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(54) ULTRASOUND ADAPTIVE POWER MANAGEMENT SYSTEMS AND METHODS

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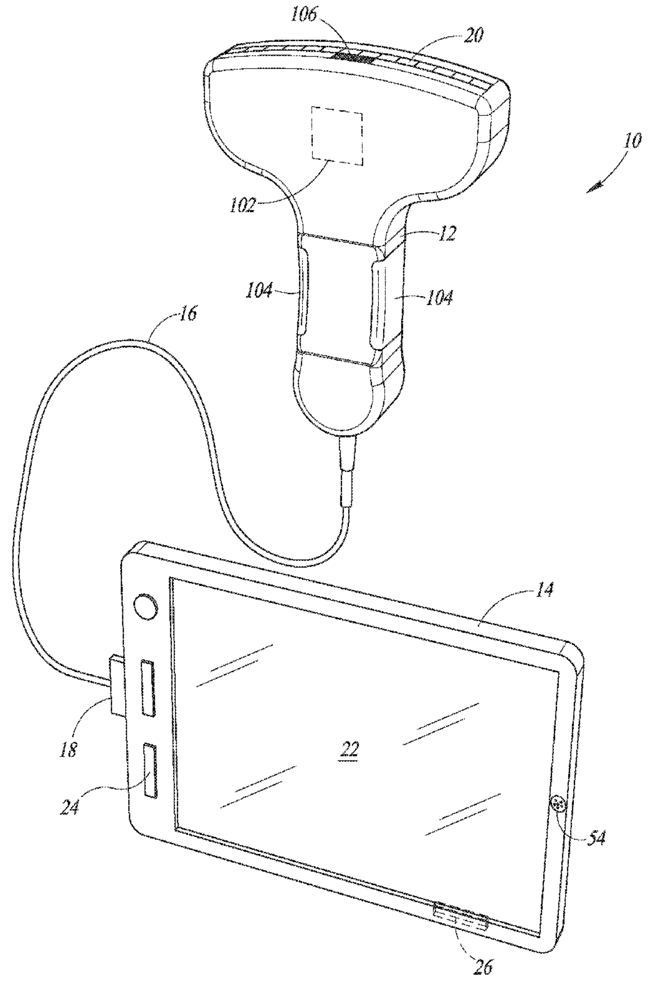
(57) **ABSTRACT**

Systems and methods for dynamically managing power consumption in an ultrasound device are provided herein. A transducer in an ultrasound device may have transmit and receive elements for respectively transmitting and receiving ultrasound signals. In at least one embodiment, the method includes sensing a motion of the transducer by a motion sensor that is coupled to the transducer. An amount of power consumed by the ultrasound device is then reduced, based on the sensed motion of the transducer. Reducing an amount of power consumption may include adjusting one or more operational parameters of the ultrasound device, such as but not limited to reducing the display frame rate, the receive aperture, or the transmit amplitude, or by decoupling power to one or more components of the ultrasound device. Alternatively or in addition, power consumption may be reduced based on signals received from a capacitive sensor and/or a patient contact sensor.



