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(54) Title: MAGNETIC AND OPTICAL ROTATING STORAGE SYSTEMS WITH AUDIO MONITORING

(57) Abstract: A control system for a rotating data storage device, comprises a drive printed circuit board (PCB). A drive module is arranged on the drive PCB and at least one of processes data, stores data and controls operation of the rotating storage device. An audio monitoring module communicates with the drive module and analyzes audio signals that are based on noise generated by the rotating storage device during operation.

## MAGNETIC AND OPTICAL ROTATING STORAGE SYSTEMS WITH AUDIO MONITORING

### CROSS-REFERENCE TO RELATED APPLICATIONS

5 [0001] This application claims the benefit of U.S. Patent Application Nos. 11/591,326, filed November 1, 2006, 11/652,203, filed January 11, 2007, 11/652,258, filed January 11, 2007, and, U.S. Provisional Application Nos. 60/828,532, filed on October 6, 2006 and 60/820,189, filed on July 24, 2006. The disclosures of the above applications are incorporated herein by reference  
10 in their entirety.

### FIELD

15 [0002] The present disclosure relates to hard disk drive (HDD) and digital versatile disc (DVD) systems, and more particularly to audio monitoring of HDD and DVD systems.

### BACKGROUND

20 [0003] The Background description provided herein is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description which may not otherwise qualify as prior art at the time of filing, are neither expressly or impliedly admitted as prior art against the present disclosure.

25 [0004] Referring now to FIG. 1, a HDD system 10 is shown to include a HDD printed circuit board (PCB) 14. A buffer 18 stores read, write and/or volatile control data that is associated the control of the HDD system 10. The buffer 18 usually employs volatile memory having low latency. For example, synchronous dynamic random access memory (SDRAM) or other types of low latency memory may be used. Nonvolatile memory 19 such as flash memory  
30 may also be provided to store critical data such as nonvolatile control code.

[0005] A processor 22 arranged on the HDD PCB 14 performs data and/or control processing that is related to the operation of the HDD system 10. A hard disk control module (HDC) 26 communicates with an input/output

interface 24 and with a spindle/voice coil motor (VCM) driver or module 30 and/or a read/write channel module 34. The HDC 26 coordinates control of the spindle/VCM driver 30, the read/write channel module 34 and the processor 22 and data input/output with a host 35 via the interface 24.

5 [0006] During write operations, the read/write channel module 34 encodes the data to be written onto a read/write device 59. The read/write channel module 34 processes the write signal for reliability and may apply, for example, error correction coding (ECC), run length limited coding (RLL), and the like. During read operations, the read/write channel module 34 converts an  
10 analog read signal output of the read/write device 59 to a digital read signal. The converted signal is then detected and decoded by known techniques to recover the data that was written on the HDD.

[0007] A hard disk drive assembly (HDDA) 50 includes one or more hard drive platters 52 that include magnetic coatings that store magnetic fields.

15 The platters 52 are rotated by a spindle motor that is schematically shown at 54. Generally the spindle motor 54 rotates the hard drive platter 52 at a controlled speed during the read/write operations. One or more read/write arms 58 move relative to the platters 52 to read and/or write data to/from the hard drive platters 52. The spindle/VCM driver 30 controls the spindle motor 54, which rotates the  
20 platter 52. The spindle/VCM driver 30 also generates control signals that position the read/write arm 58, for example using a voice coil actuator, a stepper motor or any other suitable actuator.

[0008] The read/write device 59 is located near a distal end of the read/write arm 58. The read/write device 59 includes a write element such as an  
25 inductor that generates a magnetic field. The read/write device 59 also includes a read element (such as a magneto-resistive (MR) element) that senses the magnetic field on the platter 52. The HDDA 50 includes a preamp circuit 60 that amplifies the analog read/write signals. When reading data, the preamp circuit 60 amplifies low level signals from the read element and outputs the amplified  
30 signal to the read/write channel module 34. While writing data, a write current is generated that flows through the write element of the read/write device 59. The write current is switched to produce a magnetic field having a positive or

negative polarity. The positive or negative polarity is stored by the hard drive platter 52 and is used to represent data.

**[0009]** Referring now to FIG. 2, a digital versatile disc (DVD) system 110 is shown to include a DVD PCB 114, which includes a buffer 118 that stores 5 read data, write data and/or volatile control code that is associated the control of the DVD system 110. The buffer 118 may employ volatile memory such as SDRAM or other types of low latency memory. Nonvolatile memory 119 such as flash memory can also be used for critical data such as data relating to DVD write formats and/or other nonvolatile control code.

10 **[0010]** A processor 122 arranged on the DVD PCB 114 performs data and/or control processing that is related to the operation of the DVD system 110. The processor 122 also performs decoding of copy protection and/or compression/decompression as needed. A DVD control module 126 communicates with an input/output interface 124 and with a spindle/feed motor 15 (FM) driver 130 and/or a read/write channel module 134. The DVD control module 126 coordinates control of the spindle/FM driver 130, the read/write channel module 134 and the processor 122 and data input/output via the interface 124.

20 **[0011]** During write operations, the read/write channel module 134 encodes the data to be written by an optical read/write (ORW) or optical read only (OR) device 159 to the DVD platter. The read/write channel module 134 processes the signals for reliability and may apply, for example, ECC, RLL, and the like. During read operations, the read/write channel module 134 converts an 25 analog output of the ORW or OR device 159 to a digital signal. The converted signal is then detected and decoded by known techniques to recover the data that was written on the DVD.

30 **[0012]** A DVD assembly (DVDA) 150 includes a DVD platter 152 that stores data optically. The platter 152 is rotated by a spindle motor that is schematically shown at 154. The spindle motor 154 rotates the DVD platter 152 at a controlled and/or variable speed during the read/write operations. The ORW or OR device 159 moves relative to the DVD platter 152 to read and/or write data

to/from the DVD platter 152. The ORW or OR device 159 typically includes a laser and an optical sensor.

**[0013]** For DVD read/write and DVD read only systems, the laser is directed at tracks on the DVD that contain lands and pits during read operations.

5 The optical sensor senses reflections caused by the lands/pits. For DVD read/write (RW) applications, a laser may also be used to heat a die layer on the DVD platter during write operations. If the die is heated to one temperature, the die is transparent and represents one binary digital value. If the die is heated to another temperature, the die is opaque and represents the other binary digital

10 value.

**[0014]** The spindle/FM driver 130 controls the spindle motor 154, which controllably rotates the DVD platter 152. The spindle/FM driver 130 also generates control signals that position the feed motor 158, for example using a voice coil actuator, a stepper motor or any other suitable actuator. The feed 15 motor 158 typically moves the ORW or OR device 159 radially relative to the DVD platter 152. A laser driver 161 generates a laser drive signal based on an output of the read/write channel module 134. The DVDA 150 includes a preamp circuit 160 that amplifies analog read signals. When reading data, the preamp circuit 160 amplifies low level signals from the ORW or OR device and outputs 20 the amplified signal to the read/write channel module 134.

**[0015]** The DVD system 110 further includes a codec module 140 that encodes and/or decodes video such as any of the MPEG formats. Audio and/or video digital signal processors and/or modules 142 and 144, respectively, perform audio and/or video signal processing, respectively.

25

## SUMMARY

**[0016]** A control system for a rotating data storage device, comprises a drive printed circuit board (PCB). A drive module is arranged on the drive PCB and at least one of processes data, stores data and controls operation of the rotating storage device. An audio monitoring module communicates with the 30 drive module and analyzes audio signals that are based on noise generated by the rotating storage device during operation.

**[0017]** In other features, the drive module comprises one of a magnetic storage control module and an optical storage control module. The drive module comprises a read/write channel module. The drive module comprises a processor. The drive module comprises one of a spindle/voice coil motor drive module and a spindle/ feed motor module. A data storage device comprises the control system and further comprises the rotating storage device. A microphone generates the audio signals. The rotating storage device includes a first component. The audio monitoring module selectively adjusts an operating parameter of the first component based on the audio signals. The first component one of rotates a rotating storage medium and reads data from the rotating storage medium. The rotating storage device includes one of a magnetic storage device and an optical storage device. The audio monitoring module selectively diagnoses failures of the first component based on the audio signals.

**[0018]** In other features, the audio monitoring module selectively estimates an age of the first component based on the audio signals. The audio monitoring module selectively predicts future component failure of the first component based on the audio signals. The audio monitoring module selectively estimates product quality of the data storage device based on the audio signals.

The audio monitoring module selectively correlates the audio signals with a stored failure profile to predict failure of the first component. An analog to digital converter converts the audio signals to digital audio signals. The rotating data storage device comprises a hard disk drive that includes a hard disk drive assembly (HDDA); and a hard disk drive printed circuit board (HD PCB), wherein the microphone is arranged on one of the HDDA and the HD PCB. The hard disk drive includes a hard disk drive module; a processor; a spindle/voice coil motor (VCM) driver module; and a read/write channel module.

**[0019]** In other features, the audio monitoring module is integrated with at least one of the hard disk drive module, the processor, the spindle/VCM driver module, and the read/write channel module in a system on chip. The rotating data storage device comprises a digital versatile disc (DVD) that includes a digital versatile disk assembly (DVDA); and a digital versatile disk printed circuit

board (DVD PCB), wherein the microphone is arranged on one of the DVDA and the DVD PCB. The digital versatile disk includes a digital versatile disk control module; a processor; a spindle/feed motor (FM) driver module; and a read/write channel module. The audio monitoring module is integrated with at least one of

5 the digital versatile disk control module, the processor, the spindle/FM driver module, and the read/write channel module in a system on chip. The audio monitoring module performs sub-band analysis on the audio signals. The first component includes at least one of a spindle motor and a voice coil motor (VCM). The first component includes at least one of a spindle motor and a feed

10 motor.

**[0020]** In other features, a flex connector connects components of the HDDA and the HD PCB, wherein the microphone is arranged on the HDDA. A conductor that communicates with the audio monitoring module and the microphone is associated with the flex connector. A flex connector connects

15 components of the DVDA and the DVD PCB. The microphone is arranged on the DVDA and wherein a conductor that communicates with the audio monitoring module and the microphone is associated with the flex connector. The hard disk drive includes a power management interface module and wherein the audio monitoring module is integrated with the power management interface module in

20 a system on chip. The digital versatile disc includes a power management interface module and wherein the audio monitoring module is integrated with the power management interface module in a system on chip. The drive module is integrated with the audio monitoring module in an integrated circuit.

**[0021]** A method for operating a rotating data storage device, 25 comprises providing a drive printed circuit board (PCB); arranging a drive module on the drive PCB; at least one of processing data, storing data and controlling operation of the rotating storage device using the drive module; and analyzing audio signals that are based on noise generated by the rotating storage device during operation.

30 **[0022]** In other features, the drive module comprises one of a magnetic storage control module, an optical storage control module, a read/write channel module, a processor, a spindle/voice coil motor drive module and a spindle/ feed

motor module. The method further includes adjusting operation of a first component of the rotating storage device based on an input operating parameter; and selectively adjusting the input operating parameter of the first component based on the audio signals. The rotating storage device includes

5 one of a magnetic storage device and an optical storage device. The method further includes electively diagnosing failures of the first component based on the audio signals.

[0023] In other features, the method includes selectively estimating an age of the first component based on the audio signals. The method further

10 includes selectively predicting future component failure of the first component based on the audio signals. The method further includes selectively estimating product quality of the data storage device based on the audio signals. The method further includes selectively correlating the audio signals with a stored failure profile to predict failure of the first component. The method further

15 includes performing sub-band analysis on the audio signals. The first component includes at least one of a spindle motor and a voice coil motor (VCM). The first component includes at least one of a spindle motor and a feed motor.

20 [0024] A control system for a rotating data storage device, comprises a drive printed circuit board (PCB); drive control means, that is arranged on the drive PCB, for at least one of processing data, storing data and controlling operation of the rotating storage device; and audio monitoring means, that communicates with the drive control means, for analyzing audio signals that are

25 based on noise generated by the rotating storage device during operation.

[0025] In other features, the drive control means comprises one of magnetic storage control means for controlling a magnetic storage device and optical storage control means for controlling an optical storage device. The drive control means comprises a read/write channel means for processing read/write data. The drive control means comprises processing means for processing data. The drive control means comprises one of spindle/voice coil motor drive means for driving a spindle/voice coil motor and spindle/ feed motor drive means for

driving a spindle/ feed motor. A data storage device comprising the control system and further comprising the rotating storage device. Audio means generates the audio signals. The rotating storage device includes a first component, wherein the audio monitoring means selectively adjusts an operating

5 parameter of the first component based on the audio signals. The first component one of rotates the rotating storage medium and reads data from the rotating storage medium. The rotating storage device includes one of a magnetic storage device and an optical storage device. The audio monitoring means selectively diagnoses failures of the first component based on the audio  
10 signals. The audio monitoring means selectively estimates an age of the first component based on the audio signals. The audio monitoring means selectively predicts future component failure of the first component based on the audio signals. The audio monitoring means selectively estimates product quality of the data storage device based on the audio signals. The audio monitoring means  
15 selectively correlates the audio signals with a stored failure profile to predict failure of the first component. Analog to digital converting means converts the audio signals to digital audio signals.

**[0026]** In other features, the rotating data storage device comprises a hard disk drive that includes a hard disk drive assembly (HDDA); and a hard disk  
20 drive printed circuit board (HD PCB), wherein the audio means is arranged on one of the HDDA and the HD PCB. The hard disk drive includes hard disk drive control means for controlling; processor means for processing; spindle/voice coil motor (VCM) driver means for driving; and read/write channel means for processing read/write data.

25 **[0027]** In other features, the audio monitoring means is integrated with at least one of the hard disk drive control means, the processing means, the spindle/VCM driver means, and the read/write channel means in a system on chip. The rotating data storage device comprises a digital versatile disc (DVD) that includes a digital versatile disk assembly (DVDA); and a digital versatile disk  
30 printed circuit board (DVD PCB), wherein the audio means is arranged on one of the DVDA and the DVD PCB. The digital versatile disk includes digital versatile disk control means for controlling; processing means for processing; spindle/feed

motor (FM) driver means for driving; and read/write channel means for processing read/write data.

