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(54) BEARING CONDITION MONITOR FOR A VEHICLE, SUCH AS A TRUCK OR A TRAILER

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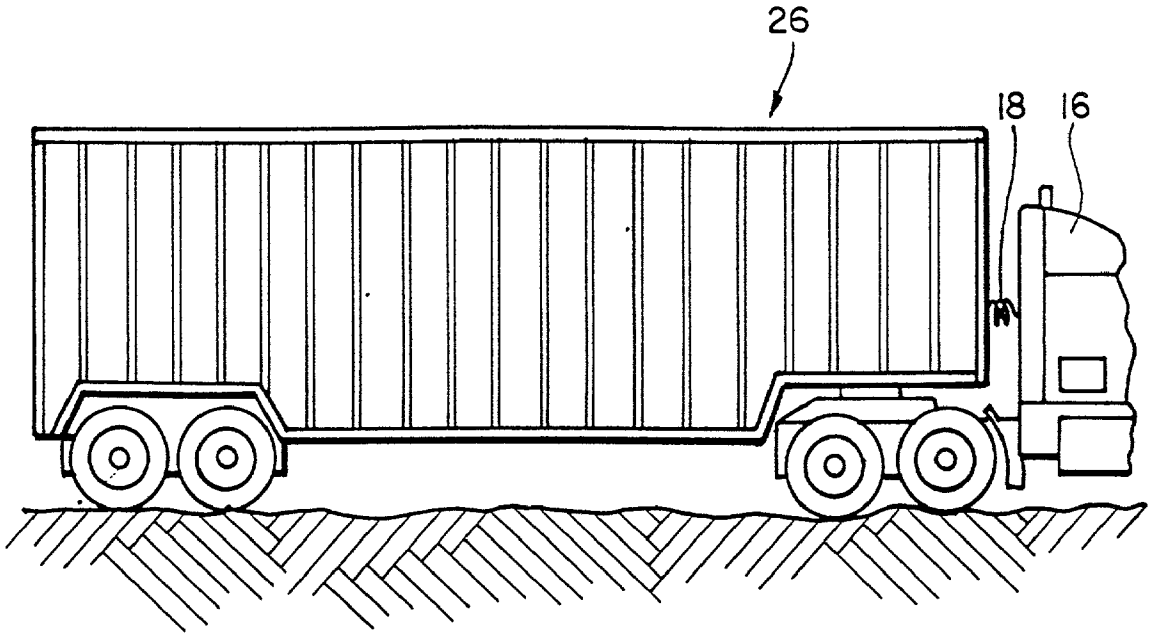
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(57) **ABSTRACT**

A system for monitoring bearing health of a wheel of a vehicle, such as a trailer, is provided. The system is configured to monitor at least one characteristic relating to the wheel bearings, such as a temperature, vibrations, and/or proximity. The monitoring system may be configured to monitor more than one of these characteristics (i.e., temperature, vibration and proximity) or even all three. The system is incorporated into a wheel speed sensor. The system may be incorporated in an anti-lock brake system (ABS) or electro-pneumatic brake system (EBS). Regardless of which characteristic is actually monitored by the system and whether the system is employed with an ABS or EBS, the bearing monitoring system provides that one or more bearings of a vehicle can be continuously and automatically monitored in the field.