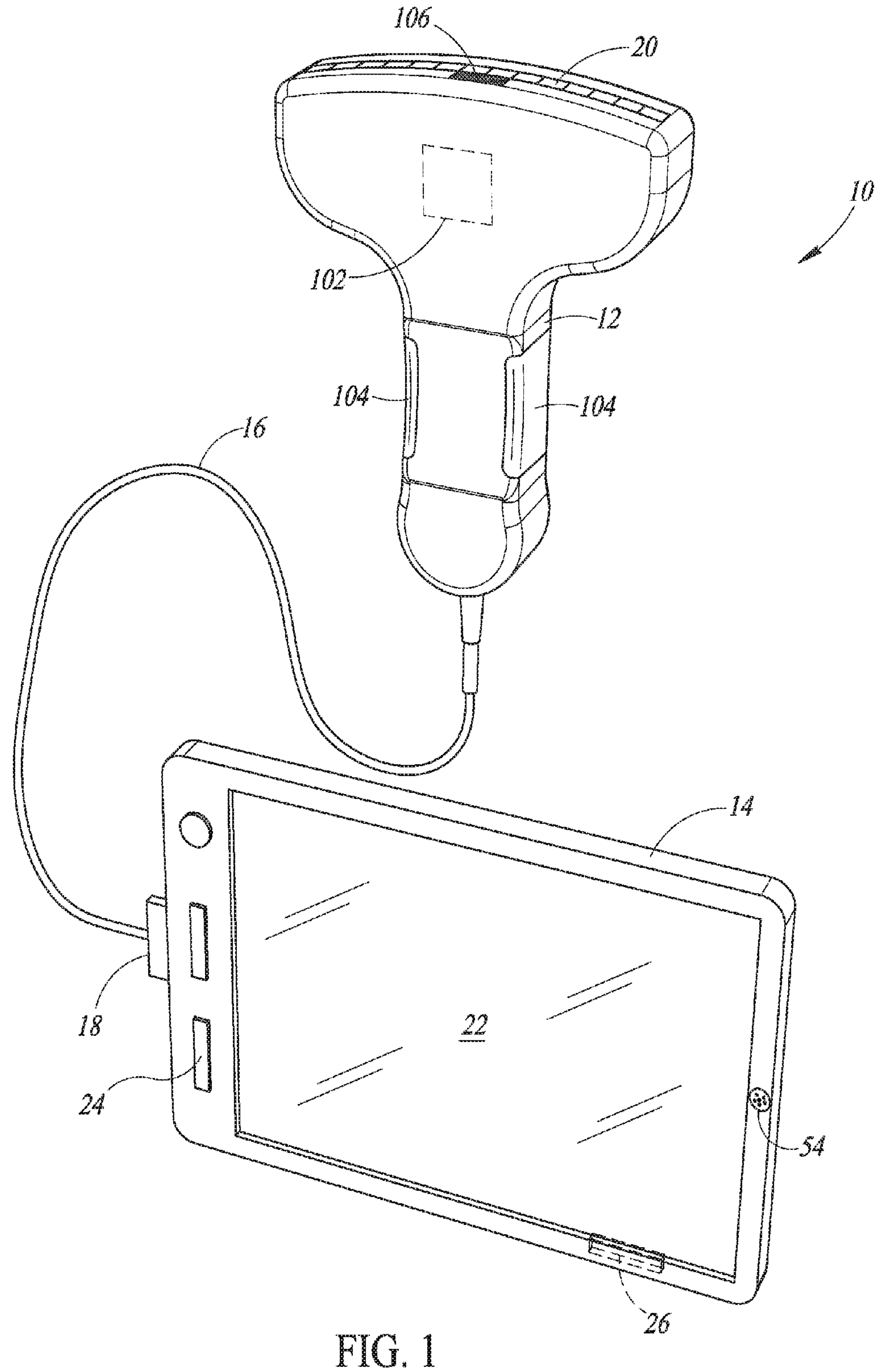


FIG. 1

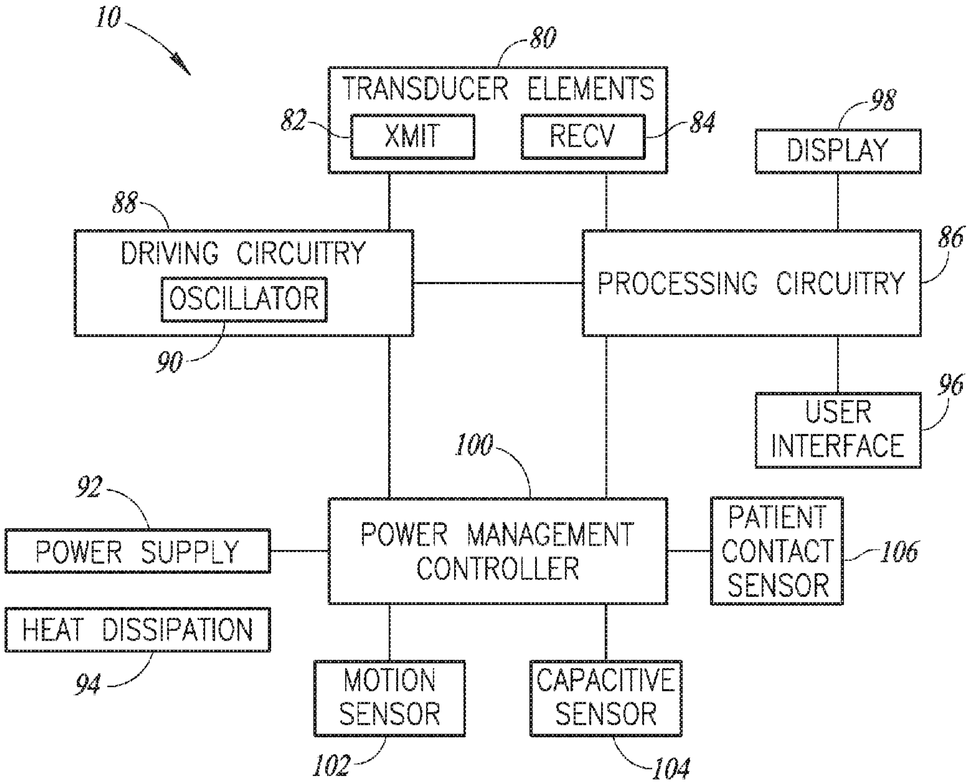

10
80
TRANSDUCER ELEMENTS
82
XMIT
RECV
84
98
DISPLAY
88
DRIVING CIRCUITRY
OSCILLATOR
90
PROCESSING CIRCUITRY
86
96
USER INTERFACE
100
92
POWER SUPPLY
POWER MANAGEMENT CONTROLLER
PATIENT CONTACT SENSOR
106
HEAT DISSIPATION
94
MOTION SENSOR
102
CAPACITIVE SENSOR
104

FIG. 2

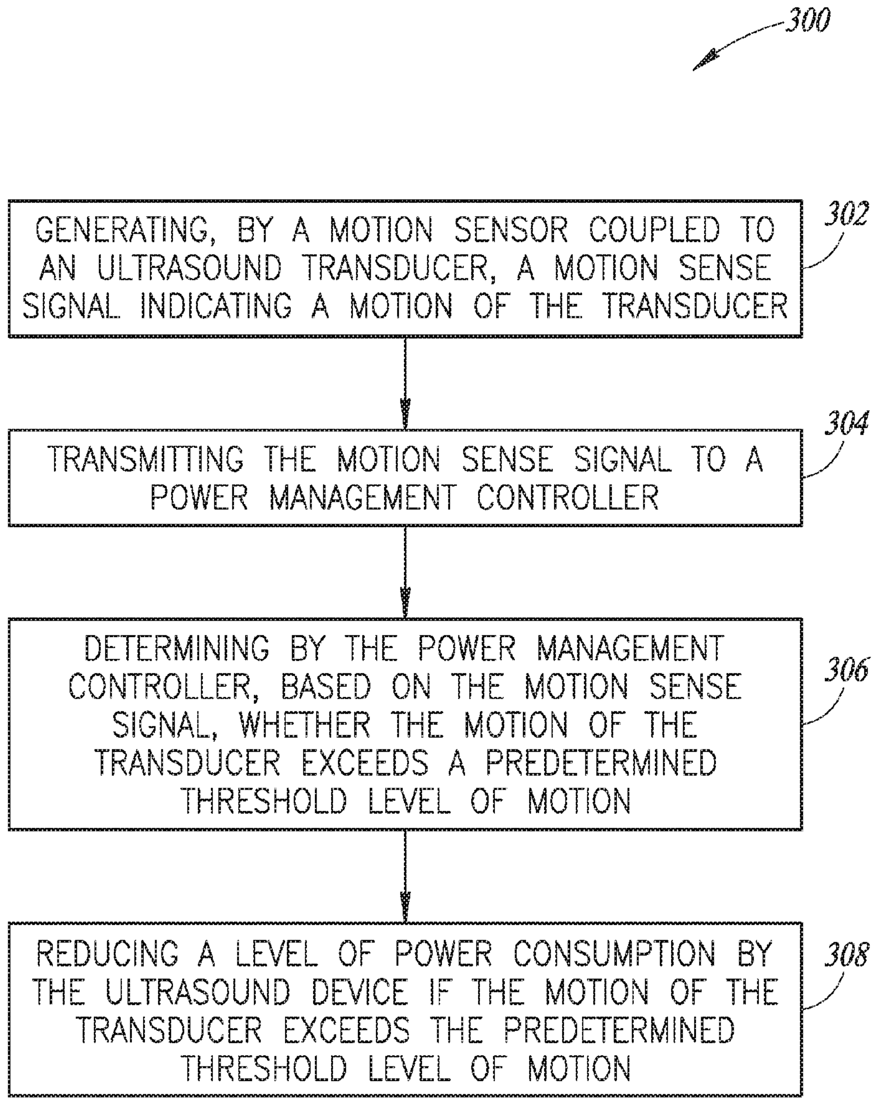

300
GENERATING, BY A MOTION SENSOR COUPLED TO AN ULTRASOUND TRANSDUCER, A MOTION SENSE SIGNAL INDICATING A MOTION OF THE TRANSDUCER
302
TRANSMITTING THE MOTION SENSE SIGNAL TO A POWER MANAGEMENT CONTROLLER
304
DETERMINING BY THE POWER MANAGEMENT CONTROLLER, BASED ON THE MOTION SENSE SIGNAL, WHETHER THE MOTION OF THE TRANSDUCER EXCEEDS A PREDETERMINED THRESHOLD LEVEL OF MOTION
306
REDUCING A LEVEL OF POWER CONSUMPTION BY THE ULTRASOUND DEVICE IF THE MOTION OF THE TRANSDUCER EXCEEDS THE PREDETERMINED THRESHOLD LEVEL OF MOTION
308

FIG. 3

ULTRASOUND ADAPTIVE POWER MANAGEMENT SYSTEMS AND METHODS

BACKGROUND

Technical Field

[0001] The present application pertains to ultrasound systems, and more particularly to ultrasound systems and methods for adaptively managing power consumption based on a sensed motion of the ultrasound transducer.