**[0028]** In other features, the audio monitoring means is integrated with at least one of the digital versatile disk control means, the processing means, the 5 spindle/FM driver means, and the read/write channel means in a system on chip. The audio monitoring means performs sub-band analysis on the audio signals. The first component includes at least one of a spindle motor and a voice coil motor (VCM). The first component includes at least one of a spindle motor and a feed motor. Flexible connecting means connects components of the HDDA and 10 the HD PCB, wherein the audio means is arranged on the HDDA and wherein conducting means for communicating with the audio monitoring means and the audio means is associated with the flexible connecting means. Flexible connecting means connects components of the DVDA and the DVD PCB, wherein the audio means is arranged on the DVDA and wherein conducting 15 means for communicating with the audio monitoring means and the audio means is associated with the flexible connecting means. The hard disk drive includes power management interface means for providing a power interface and wherein the audio monitoring means is integrated with the power management interface means in a system on chip. The digital versatile disc includes power 20 management interface means for providing a power interface and wherein the audio monitoring means is integrated with the power management interface means in a system on chip. The drive control means is integrated with the audio monitoring means in an integrated circuit.

**[0029]** An integrated circuit for controlling a rotating data storage 25 device comprises a drive module that is implemented by the integrated circuit and that at least one of processes data, stores data and controls operation of the rotating storage device; and an audio monitoring module that is implemented by the integrated circuit, that communicates with the drive module and that analyzes audio signals that are based on noise generated by the rotating storage device 30 during operation.

**[0030]** The drive module comprises one of a magnetic storage control module and an optical storage control module. The drive module comprises a

read/write channel module. The drive module comprises a processor. The drive module comprises one of a spindle/voice coil motor drive module and a spindle/feed motor module. A data storage device comprises the integrated circuit and further comprises the rotating storage device. A microphone generates the

5 audio signals. The rotating storage device includes a first component, wherein the audio monitoring module selectively adjusts an operating parameter of the first component based on the audio signals. The first component one of rotates the rotating storage medium and reads data from the rotating storage medium.

The rotating storage device includes one of a magnetic storage device and an

10 optical storage device. The audio monitoring module selectively diagnoses failures of the first component based on the audio signals. The audio monitoring module selectively estimates an age of the first component based on the audio signals. The audio monitoring module selectively predicts future component failure of the first component based on the audio signals. The audio monitoring

15 module selectively estimates product quality of the data storage device based on the audio signals. The audio monitoring module selectively correlates the audio signals with a stored failure profile to predict failure of the first component. An analog to digital converter converts the audio signals to digital audio signals.

The rotating data storage device comprises a hard disk drive that includes: a 20 hard disk drive assembly (HDDA); and a hard disk drive printed circuit board (HD PCB), wherein the microphone is arranged on one of the HDDA and the HD PCB. The hard disk drive includes a hard disk drive control module; a processor; a spindle/voice coil motor (VCM) driver module; and a read/write channel module.

25 [0031] In other features, the audio monitoring module is integrated with at least one of the hard disk drive control module, the processor, the spindle/VCM driver module, and the read/write channel module in a system on chip. The rotating data storage device comprises a digital versatile disc (DVD) that includes a digital versatile disk assembly (DVDA); and a digital versatile disk

30 printed circuit board (DVD PCB), wherein the microphone is arranged on one of the DVDA and the DVD PCB. The digital versatile disk includes a digital versatile disk control module; a processor; a spindle/feed motor (FM) driver

module; and a read/write channel module. The audio monitoring module is integrated with at least one of the digital versatile disk control module, the processor, the spindle/FM driver module, and the read/write channel module in a system on chip. The audio monitoring module performs sub-band analysis on

5 the audio signals. The first component includes at least one of a spindle motor and a voice coil motor (VCM). The first component includes at least one of a spindle motor and a feed motor. A flex connector connects components of the HDDA and the HD PCB, wherein the microphone is arranged on the HDDA and wherein a conductor that communicates with the audio monitoring module and  
10 the microphone is associated with the flex connector. A flex connector that connects components of the DVDA and the DVD PCB, wherein the microphone is arranged on the DVDA and wherein a conductor that communicates with the audio monitoring module and the microphone is associated with the flex connector.

15 [0032] In other features, the hard disk drive includes a power management interface module and wherein the audio monitoring module is integrated with the power management interface module in a system on chip. The digital versatile disc includes a power management interface module and wherein the audio monitoring module is integrated with the power management  
20 interface module in a system on chip. The drive module is integrated with the audio monitoring module in an integrated circuit.

[0033] A method for controlling a rotating data storage device comprises implementing a drive module of the rotating storage device using an integrated circuit; at least one of processing data, storing data and controlling  
25 operation of the rotating storage device using the drive module; and using an audio monitoring module that is implemented by the integrated circuit and that communicates with the drive module to analyze audio signals that are based on noise generated by the rotating storage device during operation.

[0034] In other features, the drive module comprises one of a magnetic  
30 storage control module and an optical storage control module. The drive module comprises a read/write channel module. The drive module comprises a processor. The drive module comprises one of a spindle/voice coil motor drive

module and a spindle/ feed motor module. The method include using a microphone to generate the audio signals. The rotating storage device includes a first component and further comprising selective adjusting an operating parameter of the first component based on the audio signals. The first 5 component one of rotates a rotating storage medium and reads data from the rotating storage medium. The rotating storage device includes one of a magnetic storage device and an optical storage device.

**[0035]** In other features, the method includes selectively diagnosing failures of the first component based on the audio signals. The method includes 10 selectively estimating an age of the first component based on the audio signals. The method includes selectively predicting future component failure of the first component based on the audio signals. The method includes selectively estimating product quality of the rotating storage device based on the audio signals. The method includes selectively correlating the audio signals with a 15 stored failure profile to predict failure of the first component. The method includes performing sub-band analysis on the audio signals.

**[0036]** An integrated circuit for controlling a rotating data storage device comprises drive means, that is implemented by the integrated circuit, for at least one of processing data, storing data and controlling operation of the 20 rotating storage device; and audio monitoring means, that is implemented by the integrated circuit, for communicating with the drive means and for analyzing audio signals that are based on noise generated by the rotating storage device during operation.

**[0037]** In other features, the drive control means comprises one of 25 magnetic storage control means for controlling a magnetic storage device and optical storage control means for controlling an optical storage device. The drive means comprises a read/write channel means for processing read/write data. The drive control means comprises processing means for processing data. The drive control means comprises one of spindle/voice coil motor drive means for 30 driving a spindle/voice coil motor and spindle/ feed motor drive means for driving a spindle/ feed motor. A data storage device comprises the integrated circuit and further comprises the rotating storage device. Audio means generates the

audio signals. The rotating storage device includes a first component, wherein the audio monitoring means selectively adjusts an operating parameter of the first component based on the audio signals. The first component one of rotates the rotating storage medium and reads data from the rotating storage medium.

5 The rotating storage device includes one of a magnetic storage device and an optical storage device. The audio monitoring means selectively diagnoses failures of the first component based on the audio signals. The audio monitoring means selectively estimates an age of the first component based on the audio signals. The audio monitoring means selectively predicts future component 10 failure of the first component based on the audio signals. The audio monitoring means selectively estimates product quality of the data storage device based on the audio signals. The audio monitoring means selectively correlates the audio signals with a stored failure profile to predict failure of the first component.

[0038] In other features, an analog to digital converter converts the 15 audio signals to digital audio signals. The rotating data storage device comprises a hard disk drive that includes a hard disk drive assembly (HDDA); and a hard disk drive printed circuit board (HD PCB), wherein the microphone is arranged on one of the HDDA and the HD PCB. The hard disk drive includes hard disk drive control means for controlling; processor means for processing; 20 spindle/voice coil motor (VCM) driver means for driving; and read/write channel means for processing read/write data.

[0039] In other features, the audio monitoring means is integrated with at least one of the hard disk drive control means, the processing means, the spindle/VCM driver means, and the read/write channel means in a system on 25 chip. The rotating data storage device comprises a digital versatile disc (DVD) that includes a digital versatile disk assembly (DVDA); and a digital versatile disk printed circuit board (DVD PCB), wherein the microphone is arranged on one of the DVDA and the DVD PCB. The digital versatile disk includes digital versatile disk control means for controlling; processing means for processing; spindle/feed 30 motor (FM) driver means for driving; and read/write channel means for processing read/write data.

**[0040]** In other features, the audio monitoring means is integrated with at least one of the digital versatile disk control means, the processing means, the spindle/FM driver means, and the read/write channel means in a system on chip. The audio monitoring means performs sub-band analysis on the audio signals.

- 5 The first component includes at least one of a spindle motor and a voice coil motor (VCM). The first component includes at least one of a spindle motor and a feed motor. Flexible connecting means connects components of the HDDA and the HD PCB, wherein the audio means is arranged on the HDDA and wherein conducting means for communicating with the audio monitoring means and the
- 10 audio means is associated with the flexible connecting means. Flexible connecting means connects components of the DVDA and the DVD PCB, wherein the audio means is arranged on the DVDA and wherein conducting means for communicating with the audio monitoring means and the audio means is associated with the flexible connecting means. The hard disk drive includes
- 15 power management interface means for providing a power interface and wherein the audio monitoring means is integrated with the power management interface means in a system on chip. The digital versatile disc includes power management interface means for providing a power interface and wherein the audio monitoring means is integrated with the power management interface
- 20 means in a system on chip. The drive control means is integrated with the audio monitoring means in an integrated circuit.

**[0041]** A computer system comprises a processor that performs data processing; a fan that cools the processor; and an audio monitoring module that analyzes audio signals that are based on noise generated by the fan during operation.

**[0042]** In other features, the audio monitoring module is integrated with the processor in an integrated circuit. A microphone communicates with the audio monitoring module and that generates the audio signals. A heat sink thermal communicates with the processor and the fan. The audio monitoring module selectively adjusts an operating parameter of the fan based on the audio signals. The audio monitoring module selectively diagnoses failures of the fan based on the audio signals. The audio monitoring module selectively estimates

an age of the fan based on the audio signals. The audio monitoring module selectively predicts future failure of the fan based on the audio signals. The audio monitoring module selectively estimates product quality of the fan based on the audio signals. The audio monitoring module selectively correlates the 5 audio signals with a stored failure profile to predict failure of the fan. A motherboard arranged on the chassis, wherein the fan is arranged on the chassis. The processor includes a graphics processor. The microphone is arranged on at least one of the motherboard and the chassis.

**[0043]** A computer system comprises processing means for performing 10 data processing; fan means for cooling the processing means; and audio monitoring means for analyzing audio signals that are based on noise generated by the fan means during operation.

**[0044]** In other features, the audio monitoring means is integrated with the processing means in an integrated circuit. Audio input means communicates 15 with the audio monitoring means and generates the audio signals. Heat sink means thermally communicating heat from the processing means to the fan means. The audio monitoring means selectively adjusts an operating parameter of the fan means based on the audio signals. The audio monitoring means selectively diagnoses failures of the fan means based on the audio signals. The 20 audio monitoring means selectively estimates an age of the fan means based on the audio signals. The audio monitoring means selectively predicts future failure of the fan means based on the audio signals. The audio monitoring means selectively estimates product quality of the fan means based on the audio signals. The audio monitoring means selectively correlates the audio signals 25 with a stored failure profile to predict failure of the fan means. A motherboard is arranged on the chassis. The fan means is arranged on the chassis. The processing means includes graphics processing means for processing graphics. The audio input means is arranged on at least one of the motherboard and the chassis.

30 **[0045]** A method for operating a computer system comprises providing a processor for the computer system that performs data processing; cooling the

processor using a fan; and analyzing audio signals that are based on noise generated by the fan during operation.

[0046] In other features, the method includes integrating the audio monitoring module with the processor in an integrated circuit. The method 5 includes using a microphone that communicates with the audio monitoring module to generate the audio signals. The method includes providing a heat sink to transfer heat from the processor to the fan. The method includes selectively adjusting an operating parameter of the fan based on the audio signals. The method includes selectively diagnosing failures of the fan based on 10 the audio signals. The method includes selectively estimating an age of the fan based on the audio signals. The method includes selectively predicting future component failure of the fan based on the audio signals. The method includes selectively estimating product quality of the fan based on the audio signals. The method includes selectively correlating the audio signals with a stored failure 15 profile to predict failure of the fan.

[0047] In other features, the method includes providing a chassis and a motherboard arranged on the chassis; and arranging the fan on the chassis. The processor includes a graphics processor. The method includes providing a chassis and a motherboard arranged on the chassis; and arranging the 20 microphone on at least one of the motherboard and the chassis.

[0048] In still other features, the systems and methods described above are implemented by a computer program executed by one or more processors. The computer program can reside on a computer readable medium such as but not limited to memory, non-volatile data storage and/or other 25 suitable tangible storage mediums.

[0049] A device comprises an integrated circuit. A fan cools the integrated circuit. An audio monitoring module analyzes audio signals that are based on noise generated by the fan during operation.

[0050] In other features, the audio monitoring module is implemented 30 by and integrated with the integrated circuit. A microphone communicates with the audio monitoring module and that generates the audio signals. A heat sink thermally communicates with the integrated circuit and the fan. The audio

monitoring module selectively adjusts an operating parameter of the fan based on the audio signals. The audio monitoring module selectively diagnoses failures of the fan based on the audio signals. The audio monitoring module selectively estimates an age of the fan based on the audio signals. The audio

5 monitoring module selectively predicts future failure of the fan based on the audio signals. The audio monitoring module selectively estimates product quality of the fan based on the audio signals. The audio monitoring module selectively correlates the audio signals with a stored failure profile to predict failure of the fan.

10 [0051] In other features, the device includes a chassis. At least one of a printed circuit board and a motherboard are arranged on the chassis. The fan is arranged on the chassis and the integrated circuit is arranged on the at least one of the printed circuit board and the motherboard. The integrated circuit includes one of a central processing unit, a graphics processing unit (GPU) and

15 an application specific integrated circuit (ASIC). The device includes a chassis. At least one of a printed circuit board and a motherboard is arranged on the chassis. The microphone is arranged on at least one of the chassis and the at least one of the printed circuit board and the motherboard.

20 [0052] In other features, the audio monitoring module selectively generates an indication signal based on the audio signals. The rotating storage device includes a first component and the audio monitoring module selectively adjusts a rotational speed of the first component when the audio monitoring module detects resonance of the first component. The audio monitoring module adjusts the rotational speed by one of a predetermined value or a predetermined

25 percentage of the rotation speed.