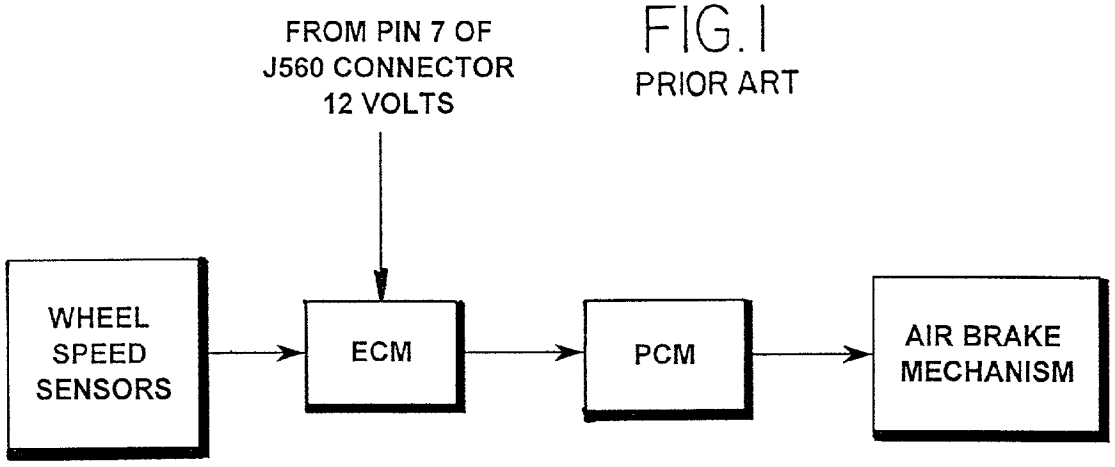


FIG.1
PRIOR ART

FIG.10

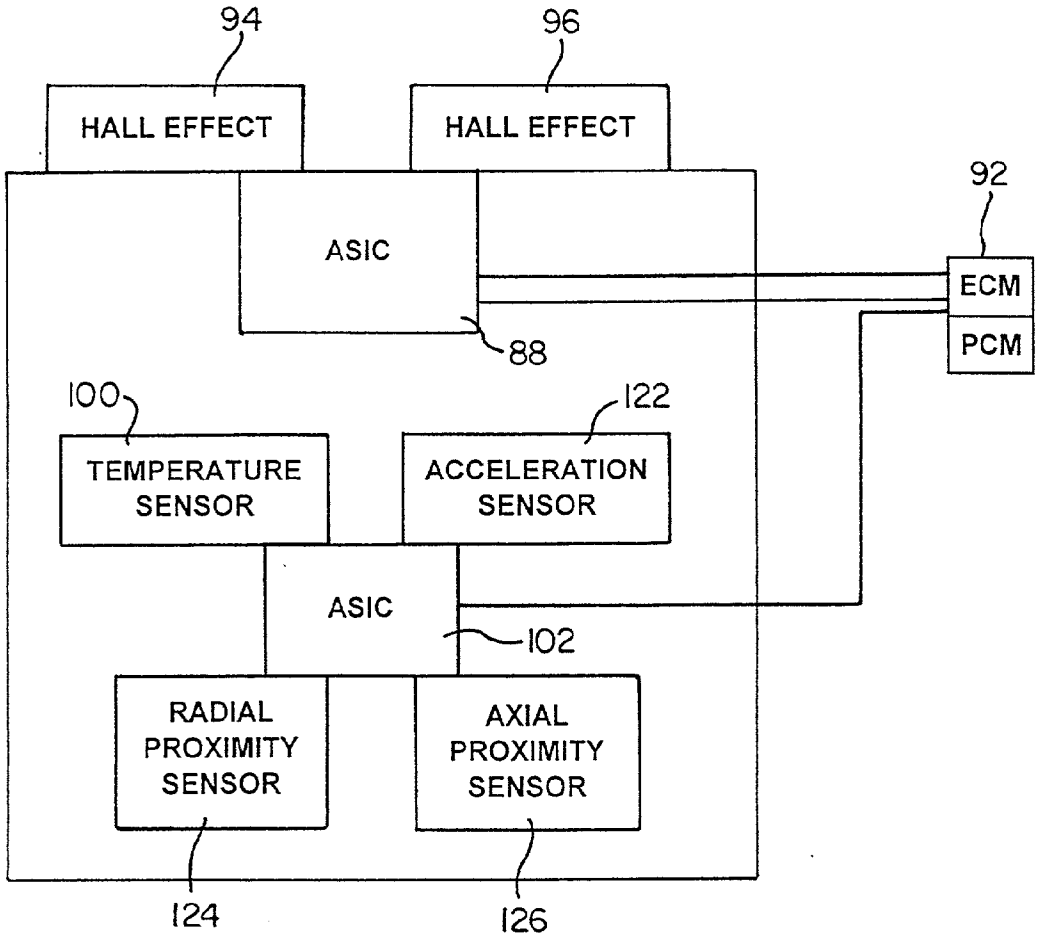


FIG.2

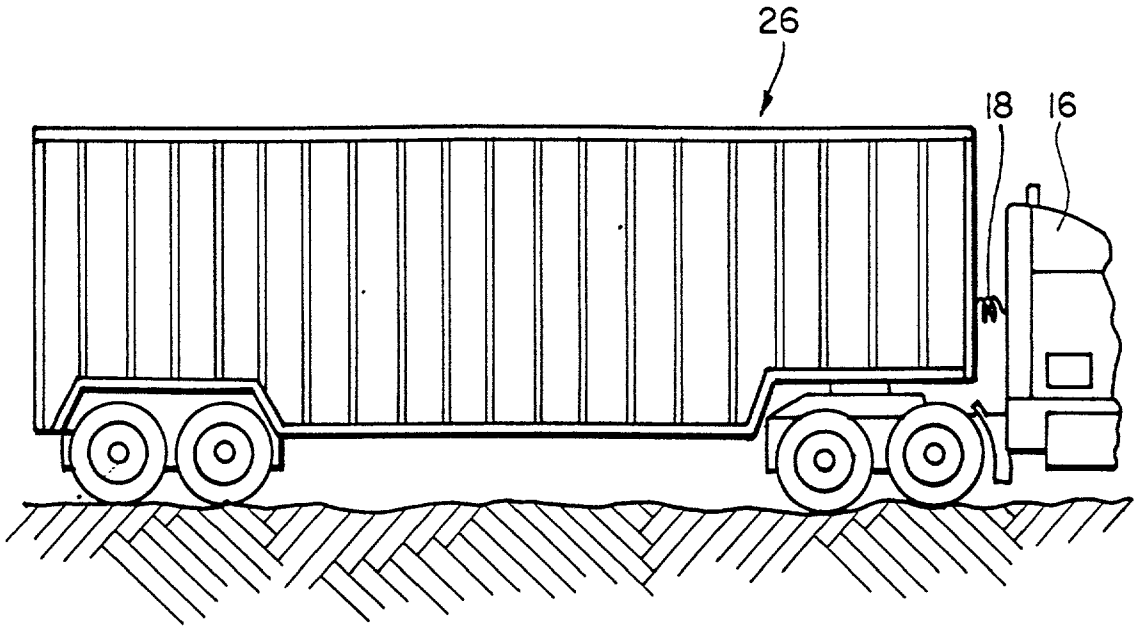
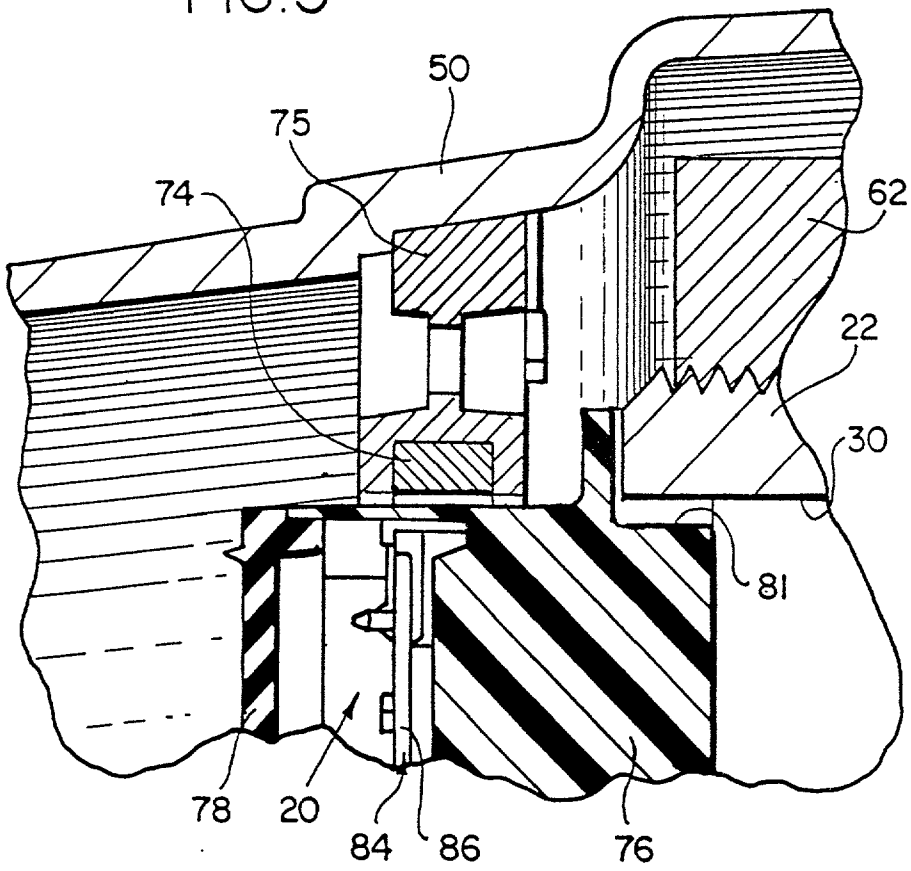


FIG.5



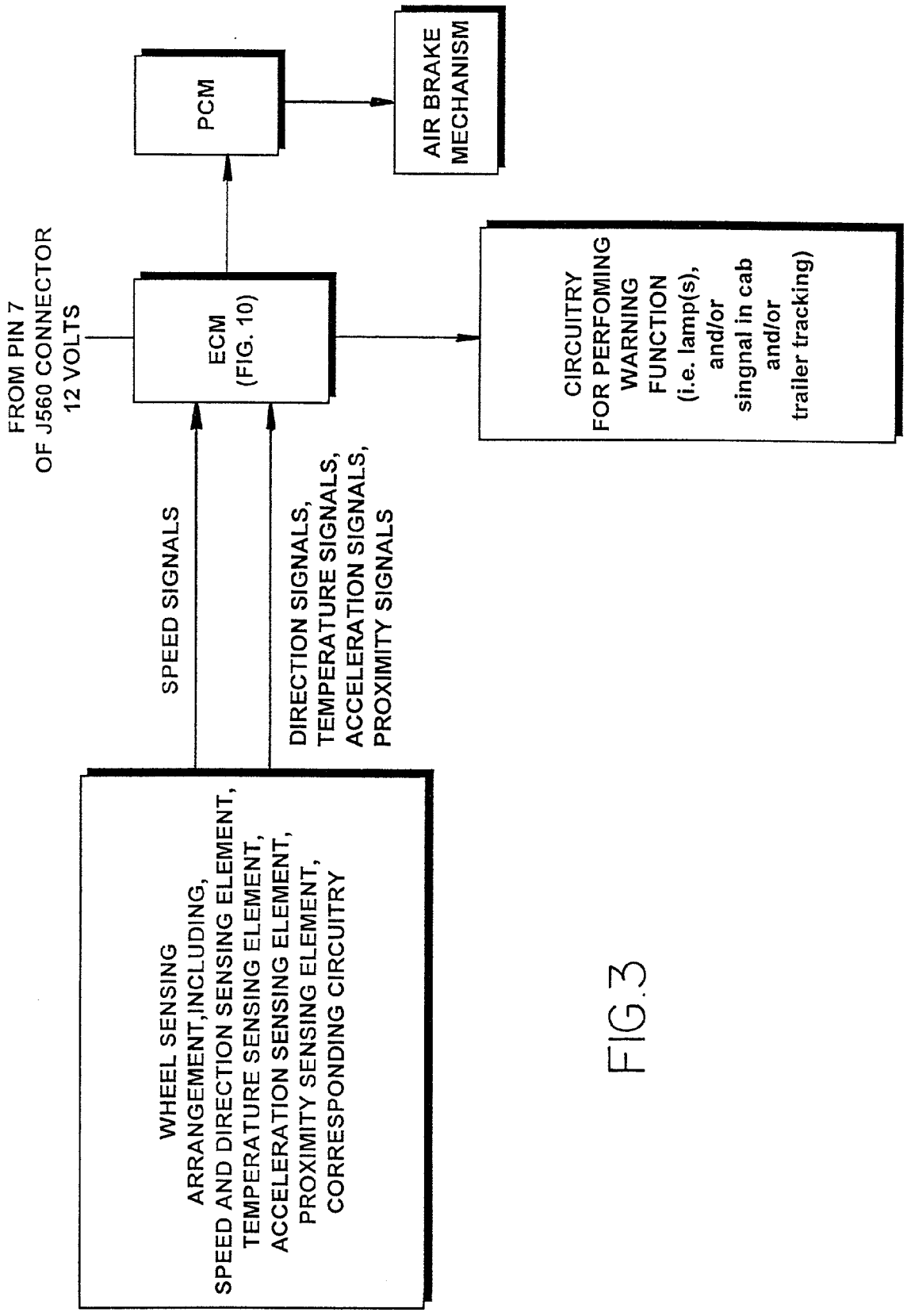

PCM
AIR BRAKE MECHANISM
FROM PIN 7
OF J560 CONNECTOR
12 VOLTS
ECM
(FIG. 10)
CIRCUITRY
FOR PERFOMING
WARNING
FUNCTION
(i.e. lamp(s),
and/or
singnal in cab
and/or
trailer tracking)
SPEED SIGNALS
DIRECTION SIGNALS,
TEMPERATURE SIGNALS,
ACCELERATION SIGNALS,
PROXIMITY SIGNALS
WHEEL SENSING
ARRANGEMENT,INCLUDING,
SPEED AND DIRECTION SENSING ELEMENT,
TEMPERATURE SENSING ELEMENT,
ACCELERATION SENSING ELEMENT,
PROXIMITY SENSING ELEMENT,
CORRESPONDING CIRCUITRY