Description of the Related Art

[0002] Ultrasound imaging is useful as an imaging modality in a number of environments. For example, in the field of healthcare, internal structures of a patient's body may be imaged before, during or after a therapeutic intervention. A healthcare professional may hold a portable ultrasound probe, or transducer, in proximity to the patient and move the transducer as appropriate to visualize one or more target structures in a region of interest in the patient. A transducer may be placed on the surface of the body or, in some procedures, a transducer is inserted inside the patient's body. The healthcare professional coordinates the movement of the transducer so as to obtain a desired representation on a screen, such as a two-dimensional cross-section of a three-dimensional volume.

[0003] Ultrasound may also be used to measure functional aspects of a patient, such as organ movement and blood flow in the patient. Doppler measurements, for example, are effective in measuring the direction and speed of movement of a structure, such as a heart valve or blood cells flowing in a vessel, relative to the transducer. Doppler echocardiography is widely used for evaluating the cardiocirculatory system of patients with known or suspected cardiovascular disease.

[0004] For many years, ultrasound imaging was effectively confined to large equipment operating in a hospital environment. Recent technological advances, however, have produced smaller ultrasound systems that increasingly are deployed in frontline point-of-care environments, e.g., doctors' offices. Nevertheless, smaller ultrasound systems typically lack the power, thermal management, and processing capabilities of larger systems. This generally results in limited runtime of the ultrasound imaging components, lower image resolution, and fewer features or modes of operation.

BRIEF SUMMARY

[0005] The present application, in part, addresses a desire for smaller ultrasound systems, having greater portability, lower cost, and ease of use for different modes of ultrasound imaging, while at the same time providing high quality measurements and effective power consumption management.

[0006] The performance of portable ultrasound devices may be limited by the available power storage, for example, by a power supply including one or more batteries. Since the amount of electrical power that may be delivered by such a power supply over a period of time may be limited, reducing the power consumption in a portable ultrasound device extends the life-cycle or charging cycle of the power supply, and thus allows the ultrasound device to be used for a longer period of time before replacing or recharging the batteries becomes necessary. Moreover, other benefits may be realized from reducing power consumption in a portable ultrasound device, such as advantageously reducing the amount of heat to be dissipated during operation. Reducing power consumption further allows for operating the ultrasound device for a longer period of time, while staying within regulatory limits with respect to the temperature of the ultrasound transducer during patient contact.

[0007] In a typical use case, the ultrasound system is not coupled to the body and producing a diagnostic image 100% of the time. This "non-imaging" time can include, for example, time spent applying ultrasound gel, moving the transducer to the patient, positioning the transducer to obtain the correct, desired view and confirming whether the image (s) captured are desirable.

[0008] The incorporation of motion sensing technology—such as, for example, accelerometers, gyroscopes and the like—in the ultrasound transducer can provide information about the motion of the transducer, and may be used to indicate the level of image quality that is possible at any given time (e.g., image quality may be reduced while the transducer is being moved). Information about the motion of the transducer (e.g., the acceleration or velocity of the transducer) can be used to control other system parameters in order to reduce the power consumption of the ultrasound device. Reducing power consumption in an ultrasound device, which may result in a lower quality ultrasound image, may be especially desirable or beneficial when the transducer motion already exceeds a predetermined threshold so as to reduce the likelihood of obtaining ultrasound images of higher quality or reliable diagnostic value. In such a case, after the motion of the transducer is reduced to a more acceptable or normal level (e.g., to a low enough level of motion that images of a desired quality may be obtained) then the power-related parameters of the system may be adjusted towards a normal operating level in order to obtain ultrasound images of a desired quality. Such capability in an ultrasound system may avoid power being wasted during an operating phase of the system where images are already likely to be unreliable or not of sufficient quality.

[0009] Other sensors may also be incorporated into the ultrasound device, which may be operatively coupled to the transducer or other portions of the ultrasound device, in order to provide information concerning the readiness of the system to capture images. For example, the ultrasound transducer may include a patient contact or pressure sensor positioned on an imaging surface of the transducer. The patient contact or pressure sensor may thus sense when the transducer is contacting, for example, a patient or a gel applied to the patient's skin. Power consumption may thus be reduced when the patient contact or pressure sensor senses that the transducer is not contacting the patient.

[0010] Similarly, the ultrasound transducer may include a capacitive sensor positioned to sense whether the transducer is being held, for example, by an operator of the ultrasound device. Power consumption may thus be reduced when the capacitive sensor senses that the transducer is not being held, and thus is not positioned to obtain ultrasound images of a desirable quality.

[0011] In at least one embodiment, a method is provided for dynamically managing power consumption in an ultrasound device having a transducer, the transducer including transmit and receive elements for respectively transmitting and receiving ultrasound signals. The method includes sensing a motion of the transducer by a motion sensor coupled to the transducer, and reducing an amount of power consumption by the ultrasound device based on the sensed motion of the transducer. Reducing an amount of power consumption may include adjusting one or more operational parameters of the ultrasound device, such as, for example, reducing a frame rate of the display, reducing a receive aperture of the transducer, reducing an amplitude of the ultrasound signals transmitted by the transducer or reducing the brightness of a display or otherwise reducing the power consumption required to deliver information to the user.

[0012] In another embodiment, the present disclosure provides a method for adaptively managing power consumption in an ultrasound device having a transducer. The method includes generating, by a motion sensor operatively coupled to the transducer, a motion sense signal indicating a motion of the transducer. The method further includes transmitting the motion sense signal to a power management controller, determining by the power management controller, based on the motion sense signal, whether the motion of the transducer exceeds a predetermined threshold level of motion, and reducing a level of power consumption by the ultrasound device if the motion of the transducer equals or exceeds the predetermined threshold level of motion.

[0013] In another embodiment, a handheld ultrasound transducer is provided that includes one or more first transducer elements, one or more second transducer elements and a motion sensor configured to sense one or more motions of the ultrasound transducer. The first transducer elements are arranged along an imaging surface of the ultrasound transducer and configured to transmit an ultrasound signal toward a target structure in a region of interest. The second transducer elements are arranged along the imaging surface of the ultrasound transducer and configured to receive echo signals returning from the target structure in response to transmission of the ultrasound signal.

[0014] In yet another embodiment, the present disclosure provides an ultrasound device that includes a handheld ultrasound transducer, processing circuitry, driving circuitry, a display and a power management controller. The handheld ultrasound transducer includes one or more first transducer elements arranged along an imaging surface of the ultrasound transducer and configured to transmit an ultrasound signal toward a target structure in a region of interest, one or more second transducer elements arranged along the imaging surface of the ultrasound transducer and configured to receive echo signals returning from the target structure in response to transmission of the ultrasound signal, and a motion sensor configured to sense a motion of the ultrasound transducer. The processing circuitry controls transmission of the ultrasound signal from the one or more first transducer elements. The driving circuitry is operatively coupled to the one or more first transducer elements and the processing circuitry, and the driving circuitry drives the transmission of the ultrasound signal by the one or more first transducer elements in response to a control signal received from the processing circuitry. The display is configured to display ultrasound images acquired by the ultrasound device, and the power management controller is coupled to the motion sensor and configured to reduce an amount of power consumption by the ultrasound device based on the sensed motion of the ultrasound transducer.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0015] FIG. **1** is a schematic illustration of an ultrasound imaging device, in accordance with one or more embodiments of the present disclosure.