[0053] A device comprises an integrated circuit. Fan means cools the integrated circuit. Audio monitoring means analyzes audio signals that are based on noise generated by the fan means during operation.

30 [0054] In other features, the audio monitoring means is implemented by and integrated with the integrated circuit. Audio input means communicates with the audio monitoring means and generates the audio signals. Heat sink means thermally communicates heat from the integrated circuit to the fan

means. The audio monitoring means selectively adjusts an operating parameter of the fan means based on the audio signals. The audio monitoring means selectively diagnoses failures of the fan means based on the audio signals. The audio monitoring means selectively estimates an age of the fan means based on

5 the audio signals. The audio monitoring means selectively predicts future failure of the fan means based on the audio signals. The audio monitoring means selectively estimates product quality of the fan means based on the audio signals. The audio monitoring means selectively correlates the audio signals with a stored failure profile to predict failure of the fan means.

10 [0055] In other features, the device includes a chassis. At least one of a printed circuit board and a motherboard is arranged on the chassis. The fan means is arranged on the chassis and the integrated circuit is arranged on the at least one of the printed circuit board and the motherboard. The integrated circuit includes one of a central processing unit, a graphics processing unit and an 15 application specific integrated circuit (ASIC).

[0056] In other features, the device includes a chassis and at least one of a printed circuit board and a motherboard. The audio input means is arranged on at least one of the chassis and the at least one of the printed circuit board and the motherboard.

20 [0057] A method for operating a device comprises providing an integrated circuit; cooling the integrated circuit using a fan; and analyzing audio signals that are based on noise generated by the fan during operation.

[0058] In other features, the method includes integrating the audio monitoring module with the integrated circuit. The method includes using a 25 microphone that communicates with the audio monitoring module to generate the audio signals. The method includes providing a heat sink to transfer heat from the integrated circuit to the fan. The method includes selectively adjusting an operating parameter of the fan based on the audio signals. The method includes selectively diagnosing failures of the fan based on the audio signals. 30 The method includes selectively estimating an age of the fan based on the audio signals. The method includes selectively predicting future component failure of the fan based on the audio signals. The method includes selectively estimating

product quality of the fan based on the audio signals. The method includes selectively correlating the audio signals with a stored failure profile to predict failure of the fan.

**[0059]** In other features, the method includes providing a chassis and 5 at least one of a printed circuit board and a motherboard arranged on the chassis and arranging the fan on the chassis. The integrated circuit includes one of a central processing unit, a graphics integrated circuit and an application specific integrated circuit (ASIC). The method includes providing a chassis and at least one of a printed circuit board and a motherboard arranged on the 10 chassis and arranging the microphone on at least one of the chassis and the at least one of the printed circuit board and the motherboard.

**[0060]** Further areas of applicability of the present disclosure will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating 15 the preferred embodiment of the disclosure, are intended for purposes of illustration only and are not intended to limit the scope of the disclosure.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0061]** The present disclosure will become more fully understood from 20 the detailed description and the accompanying drawings, wherein:

**[0062]** FIG. 1 is a functional block diagram of a HDD system according to the prior art;

**[0063]** FIG. 2 is a functional block diagram of a DVD system according to the prior art;

**[0064]** FIG. 3A is a functional block diagram of a first exemplary HDD system including an audio monitor module and microphone according to the present disclosure;

**[0065]** FIG. 3B is a functional block diagram of a first exemplary DVD system including an audio monitor module and microphone according to the 30 present disclosure;

**[0066]** FIG. 4A is a functional block diagram of a second exemplary HDD system including an audio monitor module and microphone according to the present disclosure;

5 **[0067]** FIG. 4B is a functional block diagram of a second exemplary DVD system including an audio monitor module and microphone according to the present disclosure;

**[0068]** FIG. 5A is a functional block diagram of a third exemplary HDD system including an audio monitor module and microphone according to the present disclosure;

10 **[0069]** FIG. 5B is a functional block diagram of a third exemplary DVD system including an audio monitor module and microphone according to the present disclosure;

15 **[0070]** FIG. 6A is a functional block diagram of a fourth exemplary HDD system including an audio monitor module and microphone according to the present disclosure;

**[0071]** FIG. 6B is a functional block diagram of a fourth exemplary DVD system including an audio monitor module and microphone according to the present disclosure;

20 **[0072]** FIG. 7A is a functional block diagram of a fifth exemplary HDD system including an audio monitor module and microphone according to the present disclosure;

**[0073]** FIG. 7B is a functional block diagram of a fifth exemplary DVD system including an audio monitor module and microphone according to the present disclosure;

25 **[0074]** FIG. 8 is a functional block diagram of an exemplary audio monitor module according to the present disclosure;

**[0075]** FIG. 9 is a flowchart illustrating a method for adjusting an operating parameter of a HDD or DVD system based on audio monitoring;

30 **[0076]** FIG. 10 is a flowchart illustrating a method for determining product quality of a HDD or DVD system based on audio monitoring;

**[0077]** FIG. 11 is a flowchart illustrating a method for estimating aging of a HDD or DVD system based on audio monitoring;

**[0078]** FIG. 12 is a flowchart illustrating a method for estimating future failures of a HDD or DVD system based on audio monitoring; and

**[0079]** FIG. 13 is a functional block diagram of a device including an integrated circuit such as a central processing unit, a graphic processing unit or 5 an application specific integrated circuit and a fan.

#### DETAILED DESCRIPTION

**[0080]** The following description is merely exemplary in nature and is in no way intended to limit the disclosure, its application, or uses. For purposes 10 of clarity, the same reference numbers will be used in the drawings to identify similar elements. As used herein, the term module, circuit and/or device refers to an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group) and memory that execute one or more software or firmware programs, a combinational logic circuit, and/or other 15 suitable components that provide the described functionality. As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A or B or C), using a non-exclusive logical or. It should be understood that steps within a method may be executed in different order without altering the principles of the present disclosure.

**[0081]** A microphone monitors noise generated by components of 20 hard disk assemblies (HDDAs) and/or DVD assemblies (DVDA). Due to the mechanical nature of the HDDA and/or DVDA, the noise generated by the motor, servo movement, air turbulence, intermittent head crash, loose components, and/or various mechanical resonances can be identified using an audio monitor 25 module as will be described below. When a resonance mode of the component is detected, the audio monitoring module may increase or decrease the speed of the component by a predetermined amount or percentage. The predetermined amount may include fixed values, fixed percentages of a current speed, variable values or percentages, progressive values and/or other suitable values.

**[0082]** For example, the audio monitor module can use sub-band 30 analysis. Operation of HDD and DVD systems can be improved by monitoring signal levels, frequencies and noise patterns as well as the changes of

monitored parameters as a function of time. These systems may automatically adjust HDD or DVD operating parameters to lower acoustic noise. By doing so, user annoyance may be decreased. Adjusting operation of the HDDA or DVDA away from resonance modes of the mechanical components can be optimized 5 during use for different HDD or DVD systems. In addition, real time monitoring of motor and/or servo noise may be used to predict future failure events. Analysis of historical data may be performed to estimate and monitor aging of the HDD or DVD systems.

[0083] The audio monitor module may also be used as a relatively low 10 cost method for differentiating product quality. For example, this approach can be used to separate high quality or low quality drives from other medium-quality drives. Lower noise devices tend to be more reliable than the higher noise ones, particularly for HDD or DVD systems having the same or similar designs. In addition, real time monitoring of mechanical components can be used to improve 15 future quality levels. While DVD systems are discussed herein, the present disclosure applied to compact discs (CDs) as well.

[0084] The microphone may be embedded on the HDDA or DVDA and/or embedded on a printed circuit board assembly (PCBA) of the HDD or 20 DVD systems. If embedded in the HDDA or DVDA, the microphone can share a flex connector to reduce cost. In addition, an audio analog to digital converter (ADC) can be embedded on a system on chip (SOC), motor controller and/or power management module to reduce system cost. The processor of the SOC can be shared with the audio monitoring module to perform the audio signal 25 analysis, which reduces cost.

[0085] Referring now to FIGs. 3A and 3B, the audio analysis module 25 and the microphone can be located on the PCB of the associated device. In FIG. 3A, a first exemplary HDD system 200 includes a microphone 204 and an audio monitor module 208. The microphone 204 receives audio signals during operation of the HDD system. The audio monitor module 208 converts the 30 signals to digital signals and performs audio analysis on the signals as described above and/or below. The analysis may include monitoring various signal levels, frequencies and patterns of noise occurrences as well as the changes of

monitored parameters as a function of time. The patterns may include resonances at particular frequencies or other criteria. Based on the analysis, the audio monitor module 208 selectively changes an operating parameter of the HDD system and/or performs other actions.

5 [0086] The microphone 204 and audio monitor module 208 may be associated with the HD PCB 14. As used herein, the term drive module may be used to refer to components of the HDD that help to control, store data, process data and/or otherwise operate the HDD such as but not limited to the HDC control module 26, the processor 22, the spindle/VCM driver module 30, the 10 read/write channel module 34, etc.. The microphone 204 and/or the audio monitor module 208 may be associated and/or integrated with one or more additional components such as the HDC control module 26, the processor 22, the spindle/VCM driver module 30, and/or the read/write channel module 34 in a system on chip (SOC) 210. Alternately, the processor 22 may be embedded in 15 or integrated with the HDC control module 26 as indicated by dotted lines 211.

20 [0087] In FIG. 3B, a first exemplary DVD system 230 includes an audio monitor module 232 and a microphone 234 that are associated with the DVD PCB 114. The microphone 234 receives audio signals during operation of the DVD system. The audio monitor module 232 converts the signals to digital signals and performs analysis on the signals as described above and/or below. Based on the analysis, the audio monitor module 232 selectively changes an operating parameter of the DVD system and/or performs other actions.

25 [0088] The microphone 234 and audio monitor module 232 may be associated with the DVD PCB 114. As used herein, the term drive module may also be used to refer to components of the DVD that help to control, stored data, process data and/or otherwise operate the DVD such as but not limited to the control module 126, the processor 122, the spindle/FM driver module 130, the read/write channel module 134, etc.. The microphone 234 and/or the audio monitor module 232 may be associated with and/or integrated with one or more additional devices such as the control module 126, the processor 122, the spindle/FM driver module 130, and/or the read/write channel module 134 in a 30

system on chip (SOC) 236. Alternately, the processor 122 may be embedded in or integrated with the control module 126 as indicated by dotted lines 237.

[0089] There are many different locations and/or possible implementations for the microphone and/or audio monitor module. Referring 5 now to FIG. 4A and 4B, second exemplary HDD and DVD systems including audio monitor modules and microphones are shown. In FIG. 4A, a HDD system 250 includes microphone 254 that is associated with the HDDA 50. A connection 256 from the microphone 254 to an audio monitor module 258 can be routed by a flex connector 260 to reduce cost. The flex connector 260 may also 10 include conductors for other devices such as the preamplifier 60 and servo 58. In FIG. 4B, a DVD system 270 includes a microphone 274 that is associated with the DVDA 150. A connection 276 from the microphone 274 to an audio monitor module 278 can also be provided by a flex connector 280 to reduce cost.

[0090] Referring now to FIGs. 5A and 5B, third exemplary HDD and 15 DVD systems including audio monitor modules and microphones are shown. In FIG. 5A, a HDD system 300 includes an audio monitor module 302 and a microphone 304. The microphone 304 may be associated with the HDDA 50 as shown and/or with the HD PCB 14. The audio monitor module 302 may be integrated with the processor in an SOC. Processing for the audio monitor 20 module 302 may be performed by the processor 22, which reduces cost.

[0091] In FIG. 5B, a DVD system 320 includes an audio monitor module 322 and a microphone 324. The microphone 324 may be associated with the DVDA 150 as shown and/or with the DVD PCB 114. Processing for the audio monitor module 322 may be performed by the processor 122, which 25 reduces cost. Both the audio monitor modules 302 and 322 the processors 22 and 122 may be integrated on a SOC, respectively. Other components may also be integrated on the SOC as described above.

[0092] Referring now to FIGs. 6A and 6B, fourth exemplary HDD and 30 DVD systems including an audio monitor module and microphone are shown. In FIG. 6A, a HDD system 340 includes an audio monitor module 342 and a microphone 344. The audio monitor module 342 is integrated with the spindle/VCM driver module 30. The microphone 344 may be located on the

HDDA 50 and/or the HD PCB 14. In FIG. 6B, a DVD system 360 includes an audio monitor module 362 and a microphone 364. The audio monitor module 362 is integrated with the spindle/FM driver module 130. The microphone 364 may be located on the DVDA 150 and/or the DVD PCB 114.

5 [0093] As can be appreciated, the audio monitor modules may be integrated with other components of the HDD systems such as but not limited to the HDC control module 26 and/or read/write channel module 34. Likewise, the audio monitor modules may be integrated with other components of the DVD systems such as but not limited to the DSPs 140, 144 and 142, the DVD control 10 module 126 and/or the read/write module 134. Furthermore, various components can be integrated by SOC.

15 [0094] Referring now to FIGs. 7A and 7B, fifth exemplary HDD and DVD systems including audio monitor modules and microphones are shown. In FIG. 7A, HDD system 380 includes a power management module 382 that manages power of the HDD system 380. The HDD system 380 further includes an audio monitor module 384 and a microphone 386. The audio monitor module 384 is implemented by the power management module 382. The microphone 386 may be located on the HDDA 50 and/or the HD PCB 14.

20 [0095] In FIG. 7B, a DVD system 400 includes a power management module 402 that manages power of the DVD system 400. The DVD system 402 further includes an audio monitor module 404 and a microphone 406. The audio monitor module 404 is implemented by the power management module 400, which manages power for the DVD. The microphone 406 may be located on the DVDA 150 and/or the DVD PCB 114.

25 [0096] Referring now to FIG. 8, an exemplary audio monitor module 420 according to the present disclosure is shown. The audio monitor module 420 receives an output of a microphone 422. The audio monitor module 420 includes an analog-to-digital converter (ADC) 424 that converts the analog output of the microphone to a digital audio signal. An analysis module 428 receives the digital audio output of the analog-to-digital converter 424. The analysis module 428 selectively transmits data to and receives data from memory 434. The memory may be local to the analysis module and/or shared 30

memory such as volatile memory and NV memory. A parameter adjustment module 430 selectively adjusts operating parameters of the HDD or DVD device based on the analysis.