FIG.3

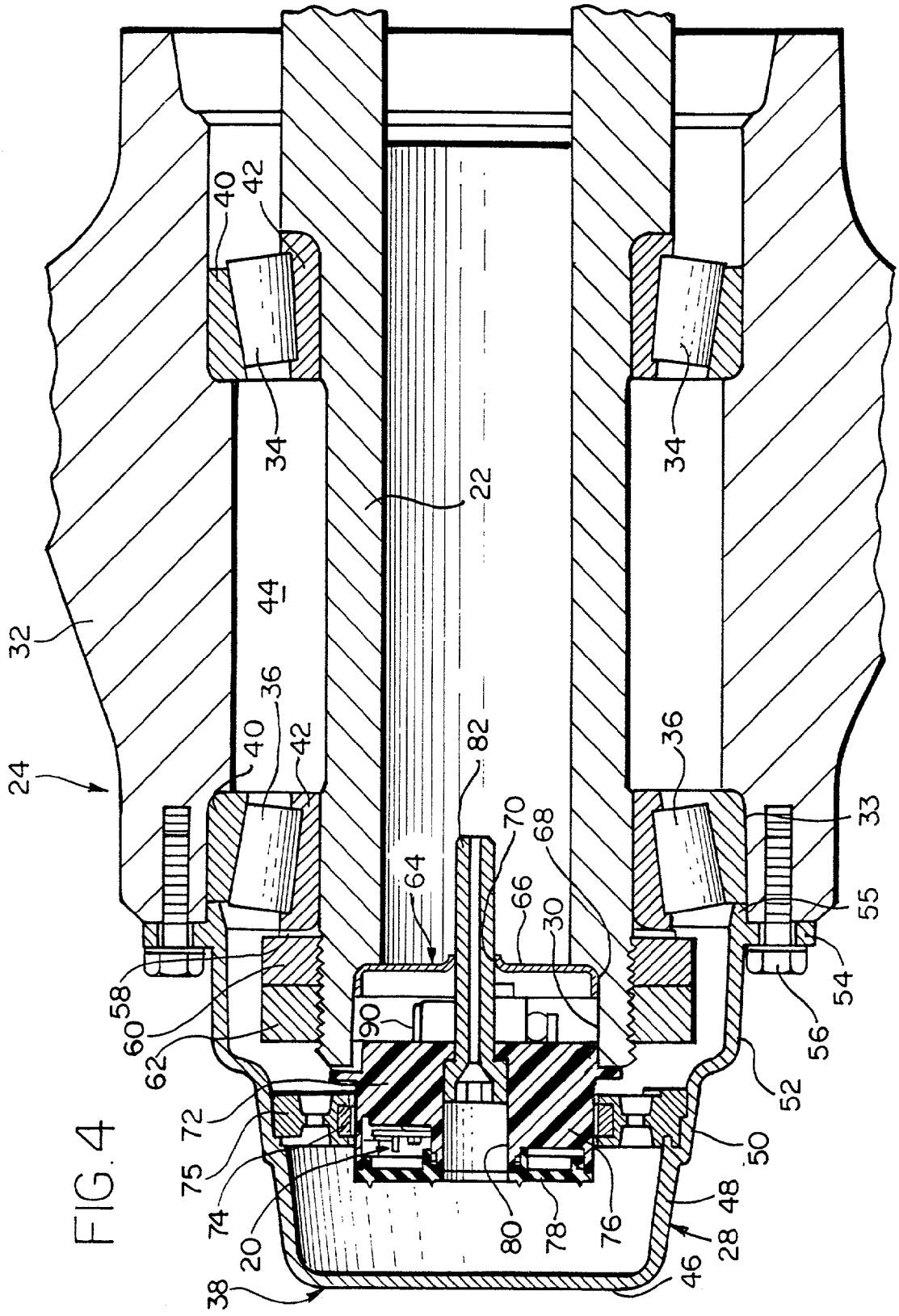
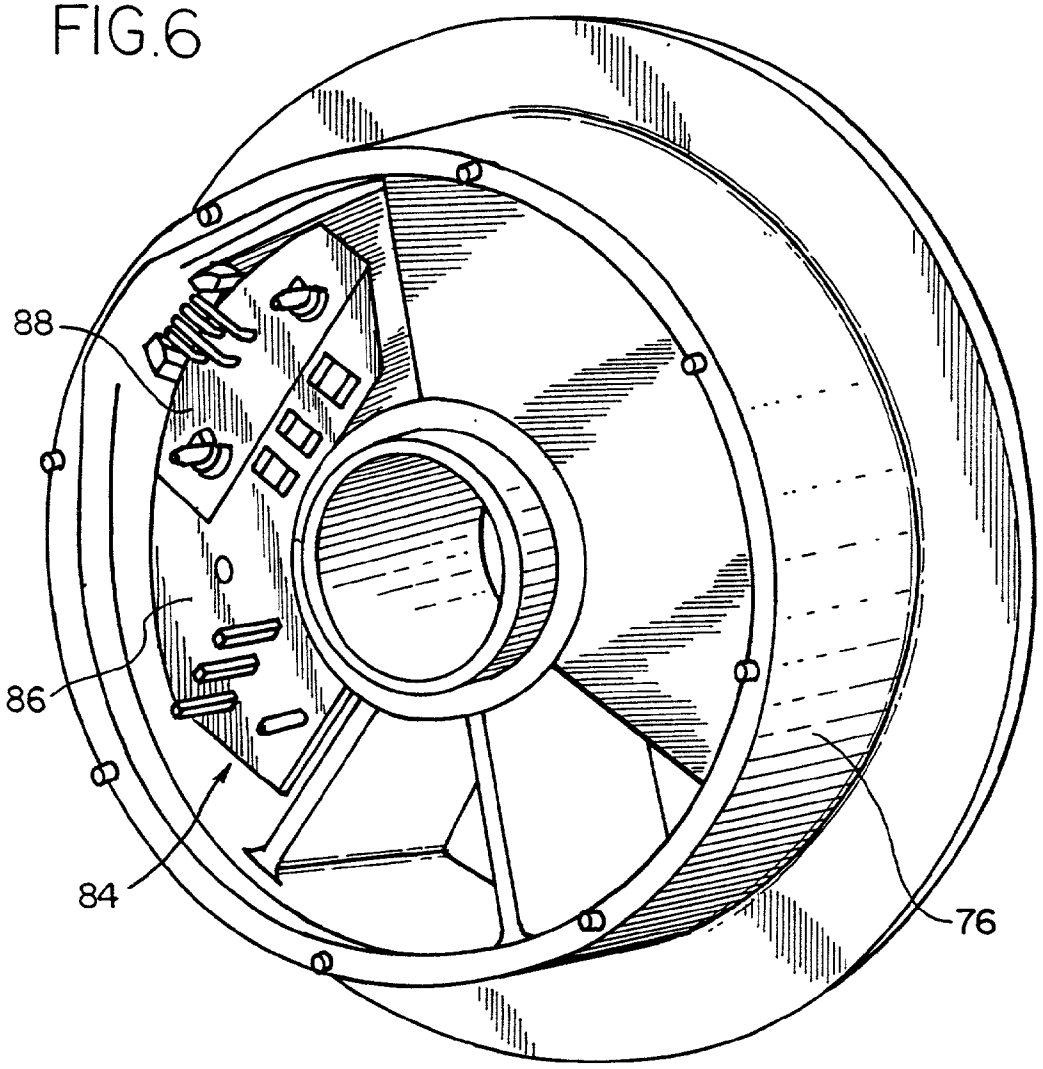

40
42
34
22
44
32
36
24
82
70
68
64
66
30
33
55
54
56
58
60
62
90
52
50
72
75
74
20
38
80
78
76
48
28
46

FIG. 4

FIG.6



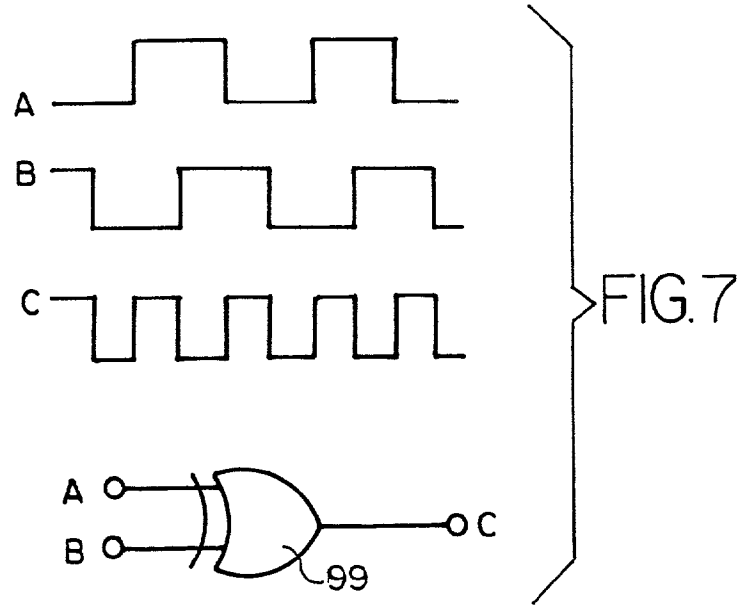
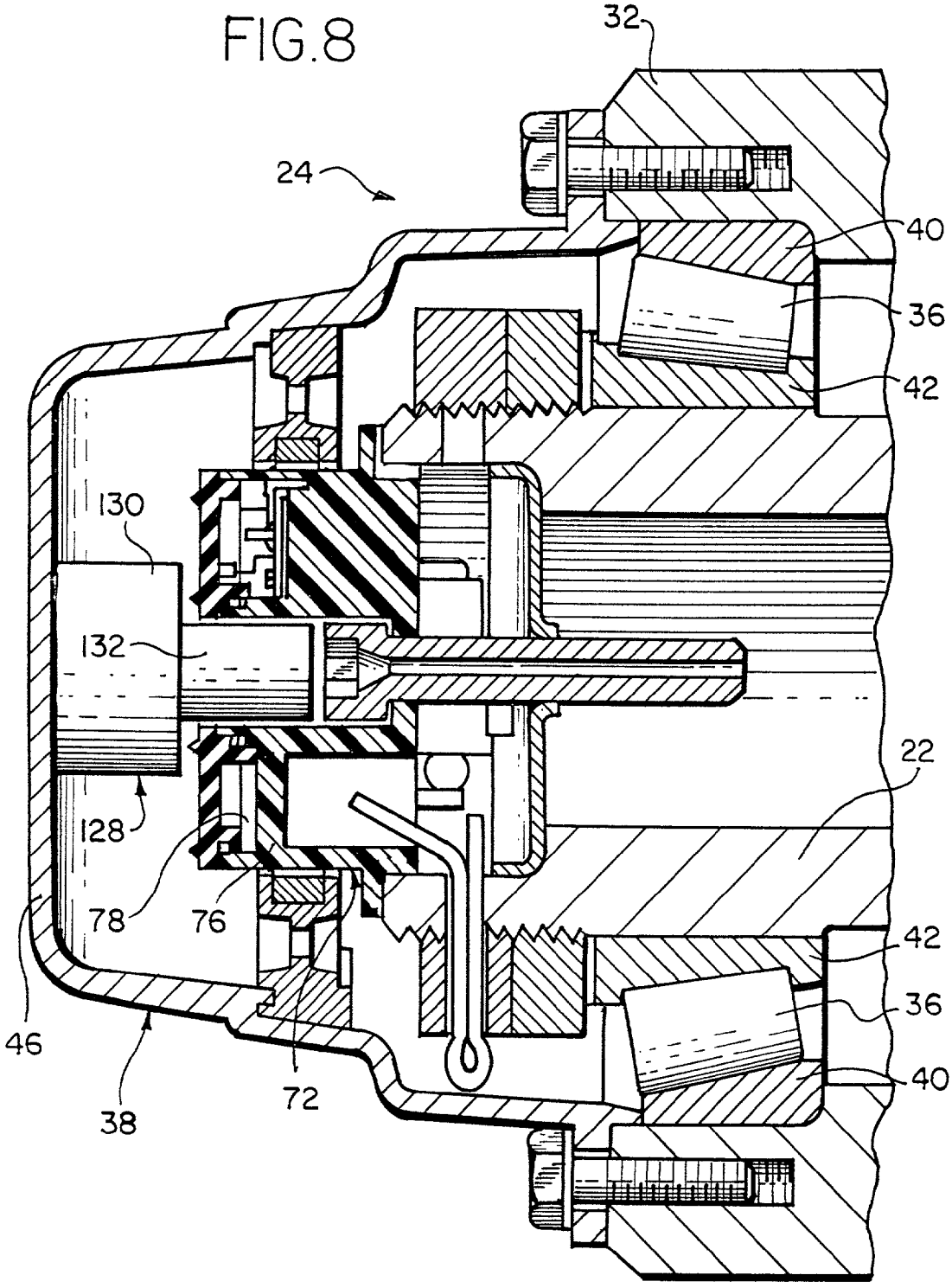


