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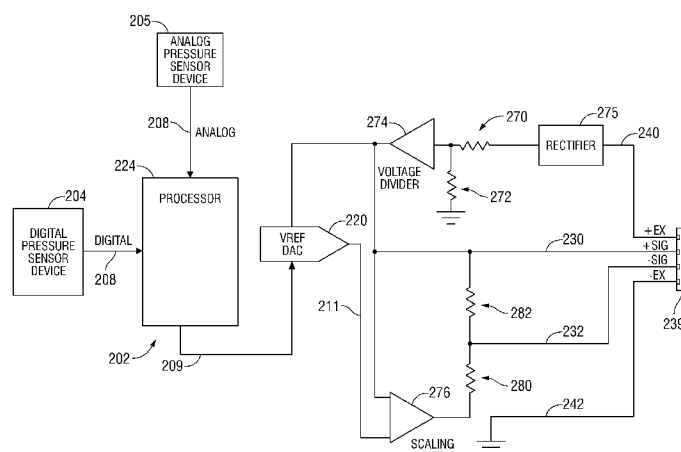


FIG. 3

(57) Abstract: Disclosed is an apparatus, system, and method for utilizing a pressure transducer simulator that is configured for use with a pressure sensor device and a patient monitoring device. The pressure transducer simulator is configured to generate a simulation of the output of an analog pressure sensing device to be compatible with the patient monitoring device. The pressure transducer simulator may include: a rectifier; a voltage divider; a processor; a DAC; and a scaling circuit. The DAC may be configured to receive a digital pressure code signal and a rectified voltage reference signal (from the rectifier and the voltage divider) and may be configured to produce an analog output pressure signal based upon the digital pressure code signal and the rectified voltage reference signal. The scaling circuit coupled to the DAC receives the analog output pressure signal and the rectified voltage reference signal and outputs a scaled analog output pressure signal.



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PRESSURE TRANSDUCER SIMULATOR WITH RECTIFIER TO IMPLEMENT AN AUTO-ZEROING COMMAND

BACKGROUND

Field

[0001] The present invention relates to a pressure transducer simulator that is configured for use with a pressure sensor device and a patient monitoring device. The pressure transducer simulator may be configured to generate a simulation of the output of an analog pressure sensing device to be compatible with the patient monitoring device and may implement an auto-zeroing command.

Relevant Background

[0002] A standard analog pressure device for measuring blood pressure (typically known as a Disposable Pressure Transducer or DPT) includes a pressure transducer, which is basically a bridge circuit in which a reference signal is applied to one branch of the bridge and the pressure signal is obtained on the other branch. The pressure sensing element (typically a piezoelectric sensor) is placed in one, two, three or four of the four arms of the bridge. The pressure sensing element is basically a variable resistance that varies with the applied pressure. The analog pressure sensing device is usually connected through a fluid filled system to a catheter placed in a vein or an artery, where the pressure pulsations are captured by the pressure sensing element. The analog pressure sensing device is typically for blood pressure monitoring.

[0003] The other side of the analog pressure sensing device is typically connected to a measurement instrument, typically a bedside monitor, a blood pressure monitor, or any

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other monitor that uses the blood pressure signal (e.g., pulse contour Cardiac Output monitors). A reference signal to the analog pressure sensing device is typically provided by the measurement instrument and it is typically used by the instrument to scale the measured blood pressure signal. Different monitors have different reference signals. The reference signal may be either DC or AC and may be typically in the 1-10 Volt range. In AC-based instruments, the operating frequency typically ranges from a few kHz up to 5 kHz.

[0004] Unfortunately, standard monitors are generally configured to only interact with particular types of analog pressure sensing devices (e.g., blood pressure devices) and cannot interact with waveforms from other types of pressure sensing devices, such as digital non-invasive blood pressure monitors (NIBMs).

SUMMARY

[0005] Embodiments of the invention may relate to an apparatus, system, and method for utilizing a pressure transducer simulator that is configured for use with a pressure sensor device and a patient monitoring device. The pressure transducer simulator may be configured to generate a simulation of the output of an analog pressure sensing device to be compatible with the patient monitoring device. The simulation may be based upon a pressure signal received from the pressure sensor device.

[0006] In one embodiment, the pressure transducer simulator may comprise: a rectifier, a voltage divider; a processor; a digital to analog converter (DAC); and a scaling circuit. The rectifier and the voltage divider may receive an excitation voltage from the patient monitoring device and may output a rectified voltage reference signal that is a fraction of the excitation voltage. The processor may select and transmit a digital pressure code

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signal based upon a pressure signal received from the pressure sensor device. The DAC may be configured to receive the digital pressure code signal and the rectified voltage reference signal and may produce an analog output pressure signal based upon the digital pressure code signal and the rectified voltage reference signal. The scaling circuit may be coupled to the DAC to receive the analog output pressure signal and the rectified voltage reference signal and may output a scaled analog output pressure signal. Based upon the outputted scaled analog output pressure signal, an analog pressure signal may be transmitted to the patient monitoring device that is approximately equivalent to the pressure signal from the pressure sensor device and that is substantially ratiometric with the excitation voltage. Further, the pressure transducer simulator may perform an auto-zeroing function as well as the operating function.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a diagram of a system in which embodiments of the invention related to a pressure transducer simulator may be practiced.

[0008] FIG. 2 is a block diagram illustrating components of the pressure transducer simulator, according to one embodiment of the invention.