[0097] The analysis module 428 may include a sub-band analysis module 442 that monitors signal levels, frequencies and patterns of noise occurrences, changes of monitored parameters as a function of time, and/or other functions of the monitored parameters. The patterns may include resonances at a particular frequency or other criteria.

[0098] A failure predicting module 444 selectively predicts failures based on current and/or historical noise information and/or functions thereof. For example, the failure predicting module may extrapolate based on current and/or historical data and estimate an expected failure date. A quality analysis module 448 may estimate the quality of the HDD or DVD device based upon measured current and/or historical noise information and/or function thereof. An age estimating module 452 estimates age of the device based upon current and/or historical noise information, changes in current or historical information and/or other functions of current and/or historical noise information. The age may be relative to an expected obsolescence or service life. For example, the age estimating module 452 may monitor changes in noise levels as a function of time. The noise levels may be compared to a function, data, curve or other stored information to estimate the age of the device or component.

[0099] A correlation module 453 may be used to compare current noise information to stored noise information to identify particular failures. The memory module 434 may store noise profiles relating to possible failure modes. The correlation module 453 may correlate current and/or historical noise profiles with stored profiles. When the correlation exceeds a predetermined correlation value, the correlation module may output a fault message, initiate diagnostics and/or take other action.

[0100] Referring now to FIG. 9, a flowchart illustrates steps of an exemplary method for adjusting an operating parameter of a HDD or DVD based on sensed noise information. Control begins in step 500. In step 502, control determines whether the device is operating. In step 504, control converts audio

signals to digital audio signals. In step 506, control analyzes digital audio signals. In step 508, control determines whether a problem has been detected. In other words, control determines where the noise information indicates a problem. For example, the monitored noise parameter exceeds a threshold. If 5 true, control adjusts an operating parameter of the HDD or DVD device in step 509. For example, rotational speed, scanning speed, voltage level, current level or any other parameter may be adjusted. If step 508 is false, control continues with step 510 and determines whether there is a potential future failure based on current and/or historical noise information and/or functions thereof. If step 510 is 10 true, control sends a message to a host device and/or adjusts an operating parameter of the HDD or DVD device in step 514.

**[0101]** Referring now to FIG. 10, a flowchart illustrates steps of a method for determining device quality of HDD or DVD systems based on sensed noise information. Control begins with step 530. In step 532, control determines 15 whether the device is operating. If true, control converts audio signals to digital audio signals in step 534.

**[0102]** In step 538, control analyzes digital audio signals. In step 540, control compares current and/or historical noise information and/or a function thereof to a first threshold. If the noise level is less than a first threshold, control 20 sets quality to a first quality value in step 542. If step 540 is false, control determines whether the current and/or historical noise information is greater than a first threshold but less than a second threshold in step 550. If true, control sets quality to a second quality value in step 554. Otherwise control sends quality to a third quality value in step 560. While three quality values or levels are 25 described, additional or fewer quality values may be used. The quality values or levels may be used for variable pricing and/or other marketing decisions.

**[0103]** Referring now to FIG. 11, a flowchart illustrates steps of a method for estimating aging of HDD or DVD systems based on current and/or historical noise levels. Control begins in step 580. In step 584, control determines whether the device is operating. In step 586, control converts audio signals to digital audio signals. In step 590, control analyzes the digital audio signals. In step 594, control compares current and/or historical noise levels to 30

predetermined thresholds, functions or other predetermined criteria. In step 596, control estimates an age of the HDD or DVD system and/or one or more components thereof based upon the comparison.

[0104] Referring now to FIG. 12, a flowchart illustrates steps of a 5 method for estimating future failures of HDD or DVD systems based on current and/or historical noise levels. Control begins in step 600. In step 604, control determines whether the device is operating. In step 606, control converts audio signals to digital audio signals. In step 610, control analyzes the digital audio signals. In step 614, control extrapolates future performance based on current 10 and/or historical noise levels and compares the extrapolations to predetermined thresholds, functions or other predetermined criteria. In step 616, control estimates future failure of the HDD or DVD system and/or one or more components thereof based upon the comparison. For example, control may provide an estimated failure date or number of estimated operating hours until 15 failure.

[0105] Referring now to FIG. 13, a device 700 is shown to include a printed circuit board (PCB) (not shown) or a motherboard 704. For example only, the device 700 may be a computer system, a network switch, a router, a server, or other type of electronic device that includes an integrated circuit, that 20 is arranged on a chassis and/or in an enclosure, and that uses a fan for cooling. One or more integrated circuits 708 may be arranged on the motherboard 704.

[0106] For example only, the integrated circuit 708 may include a central processing unit (CPU), an application specific integrated circuit (ASIC), a graphics processing unit (GPU) and/or other type of integrated circuit. A 25 heatsink 712 communicates thermally with the integrated circuit 708 and absorbs heat therefrom. A fan 716 circulates air over the heatsink 712 to dissipate heat.

[0107] One or more other types of integrated circuits such as a graphics processing unit (GPU) 718 may be arranged on the motherboard 704. A heatsink 722 communicates thermally with the GPU 718 and transfers heat 30 therefrom. A fan 726 circulates air over the heatsink 722 to dissipate heat. The motherboard 704 may be arranged on a chassis and/or in an enclosure 730. One or more additional fans 734 may provide additional cooling inside of the

enclosure. Other components 744 such as memory modules and/or other modules or devices (not shown) may be arranged on the motherboard 704.

[0108] In operation, the integrated circuit 708 may include an audio monitoring module 750 that monitors audio signals generated by the fans 716, 5 726 and/or 734. A microphone 754 may be arranged inside of the enclosure 730. Alternately, a microphone 756 may be arranged outside of the enclosure 730. Alternately, a speaker 758 may be used as a microphone. Sound waves impacting the speaker 756 may be sensed and used for analysis.

[0109] The integrated circuit 708 and/or the GPU 718 may include the 10 audio monitoring (AM) module 750 that performs audio analysis on the audio signals as described above. Alternately, the AM module 750 may be a stand alone device or integrated with any other component or integrated circuit. The AM module 750 may perform sub-band analysis. Operation of the fans can be improved by monitoring signal levels, frequencies and noise patterns as well as 15 the changes of monitored parameters as a function of time.

[0110] Fan operating parameters may be automatically adjusted to lower acoustic noise. By doing so, user annoyance may be decreased. Operation of the fan away from resonance modes can be performed. In addition, real time monitoring of fan noise may be used to predict future failure events. 20 Analysis of historical data may be performed to estimate and monitor aging of the fan.

[0111] The audio monitoring may also be used as a relatively low cost method for differentiating product quality. For example, this approach can be used to separate high quality or low quality fans from other medium-quality fans. 25 Lower noise devices tend to be more reliable than the higher noise ones, particularly for fans having the same or similar designs. In addition, real time monitoring of mechanical components can be used to improve future quality levels.

[0112] While HDD and DVD systems are disclosed, the present 30 disclosure applies to other rotating storage devices, magnetic storage devices and/or optical storage devices.

[0113] In addition to or instead of altering an operating parameter of the component as described above, the audio monitoring module may generate signals to provide an indication as to how the component is operating. For example only, when the component is making more noise that is typically 5 acceptable, the audio monitoring module may generate an indication signal to a host device. For example only, when the fan is making too much noise, the CPU may send an error message to the operating system (OS) to notify the OS and/or the user.

[0114] The audio monitoring module may provide a list of actions that 10 can be taken by the user. For example, the audio monitoring module may allow the user to select from a plurality of different options. Some of the options may include operating in restricted modes such as low power modes, limited processing modes, etc. For implementations with fans, the user may select a safe shutdown mode when the temperature of the device reaches a 15 predetermined temperature value.

[0115] Those skilled in the art can now appreciate from the foregoing description that the broad teachings of the disclosure can be implemented in a variety of forms. Therefore, while this disclosure includes particular examples, the true scope of the disclosure should not be so limited since other 20 modifications will become apparent to the skilled practitioner upon a study of the drawings, the specification and the following claims.

## CLAIMS

What is claimed is:

1. A control system for a rotating data storage device, comprising:

a drive printed circuit board (PCB);

5 a drive module that is arranged on said drive PCB and that at least one of processes data, stores data and controls operation of said rotating storage device; and

an audio monitoring module that communicates with said drive module and that analyzes audio signals that are based on noise generated by the

10 rotating storage device during operation.

2. The control system of Claim 1 wherein said drive module comprises one of a magnetic storage control module and an optical storage control module.

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3. The control system of Claim 1 wherein said drive module comprises a read/write channel module.

20 4. The control system of Claim 1 wherein said drive module comprises a processor.

5. The control system of Claim 1 wherein said drive module comprises one of a spindle/voice coil motor drive module and a spindle/ feed motor module.

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6. A data storage device comprising the control system of Claim 1 and further comprising said rotating storage device.

30 7. The data storage device of Claim 6 further comprising a microphone that generates said audio signals.

8. The data storage device of Claim 6 wherein said rotating storage device includes a first component, wherein said audio monitoring module selectively adjusts an operating parameter of said first component based on said audio signals.

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9. The data storage device of Claim 8 wherein said first component one of rotates a rotating storage medium and reads data from said rotating storage medium.

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10. The data storage device of Claim 6 wherein said rotating storage device includes one of a magnetic storage device and an optical storage device.

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11. The data storage device of Claim 8 wherein said audio monitoring module selectively diagnoses failures of said first component based on said audio signals.

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12. The data storage device of Claim 8 wherein said audio monitoring module selectively estimates an age of said first component based on said audio signals.

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13. The data storage device of Claim 8 wherein said audio monitoring module selectively predicts future component failure of said first component based on said audio signals.

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14. The data storage device of Claim 8 wherein said audio monitoring module selectively estimates product quality of said data storage device based on said audio signals.

15. The data storage device of Claim 8 wherein said audio monitoring module selectively correlates said audio signals with a stored failure profile to predict failure of said first component.

16. The data storage device of Claim 6 further comprising an analog to digital converter that converts said audio signals to digital audio signals.

17. The data storage device of Claim 7 wherein said rotating data storage device comprises a hard disk drive that includes:

- 5 a hard disk drive assembly (HDDA); and
- a hard disk drive printed circuit board (HD PCB), wherein said microphone is arranged on one of said HDDA and said HD PCB.

10 18. The data storage device of Claim 17 wherein said hard disk drive includes:

- a hard disk drive module;
- a processor;
- 15 a spindle/voice coil motor (VCM) driver module; and
- a read/write channel module.

19. The data storage device of Claim 18 wherein said audio monitoring module is integrated with at least one of said hard disk drive module, said processor, said spindle/VCM driver module, and said read/write channel module 20 in a system on chip.

20. The data storage device of Claim 7 wherein said rotating data storage device comprises a digital versatile disc (DVD) that includes:

- 25 a digital versatile disk assembly (DVDA); and
- a digital versatile disk printed circuit board (DVD PCB), wherein said microphone is arranged on one of said DVDA and said DVD PCB.

21. The data storage device of Claim 20 wherein said digital versatile disk includes:

- 30 a digital versatile disk control module;
- a processor;
- a spindle/feed motor (FM) driver module; and

a read/write channel module.

22. The data storage device of Claim 21 wherein said audio monitoring module is integrated with at least one of said digital versatile disk control module, 5 said processor, said spindle/FM driver module, and said read/write channel module in a system on chip.

23. The data storage device of Claim 1 wherein said audio monitoring module performs sub-band analysis on said audio signals.

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24. The data storage device of Claim 8 wherein said first component includes at least one of a spindle motor and a voice coil motor (VCM).

25. The data storage device of Claim 8 wherein said first component 15 includes at least one of a spindle motor and a feed motor.

26. The data storage device of Claim 17 further comprising a flex connector that connects components of said HDDA and said HD PCB, wherein said microphone is arranged on said HDDA and wherein a conductor that 20 communicates with said audio monitoring module and said microphone is associated with said flex connector.

27. The data storage device of Claim 20 further comprising a flex connector that connects components of said DVDA and said DVD PCB, wherein 25 said microphone is arranged on said DVDA and wherein a conductor that communicates with said audio monitoring module and said microphone is associated with said flex connector.

28. The data storage device of Claim 10 wherein said hard disk drive 30 includes a power management interface module and wherein said audio monitoring module is integrated with said power management interface module in a system on chip.

29. The data storage device of Claim 10 wherein said digital versatile disc includes a power management interface module and wherein said audio monitoring module is integrated with said power management interface module  
5 in a system on chip.

30. The data storage device of Claim 1 wherein said drive module is integrated with said audio monitoring module in an integrated circuit.

10 31. An integrated circuit (IC) for controlling a rotating data storage device, comprising:

a drive module that is implemented by said integrated circuit and that at least one of processes data, stores data and controls operation of said rotating storage device; and

15 an audio monitoring module that is implemented by said integrated circuit, that communicates with said drive module and that analyzes audio signals that are based on noise generated by the rotating storage device during operation.

32. The IC of Claim 31 wherein said drive module comprises one of a  
20 magnetic storage control module and an optical storage control module.

33. The IC of Claim 31 wherein said drive module comprises a read/write channel module.

25 34. The IC of Claim 31 wherein said drive module comprises a processor.

35. The IC of Claim 31 wherein said drive module comprises one of a spindle/voice coil motor drive module and a spindle/ feed motor module.

30 36. A data storage device comprising the IC of Claim 31 and further comprising said rotating storage device.

37. The data storage device of Claim 36 further comprising a microphone that generates said audio signals.

5 38. The data storage device of Claim 36 wherein said rotating storage device includes a first component, wherein said audio monitoring module selectively adjusts an operating parameter of said first component based on said audio signals.

10 39. The data storage device of Claim 38 wherein said first component one of rotates said rotating storage medium and reads data from said rotating storage medium.

15 40. The data storage device of Claim 36 wherein said rotating storage device includes one of a magnetic storage device and an optical storage device.

41. The data storage device of Claim 38 wherein said audio monitoring module selectively diagnoses failures of said first component based on said audio signals.

20 42. The data storage device of Claim 38 wherein said audio monitoring module selectively estimates an age of said first component based on said audio signals.

25 43. The data storage device of Claim 38 wherein said audio monitoring module selectively predicts future component failure of said first component based on said audio signals.