[0016] FIG. **2** is a block diagram illustrating components of the ultrasound device **10**, in accordance with one or more embodiments of the present disclosure.

[0017] FIG. **3** is a flow diagram illustrating a method for adaptively managing power consumption in an ultrasound device, in accordance with one or more embodiments of the present disclosure.

DETAILED DESCRIPTION

[0018] A portable ultrasound device may include a power management module or controller configured to selectively enter the ultrasound device into one or more “low power” (i.e., reduced power) modes. A low power mode may include reducing or eliminating the power consumption of one or more components within the ultrasound device. For example, the low power mode may include electrically decoupling a power source to a transducer, a transducer transmit element, a transducer receive element, an ultrasound device display, driving circuitry, processing circuitry and/or any other electronic component in the ultrasound device in order to temporarily reduce the power consumption of the device.

[0019] Additionally, or alternatively, the low power mode may include reducing the power consumed by one or more electronic components within the ultrasound device. The power consumption of the ultrasound device may be reduced by dynamically adjusting system parameters such as, for example, the frame rate of the ultrasound device display (i.e., the rate of user display refresh), the receive aperture (i.e., the number of elements used for display generation) and the transmission amplitude (i.e., transmission power may be reduced) or the brightness of a user display.

[0020] The power management controller may include circuitry to dynamically adjust system parameters, and may further include circuitry (e.g., one or more switches or transistors) for coupling and decoupling power from a power supply to the various electronic components within the ultrasound device.

[0021] The low power mode may be initiated based on sense signals provided from one or more sensors, such as motion sensors operatively coupled to the transducer. For example, if a motion sensor senses that the ultrasound transducer is being moved too quickly to capture an ultrasound image of sufficient quality or reliability, the power management controller may enter the ultrasound device into a low power mode in order to save power until the period of undesirably rapid movement has concluded. That is, since the ultrasound device may not be able to capture suitable ultrasound images while the transducer is being moved too quickly, the power management controller may shut down or otherwise reduce the power consumed by various electronic components within the ultrasound device, such as the transducer elements during that period.

[0022] In one or more embodiments, the sensors may include a patient contact or pressure sensor positioned on an imaging surface of the transducer. Such a sensor may thus sense when the transducer is contacting, for example, a patient or a gel applied to the patient’s skin. The power management controller may be coupled to the sensors, and thus may initiate the low power mode upon receiving a sense signal indicating that the transducer is not contacting the patient.

[0023] Similarly, the sensors may include a capacitive sensor positioned to sense whether the transducer is being held, for example, by an operator of the ultrasound device. The power management controller may thus initiate the low power mode upon receiving a sense signal indicating that the transducer is not being held, and thus is not positioned to obtain ultrasound images of a desirable quality.

[0024] FIG. **1** is a schematic illustration of an ultrasound imaging device **10** (referred to herein as "ultrasound device" **10**), in accordance with one or more embodiments of the present disclosure. The ultrasound device **10** includes an ultrasound transducer **12** that is electrically coupled to a computing device **14** by a cable **16**. The cable **16** includes a connector **18** that detachably connects the transducer **12** to the computing device **14**. As shown in FIG. **1**, the ultrasound device **10** may be a portable ultrasound device, i.e., the transducer **12** may be connected to a portable computing device **14**, such as a tablet computer, laptop, a hand-held device, or the like.

[0025] The transducer **12** is configured to transmit an ultrasound signal toward a target structure in a region of interest. The transducer **12** is further configured to receive echo signals returning from the target structure in response to transmission of the ultrasound signal. To that end, the transducer **12** includes transducer elements **20** that are capable of transmitting an ultrasound signal and receiving subsequent echo signals. In various embodiments, the transducer elements **20** may be arranged as elements of a phased array transducer. Suitable phased array transducers are known in the field of ultrasound technology.

[0026] As will be described in greater detail in connection with FIG. **2**, the ultrasound device **10** further includes processing circuitry and driving circuitry. In part, the processing circuitry controls the transmission of the ultrasound signal from the transducer elements **20**. The driving circuitry is operatively coupled to the transducer elements **20** for driving the transmission of the ultrasound signal. The driving circuitry may drive the transmission of the ultrasound signal in response to a control signal received from the processing circuitry.

[0027] The ultrasound device **10** also includes a power supply that provides power to the driving circuitry for transmission of the ultrasound signal, for example, in a pulsed wave or a continuous wave mode of operation. Further, the ultrasound device **10** includes one or more sensors and a power management controller that dynamically adjusts power consumption in the ultrasound device **10**, based on operating conditions such as motion of the transducer **12** and contact with a patient or with an operator of the ultrasound device **10**, as will be described in further detail below. The sensors may include a motion sensor **102**, a capacitive sensor **104** and a patient contact sensor **106**.

[0028] The motion sensor **102** is included in the transducer **12** and may include, for example, one or more accelerometers or gyroscopes for sensing motion of the transducer **12**. For example, the motion sensor **102** may be or include any of a piezoelectric, piezoresistive or capacitive accelerometer capable of sensing motion of the transducer **12**, preferably in three dimensions.

[0029] One or more capacitive sensors **104** may further be included in the transducer **12** to sense whether the transducer **12** is being held by a user (e.g., an operator of the ultrasound device **10**). As shown in FIG. **1**, the capacitive sensor **104** may include one or more capacitive strips or elements positioned along the periphery of the transducer **12** such that, during normal operation of the ultrasound device **10**, an operator's hand contacts the capacitive sensor **104** or is in close proximity with the capacitive sensor **104**. While FIG. **1** shows capacitive sensors **104** for sensing human touch (e.g., when holding the transducer **12**), it should be readily appreciated that any sensor capable of sensing physical contact (e.g., human touch) may be utilized in place of the capacitive sensors **104**, including for example, one or more piezoresistive, piezoelectric, capacitive and elastoresistive sensors, as well as pressure sensors, force sensors and the like.

[0030] The patient contact sensor **106** may further be included in the transducer to sense whether the transducer **12** is contacting a physical object, such as a patient, during operation of the ultrasound device **10**. The patient contact sensor **106** thus may be utilized to sense whether the transducer **12** is contacting a patient's skin or a gel applied to the patient's skin while operating the ultrasound device **10** to obtain ultrasound images. The patient contact sensor **106** may be positioned along an imaging surface of the transducer **12**, such as a surface including the transducer elements **20**, as shown in FIG. **1**. The patient contact sensor **106** may be or include any tactile sensor, capacitive sensor, force sensor, pressure sensor or the like capable of sensing physical contact of a patient or gel applied to a patient with an imaging surface of the transducer **12**.