FIG.7

FIG.8



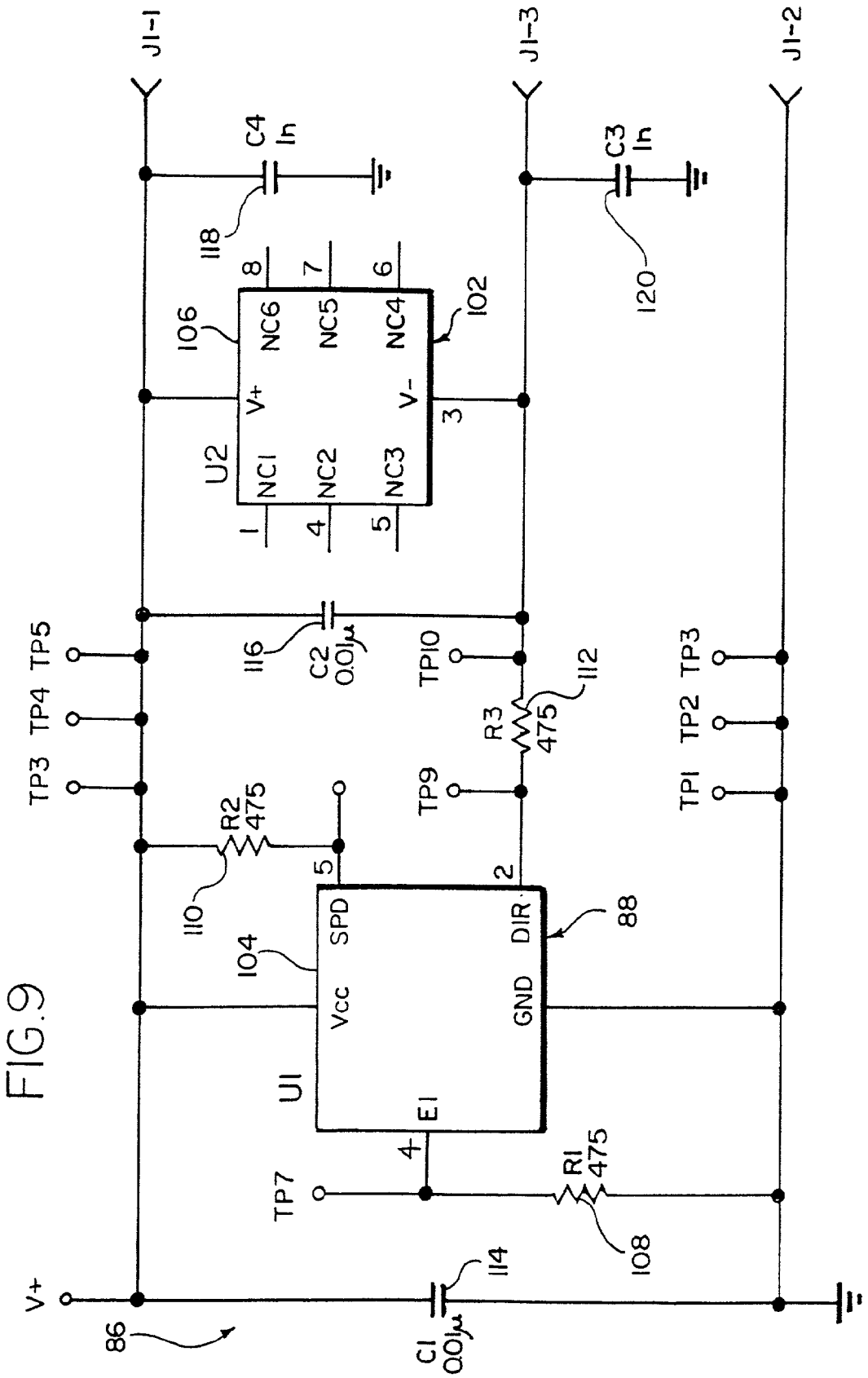

J1-1
J1-3
J1-2
C4 In
C3 In
118
120
8
7
6
106
NC6
NC5
NC4
102
V+
V-
3
U2
NC1
NC2
NC3
1
4
5
116
C2 .001μ
TP10
112
R3 475
TP5 TP4 TP3
TP9
TP3 TP2 TP1
R2 475
110
5
2
104
SPD
DIR
88
Vcc
GND
U1
E1
4
TP7
R1 475
108
V+
114
C1 .001μ
86

FIG. 9

BEARING CONDITION MONITOR FOR A VEHICLE, SUCH AS A TRUCK OR A TRAILER

[0001] This application claims the priority of provisional application Ser. No. 60/171,741, filed on Dec. 22, 1999, and entitled "Sensing System For a Trailer Wheel".

BACKGROUND OF THE INVENTION

[0002] This invention is generally directed to a bearing monitoring system for a vehicle, such as a trailer or a truck. The bearing monitoring system is provided in combination with a wheel speed sensor.

[0003] Wheel bearing failure is a serious occurrence for trucks, trailers and for all wheeled vehicles. A seized bearing can result in the complete loss of a wheel, including both rims and tires. After the wheel separates from the vehicle, the potential for catastrophic damage is present as the wheel may strike other vehicles or stationery objects. Loss of control of the vehicle itself may also result.

[0004] On trailers, both oil and grease lubrication systems are used and correct lubrication plays an important role in continued safe bearing operation. For both oil and grease, the lubrication system can fail. For oil, a seal failure can result in significant oil loss and eventual disruption of the lubricating oil film. For grease, the bearing may not have been packed properly to begin with.

[0005] An advantage with grease is that, even after seal failure, a major leakage still does not occur. In contrast, with oil, significant leakage occurs. This cause loss of lubricant and the oil may contaminate other components. Contaminated brake linings in particular can result in poor and/or unbalanced braking.

[0006] Grease, however, has the disadvantage that the grease cannot really be inspected without removing the hubcap, and ideally the entire hub assembly. In contrast, with oil, a sight glass in the hubcap allows confirmation that oil is present to the correct level.

[0007] It is desirable to have some means of monitoring the integrity of the bearing system, especially for grease applications. This enables the monitoring the presence of lubricant directly. Alternatively, the monitoring means can monitor bearing behavior and provide a warning to the operator if the bearings showed signs of operating without the appropriate lubrication, or if this is not possible, at least provide prior warning of impending failure.

[0008] If the bearing is starved of lubrication, rapid wear occurs which eventually results in bearing failure. Also, bearing temperatures increase. Characteristic vibrations tend to occur as oil films break down and metal to metal contact occurs.

[0009] These effects can potentially be used to provide warning before actual failure.

[0010] In some cases, warning can be provided even before appreciable wear has occurred. By restoring proper lubrication, the bearing system can be put back into service without component replacement. In other cases, however, the warning will be in advance of actual failure but would still require component replacement.

[0011] Either is a significant advantage for trucks and trailers. Avoidance of in service bearing failure, even if component replacement is required, is a great advantage. Not only is safety increased but fleets can potentially move to a maintenance on-demand system. With current practice, wheel hubs and bearings are normally serviced after a given mileage or service time. Wheel ends with lubrication and bearings systems intact and capable of many more miles are dismantled just because of the maintenance schedule. Extending maintenance intervals results in a direct economic advantage. Extending maintenance intervals also has secondary benefits in that for any maintenance operation, there is always the chance that something gets broken or is reassembled incorrectly. Quality control of field operations can rarely be as effective as the quality systems in place at vehicle assembly plants.

[0012] Providing the monitoring function economically is important to achieve mainstream acceptance in the trucking industry. Wiring harnesses which connect to temperature, acceleration and/or proximity sensors are expensive. Also, electronics to process the information and provide warning for the driver and/or maintenance personnel adds additional expense.

[0013] The present invention provides a bearing monitoring system for a vehicle, such as a trailer or a truck. Features and advantages of the present invention will become apparent upon a reading of the specification in combination with a study of the drawings.

OBJECTS AND SUMMARY OF THE INVENTION

[0014] A general object of the present invention is to provide a bearing monitoring system for a vehicle, such as a trailer or a truck.

[0015] An object of the present invention is to provide a bearing monitoring system for a vehicle, such as a trailer or a truck which is provided in combination with a wheel speed sensor.

[0016] Briefly, and in accordance with at least one of the foregoing objects, an embodiment of the present invention provides a bearing monitoring system for monitoring a bearing of a wheel of a vehicle, such as a truck or a trailer. The bearing monitoring system is configured to monitor at least one characteristic relating to the wheel bearings, such as a temperature generally proximate the bearings, vibrations of one or more elements of the wheel mounting apparatus, and/or the proximity of a rotating element of the wheel. The monitoring system may be configured to monitor more than one of these characteristics (i.e., temperature, vibration and proximity) or even all three. The bearing monitoring system is incorporated into a wheel speed sensor. The bearing monitoring system may be incorporated in an anti-lock brake system (ABS) or electro-pneumatic brake system (EBS). Regardless of which characteristic is actually monitored by the system and whether the system is employed with an ABS or EBS, the bearing monitoring system provides that one or more bearings of a vehicle can be continuously and automatically monitored in the field.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The organization and manner of the structure and operation of the invention, together with further objects and advantages thereof, may best be understood by reference to

the following description, taken in connection with the accompanying drawings, wherein like reference numerals identify like elements in which:

[0018] **FIG. 1** is a block diagram of a prior art anti-lock brake system;

[0019] **FIG. 2** is a side elevational view of a trailer and a partial side elevational view of a tractor on which the ABS or EBS which incorporates the features of the present invention is used;

[0020] **FIG. 3** is a block diagram of an anti-lock brake system (ABS) or an electro-pneumatic brake system (EBS) which incorporates the features of the present invention;

[0021] **FIG. 4** is a partial cross-sectional view of a wheel mounting apparatus which includes a wheel speed sensor which incorporates the features of the invention;

[0022] **FIG. 5** is an enlarged section of **FIG. 4**;

[0023] **FIG. 6** is a perspective view of a portion of the wheel speed sensor;

[0024] **FIG. 7** is an enhancement circuit which is used in the present invention;

[0025] **FIG. 8** is a partial cross-sectional view of an alternate wheel mounting apparatus which includes a wheel speed sensor which incorporates the features of the invention;

[0026] **FIG. 9** is an electronic schematic of an implementation of the present invention; and

[0027] **FIG. 10** is a schematic of the wheel speed sensor and ABS.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

[0028] While the invention may be susceptible to embodiment in different forms, there is shown in the drawings, and herein will be described in detail, a specific embodiment with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention, and is not intended to limit the invention to that as illustrated and described herein.

[0029] The present invention provides a bearing monitoring system for monitoring the health of a bearing **34**, **36** of a wheel of a vehicle **26**, such as a truck or a trailer. The bearing monitoring system is configured to monitor at least one characteristic related to the bearings **34**, **36**, such as a temperature generally proximate the bearings **34**, **36**, vibrations of one or more elements of the wheel mounting apparatus **24**, and/or the proximity of a rotating element of the wheel. The monitoring system may be configured to monitor more than one of these characteristics (i.e., temperature, vibration and proximity) or even all three. The bearing monitoring system may be incorporated in an anti-lock brake system (ABS) or electro-pneumatic brake system (EBS). Regardless of which characteristic is actually monitored by the bearing monitoring system and whether the bearing monitoring system is employed with an ABS or EBS, the bearing monitoring system provides that one or more bearings **34**, **36** of the vehicle **26** can be continuously and automatically monitored in the field. The bearing monitoring system of the present invention is provided in a wheel speed sensor **20**.