30 44. The data storage device of Claim 38 wherein said audio monitoring module selectively estimates product quality of said data storage device based on said audio signals.

45. The data storage device of Claim 38 wherein said audio monitoring module selectively correlates said audio signals with a stored failure profile to predict failure of said first component.

5 46. The data storage device of Claim 36 further comprising an analog to digital converter that converts said audio signals to digital audio signals.

47. The data storage device of Claim 37 wherein said rotating data storage device comprises a hard disk drive that includes:

10 a hard disk drive assembly (HDDA); and  
a hard disk drive printed circuit board (HD PCB), wherein said microphone is arranged on one of said HDDA and said HD PCB.

48. The data storage device of Claim 47 wherein said hard disk drive 15 includes:

a hard disk drive control module;  
a processor;  
a spindle/voice coil motor (VCM) driver module; and  
a read/write channel module.

20 49. The data storage device of Claim 48 wherein said audio monitoring module is integrated with at least one of said hard disk drive control module, said processor, said spindle/VCM driver module, and said read/write channel module in a system on chip.

25 50. The data storage device of Claim 37 wherein said rotating data storage device comprises a digital versatile disc (DVD) that includes:

a digital versatile disk assembly (DVDA); and  
a digital versatile disk printed circuit board (DVD PCB), wherein said 30 microphone is arranged on one of said DVDA and said DVD PCB.

51. The data storage device of Claim 50 wherein said digital versatile disk includes:

- 5 a digital versatile disk control module;
- 5 a processor;
- 5 a spindle/feed motor (FM) driver module; and
- 5 a read/write channel module.

52. The data storage device of Claim 51 wherein said audio monitoring module is integrated with at least one of said digital versatile disk control module, 10 said processor, said spindle/FM driver module, and said read/write channel module in a system on chip.

53. The data storage device of Claim 31 wherein said audio monitoring module performs sub-band analysis on said audio signals.

15

54. The data storage device of Claim 38 wherein said first component includes at least one of a spindle motor and a voice coil motor (VCM).

55. The data storage device of Claim 38 wherein said first component 20 includes at least one of a spindle motor and a feed motor.

56. The data storage device of Claim 47 further comprising a flex connector that connects components of said HDDA and said HD PCB, wherein said microphone is arranged on said HDDA and wherein a conductor that 25 communicates with said audio monitoring module and said microphone is associated with said flex connector.

57. The data storage device of Claim 50 further comprising a flex connector that connects components of said DVDA and said DVD PCB, wherein 30 said microphone is arranged on said DVDA and wherein a conductor that communicates with said audio monitoring module and said microphone is associated with said flex connector.

58. The data storage device of Claim 40 wherein said hard disk drive includes a power management interface module and wherein said audio monitoring module is integrated with said power management interface module 5 in a system on chip.

59. The data storage device of Claim 40 wherein said digital versatile disc includes a power management interface module and wherein said audio monitoring module is integrated with said power management interface module 10 in a system on chip.

60. The data storage device of Claim 31 wherein said drive module is integrated with said audio monitoring module in an integrated circuit.

15 61. A device comprising:  
an integrated circuit;  
a fan that cools said integrated circuit; and  
an audio monitoring module that analyzes audio signals that are based on noise generated by said fan during operation.

20 62. The device of Claim 61 wherein said audio monitoring module is implemented by and integrated with said integrated circuit.

25 63. The device of Claim 61 further comprising a microphone that communicates with said audio monitoring module and that generates said audio signals.

64. The device of Claim 61 further comprising a heat sink in thermal communication with said integrated circuit and said fan.

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65. The device of Claim 61 wherein said audio monitoring module selectively adjusts an operating parameter of said fan based on said audio signals.

5 66. The device of Claim 61 wherein said audio monitoring module selectively diagnoses failures of said fan based on said audio signals.

67. The device of Claim 61 wherein said audio monitoring module selectively estimates an age of said fan based on said audio signals.

10 68. The device of Claim 61 wherein said audio monitoring module selectively predicts future failure of said fan based on said audio signals.

69. The device of Claim 61 wherein said audio monitoring module 15 selectively estimates product quality of said fan based on said audio signals.

70. The device of Claim 61 wherein said audio monitoring module selectively correlates said audio signals with a stored failure profile to predict failure of said fan.

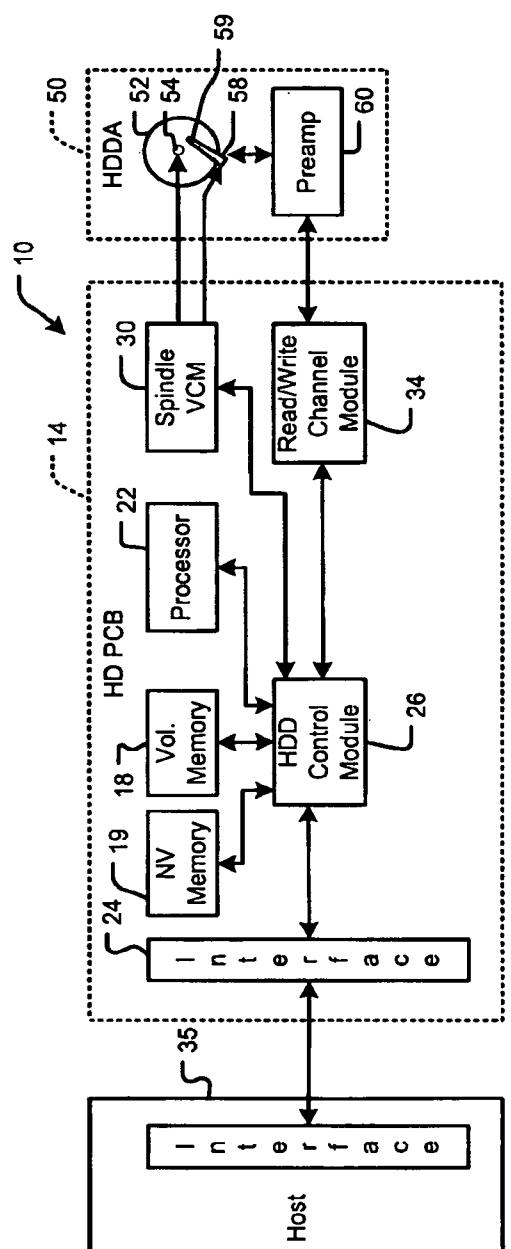
20 71. The device of Claim 61 further comprising  
a chassis;  
at least one of a printed circuit board and a motherboard arranged on said chassis, wherein said fan is arranged on said chassis and said integrated circuit  
25 is arranged on said at least one of said printed circuit board and said motherboard.

72. The device of Claim 61 wherein said integrated circuit includes one  
of a central processing unit, a graphics processing unit (GPU) and an application  
30 specific integrated circuit (ASIC).

73. The device of Claim 63 further comprising

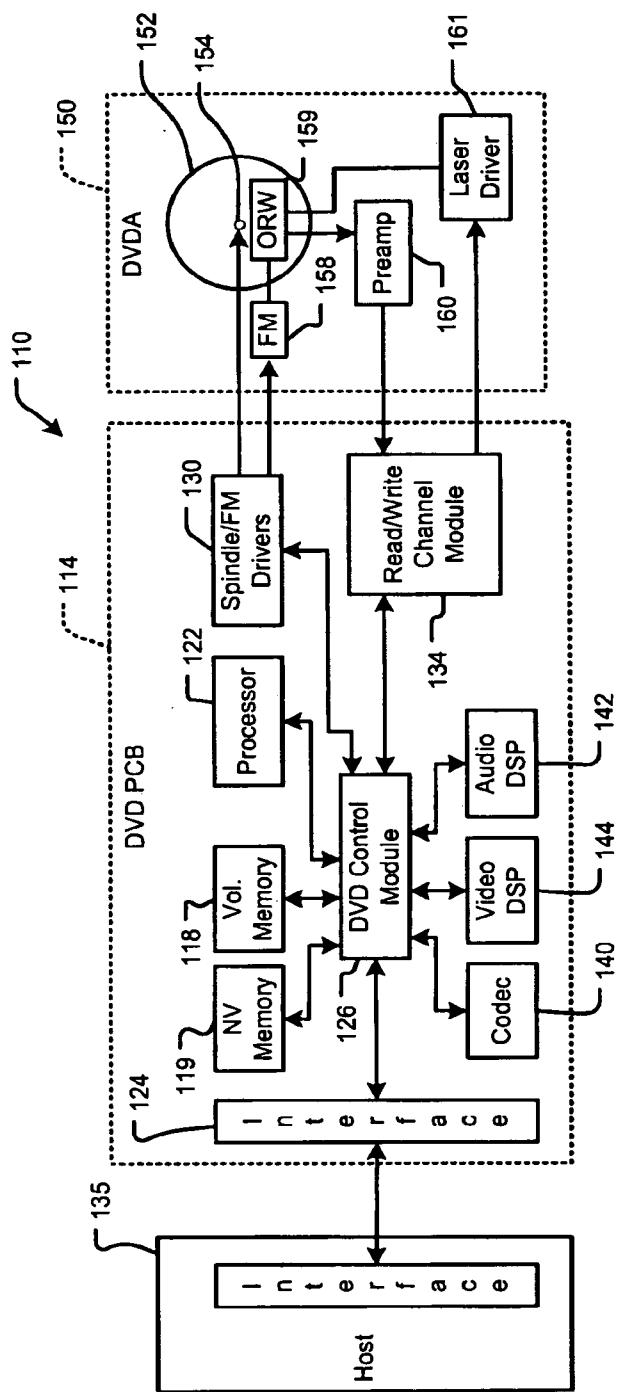
a chassis;

at least one of a printed circuit board and a motherboard arranged on said chassis, wherein said microphone is arranged on at least one of said chassis and said at least one of said printed circuit board and said motherboard.

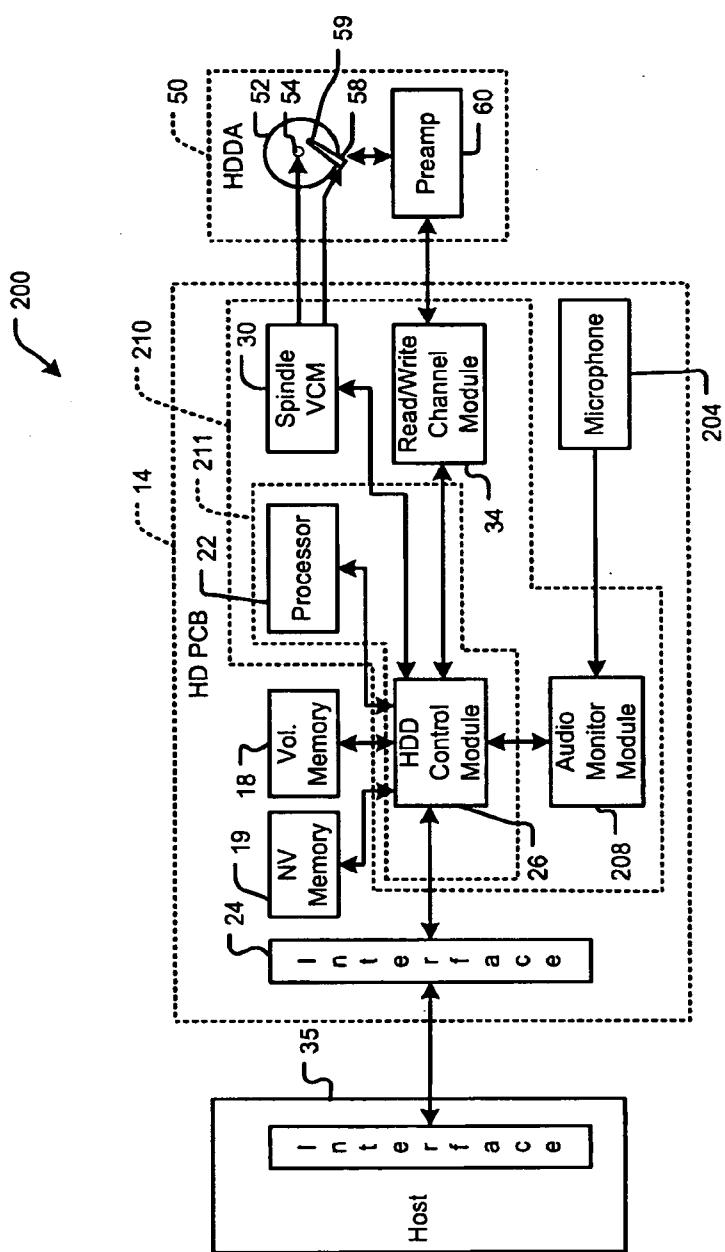


**FIG. 1**  
Prior Art

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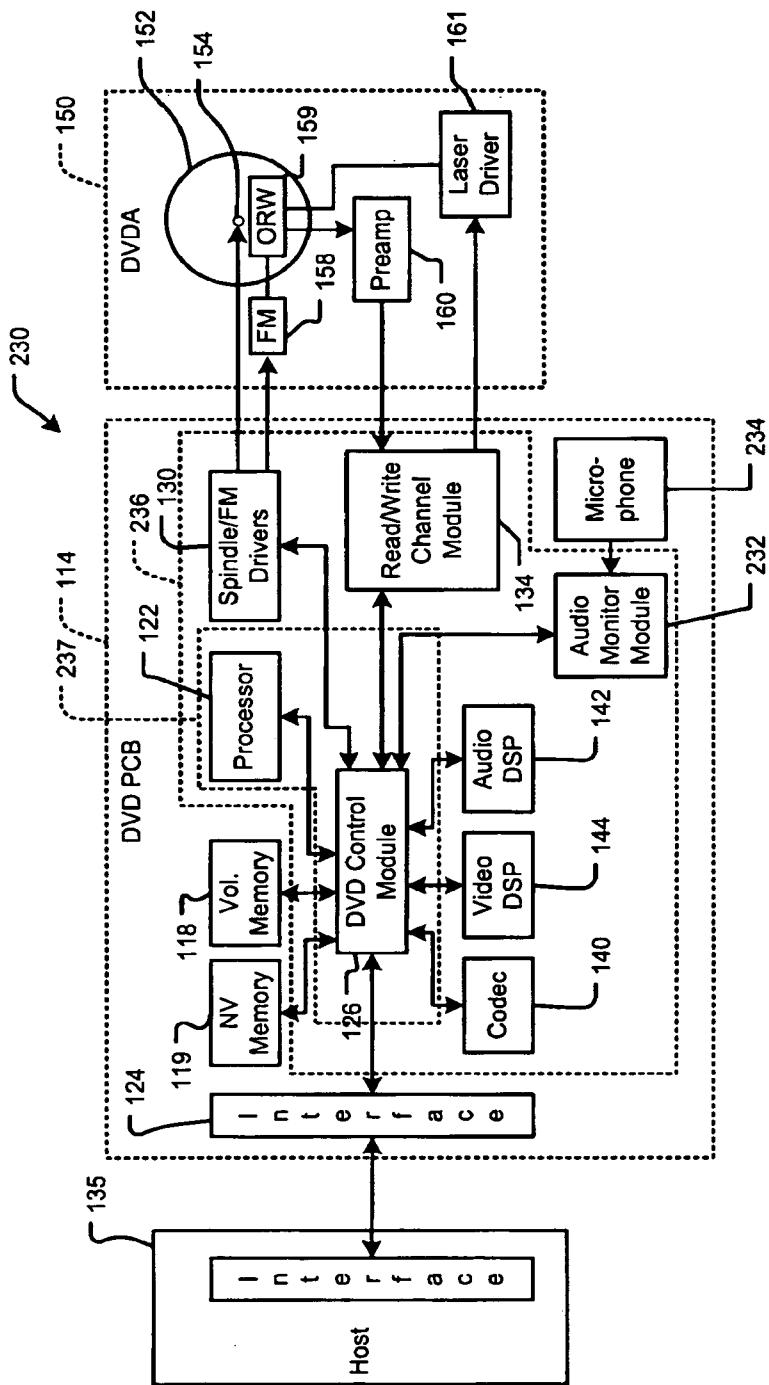