[0009] FIG. 3 is a diagram illustrating examples of circuit components of the pressure transducer simulator, according to one embodiment of the invention.

DETAILED DESCRIPTION

[0010] Embodiments of the invention generally relate to an apparatus, system, and method to simulate the function of a standard analog pressure sensor. In particular, an

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apparatus, system, and method is provided that allows for broad and universal connectivity to existing pressure monitoring devices, regardless of the type of reference signal and/or the amplitude of the reference signal, and regardless of the type of input signal (e.g., analog or digital). Embodiments of the invention have many practical applications.

[0011] In particular, embodiments of the invention provide an easy and universal connectivity to all types of blood pressure measuring monitors. This capability of universal connectivity makes it possible to connect various continuous noninvasive blood pressure monitors (NIBMs) (i.e., blood pressure sensing devices) to already existing and clinically adopted blood pressure measuring monitors, which are currently used for invasive measurements only (i.e., from analog blood pressure sensing devices, or disposable pressure transducers - DPTs).

[0012] Many new technologies for noninvasive continuous measurement of blood pressure (i.e., digital pressure sensor devices) are available today. The possibility of connecting those various technologies to standard patient monitoring devices is an easy and low cost way to provide noninvasive measurements in the clinical setting. Embodiments of the invention allow for the noninvasive pressure signal to be directly acquired through the regular pressure transducer connector with no need to develop special modules for the different blood pressure measuring devices or patient monitors. This allows the display of the noninvasive pressure measurements (i.e., measurements from noninvasive pressure sensor devices) on the patient monitoring device in the exact same way as the currently used invasive pressure measurements (i.e., analog measurements from analog pressure sensor devices, or DPTs).

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[0013] Embodiments of the invention to achieve this functionality will be hereinafter described. It should be noted that although digital pressure sensor devices and analog pressure sensor devices in conjunction with a patient monitoring device have been previously described for use with blood pressure measurements that embodiments of the invention may relate to the pressure measurements of many different types of patient measurements (e.g., cardiac measurements, breathing measurements, intracranial pressure measurements etc.)

[0014] In order to achieve this functionality, with reference to FIGs. 1 and 2, in one embodiment, a pressure transducer simulator integrated into a noninvasive blood pressure measuring instrument 202 may be configured for use with an invasive or noninvasive blood pressure module 204 and a patient monitoring device 206. The patient monitoring device 206 may include a display screen to show a patient's blood pressure reading. The pressure transducer simulator integrated in the noninvasive blood pressure measuring instrument 202 may be directly connected to a pre-existing connector of the invasive blood pressure module of the patient monitoring device 206.

[0015] The pressure transducer simulator in measuring instrument 202 may be configured to generate a simulation of the output of an analog pressure sensing device compatible with the monitoring device 206, wherein the simulation is based upon a pressure signal 208 received from the pressure sensor device 204. The pressure transducer simulator in 202 may comprise a digital to analog converter (DAC) 220 and a processor 224, as well as other components to be hereinafter described. The pressure transducer simulator in measuring instrument 202 will hereinafter be referred to as pressure transducer simulator 202.

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[0016] In one embodiment, the pressure transducer simulator 202 may include a DAC 220 that in cooperation with other components is configured to generate an analog signal 230/232 that is transmitted to the patient monitoring device 206 for display on the patient monitoring device 206. It should be noted that the connections of digital or analog signals between a patient (not shown) to digital or analog pressure sensor devices 204, to pressure transducer simulator 202, to patient monitoring device 206, etc., may be through wired or wireless connections. Further, as will be described, the pressure transducer simulator 202 may be utilized with either digital or analog pressure sensing devices 204 that transmit digital or analog pressure signals 208. Also, it should be appreciated that pressure sensing device 204 may relate to the pressure measurements of many different types of patient measurements (e.g., blood pressure measurements, cardiac measurements, breathing measurements, intracranial pressure measurements etc.) and may communicate in a wired or wireless manner and may be connected to different patient body parts (e.g., finger, ear, nose, arm, etc.). Any type of commonly utilized pressure sensing device 204 may be utilized with embodiments of invention utilizing the pressure transducer simulator.

[0017] With additional reference to FIG. 3, components of the pressure transducer simulator 202 include the DAC 220 which is configured to generate analog signals based upon a digital pressure code signal 209. Further, the analog signals 230 and 232 are later transmitted to the patient monitoring device 206, as will be described. It should be noted that a connector 239 may connect the circuitry of the pressure transducer simulator 202 to the patient monitoring device 206. This may be to a pre-existing connector of the patient monitoring device 206. In this way, the pressure transducer simulator 202 is directly attachable to existing patient monitoring devices 206 and can provide signal inputs from

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either digital pressure sensor devices 204 or analog pressure sensor devices 205, as will be described. It should be noted that only one digital pressure sensor device 204 or one analog pressure sensor device 205 may be attached at a given time. Further, as is known to those of skill in the art, a DAC is a device that converts a digital (usually binary) code signal to a voltage or current.

[0018] In one particular example, as will be hereinafter described, the pressure transducer simulator 202 may comprise: a voltage divider, consisting of resistors 270 and 272 and the amplifier 274; a rectifier 275; a processor 224; a digital to analog converter (DAC) 220; and a scaling amplifier 276. The voltage divider consisting of resistors 270 and 272 and the amplifier 274 in conjunction with the rectifier 275 may receive an excitation voltage 240 from the monitoring device and may output a voltage reference signal that is a fraction of the excitation voltage, as will be described in more detail later. The processor 224 may select and transmit a digital pressure code signal 209 based upon a pressure signal 208 received from a pressure sensor device.