[0030] The specifics of the physical parameters of the sensor **20** is described in copending patent application Serial No. (Not Yet Assigned), filed on Dec. 21, 2000, entitled "Axle End Wheel Sensor For A Truck Or A Trailer". The specifics of the wheel speed and direction sensing by the sensor **20** is described in co-pending patent application Ser. No. (Not Yet Assigned), filed on Dec. 21, 2000, entitled "Anti-Lock Brake System For A Truck Or A Trailer, Including Back-up Alarm And/or Lamps". Each of these patent applications claim the priority of provisional application Ser. No. 60/171,741 upon which the present application claims priority. Each disclosure of these patent applications are commonly owned by the assignee herein and are incorporated herein in their entirety. The sensor **20** is provided in an apparatus **24** for mounting a wheel on the trailer **26**.

[0031] A block diagram an anti-lock brake system (ABS) or an electro-pneumatic brake system (EBS) for a trailer **26** in accordance with the present invention is shown in **FIG. 3**. The present invention provides a wheel sensing arrangement which provides information to a controller, such as an electronic control module (ECM). Power (12 Volts) to the ECM is supplied from pin 7 of the J560 connector **18** between the tractor **16** and the trailer **26**. The ECM controls a pneumatic control module (PCM) which controls the brake mechanism on the trailer **26**. The ECM also controls the function of a system, such as a warning system in the cab of the tractor **16** which is used to alert the operator, as described herein. The ECM of the ABS or EBS signals the PCM of the ABS or EBS to modify air pressure level at the brake chambers. The braking level is controlled so that the wheels continue to rotate, or at least rotate most of the time, even during heavy braking. The overall process is described in detail in numerous patents and in the pending U.S. patent application Ser. No. 09/306,921, which is commonly owned by the assignee herein and which is incorporated by reference.

[0032] The wheel mounting apparatus **24** generally includes the axle **22**, a wheel hub assembly **28** and a brake mechanism. The brake mechanism is of known construction and as such is not described in detail herein.

[0033] The axle **22** is fixedly mounted on the body of the trailer **26** by suitable means and is formed from a hollow tube (only one end of which is shown in **FIG. 4**). The ends of the hollow axle **22** have a thread form on the exterior surface thereof. The inner surface of each end of the axle **22** has a portion **30** which has an increased inner diameter relative to an inner diameter of a central portion of the axle **22**. The axle **22** is formed from a suitable strong rigid material.

[0034] The wheel hub assembly **28** is mounted on the end of the axle **22** and generally surrounds the axle **22**. The wheel hub assembly **28** includes a wheel hub **32**, a plurality of inner bearings **34**, a plurality of outer bearings **36**, and a metal hub cap **38**. The wheel hub **32** is attached to the brake drum by suitable known means, such as bolts.

[0035] The inner and outer bearings **34**, **36** are mounted between the wheel hub **32** and the axle **22** by respective bearing cups **40** and bearing cones **42** and allow for rotation between the fixed axle **22** and the rotating wheel hub assembly **28** and the brake mechanism. The outer bearings **36** are mounted in the portion **33** such that the bearing cups **40** abut against a shoulder formed by the portion **33**. This

precisely mounts the outer bearings **36** on the axle **22**. The inner and outer bearings **34**, **36** are mounted at locations which are spaced apart from each other along the length of the axle **22** such that a cavity **44** is provided between the wheel hub **32**, the axle **22** and the bearings **34**, **36**. A bath of oil or semi-fluid synthetic grease is contained within the cavity **44**. The bearings **34**, **36** are lubricated by the bath of oil or semi-fluid synthetic grease contained therewithin.

[**0036**] The hub cap **38** surrounds the end of the axle **22** and prevents the oil or grease from leaking out of the end of the wheel hub assembly **28**. The hub cap **38** includes a circular outer end wall **46**, a first side wall **48**, a second side wall **50**, a third side wall **52** and an inner end wall **54**. The walls **46**, **48**, **50**, **52**, **54** are integrally formed with each other. The first side wall **48** is generally perpendicular to the outer end wall **46** and has a first end connected to the outer end wall **46** and tapers from its first end to its second, larger end. The second side wall **50** has a first end connected to the second end of the first side wall **48** and tapers from its first end to its second, larger end. The third side wall **52** has a first end connected to the second end of the second side wall **50** and tapers from its first end to its second, larger end. The inner end wall **54** is annular and is generally perpendicular to the third side wall **52** and has a first end connected thereto and extends outwardly therefrom. The inner end wall **54** is parallel to the outer end wall **46**. A plurality of apertures are provided through the inner end wall **54** through which the hub cap **38** is attached to the end of the wheel hub **32** by suitable means, such as bolts **56**.

[**0037**] The third side wall **52** has an end portion **55** which extends past the inner end wall **54**. When the hub cap **38** is mounted on the wheel hub **32**, the end portion **55** seats within the portion **33** of the wheel hub **32** and abuts against the cones **40** of the outer bearings **36**. This locates the hub cap **38** precisely on the wheel hub **32** and on the axle **22**.

[**0038**] A washer **58** is mounted on the threaded end of the axle **22** and bears against the bearing cones **42** of the outer bearings **36**. An inner adjusting nut is **60** threaded onto the threaded end of the axle **22** and bears against the washer **58**. The adjusting nut **60** is locked onto the axle **22** by threading an outer jam nut **62** on the threaded end of the axle **22**. The adjusting nut **60** is used to properly position the outer bearings **36**. The washer **58**, the inner adjusting nut **60** and the outer jam nut **62** are proximate to the third side wall **52** of the hub cap **38**. The washer **58**, the inner adjusting nut **60** and the outer jam nut **62** do not completely fill the space between the axle **22** and the hub cap **38** such that a space is formed therebetween. It is to be understood that other components can be threaded on the end of the axle **22** to properly position the outer bearings **36**.

[**0039**] A freeze plug **64** sits within and fills the end portion **30** of the axle **22**. The freeze plug **64** has a circular central portion **66** and an annular skirt **68** which depends therefrom. The skirt **68** tightly engages with the inner surface of the end portion **30** of the axle **22**. A central aperture **70** and a second aperture (not shown) therethrough which is offset from the central aperture **70** are provided through the central portion **66** of the freeze plug **64**. A grommet (not shown) is provided within the second aperture. The freeze plug **64** prevents oil or grease from entering into the axle **22** and prevents debris from going from within the axle **22** outwardly therefrom.

[**0040**] The sensor **20** includes a sensor member **72** which is mounted in the end of the axle **22** and is spaced from the freeze plug **64**. The sensor member **72** includes a plastic body **76** which extends partially into the end of the axle **22** and extends outwardly therefrom, and a plastic cover **78** which covers the section of the body **76** which extends outwardly from the end of the axle **22**. The cover **78** is suitably secured to the body **76**. A recess is formed between the body **76** and the cover **78**. A central aperture **80** is provided through the body **76** and the cover **78** and aligns with the central aperture **70** through the freeze plug **64**. A plurality of L-shaped vents **81** are provided through the periphery of body **76** to provide an air passageway from the space between the freeze plug **64** and the body **76** and the space between the sensor member **72** and the hub cap **38**.

[**0041**] The body **76** of the sensor member **72** is fastened to the axle **22** by a bolt **82** which is mounted in the central aperture **80** through the body **76**. The bolt **82** threads with the central aperture **70** through the freeze plug **64**. The thread form in the freeze plug **64** may be pre-tapped or may be generated using a thread forming bolt.

[**0042**] The central aperture **80** in the body **76** allows for the possibility of an air passage through the body **76** if a hollow bolt **82** is utilized as shown. This allows for the incorporation of a central tire inflation (CTI) in the present system. CTI systems automatically keep tires inflated by passing air from a compressed air reservoir mounted on the trailer **26** to the tires. One possible implementation of a CTI system with the present invention passes air through a tube in the hollow axle **22**, then through a swivel connection with a rotating seal to air fittings on the outside of the hub cap **38**. The air is then piped to the inflation valves for the tires. A suitably designed hollow bolt **82** allows for the air to pass from the tube in the hollow axle **22** to the rotating seal in the hub cap **38**. The sensor member **72** of the present invention allows for CTI but does not economically penalize the majority of applications where CTI is not used.

[**0043**] To protect the bearings **36**, **38**, the entire axle end area is sealed from moisture, dirt and other contaminants. Suitable venting is provided so that the seals within the wheel mounting apparatus **24** are not subjected to excessive pressure buildup. Depending on the wheel end construction, different methodologies may be used which use suitable vents in the hub cap **38**, seals and/or the freeze plug **64**. The sensor member **72** of the present invention is compatible with all such approaches. Consequently, the periphery of the body includes the L-shaped venting slots **81** such that pressure on both the front and back of the sensor member **72** remains equalized. As for a conventional wheel end construction, venting and sealing are controlled by the hub cap, freeze plug and bearing seals. It should be noted that, depending on the application and the method of lubrication of the bearings, all parts of the sensor member **72** may be subject to oil splash. The design and material of the sensor member **72** of the present invention allows for operation in this environment.

[**0044**] An electronic circuit assembly **84** is provided between the body **76** and the cover **78** of the sensor member **72**. The electronic circuit assembly **84** includes a printed circuit board **86** mounted on the body **76** by suitable means such that the printed circuit board **86** is positioned between the body **76** and the cover **78** of the sensor member **72**. Wires **90** extend from the printed circuit board **86** through the grommet in the freeze plug **64**, through the hollow axle **22**

to a current supplying controller **92**. The controller **92** is preferably the ECM of the ABS or EBS of the trailer **26**. If desired, a second controller can be provided.

[**0045**] Wheel speed sensing elements **94, 96** are provided on the printed circuit board **86** in the form of an application specific integrated circuit (ASIC) **88**. The preferred embodiment of the present invention uses "active" technology.