[0031] The computing device **14** shown in FIG. **1** includes a display screen **22** and a user interface **24**. The display screen **22** may use any type of display technology including, but not limited to, LED display technology. The display screen **22** is used to display one or more images generated from echo data obtained from the echo signals received in response to transmission of an ultrasound signal. In some embodiments, the display screen **22** may be a touch screen capable of receiving input from a user that touches the screen. In some embodiments, the user interface **24** may include one or more buttons, knobs, switches, and the like, capable of receiving input from a user of the ultrasound device **10**.

[0032] The computing device **14** may further include one or more audio speakers **54** that may be used to generate audible representations of echo signals or other features derived from operation of the ultrasound device **10**.

[0033] FIG. **2** is a block diagram illustrating components of the ultrasound device **10**, including the ultrasound transducer **12** and the computing device **14**. In FIG. **2**, the ultrasound device **10** includes transducer elements **80** (e.g., transducer elements **20** shown in FIG. **1**) configured for transmission of an ultrasound signal toward a target structure in a region of interest. The transducer elements **80** include one or more first transducer elements **82** that transmit the ultrasound signal and one or more second transducer elements **84** that receive echo signals returning from the target structure in response to transmission of the ultrasound signal. In some embodiments, some or all of the transducer elements **80** may act as first transducer elements **82** during a first period of time and as second transducer elements **84** during a second period of time that is different than the first period of time (i.e., the same transducer elements are usable to transmit the ultrasound signal and to receive echo signals at different times). In other embodiments, some or all of the first and second transducer elements **82**, **84** may be different transducer elements, each configured for transmitting an ultrasound signal or receiving echo signals.

[0034] The ultrasound device **10** further includes processing circuitry **86** coupled to driving circuitry **88**. In various embodiments, the processing circuitry **86** includes one or more programmed processors that operate in accordance with computer-executable instructions that, in response to execution, cause the programmed processor(s) to perform various actions. For example, the processing circuitry **86** may be configured to send one or more control signals to the driving circuitry **88** to control the transmission of an ultrasound signal by the ultrasound transducer **12**.

[0035] The processing circuitry **86** is further coupled to a user interface **96** and a display **98**. In at least one embodiment, the display **98** may comprise the screen **22** described with respect to FIG. **1**, while the user interface **96** may comprise the interface elements **24** described with respect to FIG. **1**.

[0036] The processing circuitry **86** may control a variety of operational parameters associated with the driving circuitry **86**, the display **98** and the user interface **96**.

[0037] The driving circuitry **88** may include an oscillator **90** that is used when generating an ultrasound signal to be transmitted by the one or more first transducer elements **82**. The oscillator **90** is used by the driving circuitry **88** to generate and shape the ultrasound pulses that form the ultrasound signal.

[0038] The ultrasound device **10** includes a power supply **92** that is electrically coupled to component parts of the ultrasound device **10** through a power management controller **100**. Such component parts may include, but are not limited to, the processing circuitry **86** and the driving circuitry **88**. The power supply **92** provides power for operating the processing circuitry **86** and the driving circuitry **88**. In particular, the power supply **92** provides power for generating the ultrasound signal by the driving circuitry **88** and transmitting the ultrasound signal, with stepped-up voltage as needed, by the one or more first transducer elements **82**. The power provided by the power supply **92** also provides power for the driving circuitry **88** and the processing circuitry **86** when receiving echo signals via the one or more second transducer elements **84**. The power supply **92** may further provide power for the display **98** and the user interface **96**. The power supply **92** may be, for example, one or more batteries in which electrical energy is stored and which may be rechargeable.

[0039] During operation, components of the ultrasound probe **10**, including but not limited to the power supply **92**, generate heat that must be dissipated by the ultrasound probe **10**. Accordingly, the ultrasound probe **10** may include one or more heat dissipation elements **94** configured to draw away and dissipate heat from the components of the ultrasound probe **10**. For example, the heat dissipation elements **94** may include one or more thermal circuits that are thermally coupled to the components of the ultrasound device **10**, including the power supply **92**, and conduct heat toward a surface of the ultrasound device **10** for dissipation by convection to a user's hand or the surrounding environment.

[0040] The power management controller **100** controls the power drawn by the ultrasound device **10** based on sense signals provided from one or more of the motion sensor **102**, the capacitive sensor **104** and the patient contact sensor **106**. The power management controller **100** may control the power draw by adjusting operational parameters of the ultrasound device **10**, and may further electrically decouple power from one or more components of the ultrasound device **10**.

[0041] In one or more embodiments, the power management controller **100** may be included in, or executed by, the processing circuitry **86**. For example, the power management controller **100** may be a module executed by one or more processors included in the processing circuitry **86**. In other embodiments, the power management controller **100** may be configured with processing circuitry separate from the main processing circuitry **86** and may operate in cooperation with the processing circuitry **86**. The processing circuitry of the power management controller **100** may be a programmed processor and/or an application specific integrated circuit configured to provide the power management functions described herein.

[0042] During operation of the ultrasound device **10**, the motion sensor **102** senses motion of the transducer **12**. The motion of the transducer **12** may indicate a level of ultrasound image quality which may be obtained at any given time. For example, obtaining high quality or clinically desirable ultrasound images may not be possible while moving the transducer **12** at a high rate of speed or acceleration in any direction. In contrast, by holding the transducer **12** still, at a proper position with respect to a target structure in a region of interest, a high or clinically desirable quality ultrasound image may be obtained. Thus, the sensed motion of the transducer **12** may be used as a proxy for, and may indicate, a level of ultrasound image quality which may be obtained at any instant in time.

[0043] The power management controller **100** receives a signal indicating motion of the transducer **12** from the motion sensor **102**. Based on the sensed motion, the power management controller **100** may reduce the power consumption of the ultrasound device **10** by adjusting one or more operational parameters of the ultrasound device **10** or by adjusting the coupling of power to one or more components of the ultrasound device **10**.

[0044] In one or more embodiments, the power management controller **100** may process the signal received from the motion sensor **102** to determine a motion of the transducer **12**, and may compare the determined motion of the transducer **12** with a predetermined threshold motion. The motion of the transducer **12** may be reflected in terms of acceleration, velocity or other such parameter indicative of motion which may be detected by the motion sensor **102**. The predetermined threshold motion may represent, for example, an acceleration or velocity at which (or above which) ultrasound images of a desired quality cannot be obtained. If the signal received from the motion sensor **102** indicates a motion (e.g., an acceleration or velocity) below the predetermined threshold motion, then the power management controller **100** will cause the components of the ultrasound device **10** (including, for example, the driving circuitry **88**, the transducer elements **80**, the display **98**, the user interface **96** and/or the processing circuitry **86**) to draw electrical power from the power supply **92** at a normal operating level. That is, the power management controller **100** will configure the ultrasound device **10** to operate in a normal or an "image acquisition" mode, as the motion of the transducer **12** is below a threshold level of motion and thus the ultrasound device **10** may obtain ultrasound images of a desired quality.