[0019] The DAC 220 may be configured to receive the digital pressure code signal 209 and the voltage reference signal and may produce an analog output pressure signal 211 based upon the digital pressure code signal 209 and the voltage reference signal. The scaling amplifier 276 may be coupled to the DAC 220 to receive the analog output pressure signal 211 and the voltage reference signal and may output a scaled analog output pressure signal. Based upon the outputted scaled analog output pressure signal, an analog pressure signal may be transmitted to the monitoring device that is approximately equivalent to the pressure signal 208 from the pressure sensor device and that is

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substantially ratiometric with the excitation voltage. As will be described, the analog pressure signal is the difference +SIG 230 and –SIG 232.

[0020] In one embodiment, processor 224 may implement a DAC converter program to select the appropriate digital pressure code signal to transmit to DAC 220. It should be appreciated that the DAC may have a particular pre-determined bit resolution (e.g., 8-bit, 10-bit, 12-bit, 14-bit, 16-bit, etc.) and that the DAC converter program may select an appropriate digital pressure code signal 209 that correlates to the inputted digital or analog pressure signal 208 for conversion based upon the type of DAC being utilized and the technical characteristics of the circuit. As one explanatory example, for a 12-bit DAC and assuming a DAC reference voltage V_{REF} of 3V: a digital pressure code signal 209 of 4096 may correspond to a conversion of an input of 0 mmHG/0 V; a digital pressure code signal 209 of 0 may correspond to a conversion of an input of 300 mmHG/3 V; and a digital pressure code signal 209 of 1365 may correspond to a conversion of an input of 100 mmHG/1 V. It should be appreciated that a wide variety of different types of DACs and DAC conversion programs may be utilized to implement embodiments of the invention.

[0021] In one embodiment, processor 224 of the pressure transducer simulator 202 may implement an auto-zeroing command. Pressure zeroing is a function that many standard pressure monitoring devices typically have to zero the pressure signal from the standard DPTs to the atmospheric pressure. Zeroing is typically performed prior to pressure measurement and is commonly repeated when the patient or the DPT position is changed. So, in order to operate with the patient monitoring device 206, the pressure transducer simulator 202 may include a zeroing functionality that mimics the DPT behavior when the

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DPT line is open to the atmospheric pressure for zeroing. For example, an auto-zeroing button 243 may be configured for pressing by a medical technician to implement the auto-zeroing command. When the auto-zeroing command is implemented, a digital pressure code signal 209 may be selected such that the DAC 220 may be set so that the analog signals (+SIG and -SIG) 230 and 232 produced by the DAC 220 are equal to one another. In the patient monitoring device, where an instrumentation type of amplifier is commonly used in the front-end circuitry, they subtract each other out and the resulting signal is approximately zero. Based upon the auto-zeroing function, the patient monitoring device 206 can calibrate itself to the pressure transducer simulator 202. The auto-zeroing command will be described in more detail hereinafter.

[0022] Processor 224 may also implement an operate command. For example, an operate button 244 configured for pressing may be pressed by a medical technician and the operate command implemented. After implementation of the operate command, the DAC 220 in conjunction with other circuitry produces analog signals (+SIG and -SIG) 230 and 232 based upon the digital pressure code signal 209, which is, representative of input signals from either digital or analog pressure sensor devices 204 or 205. The analog signals (+SIG and -SIG) 230 and 232 are transmitted to the patient monitoring device 206. It should be appreciated that the use of an auto-zeroing button 243 and an operate button 244 to implement auto-zeroing commands and operate commands by processor 224 are merely examples, and that processor 224 may implement these commands automatically without the use of input commands from buttons or other input mechanisms. Further, a wide variety of different types of command input mechanisms at the pressure transducer simulator or at other locations may be utilized.

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[0023] In particular, the pressure transducer simulator 202 of FIG. 3 accepts the DC or AC excitation voltage typically applied to an industry standard bridge type disposable pressure transducer (DPT) and outputs a standard differential signal of 5 μ V per mmHg per volt of excitation. The pressure transducer simulator 202 accepts any excitation voltage within the range of -10 volts to +10 volts at pin 1 of connector 239 (signal name +EX) referenced to the excitation reference at pin 4 connector 239 (signal name -EX). The excitation can be constant or varying.

[0024] The pressure transducer simulator 202 is universally compatible with a myriad of commercially available patient monitoring devices 206, because the differential output signals between +SIG and -SIG 230 and 232 are ratiometric to the instantaneous applied excitation voltage at 5 μ V per mmHg per volt of excitation, and the differential output signals 230 and 232 ride on a common mode level.

[0025] Additionally, many commercially available patient monitor devices 206 place limits on the allowable zero offset voltage in the zero pressure state, and many require that the pressure sensor device provide a differential output signal (+SIG-(-SIG)) 230 and 232 very near 0 uV, when zero output is commanded. In one embodiment, processor 224 of the pressure transducer simulator 202 may implement an auto-zeroing command. When the auto-zeroing command is implemented, the digital pressure code signal 209 may be selected such that the DAC 220 may be set so that the analog signals (+SIG and -SIG) 230 and 232 produced by the DAC 220 and other circuitry are equal to one another such that they subtract each other out in the instrumentation amplifier of the patient monitoring device 206 and the resulting signal is approximately zero.