**FIG. 2**  
Prior Art

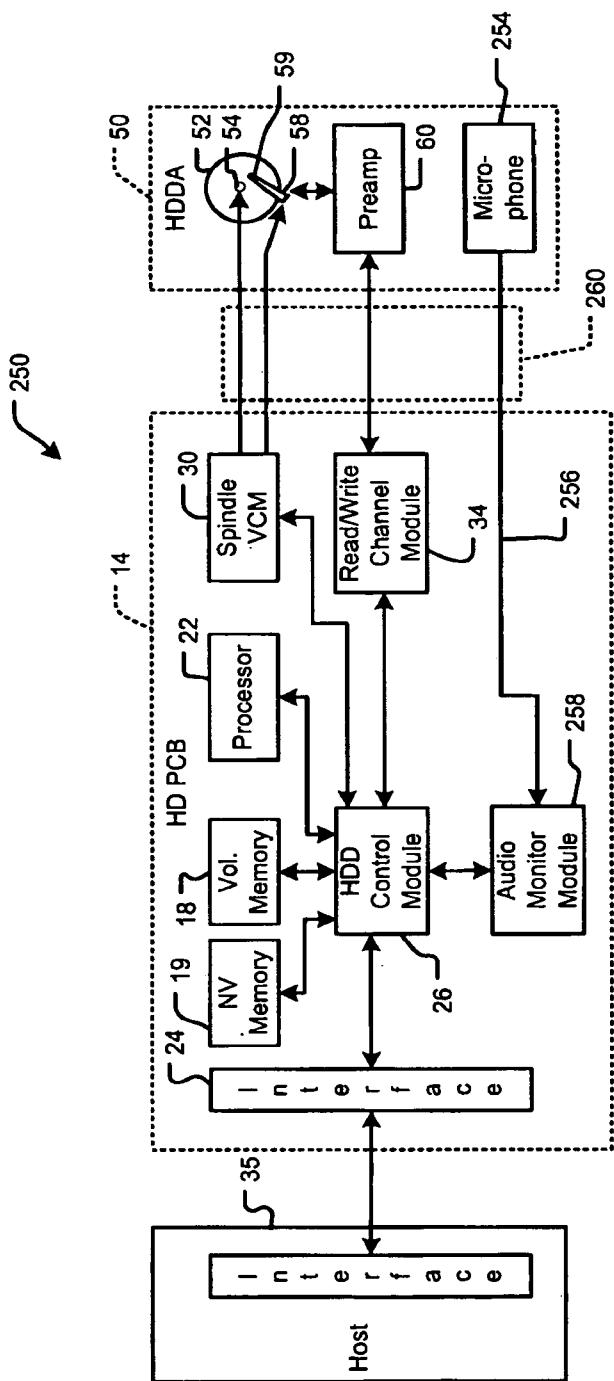


**FIG. 3A**

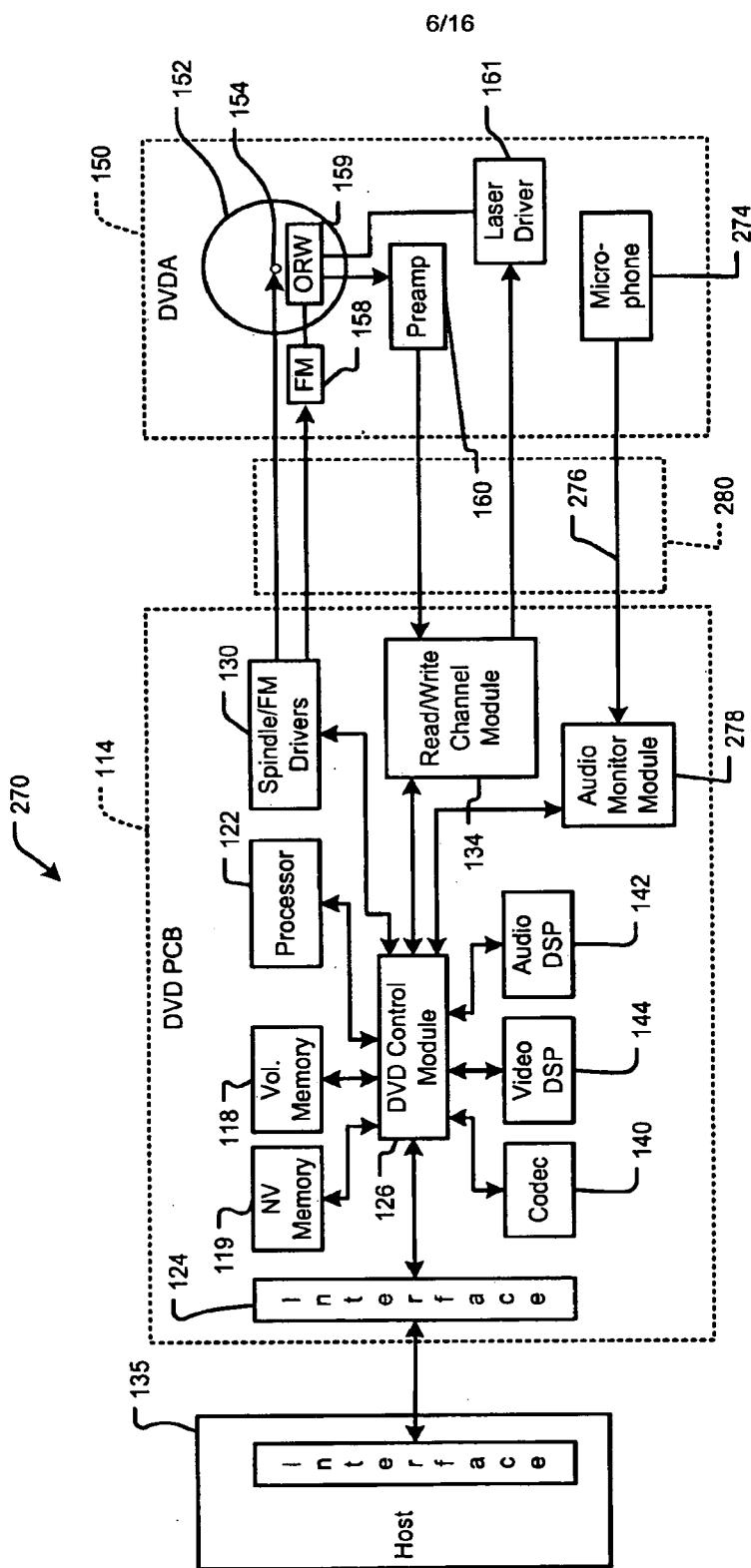
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**FIG. 3B**

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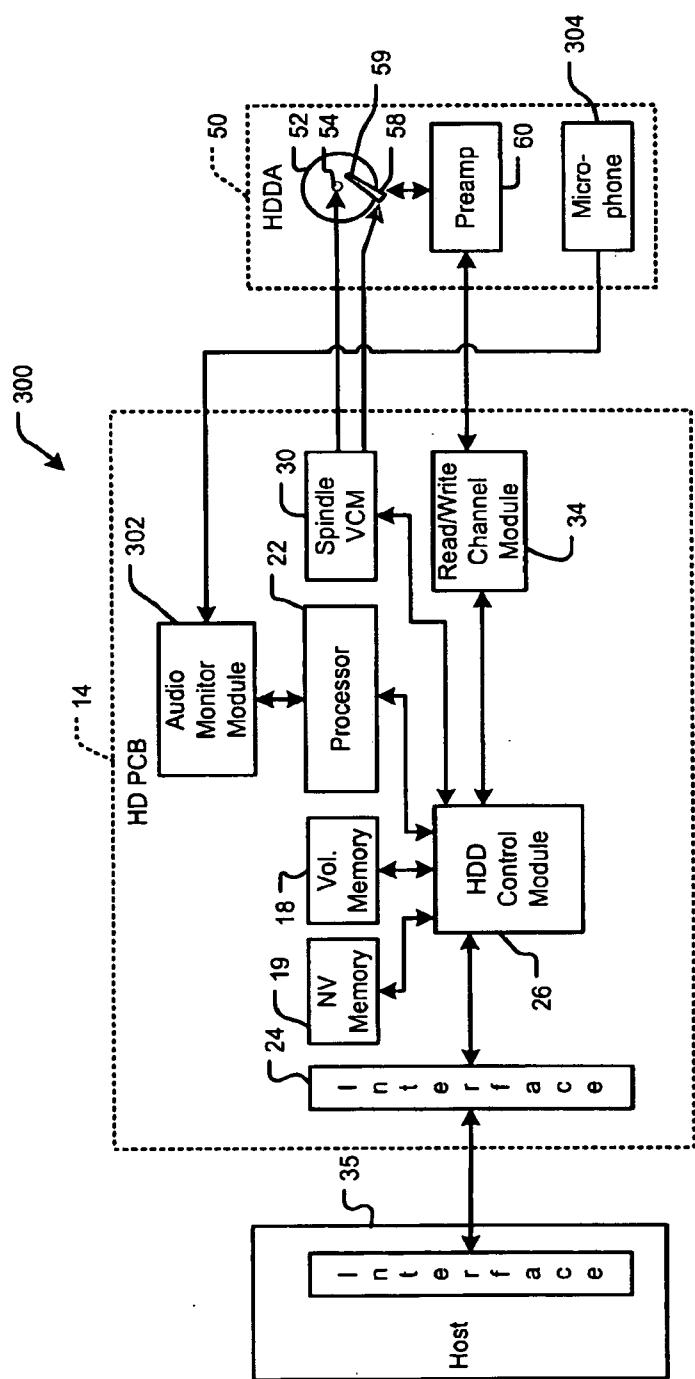