[**0046**] The wheel speed sensing elements **94, 96** are preferably a pair of hall effect semiconductor elements. The hall effect semiconductor elements **94, 96** can be soldered to the printed circuit board **86** at the outermost end thereof and at spaced locations from each other. Preferably, however, the hall effect semiconductor elements **94, 96** are located on the same silicon chip. This aids in overall economy and, because of the use of standard integrated circuit fabrication techniques, relative location can be controlled. The face of each hall effect semiconductor sensing element **94, 96** is parallel to the axis of rotation of the axle **22**. It is to be understood that conventional VR sensors can be used instead of hall effect semiconductor sensing elements **94, 96**.

[**0047**] The second side wall **50** of the hub cap **38** is machined to provide a recess in which a mounting wheel **75** is located. To secure the mounting wheel **75** to the inside of the second side wall **50**, the metal second side wall **50** is deformed. This precisely locates the mounting wheel **75** on the hub cap **38**. Because the hub cap **38** is precisely mounted on the wheel hub **32** and axle **22** as discussed herein, the mounting wheel **75** is precisely mounted on the wheel hub **32** and axle **22**.

[**0048**] An exciting ring **74** is mounted on the inner surface of the mounting wheel **75** and is proximate to, but spaced from the hall effect semiconductor sensing elements **94, 96**. Because the mounting wheel **75** is precisely mounted on the wheel hub **32** and axle **22**, the exciting ring **74** is precisely mounted on the wheel hub **32** and axle **22**. The exciting ring **74** and the sensor member **20** are concentric with each other when mounted. As such, a defined radial gap is provided between the exciting ring **74** and the hall effect semiconductor sensing elements **94, 96**. The hall effect semiconductor sensing elements **94, 96** are mounted on the printed circuit board **86** so as to precisely line up with the exciting ring **74** when the hub cap **38** is mounted on the wheel hub **32**.

[**0049**] Because the face of each hall effect semiconductor sensing element **94, 96** is parallel to the axis of rotation of the axle **22**, a constant gap is maintained by the bearings **36**. Axial movement of the wheel hub **32** does not have a significant effect and no gap adjustment is required. The gap is set by design, and gap variation is directly controlled by the bearings **36**. The gap is dependent on the concentricity of the mounting of the exciting ring **74** within the hub cap **38**.

[**0050**] In the preferred implementation, the exciting ring **74** is a multi-pole magnet fabricated using ferrite in a plastic matrix material. Because the exciting ring **74** is carried on the mounting wheel **75** mounted inside the hub cap **38**, the magnet poles can be located precisely both circumferentially around the sensor member **72** and radially relative to the sensor member **72**. The gap between the exciting ring **74** and the hall effect semiconductor sensing elements **94, 96** is radial so that the gap is directly controlled by the position of the bearings **36** and is not influenced by axial movement of the wheel hub **32**. Alternatively, a stamped, toothed ring can be used as the exciting ring **74**.

[**0051**] The hall effect semiconductor sensing elements **94, 96** are spaced apart from each by an integral number of pole pairs or teeth, depending on the type of exciting ring **74** that is used, plus or minus approximately ninety degrees.

[**0052**] To allow for overall optimization of the sensor member **72** and for ABS function or EBS function, when the present invention is used in an ABS or EBS as described herein, the preferred embodiment of the exciting ring **74** does not conform to the present industry standard of one hundred teeth. Instead, the present invention uses twenty-five pole pairs in the exciting ring **74**. These pole pairs are precisely located so that with use of suitable electronic resolution enhancement techniques, an information rate equivalent to fifty pole pairs using standard techniques is achieved.

[**0053**] **FIG. 7** illustrates a circuit which implements this resolution enhancement technique. Signals A and B originate from the hall effect semiconductor sensing elements **94, 96**. Signals A and B are input into an XOR gate **99**. The resulting waveform is generated as output C. Other suitable circuits can be used.

[**0054**] Individual active sensing elements are the preferred sensing elements for the sensing elements **94, 96** of the present invention. The chips which implement the Hall effect function are small. Relative location can be tightly controlled by mounting on the same printed circuit board. The two hall effect semiconductor elements **94, 96** can be located on the same silicon chip. This aides overall economy and, because of the use of standard integrated circuit fabrication techniques, relative location becomes almost a non-issue. Two integrated circuits can be provided on the silicon chip, each having a hall effect element thereon.

[**0055**] A temperature sensing element **100** is provided on the printed circuit board **86** and may be in the form of an application specific integrated circuit (ASIC) **102**. Numerous implementations of the temperature sensing element **100** are possible as would be understood by one of ordinary skill in the art. The temperature sensing element **100** is used to monitor the temperature of the bearings **34, 36** in the wheel mounting apparatus **24** by measuring the temperature of the components of the wheel mounting apparatus **24**. The temperature of the bearings **34, 36** will increase under operating conditions if the bearings **34, 36** are insufficiently lubricated which occurs when insufficient oil or grease is present in the chamber **44**. The provision of the temperature sensing element **100** in the electronic circuit assembly **84** is ideal for monitoring the bearings **34, 36** as the printed circuit board **86** is in close proximity to the bearings **34, 36**.

[**0056**] The details of an implementation of the sensor electronics which are used to determine speed, direction and temperature is shown in **FIG. 9**. One of ordinary skill in the art could form other suitable implementations. The circuit as shown in **FIG. 9** includes an integrated circuit **104**, integrated circuit **106**, resistors **108, 110, 112**, and capacitors **114, 116, 118, 120**.

[**0057**] A suitable integrated circuit **104** is an Allegro A3422LKA integrated circuit. The two hall effect semiconductor elements **94, 96** are embedded on one piece of silicon

in the integrated circuit **104** such that the two hall effect semiconductor elements **94**, **96** are spaced a suitable distance for quadrature implementation. The Vcc pin 1 of integrated circuit **104** is a voltage input. The DIR pin 2 of integrated circuit **104** outputs direction information using high/low logic. The GND pin 3 of integrated circuit **104** is connected to ground. The SPD pin 5 of integrated circuit **104** outputs a frequency signal proportional to wheel speed. The SPD pin 5 of integrated circuit **104** implements the resolution enhancement functionality shown in **FIG. 7**. Resistor **110** is connected to pin 5. The EI pin 4 of integrated circuit **104** is connected to ground by resistor **108**.

[**0058**] Integrated circuit **106** senses the temperature of the components of the wheel mounting apparatus **24** and provides a current output which varies with temperature. A suitable integrated circuit **106** is an AD TMP17 integrated circuit.

[**0059**] In operation, to determine the speed and direction of rotation of the wheels, the wheel hub **32**, the hub cap **38**, the mounting wheel **75** and the exciting ring **74** rotate relative to the fixed axle **22** and the sensor member **72** mounted thereon. The controller **92** supplies electric current to the sensor member **72** through connection **J1-1**. The sensor member **72** is a current sink. The hall effect semiconductor sensing elements **94**, **96** sense whether a north pole or a south pole of the exciting ring **74** is present.

[**0060**] If a multi-pole magnet is used as the exciting ring **74**, if a north pole is present, the hall effect semiconductor sensing elements **94**, **96** sink 14 mamps, for example, from the controller **92**, and if a south pole is present, the hall effect semiconductor sensing elements **94**, **96** sink 7 mamps, for example, from the controller **92**. This information is conveyed to another part of the ASIC **88**, to obtain a square wave as the poles are going by. The controller **92** determines how many times the sensor member **72** switches between 14 mamps and 7 mamps. This change happens one hundred times every revolution of the wheel. If a toothed wheel is used as the exciting ring **74** and a tooth is present, the hall effect semiconductor sensing elements **94**, **96** sink 14 mamps, for example, from the controller **92**. On the other hand, if a space is present, the hall effect semiconductor sensing elements **94**, **96** sink 7 mamps, for example, from the controller **92**. This information is conveyed to another part of the ASIC **88**, to obtain a square wave as the poles are going by. The controller **92** determines how many times the sensor member **72** switches between 14 mamps and 7 mamps. This change happens one hundred times every revolution of the tire. It is to be understood that the 14 mamps and 7 mamps values described herein are nominal. These values could be other nominal values, such as 12 mamps and 6 mamps, or 10 mamps and 5 mamps.

[**0061**] The frequency of the change is proportional to the wheel speed. This information is used by the ABS or EBS to function in a like manner to how a conventional wheel speed sensor information is used to slow the trailer **26**, if necessary.

[**0062**] The frequency output on the SPD pin 5 of integrated circuit **104** is implemented using high/low voltage levels. As implemented in the circuit shown in **FIG. 9**, this voltage signal is converted into a two level current signal by the presence of resistor **110**. SPD pin 5 pulls current through resistor **110** when SPD pin 5 is low. When SPD pin 5 is high, current is not pulled through resistor **110**. The interface electronics then senses the current variation. This keeps the overall wiring interface to three leads, power, ground and direction. Current pulses in the power lead correspond to the passage of poles as the exciting ring **74** rotates or to the passage of teeth if a toothed ring is used. The E1 signal output on pin 4 from the integrated circuit **104** is not required in this application and is held at ground by resistor **108**. The capacitors **114**, **116** provide noise suppression.

[**0063**] The integrated circuit **104** does not output a current, such that a low is provided, on DIR pin 2 when the trailer **26** is backing up. The controller **92**, which is the ECM of the ABS or EBS, detects that the integrated circuit **104** is not outputting current and determines that the trailer **26** is backing up. Because the forward and reverse wheel speed information is available to the controller **92**, the information can be used to provide enhanced functionality over and above that of ABS or EBS without the forward and reverse wheel speed information.

[**0064**] Current is supplied from the ECM through connection **J1-1**, flows through integrated circuit **106** and then out to the ECM through connection **J1-3**. The ECM completes the current path to ground and monitors this current.

[**0065**] The signal is shared with the reverse indication. When reverse rotation occurs, the DIR output of integrated circuit **104** is pulled low so the current from integrated circuit **104** flows to ground through resistor **112**. The current flow to the ECM (via **J1-3**) goes to near zero. This is interpreted by the ECM as an indication that the trailer **26** is backing up and that the temperature indication is not available. Because the temperature information and the direction information are output on the same pin (i.e. **J1-3**), the ECM determines what sensor, whether from the semi-conductor sensing elements **94**, **96** or the temperature sensing element **100**, the signal is being sent from. Utilization of connection **J1-3** for both functions is important because extra wiring and connections are very expensive. The entire sensing system, including wheel speed sensing, direction sensing and temperature sensing is implemented with only three wires (i.e. **J1-1**, **J1-2** and **J1-3**), thereby generating significant cost savings. Also, by incorporating the signal processing and warning electronics into the ECM of the ABS, further savings are achieved in overall system cost.