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[0026] In order to accomplish this, in one embodiment of the invention, resistors 270 and 272 are configured to apply 50% of the excitation voltage (+EX 240) to the voltage divider consisting of resistors 270 and 272 and the amplifier 274. The output of the voltage divider becomes +SIG 230, producing the desired 50% of excitation as common mode voltage on the output. The output of the voltage divider also becomes the reference input (VREF) to DAC 220. Further, in one embodiment, a rectifier 275 may rectify the excitation voltage 240 from negative to positive in a situation where the excitation voltage is generated by a monitoring device 206 that operates with an alternating current (AC). Although a rectifier 275 is not necessary, as many DACs 220 may operate on a negative or positive voltage reference (VREF), the use of a rectifier 275 may provide for a more consistent voltage reference and may allow for the use of a wider range of DACs.

[0027] The pressure to be represented as the analog output pressure signal 211 of DAC 220 is set by adjusting the output of DAC 220. As an example, the analog output pressure signal 211 of DAC 220 may be represented as: $-VREF \times D/4096$, such that the output of the DAC 220 may range from: 0 to $-(50\% \text{ of Excitation}) \times (4096/4096)$, or, 0 to -50% of Excitation (EX). It should be noted that the number 4096 is the bit number associated with the DAC and any bit number associated with a DAC may be utilized.

[0028] Further, a scaling amplifier 276 is provided that may have a gain of 2, as an example. Scaling amplifier 276 scales the analog output pressure signal 211 and scales in 50% of Excitation (EX) from voltage divider 274. Therefore, the output analog pressure signal across resistor 282 is equal to: $-(Excitation) \times (D/4096) + (0.5 \times Excitation)$, such that the output can range from -50% of Excitation (EX) to +50% of Excitation (EX). The

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output of the scaling amplifier is applied to voltage divider resistor 280 and voltage divider resistor 282. This circuitry may be referred to as the scaling circuitry.

[0029] Because resistor 282 is connected to +SIG, which is at +50% Excitation from voltage divider 274, the differential signal between +SIG 230 and -SIG 232 will be zero when the output of scaling amplifier 276 is at +50% Excitation. Also, the analog output pressure signal transmitted as differential output signals (+SIG 230 and -SIG 232) is ratiometric to the instantaneous applied excitation voltage at 5 μ V per mmHg per volt of excitation, and the differential output signals 230 and 232 ride on a common mode level tracking 50% of the instantaneous applied excitation voltage.

[0030] Those skilled in the art will understand that operational amplifiers have some offset voltage and all electronic components have tolerances, so when the output of scaling amplifier 276 should be 50% of Excitation (EX), it may not be exactly 50% of Excitation. Advantageously, the ratio of resistors 280 and 282 is large enough that the error at the output of scaling amplifier 276 is reduced by the divider ratio and results in relatively small absolute differential offset voltages at the output. For example, a 2mV error at the output of scaling amplifier 276 would be reduced to 3.5 μ V at the differential output. In particular, resistor dividers 280 and 282 may be selected such that when the output of scaling amplifier 276 is at -50% Excitation, the differential signal between +SIG and -SIG may be the desired full scale output. Also advantageously, any error in the output of voltage divider 274 appears at +SIG, and at the DAC reference, and also in the scaling amplifier 276, effectively removing errors in the voltage divider 274 from contributing to output offset error.

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[0031] In particular, in this implementation, the desired output is 5 μ V per mmHg per volt of excitation, with 300mmHg as full scale, so that the differential output is 1500 μ V per volt of excitation, and the ratio of resistors 280 and 282 is established. In one example, the value of resistor 282 may be near 300 ohms, to approximate the resistance seen at the corresponding terminals of a pressure transducer. It should be appreciated by persons of ordinary skill in the art that other divider ratios could be used for resistors 280 and 282 to accommodate other full scale ranges.

[0032] As previously described, the pressure to be represented at the output is accomplished by the processor 224 implementing a DAC converter program to select the appropriate digital pressure code signal 209 to transmit to DAC 220 such that the pressure to be represented at the output [(+SIG-(-SIG)) 230 and 232 matches the digital input signal 208 from the digital pressure device 204. Because of the known excitation voltage of 5 μ V per mmHg per volt of excitation utilized for patient monitoring devices and the previously described circuitry, the DAC converter program of the processor selects the appropriate digital pressure code signal 209 to transmit to DAC 220 such that the pressure to be represented at the output matches or is approximately equivalent to the digital input signal 208.

[0033] To provide an example of the operate command 244 being implemented by processor 224, assuming a digital input 208 from digital pressure sensor device 204 of 100 mmHg or 1V, processor 224 would determine a digital pressure code signal of 1365 [from the range 0-4096 (e.g., assuming a 12-bit DAC)] that would be transmitted to DAC 220. Based upon this, and assuming VREF of 1.5 V (assuming an Excitation voltage 240 of 3 V to which $\frac{1}{2}$ is set to VREF) the output 211 from the DAC 220 will be equal to 0.5V, as

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scaled by scaling amplifier 276 (e.g., assuming an Excitation voltage 240 of 3 V to which $\frac{1}{2}$ is set to +SIG 230 (1.5 V)) and the rest of the circuitry, a -SIG 232 value of approximately .5 V would be yielded resulting in an analog output voltage (+SIG-(-SIG))=(1.5V-(.5V))=1V or 100mmHG which is equivalent to the digital input 208 from digital pressure sensor device 204. In this way, the circuitry and processor 224 can ensure that analog output voltages (+SIG and -SIG) 230 and 232 result in a match to the digital pressure input 208 from the digital pressure sensor device 204.