**FIG. 4A**



**FIG. 4B**

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**FIG. 5A**

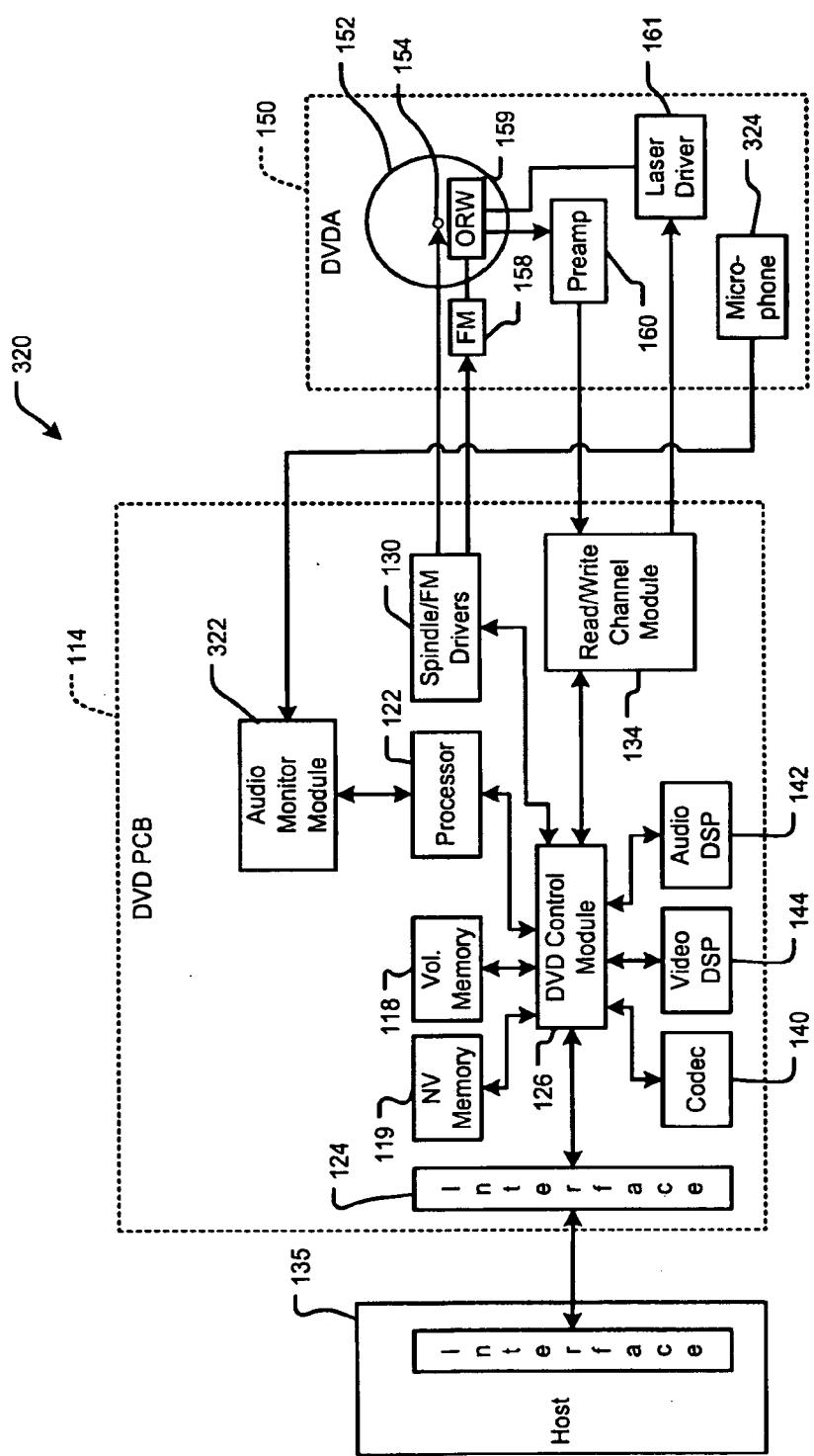
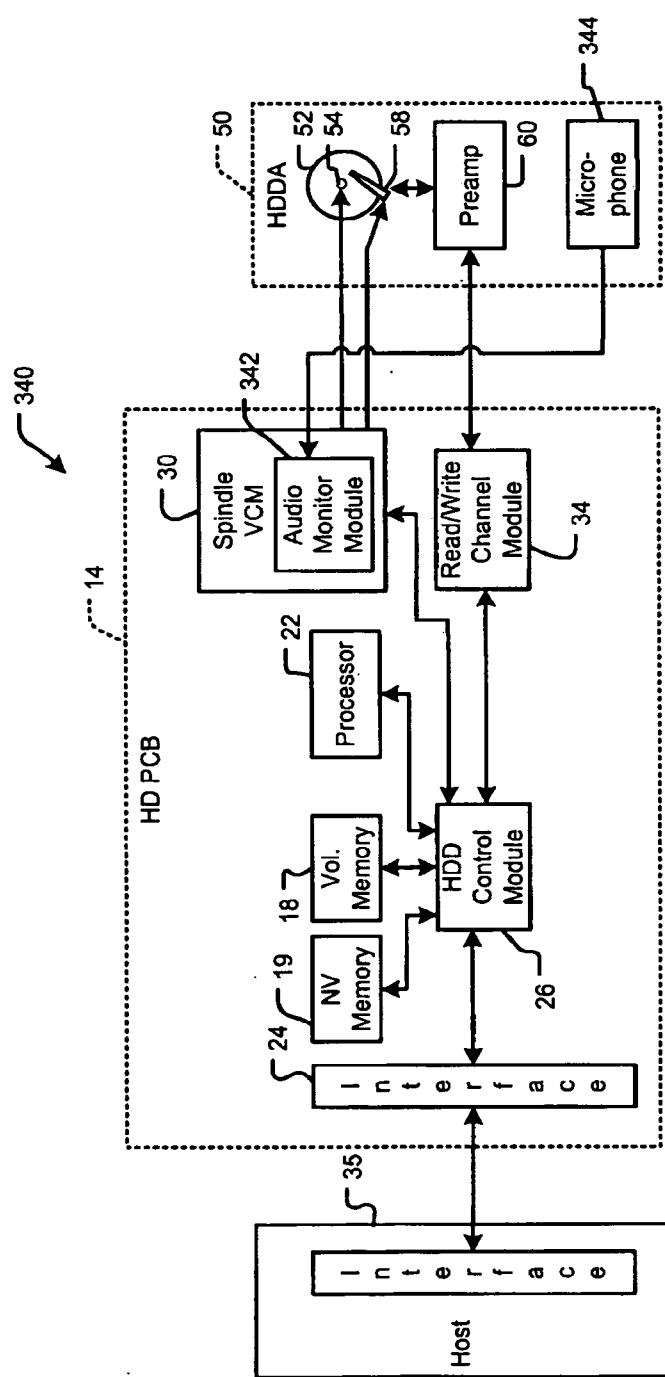
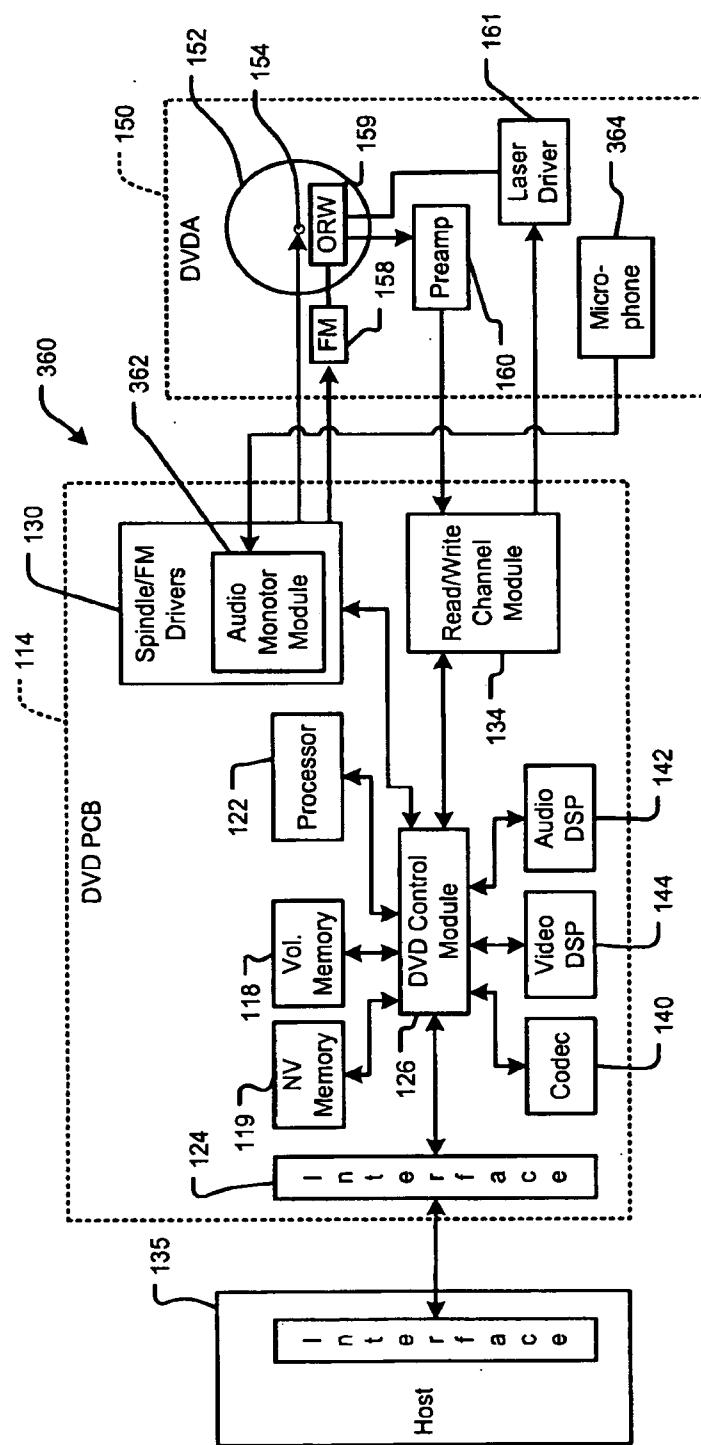


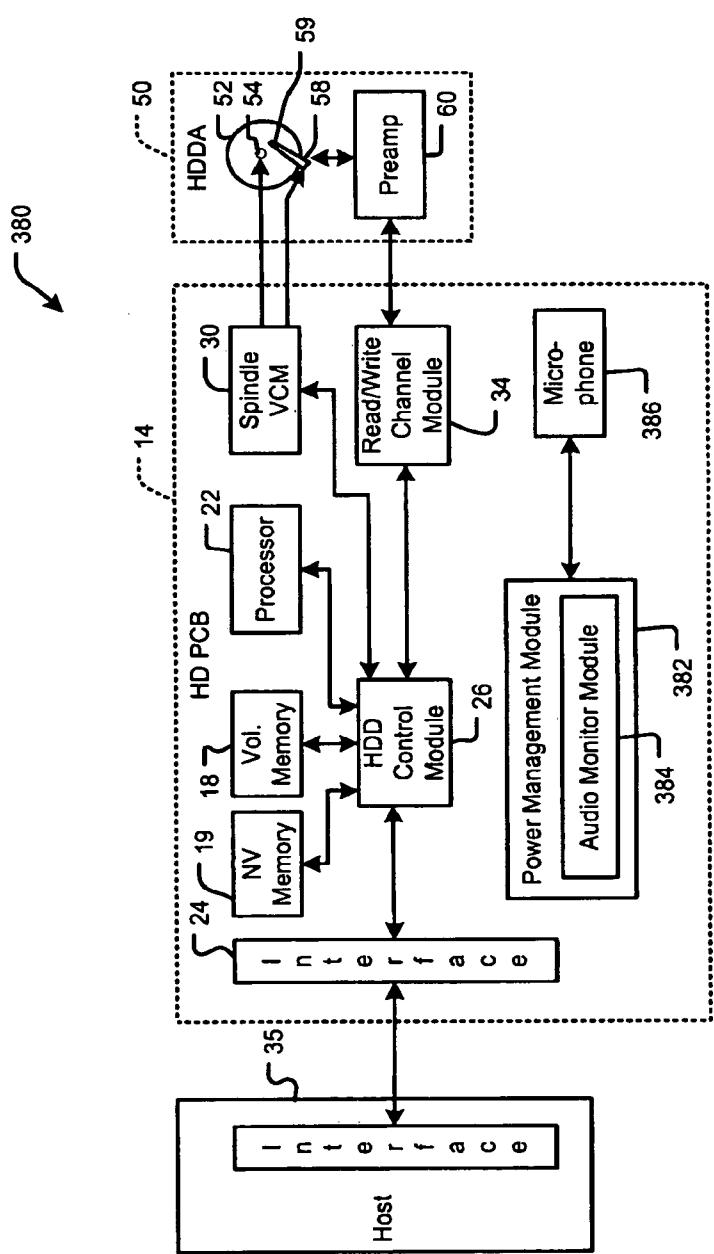
FIG. 5B

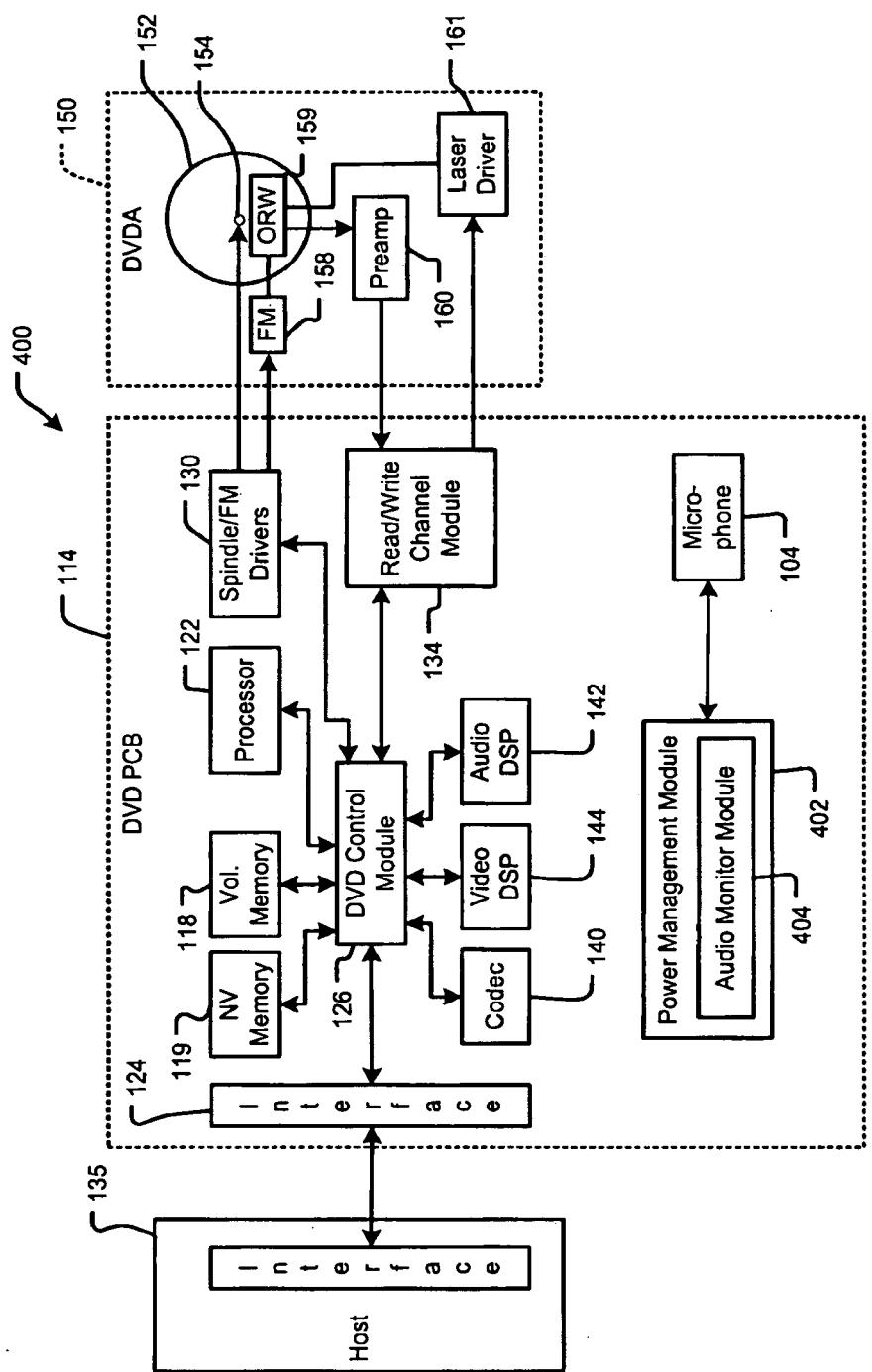
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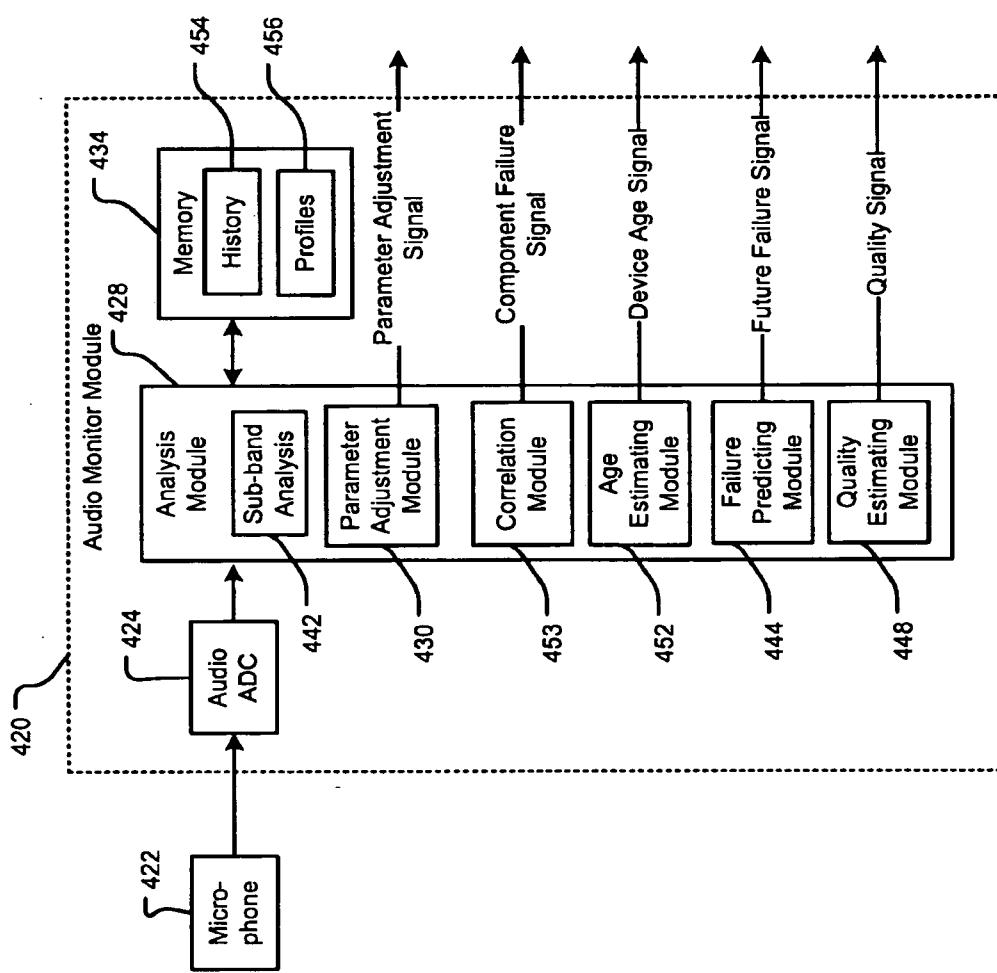
**FIG. 6A**