[0045] On the other hand, if the signal received from the motion sensor **102** indicates a motion (e.g., an acceleration or velocity) of the transducer **12** that equals or exceeds the predetermined threshold motion, then the power management controller **100** may determine that acquiring an ultrasound image of a desired quality is not possible. Accordingly, the power management controller **100** may configure the ultrasound device **10** to operate in a reduced or "low power" mode. That is, the power management controller **100** may adjust one or more operational parameters of the driving circuitry **88**, the transducer elements **80**, the display **98**, the user interface **96**, the processing circuitry **86** or any other electrical power consuming component of the ultrasound device **10**, in order to reduce the power consumed by the ultrasound device **10** when the transducer **12** is moving too quickly or too fast to obtain ultrasound images of a desired quality. Alternatively, or in addition, the power management controller **100** may adjust the coupling of power to any of the electrical power consuming components to reduce the power consumption in the low power mode.

[0046] For example, in the low power mode, the power management controller **100** may reduce the power consumed by the ultrasound device **10** by reducing the frame rate of the display **98** (i.e., the rate at which the display **98** displays consecutive images acquired by the ultrasound device **10**). Because ultrasound images of a desired quality cannot be obtained when the transducer **12** is moving at an acceleration or velocity that exceeds a predetermined threshold level of motion (e.g., acceleration or velocity), displaying the images acquired by the ultrasound device **10** at a normal frame rate while moving at such a rate may be of lesser importance than the amount of power consumed by the ultrasound device in such a scenario. Accordingly, the power management controller **100** may reduce the power consumption of the ultrasound device **10** by reducing the frame rate of the display **98**.

[0047] Further, in the low power mode, the power management controller **100** may reduce the power consumed by the ultrasound device **10** by adjusting various parameters associated with the transducer elements **80** (e.g., transmit elements **82** and receive elements **84**) and with beamforming or processing information received by the receive elements **84**. For example, the power management controller **100** (or the driving circuitry **88** or processing circuitry **86**, based on a control signal received from the power management controller **100**) may dynamically reduce the receive aperture, or the number of transducer elements **80** used for image generation and display. By reducing the number of transducer elements **80** (e.g., the receive elements **84**) used for display generation, the power required for low noise amplification and analog-to-digital conversion for forming the image is reduced.

[0048] Additionally, in the low power mode, the power management controller **100** may reduce the power used for transmission of an ultrasound signal (e.g., a transmit beam) by the transmit elements **82**. For example, an amplitude of the transmit beam may be reduced, thereby reducing the power used by the ultrasound device **10** in the low power mode.

[0049] Any other operational parameters of the ultrasound device **10** may be adjusted in order to reduce the power consumed by the ultrasound device **10** when the power management controller **100** determines, based on the motion sensed by the motion sensor **102**, that the transducer **12** is moving at a rate such that ultrasound images of a desired quality cannot be obtained.

[0050] A high rate of motion of the transducer **12** may indicate that the operator of the ultrasound device **10** is holding the transducer **12**, but is moving the transducer **12**, for example, to apply ultrasound gel to a patient or to position the transducer **12** in order to obtain a desired view. Since the operator is likely holding the transducer **12** in such a scenario, it may be preferable to decrease power consumption by entering a low power mode, as opposed to decoupling power to one or more components in the ultrasound device. However, in one or more embodiments, the power management controller **102** may electrically decouple one or more components of the ultrasound device **10** (e.g., the transducer elements **80**, the driving circuitry **88**, the display **98**, etc.) from the power supply **92** based on motion sensed by the motion sensor **102**. For example, the power management controller **100** may include one or more switches or transistors through which power from the power supply **92** is provided to the various components of the ultrasound device **10**, and these switches or transistors may be opened if the motion of the transducer **12** exceeds a predetermined threshold, thereby decoupling power from the power supply **92** to those components.

[0051] In addition to the motion sensor **102**, the power management controller **100** may reduce the power consumption of the ultrasound device **10** by adjusting one or more operational parameters of the ultrasound device **10** based on signals received from the capacitive sensor **104** and/or the patient contact sensor **106**. For example, if the power management controller **100** receives a signal from the capacitive sensor **104** indicating that the transducer **12** is not being held, then the power management controller **100** may reduce the power consumed by one or more components of the ultrasound device **10**, such as by reducing the frame rate, the receive aperture or the transmit amplitude.

[0052] Moreover, the power management controller **100** may decouple power from one or more components of the ultrasound device **10** based on a signal received from the capacitive sensor **104** indicating that the transducer **12** is not actively being held, e.g., by an operator. In such a case, for example, the power management controller **100** may decouple power from the power supply **92** to the driving circuitry **88**, the transducer elements **80**, the processing circuitry **86** or the display **98**. Since the transducer **12** is not being held, it may be assumed that the operator is not actively trying to acquire ultrasound images, and as such, the power management controller **100** may effectively reduce power consumption by decoupling power from components while those components are not being used to obtain ultrasound images.

[0053] Similarly, if the power management controller **100** receives a signal from the patient contact sensor **106** indicating that the transducer **12** is not contacting a physical structure (e.g., a patient or gel applied to a patient), then the power management controller **100** may reduce the power consumed by one or more components of the ultrasound device **10**, such as by reducing the frame rate, the receive aperture or the transmit amplitude. Additionally, or alternatively, the power management controller **100** may decouple power from one or more components of the ultrasound device **10** based on a signal received from the patient contact sensor **106** indicating that the transducer **12** is not positioned to obtain an ultrasound image (i.e., the transducer **12** is not contacting a structure or a subject containing the structure for imaging). In such a case, for example, the power management controller **100** may decouple or substantially reduce power from the power supply **92** to the driving circuitry **88**, the transducer elements **80**, the processing circuitry **86** or the display **98**. Since the transducer **12** is not contacting a physical structure, it may be assumed that the operator is not actively trying to acquire ultrasound images, and thus the power management controller **100** may effectively reduce power consumption by decoupling power from components while those components are not being used to obtain ultrasound images.

[0054] FIG. **3** is a flow diagram illustrating a method for adaptively managing power consumption in an ultrasound device **10** having a transducer **12**, in accordance with one or more embodiments of the present disclosure. In at least one embodiment, the method **300** includes generating, by a motion sensor **102** coupled to the transducer **12**, a motion sense signal indicating a motion of the transducer **12**, as indicated at block **302**. The motion sensor **102** may be, for example, one or more accelerometers or gyroscopes.

[0055] At block **304**, the method **300** includes transmitting the motion sense signal to a power management controller **100**. The power management controller **100** is coupled to a power supply **92** for supplying power to the ultrasound device **10**, and is configured to adjust one or more operational parameters of one or more components in the ultrasound device **10**.

[0056] At block **306**, the method **300** includes determining by the power management controller **100**, based on the motion sense signal, whether the motion of the transducer **12** exceeds a predetermined threshold level of motion. The predetermined threshold level of motion may be, for example, a predetermined threshold acceleration or velocity of the transducer **12** at or above which a desirable ultrasound image cannot be obtained by the transducer **12** or at least is not expected to be obtainable by the transducer **12**.

