-10-24 US		
其他公开文献	EP1318753B1		
外部链接	Espacenet		

摘要(译)

描述了一种超声系统，其可以通过操作员命令或响应于交流电的中断而快速关闭。给系统供电。当a.c.电源切断后，系统切换到备用电池，同时处理器执行有序关机序列。系统可以完全关闭，或者可以通过易失性或非易失性存储器中的备用电池最小程度地保持系统状态，以便系统可以重新启动而无需按顺序完成整个启动过程。这使得即使超声系统被拔出和移动，系统也能保持活动状态。