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**FIG. 6B**

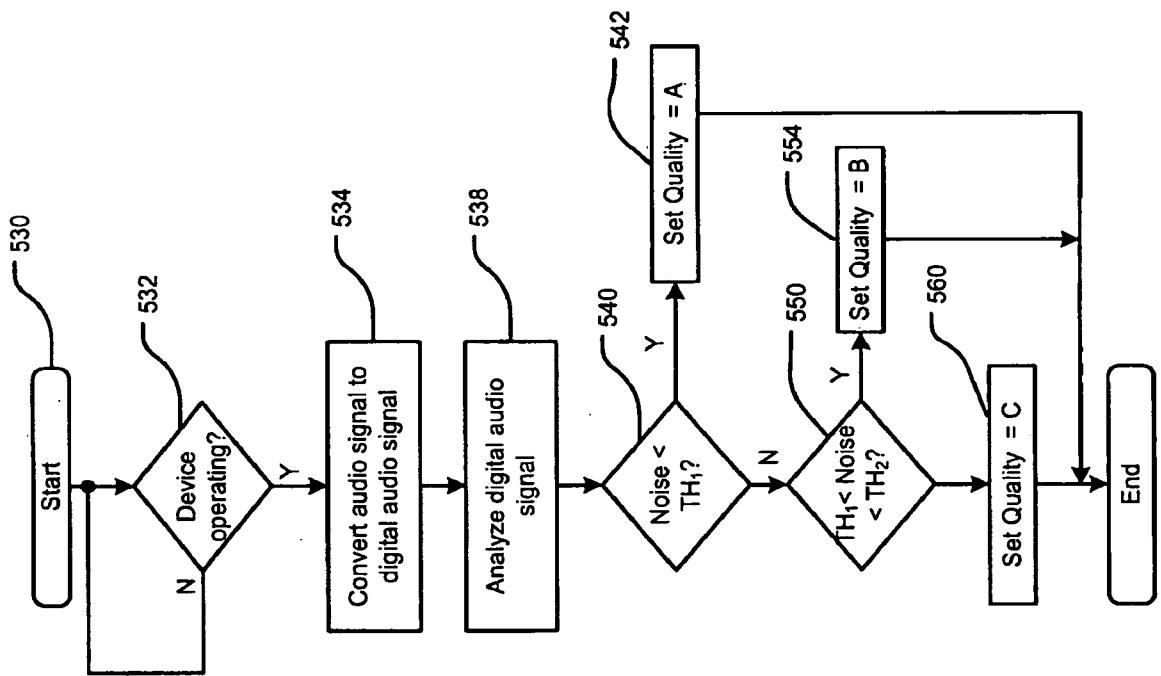
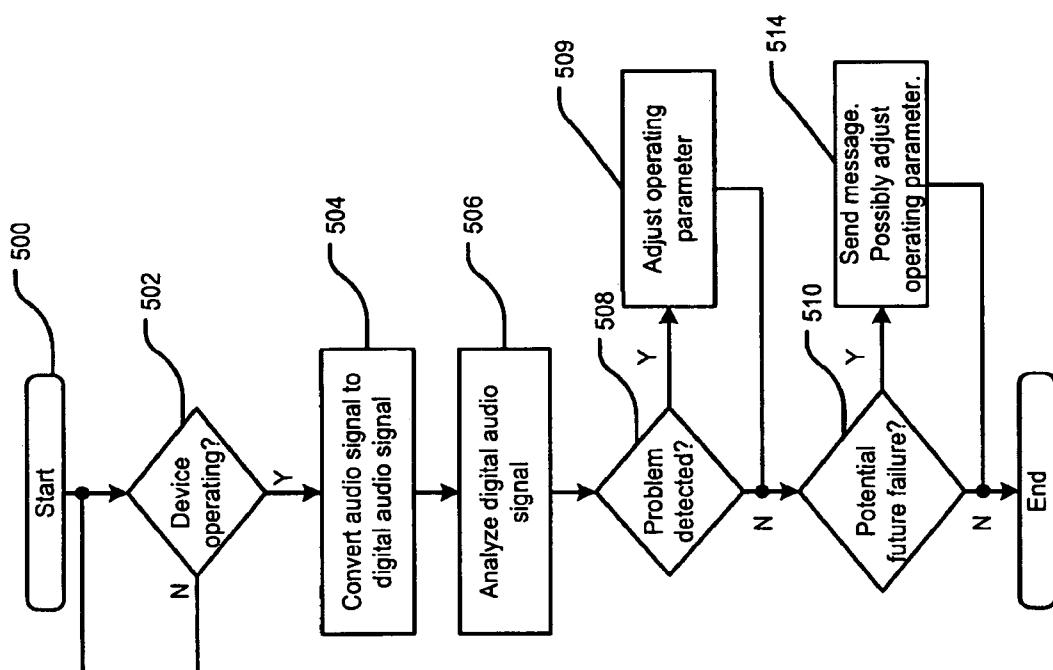
**FIG. 7A**

**FIG. 7B**

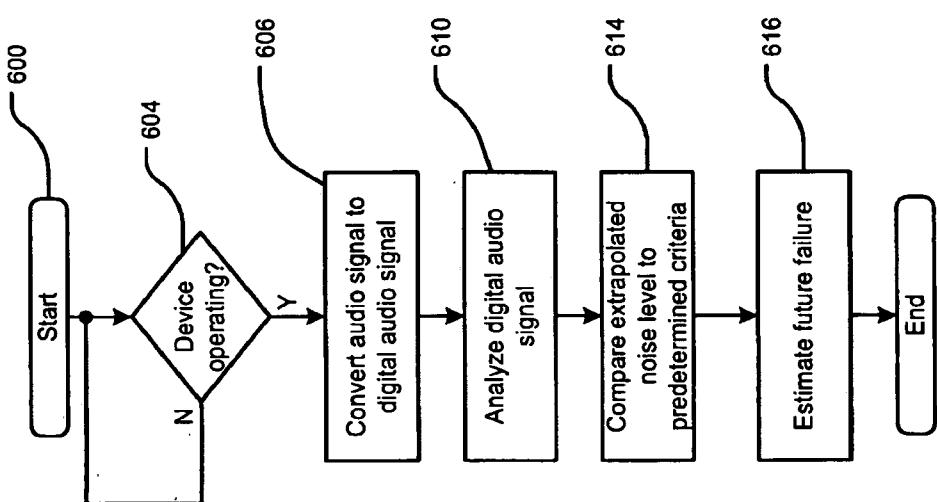
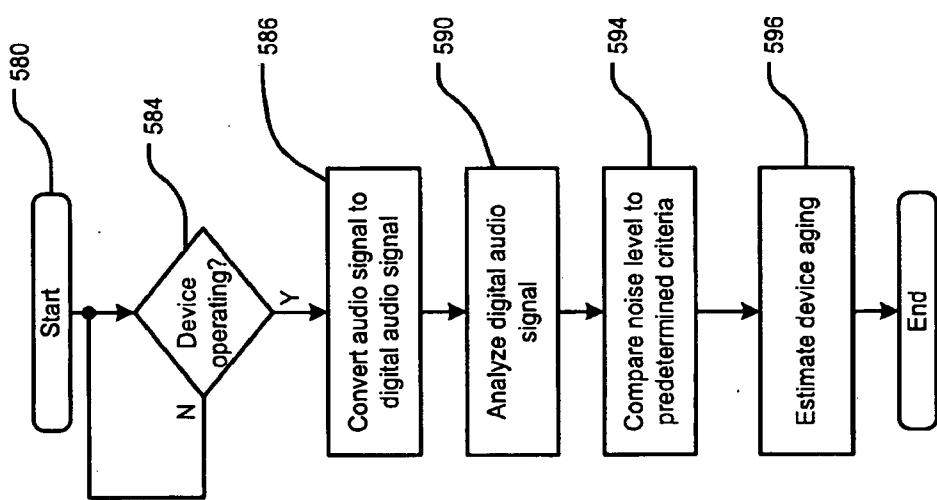


**FIG. 8**

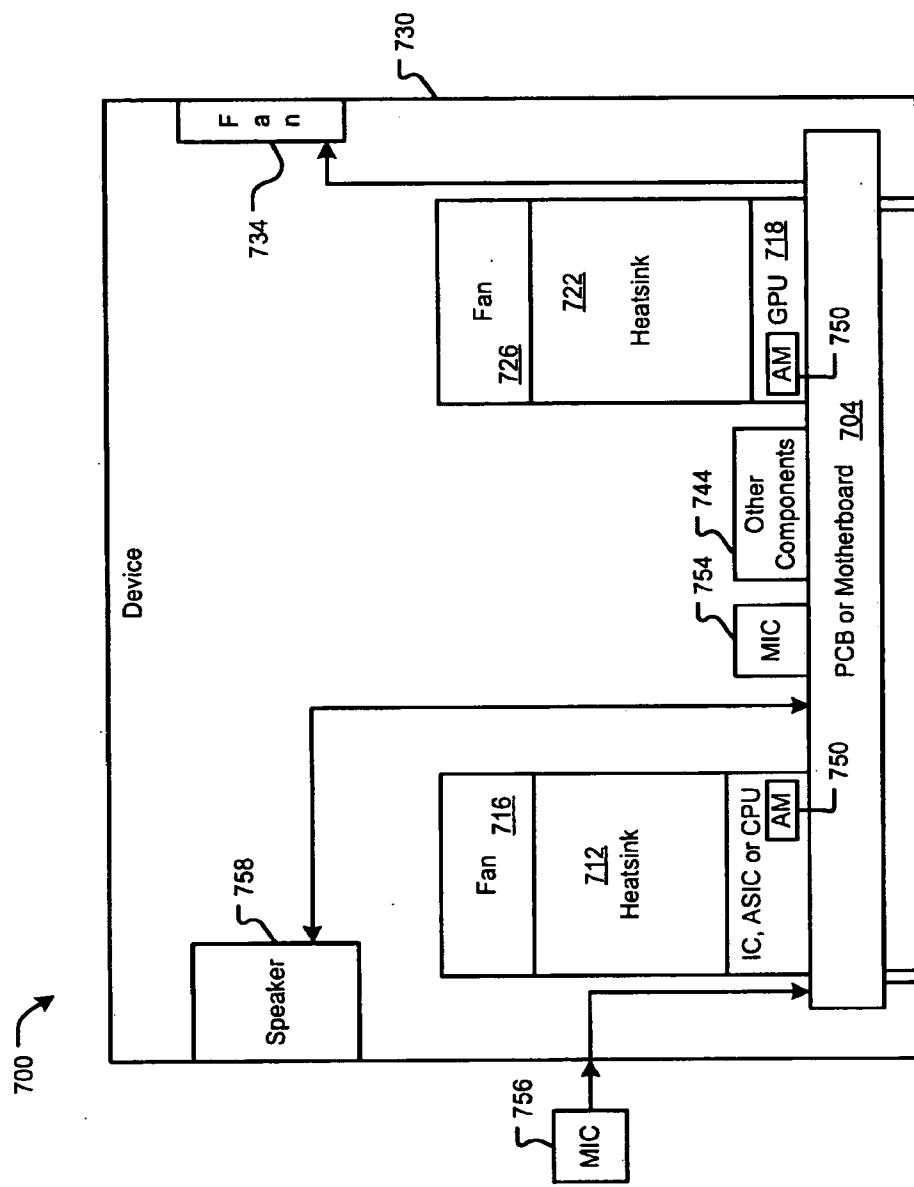
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**FIG. 10****FIG. 9**

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**FIG. 12****FIG. 11**

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**FIG. 13**