[0057] At block **308**, the method **300** includes reducing a level of power consumption by the ultrasound device **10** if the motion of the transducer **12** exceeds the predetermined threshold level of motion. The level of power consumption may be reduced by adjusting one or more operating parameters of the ultrasound transducer, including for example, reducing a frame rate of a display **98** of the ultrasound device **10**, reducing a receive aperture of the transducer **12** and reducing an amplitude of the ultrasound signals transmitted by the transducer **12**.

[0058] The ultrasound device **10** may further include one or more of a patient contact sensor **106** and a capacitive sensor **104**. Thus, a method for adaptively managing power consumption in the ultrasound device **10** may further include generating, by the patient contact sensor **102**, a contact sense signal indicating whether an imaging surface of the transducer **12** is contacting a physical structure; transmitting the contact sense signal to the power management controller **100**; and reducing the level of power consumption by the ultrasound device **10** if the contact sense signal indicates that the imaging surface of the transducer **12** is not contacting a physical structure.

[0059] A method for adaptively managing power consumption in the ultrasound device **10** may further include generating, by the capacitive sensor **104**, a capacitive sense signal indicating whether the transducer **12** is being held by an operator of the ultrasound device **10**; transmitting the capacitive sense signal to the power management controller **100**; and reducing the level of power consumption by the ultrasound device **10** if the capacitive sense signal indicates that the transducer **12** is not being held by the operator.

[0060] Reducing the level of power consumption by the ultrasound device may include electrically decoupling power to one or more of the transducer elements **80**, the display **98**, the driving circuitry **88** and the processing circuitry **86**.

[0061] As may be appreciated by persons having ordinary skill in the art, aspects of the various embodiments described above can be combined to provide further embodiments. Aspects of the embodiments can also be modified, if necessary, to employ concepts of various patents, applications and publications in the relevant art to provide yet further embodiments.

[0062] These and other changes can be made to the embodiments in light of the above-detailed description. For example, in one or more embodiments a method, transducer and ultrasound device may be provided in which the power management controller **100** dynamically adjusts power consumption based on a signal received from a patient contact sensor **106**, without a motion sensor **102**. As such, the power management controller **100** may reduce power consumption based only on receiving a signal from the patient contact sensor **106** indicating that the transducer **12** is not contacting a physical structure (e.g., a patient or gel applied to a patient), such as by reducing the frame rate, the receive aperture or the transmit amplitude and/or by decoupling power to one or more components of the ultrasound device **10**.

[0063] In yet another embodiment, a method, transducer and ultrasound device may be provided in which the power management controller **100** dynamically adjusts power consumption based on a signal received from a sensor configured to sense contact of a hand of an operator of the ultrasound device **10** with the transducer **12**, e.g., capacitive sensor **104**, without a motion sensor **102**. As such, the power management controller **100** may reduce power consumption based only on receiving a signal from the capacitive sensor **104** indicating that the transducer **12** is not being held, such as by reducing the frame rate, the receive aperture or the transmit amplitude and/or by decoupling power to one or more components of the ultrasound device **10**.

[0064] In still another embodiment, a method, transducer and ultrasound device may be provided in which the power management controller **100** dynamically adjusts power consumption based on signals received from any combination of the motion sensor **102**, capacitive sensor **104** and/or patient contact sensor **106**.

[0065] Additionally, in one or embodiments, a method, transducer and ultrasound device may be provided that include an "override" feature, which may be activated by a user, and which, when activated, prevents the system from entering a low power mode (i.e., in the override mode, the ultrasound device will continue to operate in a normal operational mode regardless of the parameters sensed by the motion sensor **102**, capacitive sensor **104** and/or patient contact sensor **106**). A user may activate the override feature, for example, via actuation of a physical button or switch, by adjusting a software setting (e.g., via a user interface provided through a display of the ultrasound device), or the like.

[0066] Further, in one or more embodiments, power may be conserved by turning off or otherwise reducing the power consumed by various features or elements of the ultrasound device once a certain level of battery power is detected. For example, the power management controller **100** may monitor a level of charge (e.g., a percentage of available battery power) of the batteries, and if the level of charge reaches or drops below a predetermined threshold (e.g., 10% of power, 20% of power, etc.), then the power management controller **100** may decouple power to and/or adjust one or more operational parameters associated with any feature or element of the ultrasound device as described herein in order to reduce power consumption. One such feature may include, for example, automatically uploading and/or downloading "deep learning" information from the cloud (e.g., downloading ultrasound image knowledge generated through a cloud-based artificial intelligence network and/or uploading acquired images to the cloud-based artificial intelligence network for further training). This feature is described, for example, in U.S. Provisional Patent Application No. 62/313,601 filed Mar. 25, 2016. The power management controller **100** may disable this feature (i.e., the ultrasound device will not download or upload information to the cloud-based artificial intelligence network) when the batteries are below a predetermined level of charge, and may cause the feature to remain disabled until the batteries are recharged to a level above the predetermined threshold level of charge. Any other features or elements of the ultrasound device may be disconnected from battery power and/or may have operational parameters that are adjusted in order to reduce power consumption when a level of charge of the batteries drops to or below the predetermined threshold. This may prevent, for example, a condition in which the ultrasound device loses power during an ultrasound imaging session.

[0067] In yet another embodiment, the ultrasound device may include a "sleep" mode feature that places the ultrasound device into a low or reduced power mode when the ultrasound transducer has not moved (e.g., as sensed by the motion sensors **102**) for a period of time that exceeds a predetermined threshold (e.g., 10 seconds, 20 seconds, etc.). Additionally, or alternatively, the sleep mode may be initiated when the ultrasound transducer has not been held (e.g., as sensed by the capacitive sensor **104**) for a period of time that exceeds a predetermined threshold. The ultrasound device may be returned to a normal (i.e., non-sleep mode) mode of operation upon detecting motion of the ultrasound transducer and/or upon detecting that the ultrasound transducer is being held.

[0068] In another embodiment, the power consumption of the ultrasound device may be reduced in a stepped manner based on an amount of time that the ultrasound transducer is motionless and/or is not being held (e.g., as sensed by the motion sensor **102** and/or the capacitive sensor **104**). For example, the power management controller **100** may monitor an amount of time that the transducer is motionless and/or is not being held and may initiate a first low or reduced power mode after a first predetermined period of time (e.g., 10 seconds) has elapsed. The power management controller **100** may continue monitoring the amount of time that the transducer is motionless and/or is not being held and may initiate a second low or reduced power mode (e.g., by reducing power consumption of the ultrasound device even further than in the first low power mode) after a second predetermined period of time (e.g., 20 seconds) has elapsed. In the first low or reduced power mode, the power management controller **100** may, for example, adjust one or more operational parameters of the ultrasound device (e.g., by reducing the frame rate, the receive aperture, the transmit amplitude, the display brightness, etc.), while in the second low or reduced power mode, the power management controller **100** may further reduce power consumption by decoupling power to one or more components of the ultrasound device (e.g., the transducer elements **80**, the display **98**, the driving circuitry **88** and the processing circuitry **86**).