[**0066**] If the bearings **34**, **36** heat up to a predetermined amount, the ECM determines that there is a bearing problem by comparing the signals received from the temperature sensing element **100** to a known value, and activates the circuitry to alert the operator that the bearings **34**, **36** need to be serviced. The circuitry can light a warning light on the trailer **26**, a warning light in the cab of the tractor **16** and/or can send the information to a trailer tracking system.

[**0067**] While the practical implementation of this sensor **20** is with the ABS, the sensor **20** can be used without ABS and with a current supplying controller. As noted earlier many tractors have power available on Pin 7 of the auxiliary connector. In all cases, on new trailers, Pin 7 is connected to the ECM of the ABS or EBS. It should also be noted that this power supply, under current mandated requirements, is not required to be dedicated solely to the ABS function or EBS function.

[**0068**] An acceleration sensing element **122**, such as an accelerometer, is also provided on the printed circuit board

86 and may form part of the ASIC 102 or may be a separate integrated circuit sensing element on the printed circuit board 86. Other suitable implementations of the acceleration sensing element 122 can be implemented by one of ordinary skill in the art. The acceleration sensing element 122 senses vibrations of one or more elements of the wheel mounting apparatus 24 and transmits this information to the controller 92. The acceleration sensing element 122 may be a silicon micromachined integrated circuit. Because the printed circuit board 86 is mounted to the body 76 of the sensor 20 and the sensor 20 is mounted to the end of the axle 22, vibrations of one or more elements of the wheel mounting apparatus 24 with some attenuation, are transmitted to the acceleration sensing element 122. The provision of the acceleration sensing element 122 in the electronic circuit assembly 84 is ideal for monitoring the bearings 34, 36 as the printed circuit board 86 is in close proximity to the bearings 34, 36.

[0069] As lubrication fails or partially fails and some direct metal to metal contact occurs between the bearing 34, 36 and the cups 40 and/or cones 42, some characteristic vibrations occur. The acceleration sensing element 122 detects these vibrations. The raw signal is sent to the ECM and the ECM processes the raw signal and extracts frequency information. The ECM compares this frequency to known frequencies to determine whether this is an incorrect signal. If an incorrect signal is determined by the ECM, the ECM determines that there is a bearing problem and activates the circuitry to alert the operator that the bearings 34, 36 need to be serviced. The circuitry can light a warning light on the trailer 26, a warning light in the cab of the tractor 16 and/or can send the information to a trailer tracking system. Alternatively, the acceleration signals from the acceleration sensing element 122 can be processed locally in the printed circuit board 86. The ECM of the ABS is preferably used to process the raw signal, because the ECM is comprised of relatively inexpensive electronic hardware, and because the ECM also allows comparison of signals from two or all wheels on the trailer 26 as discussed herein.

[0070] Metal proximity sensing elements 124, 126, see FIG. 10, are provided on the printed circuit board 86 and may form part of the ASIC 102. Proximity sensing element 124 senses radial proximity of the wheel mounting apparatus 24 and proximity sensing element 126 senses axial proximity of the wheel mounting apparatus 24. The proximity sensors 124, 126 measure the instantaneous location of the hub cap 38 relative to the axle 22 and, as such, can be used to determine disturbances in the circular trajectory of the rotating components of the wheel mounting apparatus 24. These disturbances may result from poor or loose adjustment of the bearings 34, 36 or the onset of wear in the bearings 34, 36. It should also be noted that axial free play results from bearing 34, 36 adjustment which is too loose and which eventually would result in premature wear of the bearings 34, 36. If there are issues with bearing wear, the wheel hub 32 will not move in a circular movement.

[0071] If the bearings 34, 36 are loose, axial movement of the wheel hub 32 occurs. It is to be understood that either of, or both of, the radial proximity sensing element 124 and the axial proximity sensing element 126 may be incorporated to help determine bearing system integrity. Because the body 76 and the cover 78 of the sensor 20 are constructed of a plastic material, the body 76 and the cover 78 do not have an effect on the metal sensing proximity sensing elements 124, 126. The provision of the proximity sensing elements 124, 126 in the electronic circuit assembly 84 is ideal for monitoring the bearings 34, 36 as the printed circuit board 86 is in close proximity to the bearings 34, 36.

[0072] An inwardly protruding metal extension 128 which is mounted on the end wall 46 of the hub cap 38 and extends inwardly along the axis of rotation of the axle 22.

[0073] The extension 128 has a first portion 130 which is mounted to the end wall 46 and a second portion 132 which extends therefrom. The first portion 130 has a larger diameter than the second portion 132. The second portion 132 of the extension 128 extends into the hollow center of the sensor member 20 and is monitored by the radial proximity sensing element 124 and/or an axial proximity sensing element 126. The radial proximity sensing element 124 and/or the axial proximity sensing element 126 may be a suitable eddy current or other proximity sensing element along with the electronic circuit assembly 84. Alternatively, the extension 128 may be mounted in the body 76 of the sensor member 20 and be wired to the electronic circuit assembly 86.

[0074] The radial sensing element 124 senses the position of the metal second portion 132 of the extension 128 in that it senses the distance between the second portion 132 and the radial sensing element 124. Therefore, the distance between the entire rotating portion of the wheel mounting apparatus 24 relative to the axle 22 is sensed. The radial sensing element 124 sends this information to the ECM. The ECM processes this information. If the ECM detects some change in distance, the ECM activates the circuitry to provide the warning that the bearings 34, 36 need to be serviced. The circuitry can light a warning light on the trailer 26, a warning light in the cab of the tractor 16 and/or can send the information to a trailer tracking system.

[0075] The axial sensing element 126 senses the position of the metal first portion 130 of the extension 128 in that it senses the distance between the first portion 130 and the axial sensing element 126. Therefore, the distance between the entire rotating portion of the wheel mounting apparatus 24 relative to the axle 22 is sensed. The axial sensing element 126 sends this information to the ECM. The ECM processes this information. If the ECM detects some change in distance, for example 12 thousandths, the ECM activates the circuitry to provide the warning that the bearings 34, 36 need to be serviced. The circuitry can light a warning light on the trailer 26, a warning light in the cab of the tractor 16 and/or can send the information to a trailer tracking system.

[0076] The signals from the proximity sensing elements 124, 126 can processed locally in the printed circuit board 86 or can be fed back as a raw signal to the ECM. The ECM of the ABS is preferably used to process the raw signal, because the ECM is comprised of relatively inexpensive electronic hardware, and because the ECM also allows comparison of signals from all wheels on the vehicle as discussed herein.

[0077] Preferably, a sensor member 20 is provided on each wheel of the vehicle 26. The ECM compares the two (single axle vehicle) or four (double axle vehicle) temperature, acceleration and/or proximity signals from all wheels on the vehicle 26 and compares the signals with each other in the ECM as part of an abnormality detection routine carried out

in the ECM. This is particularly important with regard to temperature. The ambient temperature widely varies with the operating environment of the vehicle **26**. By comparing the temperature signals from each wheel, the variation due to ambient temperature can be ignored. Temperature deviations due to bearing abnormalities can then be isolated. This approach can also be important for acceleration or proximity sensing. For example, on a very smooth road surface, it is possible to be more sensitive in detection of bearing health. In contrast, on a rough road surface, it is necessary for the system to be more tolerant of the severe vibrations generated by the travel over the rough road to avoid false warning signals. By comparing signals from all wheels of the vehicle **26**, the prevailing normal condition can be determined, and therefore abnormal deviations can be detected.

[**0078**] The sensor member **20** utilizes some or all of the wiring to the ABS. As shown in **FIG. 9**, the temperature sensing element **100** shares the same signal wire which also provides the direction signal from the speed sensing elements **92, 94**. It is to be noted that temperature sensing is not active when the trailer **26** is in reverse.

[**0079**] The temperature sensing element **100** and the acceleration sensing element **122** can share the same signal wire (and may also share the signal wire with the direction sensing elements **92, 94**). Signals from the acceleration sensing element **122** are AC signals, while signals from the temperature sensing element **100** are slowly varying DC signals. Thus, the acceleration and temperature signals can share the same wire and can be separated in the ECM.

[**0080**] The direction sensing elements **92, 94**, the temperature sensing element **100**, the acceleration sensing element **122** and the proximity sensing elements **124, 126** can also share the same signal wire. This is dependent on the frequency ranges of the signals which are usable by the ECM. It is possible to time multiplex these signals so that they are examined in rotation by the ECM.

[**0081**] Another implementation (not shown) of this aspect of the present invention can utilize magnetic field sensors in the electronic circuit assembly **84** to track the location of the existing exciting ring **74**. A further implementation provides an additional magnet (not shown) located on the mounting wheel **76**.

[**0082**] While a preferred embodiment of the present invention is shown and described, it is envisioned that those skilled in the art may devise various modifications of the present invention without departing from the spirit and scope of the appended claims.

The invention claimed is:

1. A bearing monitoring system for a vehicle comprising:

an axle;

a wheel mounting apparatus surrounding said axle, said wheel mounting apparatus including at least one bearing;

a wheel mounted on said wheel mounting apparatus;

a sensor member mounted on said axle, said sensor member having a first sensing element mounted thereon for use in determining the temperature of said at least one bearing; and

circuitry for processing information from said sensor member regarding the temperature of said at least one bearing and for performing a function on the vehicle depending on the information sensed by said first sensing element.

2. A bearing monitoring system as defined in claim 1, wherein said circuitry is part of an anti-lock brake system or an electro-pneumatic brake system for the vehicle.

3. A bearing monitoring system as defined in claim 1, wherein said first sensing element is an application specific integrated circuit.

4. A bearing monitoring system as defined in claim 1, wherein said axle including at least two wheel mounting assemblies surrounding said axle, each said wheel mounting apparatus including at least one bearing; a wheel mounted on each said wheel mounting apparatus; a sensor member mounted on each said axle and associated with each said wheel, each said sensor member having a first sensing element mounted thereon for use in determining the temperature of said at least one bearing associated with said respective wheel; the information from each said sensor member being transmitted to said circuitry, and wherein said circuitry compares the information from each said sensor member prior to performing said function.

5. A bearing monitoring system as defined in claim 1, wherein two axles are provided, said axle including at least two wheel mounting assemblies surrounding said axle, each said wheel mounting apparatus including at least one bearing; a wheel mounted on each said wheel mounting apparatus; a sensor member mounted on each said axle and associated with each said wheel, each said sensor member having a first sensing element mounted thereon for use in determining the temperature of said at least one bearing associated with said respective wheel; the information from each said sensor member being transmitted to said circuitry, and wherein said circuitry compares the information from each said sensor member prior to performing said function.