[0034] Further, as previously described, the pressure simulator transducer 202, in the same way, operates with analog pressure sensor devices during operation. For example, analog pressure sensor device 205 may output a 100 mmHg or 1V analog input signal 208. Analog to digital converter (ADC) 207 may convert this to a digital input signal for use by processor 224, as previously described. It should be noted that ADC 207 may be a part of processor 224 or may be a separate component of the pressure transducer simulator 202 connected to processor 224.

[0035] In the same way, assuming a converted to digital input from an analog pressure sensor device 205 of 100 mmHg or 1V, processor 224 would determine a digital pressure code signal of 1365 [from the range 0-4096 (e.g., assuming a 12-bit DAC)] that would be transmitted to DAC 220. Based upon this, and assuming VREF of 1.5 V (assuming an Excitation voltage 240 of 3 V to which $\frac{1}{2}$ is set to VREF) the output 211 from the DAC 220 will be equal to 0.5V, as scaled by scaling amplifier 276 (e.g., assuming an Excitation voltage 240 of 3 V to which $\frac{1}{2}$ is set to +SIG 230 (1.5 V)) and the rest of the circuitry, a -SIG 232 value of approximately .5 V would be yielded resulting in an analog output voltage (+SIG-(-SIG))=(1.5V-(.5V))=1V or 100mmHG which is equivalent to the analog

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input 208 from analog pressure sensor device 205. In this way, the circuitry and processor 224 can ensure that analog output voltages (+SIG and -SIG) 230 and 232 result in a match to the analog pressure input 208 from the analog pressure sensor device 205.

[0036] Further, as previously described, processor 224 of the pressure transducer simulator 202 may implement an auto-zeroing command. For example, an auto-zeroing button 243 may be configured for pressing by a medical technician to implement the auto-zeroing command. When the auto-zeroing command is implemented, the digital pressure code signal 209 may be selected such that the DAC 220 may be set so that the analog signals (+SIG and -SIG) 230 and 232 produced by the DAC 220 are equal to one another such that they subtract each other out and are approximately zero. The auto-zeroing command is beneficial because pressure zeroing is a function that many pressure monitoring devices typically require in their standard operation to zero the pressure signal from the standard DPTs to the atmospheric pressure. With the standard DPTs, zeroing is typically performed prior to pressure measurement and is commonly repeated when the patient or the DPT position is changed. So, in order to operate with the patient monitoring device 206, the pressure transducer simulator 202 should include a zeroing functionality that mimics the DPT behavior when the DPT line is open to the atmospheric pressure for zeroing. Also, based upon the auto-zeroing function, the patient monitoring device 206 can calibrate itself to the pressure transducer simulator 202.

[0037] This is beneficial in that many commercially available patient monitor devices 206 place limits on the allowable zero offset voltage in the zero pressure state, and many require that the pressure sensor device 204 provide a differential output signal (+SIG-(-SIG)) 230 and 232 very near 0 uV, when zero output is commanded.

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[0038] To provide an example of the auto-zeroing command 243 being implemented by processor 224, assuming a digital input signal of minimal capacity (0mmHg or 0V) may be utilized such that processor 224 utilizes a maximum digital pressure code signal of 4096 [from the range 0-4096 (e.g., assuming a 12-bit DAC)] that would be transmitted to DAC 220. Based upon this, the output 211 from the DAC 220, as scaled by scaling amplifier 276 (e.g., assuming an Excitation voltage 240 of .5 V which is set to +SIG 230) and the rest of the circuitry, a -SIG 232 value of approximately .5 V would be yielded resulting in an analog output voltage $(+SIG - (-SIG)) = (.5V - (.5V)) = 0V$ or 0mmHG.

[0039] Thus, embodiments of the invention relate to a pressure transducer simulator 202 that allows for broad and universal connectivity of a patient monitoring device 206 to both digital pressure sensor devices 204 and analog pressure sensor devices 205, regardless of the excitation voltages of the patient monitoring device and/or the type of input signals (e.g., analog or digital) from either digital or analog pressure sensor devices.

[0040] In particular, embodiments of the invention provide an easy and universal connectivity to all types of blood pressure measuring monitors. This capability of universal connectivity makes it possible to connect various continuous noninvasive blood pressure monitors (NIBMs) (i.e., blood pressure sensing devices) to already existing and clinically adopted blood pressure measuring monitors, which are currently used for invasive measurements only (i.e., from analog blood pressure sensing devices, or disposable pressure sensors - DPTs). Embodiments of the invention allow for the noninvasive pressure signal to be directly acquired through the regular pressure transducer connector with no need to develop special modules for the different blood pressure measuring devices or patient monitors. This allows the display of the noninvasive pressure

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measurements (i.e., measurements from noninvasive pressure sensor devices) on the patient monitoring device in the exact same way as the currently used invasive pressure measurements (i.e., analog measurements from analog pressure sensor devices, or DPTs).