[0069] In still another embodiment, the power management controller **100** may monitor a level of charge of the batteries, and may be configured to prevent the ultrasound device **10** from operating or otherwise being used to begin an ultrasound imaging session if the level of charge of the batteries is at or below a predetermined threshold level of charge. If the batteries are at or below the predetermined threshold level of charge, the ultrasound device may provide a message (e.g., a visual message provided via the display **22**, an audible message or the like) informing the user to charge the ultrasound device **10** before beginning an ultrasound imaging session.

[0070] In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

1. A method for dynamically managing power consumption in an ultrasound device having a transducer, the transducer including transmit and receive elements for respectively transmitting and receiving ultrasound signals, the method comprising:
- sensing a motion of the transducer by a motion sensor coupled to the transducer; and
- automatically reducing an amount of power consumption by the ultrasound device based on the sensed motion of the transducer.

2. The method of claim **1**, wherein automatically reducing an amount of power consumption includes adjusting one or more operational parameters of the ultrasound device.

3. The method of claim **2**, wherein the ultrasound device includes a display for displaying ultrasound images acquired by the ultrasound device, and wherein adjusting one or more operational parameters includes reducing a frame rate of the display.

4. The method of claim **2**, wherein adjusting one or more operational parameters includes reducing a receive aperture of the transducer.

5. The method of claim **2**, wherein adjusting one or more operational parameters includes reducing an amplitude of the ultrasound signals transmitted by the transducer.

6. A method for adaptively managing power consumption in an ultrasound device having a transducer, the method comprising:
- generating, by a motion sensor coupled to the transducer, a motion sense signal indicating a motion of the transducer;
- transmitting the motion sense signal to a power management controller;

determining by the power management controller, based on the motion sense signal, whether the motion of the transducer exceeds a predetermined threshold level of motion; and

automatically reducing a level of power consumption by the ultrasound device if the motion of the transducer exceeds the predetermined threshold level of motion.

7. The method of claim **6**, wherein the predetermined threshold level of motion comprises at least one of a predetermined threshold acceleration and a predetermined threshold velocity of the transducer.

8. The method of claim **6**, wherein the motion sensor includes at least one of an accelerometer and a gyroscope.

9. The method of claim **6**, further comprising:

generating, by a patient contact sensor, a contact sense signal indicating whether an imaging surface of the transducer is contacting a physical structure;

transmitting the contact sense signal to the power management controller; and

automatically reducing the level of power consumption by the ultrasound device if the contact sense signal indicates that the imaging surface of the transducer is not contacting a physical structure.

10. The method of claim **9**, wherein the patient contact sensor includes at least one of: a tactile sensor, a capacitive sensor, a force sensor and a pressure sensor.

11. The method of claim **9**, wherein automatically reducing the level of power consumption by the ultrasound device if the contact sense signal indicates that the transducer is not contacting a physical structure includes electrically decoupling power to at least one of: a transducer element, a display, a driving circuit and a processing circuit.

12. The method of claim **6**, further comprising:

generating, by a capacitive sensor, a capacitive sense signal indicating whether the transducer is being held by an operator of the ultrasound device;

transmitting the capacitive sense signal to the power management controller; and

automatically reducing the level of power consumption by the ultrasound device if the capacitive sense signal indicates that the transducer is not being held by an operator.

13. The method of claim **12**, wherein automatically reducing the level of power consumption by the ultrasound device if the capacitive sense signal indicates that the transducer is not being held by an operator includes electrically decoupling power to at least one of: a transducer element, a display, a driving circuit and a processing circuit.

14. A handheld ultrasound transducer, comprising:

one or more first transducer elements configured to transmit an ultrasound signal toward a target structure in a region of interest;

one or more second transducer elements configured to receive echo signals returning from the target structure in response to transmission of the ultrasound signal;

a motion sensor configured to sense a motion of the ultrasound transducer; and

a power management controller configured to automatically reduce an amount of power consumption by the handheld ultrasound transducer based on a sensed motion of the ultrasound transducer.

15. The handheld ultrasound transducer of claim **14**, further comprising:

a patient contact sensor arranged along an imaging surface of the ultrasound transducer, the patient contact sensor being configured to generate a contact sense signal indicating whether the imaging surface of the ultrasound transducer is contacting a physical structure.

16. The handheld ultrasound transducer of claim **14**, further comprising:

a capacitive sensor configured to sense whether the transducer is being held by an operator of the ultrasound device.

17. An ultrasound device, comprising:

a handheld ultrasound transducer including:

one or more first transducer elements arranged along an imaging surface of the ultrasound transducer and configured to transmit an ultrasound signal toward a target structure in a region of interest,

one or more second transducer elements arranged along the imaging surface of the ultrasound transducer and configured to receive echo signals returning from the target structure in response to transmission of the ultrasound signal, and

a motion sensor configured to sense a motion of the ultrasound transducer;

processing circuitry that controls transmission of the ultrasound signal from the one or more first transducer elements;

driving circuitry operatively coupled to the one or more first transducer elements and the processing circuitry, wherein the driving circuitry drives the transmission of the ultrasound signal by the one or more first transducer elements in response to a control signal received from the processing circuitry;

a display configured to display ultrasound images acquired by the ultrasound device; and

a power management controller coupled to the motion sensor, the power management controller being configured to automatically reduce an amount of power consumption by the ultrasound device based on the sensed motion of the ultrasound transducer.

18. The ultrasound device of claim **17**, wherein the handheld ultrasound transducer further includes a patient contact sensor arranged along an imaging surface of the ultrasound transducer, the patient contact sensor being configured to generate a contact sense signal indicating whether the imaging surface of the ultrasound transducer is contacting a physical structure,

wherein the power management controller is coupled to the patient contact sensor and configured to automatically reduce an amount of power consumption by the ultrasound device based on the contact sense signal.

19. The ultrasound device of claim **17**, wherein the handheld ultrasound transducer further includes a capacitive sensor configured to sense whether the transducer is being held by an operator of the ultrasound device,

wherein the power management controller is coupled to the capacitive sensor and configured to automatically reduce an amount of power consumption by the ultrasound device based on an output of the capacitive sensor.

20. The ultrasound device of claim **17**, wherein the power management controller is configured to automatically reduce an amount of power consumption by adjusting one or more operational parameters of the ultrasound device.

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摘要(译)

本文提供了用于动态管理超声设备中的功耗的系统和方法。超声设备中的换能器可以具有用于分别发送和接收超声信号的发送和接收元件。在至少一个实施例中，该方法包括通过耦合到换能器的运动传感器感测换能器的运动。然后，基于感测到的换能器的运动，减少超声设备消耗的功率量。减少功耗量可以包括调整超声设备的一个或多个操作参数，例如但不限于降低显示帧速率，接收孔径或发射幅度，或者通过将功率去耦到一个或多个组件。超声设备。替代地或另外地，可以基于从电容传感器和/或患者接触传感器接收的信号来降低功耗。