6. A bearing monitoring system as defined in claim 1, wherein said sensor member further includes a second sensing element mounted thereon for use in determining the vibrations of one or more elements of the wheel mounting apparatus; and

wherein said circuitry is capable of processing information from said second sensing element regarding the acceleration of said wheel.

7. A bearing monitoring system as defined in claim 6, further including a signal wire connected between said sensor member and said circuitry, wherein said information from said sensor member regarding the temperature of said at least one bearing and said information from said sensor member regarding the acceleration of said wheel are transmitted to said circuitry on said signal wire.

8. A bearing monitoring system as defined in claim 7, wherein said sensor member further includes a third sensing element mounted thereon for use in determining the direction of rotation of said wheel; and

wherein said circuitry is capable of processing information from said sensor member regarding the direction of rotation of said wheel, said information from said sensor member regarding the direction of rotation of said wheel is transmitted to said circuitry on said signal wire.

9. A bearing monitoring system as defined in claim 7, further including an element mounted on said wheel mounting apparatus;

and wherein said sensor member further includes a fourth sensing element mounted thereon for use in determining the proximity of said element relative thereto by sensing the position of said element; and

wherein said circuitry is capable of processing information from said fourth sensing element regarding the proximity of said element, said information from said sensor member regarding the proximity of said element is transmitted to said circuitry on said signal wire.

10. A bearing monitoring system as defined in claim 1, further including an element mounted on said wheel mounting apparatus;

and wherein said sensor member further includes a second sensing element mounted thereon for use in determining the radial and/or axial proximity of said element relative thereto by sensing the radial and/or axial position of said element;

wherein said circuitry is capable of processing information from said sensor member regarding the radial and/or axial position of said element.

11. A bearing monitoring system as defined in claim 1,

further including an element mounted on said wheel mounting apparatus;

wherein said sensor member further includes a second sensing element mounted thereon for use in sensing vibrations of one or more elements of the wheel mounting apparatus and a third sensing element mounted thereon for use in determining the radial and/or axial proximity of said element relative thereto by sensing the position of said element; and

wherein said circuitry is capable of processing information from said sensor member regarding the vibrations of one or more elements of the wheel mounting apparatus and said circuitry is capable of processing information from said sensor member regarding the radial and/or axial position of said element.

12. A bearing monitoring system as defined in claim 1, wherein said sensor member further includes a second sensing element mounted thereon for use in determining the speed of rotation of said wheel; and

wherein said circuitry is capable of processing information from said second sensing element regarding the speed of said wheel.

13. A bearing monitoring system as defined in claim 12, further including an exciting element mounted on said wheel mounting apparatus; and wherein said second sensing element determines the speed of rotation of said wheel by sensing said exciting element.

14. A bearing monitoring system for a vehicle comprising:

an axle;

a wheel mounting apparatus surrounding said axle, said wheel mounting apparatus including at least one bearing;

a wheel mounted on said wheel mounting apparatus;

a sensor member mounted on said axle, said sensor member having a first sensing element mounted thereon for use in sensing vibrations of one or more elements of the wheel mounting apparatus; and

circuitry for processing information from said sensor member regarding the vibrations of one or more elements of said wheel mounting apparatus and for performing a function on the vehicle depending on the information sensed by said first sensing element.

15. A bearing monitoring system as defined in claim 14, wherein said circuitry is part of an anti-lock brake system or an electro-pneumatic brake system for the vehicle.

16. A bearing monitoring system as defined in claim 14, wherein said first sensing element is a silicon micromachined integrated circuit.

17. A bearing monitoring system as defined in claim 14, wherein said axle including at least two wheel mounting assemblies surrounding said axle, each said wheel mounting apparatus including at least one bearing; a wheel mounted on each said wheel mounting apparatus- a sensor member mounted on each said axle and associated with each said wheel, each said sensor member having a first sensing element mounted thereon for use in sensing vibrations of one or more elements of each said wheel mounting apparatus; the information from each said sensor member being transmitted to said circuitry, and wherein said circuitry compares the information from each said sensor member prior to performing said function.

18. A bearing monitoring system as defined in claim 14, wherein two axles are provided, each said axle including at least two wheel mounting assemblies surrounding said axle, each said wheel mounting apparatus including at least one bearing; a wheel mounted on each said wheel mounting apparatus; a sensor member mounted on each said axle and associated with each said wheel, each said sensor member having a first sensing element mounted thereon for use in determining the acceleration of said wheel by sensing vibrations of one or more elements of each said wheel mounting apparatus; the information from each said sensor member being transmitted to said circuitry, and wherein said circuitry compares the information from each said sensor member prior to performing said function.

19. A bearing monitoring system as defined in claim 14, wherein signals accumulated by said first sensing element are processed in said sensor member.

20. A bearing monitoring system as defined in claim 14, wherein signals accumulated by said first sensing element are processed by said circuitry.

21. A bearing monitoring system as defined in claim 14, wherein said sensor member further includes a second sensing element mounted thereon for use in determining the speed of rotation of said wheel; and

wherein said circuitry is capable of processing information from said sensor member regarding the speed of said wheel.

22. A bearing monitoring system as defined in claim 14, further including an exciting element mounted on said wheel mounting apparatus; and wherein said second sensing element determines the speed of rotation of said wheel by sensing said exciting element.

23. A bearing monitoring system as defined in claim 14, further including an element mounted on said wheel mounting apparatus;

and wherein said sensor member further includes a second sensing element mounted thereon for use in determining the radial and/or axial proximity of said element relative thereto by sensing the position of said element; and

wherein said circuitry is capable of processing information from said second sensing element regarding the radial and/or axial position of said element.

24. A bearing monitoring system for a vehicle comprising:

an axle;

a wheel mounting apparatus surrounding said axle, said wheel mounting apparatus including at least one bearing;

a wheel mounted on said wheel mounting apparatus;

an element mounted on said wheel mounting apparatus;

a sensor member mounted on said axle, said sensor member having a first sensing element mounted thereon for use in determining the radial and/or axial proximity of said element relative thereto by sensing the radial and/or axial position of said element relative to said first sensing element; and

circuitry for processing information from said sensor member regarding the radial and/or axial proximity of said element and for performing a function on the vehicle depending on the information sensed by said first sensing element.

25. A bearing monitoring system as defined in claim 24, wherein said circuitry is part of an anti-lock brake system or an electro-pneumatic brake system for the vehicle.

26. A bearing monitoring system as defined in claim 24, wherein said wheel mounting apparatus includes a hub cap and wherein said element is an exciting element mounted on said hubcap which surrounds said sensor member.

27. A bearing monitoring system as defined in claim 24, wherein said wheel mounting apparatus includes a hub cap and wherein said element is mounted on said hubcap and extends into said sensor member.

28. A bearing monitoring system as defined in claim 24, wherein said axle includes at least two wheel mounting assemblies surrounding said axle, each said wheel mounting apparatus including at least one bearing; a wheel mounted on each said wheel mounting apparatus; a sensor member mounted on each said axle and associated with each said wheel, each said sensor member having a first sensing element mounted thereon for use in determining the radial and/or axial proximity of said element relative thereto by sensing the position of said element associated with said respective wheel relative to the respective first sensing element; the information from each said sensor member being transmitted to said circuitry, and wherein said circuitry compares the information from each said sensor member prior to performing said function.

29. A bearing monitoring system as defined in claim 24, wherein two axles are provided, each said axle including at least two wheel mounting assemblies surrounding said axle, each said wheel mounting apparatus including at least one bearing; a wheel mounted on each said wheel mounting apparatus; a sensor member mounted on each said axle and associated with each said wheel, each said sensor member having a first sensing element mounted thereon for use in determining the radial and/or axial proximity of said element relative thereto by sensing the position of said element associated with said respective wheel relative to the respective first sensing element; the information from each said sensor member being transmitted to said circuitry, and wherein said circuitry compares the information from each said sensor member prior to performing said function.

30. A bearing monitoring system as defined in claim 24, wherein said sensor member further includes a second sensing element mounted thereon for use in determining the speed of rotation of said wheel; and

wherein said circuitry is capable of processing information from said second sensing element regarding the speed of said wheel.

31. A bearing monitoring system as defined in claim 30, wherein said element is an exciting element; and wherein said second sensing element determines the speed of rotation of said wheel by sensing said exciting element.

32. A bearing monitoring system for monitoring a bearing of a wheel of a vehicle, said bearing monitoring system comprising:

brake mechanisms;

circuitry in operable communication with said brake mechanisms;

wheel speed sensors in communication with said circuitry, said circuitry configured to operate said brake mechanisms depending on what is sensed by said wheel speed sensors; and

at least one bearing sensor configured to monitor at least one characteristic at least generally relating to the bearing, said characteristic being at least one of a temperature proximate the bearing, vibrations of one or more elements of said wheel mounting apparatus and proximity of a rotating element of the wheel.

33. A bearing monitoring system as defined in claim 32, wherein said circuitry comprises a pneumatic control module in operable communication with said brake mechanisms and an electronic control module in communication with said pneumatic control module, said at least one bearing sensor and said wheel speed sensors in communication with said electronic control module.

34. A bearing monitoring system as defined in claim 32, further comprising an electronic circuit assembly, said electronic circuit assembly including said bearing sensor and at least one of said wheel speed sensors.

35. A bearing monitoring system as defined in claim 32, wherein said at least one bearing sensor comprises a plurality of sensors including a first sensor configured to sense a temperature generally proximate the bearing, a second sensor configured to monitor vibrations of one or more elements of said wheel mounting apparatus, and a third sensor configured to monitor the proximity of the rotating element of the wheel.

36. A bearing monitoring system as defined in claim 35, further comprising an electronic circuit assembly, said electronic circuit assembly including said first, second and third sensor and at least one of said wheel speed sensors.

37. A bearing monitoring system as defined in claim 32, wherein said at least one bearing sensor is configured to monitor at least one of a radial and axial position of the rotating member of the wheel.

38. A bearing monitoring system as defined in claim 32, wherein said at least one bearing sensor comprises at least

one magnetic field sensor configured to monitor a magnetic feature relating to the bearing.

39. A bearing monitoring system as defined in claim 32, wherein said bearing monitoring system is configured to monitor a plurality of bearings, and comprises at least one bearing sensor associated with each bearing, wherein said circuitry is configured to receive information from each of the bearing sensors and compare the information.

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