[0041] It should be appreciated that aspects of the invention previously described may be implemented in conjunction with the execution of instructions by processor 224 of pressure transducer simulator 202. Processor 224 may operate under the control of a program, routine, or the execution of instructions to execute methods or processes in accordance with embodiments of the invention. For example, such a program may be implemented in firmware or software (e.g. stored in memory and/or other locations) and may be implemented by processors and/or other circuitry of the pressure transducer simulator 202. Further, it should be appreciated that the terms processor, microprocessor, circuitry, controller, etc., refer to any type of logic or circuitry capable of executing logic, commands, instructions, software, firmware, functionality, etc

[0042] The various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a microcontroller, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A processor may be a microprocessor or any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of

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microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0043] The steps of a method or algorithm described in connection with the embodiments disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor.

[0044] The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

WHAT IS CLAIMED IS:

1. A method for simulating a pressure sensor device as an analog pressure sensing device to generate a simulation of the output of an analog pressure sensing device compatible with a monitoring device, the method comprising:
 - selecting a digital pressure code signal to implement an auto-zeroing command or an operate command;
 - transmitting the digital pressure code signal;
 - rectifying a voltage reference signal;
 - configuring a digital to analog converter (DAC) to receive the digital pressure code signal and the rectified voltage reference signal and to produce an analog output pressure signal based upon the digital pressure code signal and the rectified voltage reference signal; and
 - outputting a scaled analog output pressure signal to the monitoring device.
2. The method of claim 1, wherein, when the auto-zeroing command is implemented, further comprising selecting the digital pressure code signal such that the analog pressure signal outputted to the monitoring device is approximately zero.
3. The method of claim 2, wherein, the digital pressure code signal is a maximum digital pressure code signal associated with the DAC.
4. The method of claim 1, wherein, when the operate command is implemented, the analog pressure signal outputted to the monitoring device is approximately equivalent to the pressure signal from the pressure sensor device and is substantially ratiometric with an excitation voltage.
5. The method of claim 1, wherein, the pressure sensor device is a digital pressure sensor device.

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6. The method of claim 1, wherein, the pressure sensor device is an analog pressure sensor device.

7. A pressure transducer simulator configured for use with a pressure sensor device and a monitoring device, the pressure transducer simulator configured to generate a simulation of the output of an analog pressure sensing device compatible with the monitoring device, the pressure transducer simulator comprising:

a processor to:

select and transmit a digital pressure code signal; and

implement an auto-zeroing command or an operate command;

a rectifier to receive a voltage reference signal and to rectify the voltage reference signal;

a digital to analog converter (DAC) configured to receive the digital pressure code signal and the rectified voltage reference signal, the DAC being configured to produce an analog output pressure signal based upon the digital pressure code signal and the rectified voltage reference signal; and

a scaling circuit coupled to the DAC to receive the analog output pressure signal and the rectified voltage reference signal, the scaling circuit to output a scaled analog output pressure signal to the monitoring device.

8. The pressure transducer simulator of claim 7, wherein, when the auto-zeroing command is implemented, the processor selects the digital pressure code signal such that the analog pressure signal outputted to the monitoring device is approximately zero.

9. The pressure transducer simulator of claim 8, wherein, the digital pressure code signal is a maximum digital pressure code signal associated with the DAC.

10. The pressure transducer simulator of claim 7, wherein, when the operate command is implemented, the analog pressure signal outputted to the monitoring device is approximately equivalent to the pressure signal from the pressure sensor device and is substantially ratiometric with an excitation voltage.

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11. The pressure transducer simulator of claim 7, wherein, the pressure sensor device is a digital pressure sensor device.

12. The pressure transducer simulator of claim 7, wherein, the pressure sensor device is an analog pressure sensor device.

13. A system for patient monitoring comprising:
a pressure sensor device;
a monitoring device; and
a pressure transducer simulator configured for use with the pressure sensor device and the monitoring device, the pressure transducer simulator configured to generate a simulation of the output of an analog pressure sensing device compatible with the monitoring device, the pressure transducer simulator comprising:
a processor to:
select and transmit a digital pressure code signal; and
implement an auto-zeroing command or an operate command;
a rectifier to receive a voltage reference signal and to rectify the voltage reference signal;
a digital to analog converter (DAC) configured to receive the digital pressure code signal and the rectified voltage reference signal, the DAC being configured to produce an analog output pressure signal based upon the digital pressure code signal and the rectified voltage reference signal; and
a scaling circuit coupled to the DAC to receive the analog output pressure signal and the rectified voltage reference signal, the scaling circuit to output a scaled analog output pressure signal to the monitoring device.

14. The system of claim 13, wherein, when the auto-zeroing command is implemented, the processor selects the digital pressure code signal such that the analog pressure signal outputted to the monitoring device is approximately zero.

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15. The system of claim 14, wherein, the digital pressure code signal is a maximum digital pressure code signal associated with the DAC.
16. The system of claim 13, wherein, when the operate command is implemented, the analog pressure signal outputted to the monitoring device is approximately equivalent to the pressure signal from the pressure sensor device and is substantially ratiometric with an excitation voltage.
17. The system of claim 13, wherein, the pressure sensor device is a digital pressure sensor device.
18. The system of claim 13, wherein, the pressure sensor device is an analog pressure sensor device.

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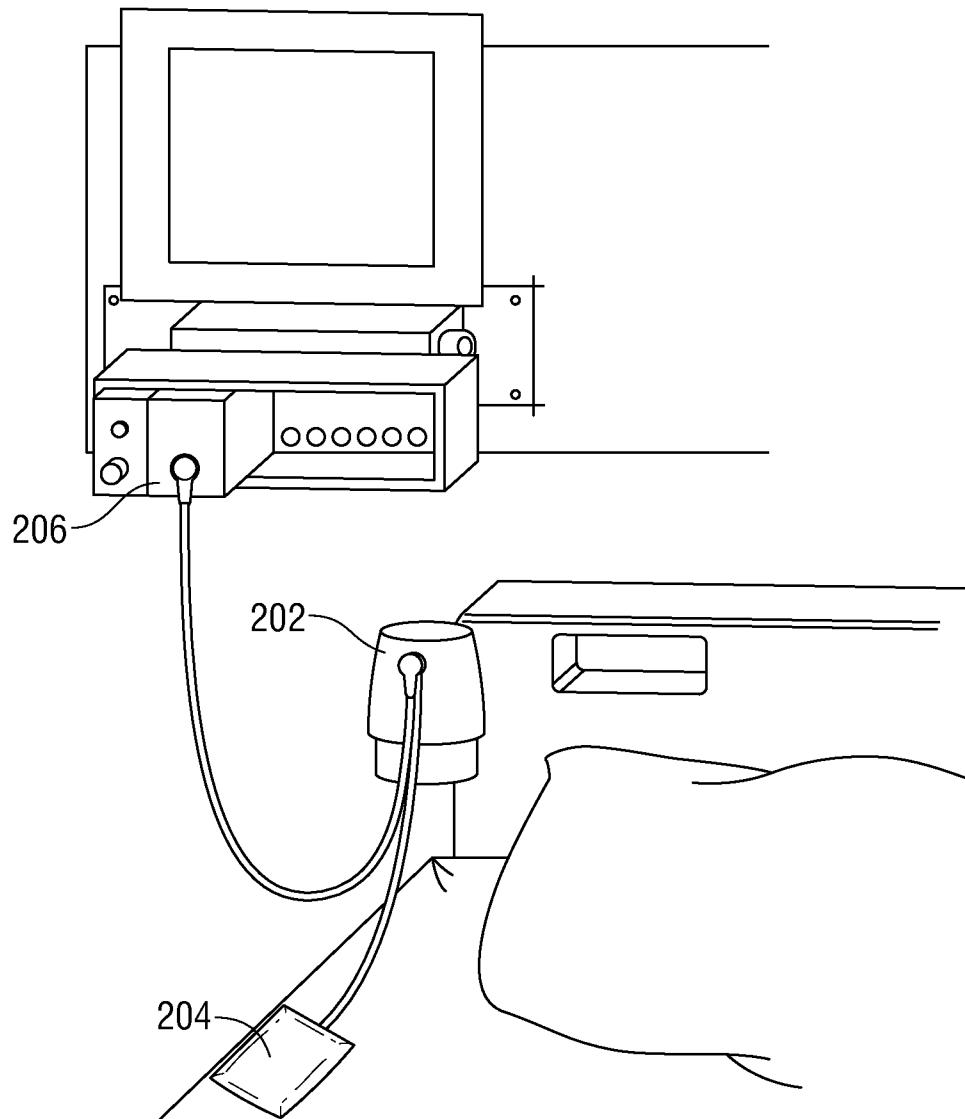


FIG. 1

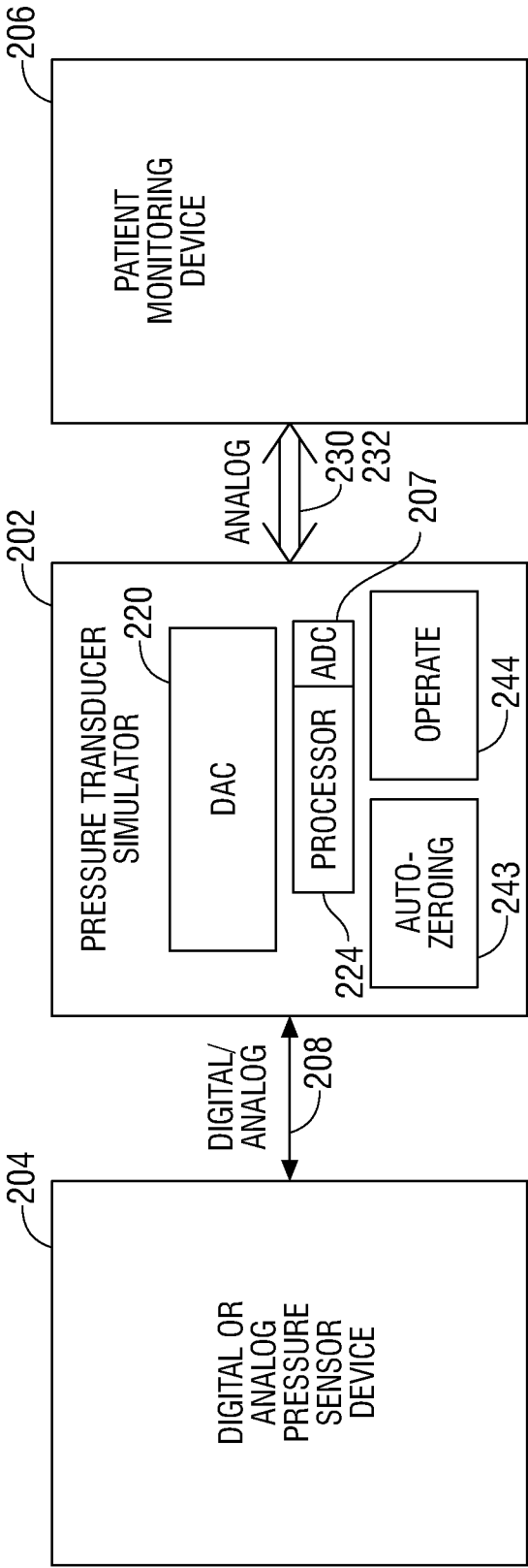


FIG. 2

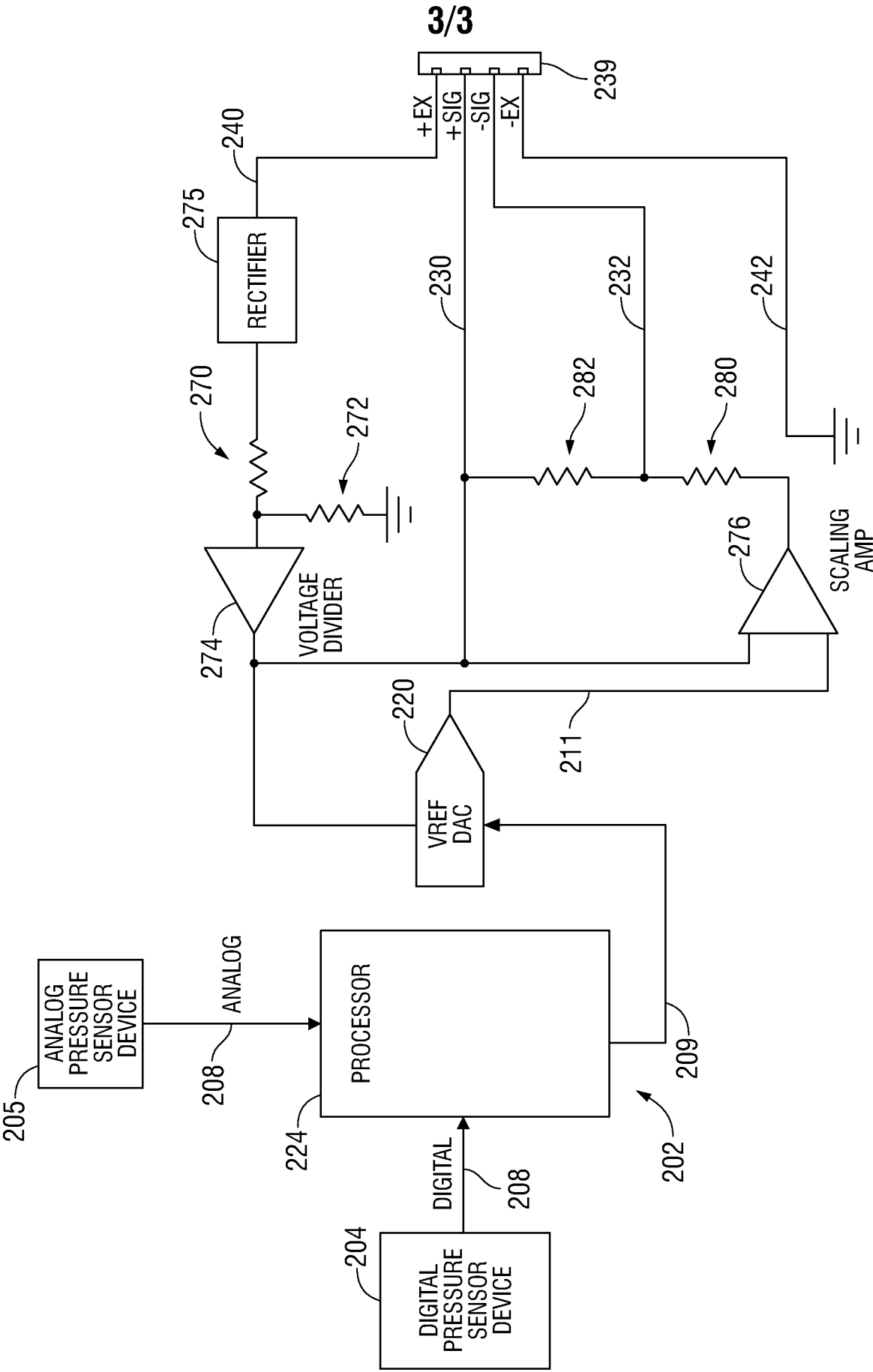


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/054748

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/00 A61B5/021
ADD.

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)
A61B

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/147847 A1 (KIM-GAU NG [SG] ET AL NG KIM-GAU [SG] ET AL) 29 July 2004 (2004-07-29) paragraphs [0009] - [0011], [0223], [0262] - [0263], [0275] - [0309]; figures 5,11	1-18
A	US 2002/173724 A1 (DORANDO DALE GENE [US] ET AL) 21 November 2002 (2002-11-21) figures 5,6,9 paragraphs [0029], [0055] - [0056], [0086] - [0088]	1,7
X	US 2003/141916 A1 (CONERO RONALD S [US]) 31 July 2003 (2003-07-31) figure 8 paragraphs [0033], [0063] - [0080], [0095] - [0097]	1-18



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

"&" document member of the same patent family

Date of the actual completion of the international search

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Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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