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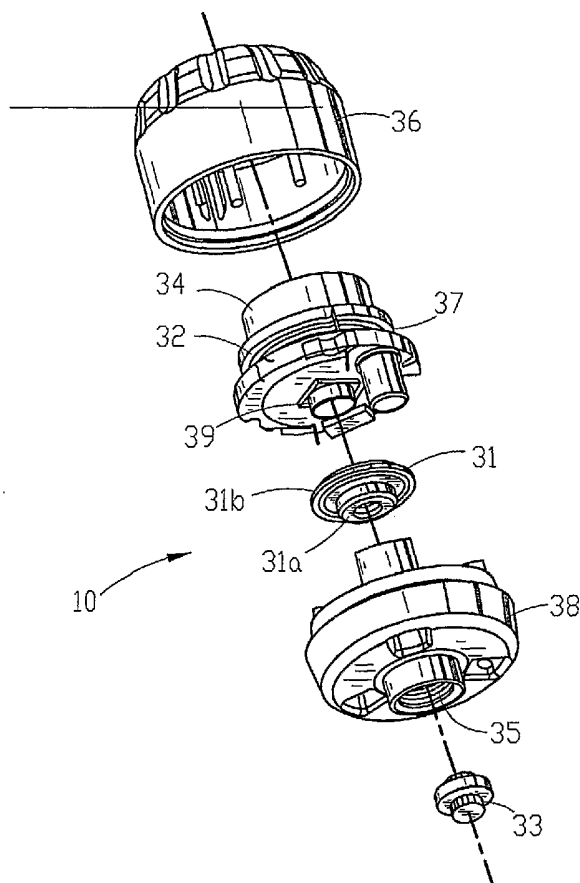
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[Continued on next page]

(54) Title: PRESSURE MONITORING SYSTEM



(57) Abstract: A pressure monitoring system is provided. The pressure monitoring system includes a pressure sensor assembly for measuring a pressure in a pressurized object and a monitor assembly for receiving a transmission from the pressure sensor assembly. The pressure sensor assembly includes a pressure sensor connected to an input of a microcontroller, and a radio frequency transmitter connected to an output of the microcontroller. The monitor assembly includes a radio frequency receiver connected to an input of a microcontroller, and an output for the microcontroller. The sensor assembly is constructed to include a triple-safe mechanism to minimize pressure leakage and to be easily manufactured. A bit pair transmission protocol is used to transmit signals from the pressure sensor assembly to the monitor assembly to reduce transmission time and thus increase battery life. The sensor assembly includes a Folded Inverted F type antenna to increase transmission signal integrity. The pressure sensor assembly also includes a symmetrical valve stem seal to minimize pressure leakage and for ease of assembly. The pressure monitoring system monitors a plurality of pressurized objects at a single time, including options for temporarily disabling the monitoring of selected objects. The pressure monitoring system includes a missing sensor alert and special sensor installation signal. Monitored pressure levels are automatically programmed in the pressure sensor upon installation, and a plurality of alerts are triggered based upon the installation pressure.

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PRESSURE MONITORING SYSTEM

[0001] This application claims priority pursuant to 35 U.S.C. 119(e) to co-pending U.S. Provisional Patent Application Serial No. 60/520,972, filed November 18, 2003, the entire disclosure of which is incorporated herein by reference.

Field of the Invention

[0002] The invention relates generally to the field of monitoring air pressure in vehicle tires, pressurized air shafts, and other pressurized items. More particularly, the invention is concerned with systems, methods and apparatuses of sensing pressure within a pressurized object and monitoring the pressure from a remote location via a wireless transmission.

Background of the Invention

[0003] Pressure sensors, have long been used to sense the pressure of vehicle tires (as well as other pressurized objects) to indicate when the tire is below a predetermined tire pressure. These sensors use various means, typically diaphragms screwed into tire valve stems and responsive to tire pressure for activating an electrical switch for generating an alarm when the tire pressure drops below a predetermined value. Various types of tire monitoring systems have been used to provide continuous vehicle tire pressure sensing and monitoring during vehicular operation. Such systems typically include a monitor located in the passenger compartment of the vehicle for receiving encoded transmitted signals (such as RF signals) for respective tires and for alerting the vehicular operator through the use of audio alarms and/or graphic display indicators when low tire pressure values are measured. The ability to selectively sense the pressure of each tire is desirable so that the subject tire can then be inflated to proper air pressure levels for safety and long tire wear life. The tire sensors unidirectionally communicate with the monitor transmitting tire pressure values received and processed by the monitor. Hence, these systems

typically have tire pressure sensors located on the valve stems for the respective tires each with an associated embedded transmitter for generating respective encoded signals identifying the tire. The cab mounted monitor has a receiver graphically displaying the signals for alerting the operator in the event of low tire pressures.

[0004] Examples of various prior art pressure monitoring systems are shown in U.S. Pat. No. 4,814,745 issued to Wang on Mar. 12, 1998, U.S. Pat. No. 4,814,744 issued to Collins on Mar. 21, 1989, U.S. Pat. No. 4,804,808 issued to Dal Cero on Feb. 14, 1989, U.S. Pat. No. 4,694,273 issued to Franchino on Sep. 15, 1987, U.S. Pat. No. 5,289,161 issued to Huang on Feb 22, 1994, U.S. Pat. No. 5,694,111 issued to Huang on Dec. 2, 1997, U.S. Pat. No. 4,734,674 issued to Thomas on Mar 29, 1988, U.S. Pat. No. 4,737,760 issued to Huang on Apr. 12, 1988, U.S. Pat. No. 4,319,220 issued to Pappas on Mar. 9, 1982, U.S. Pat. No. 5,001,457 issued to Wang, U.S. Pat. No. 4,970,491 issued to Saint on Nov. 13, 1990, and US 6,453,737 issued to Young et al. on September 24, 2002, the entire disclosures of which are incorporated herein by reference.

[0005] Typically, prior art pressure monitoring systems teach valve mounted pressure sensors, such as tire sensors, responsive to respective tire pressures of the tires for generating respective encoded signals transmitted to a receiver in a cab mounted monitor having graphic visual displays and/or audio alarms for indicating which one of the tires has low tire pressure. Typically, these prior art systems have difficulty maintaining signal integrity between the respective tire pressure sensors and the receiver in the cab monitor. This is the case for several reasons, including the location of the sensor relative to the monitor, the constant rotation of the tire and corresponding sensor which continuously changes the orientation of the sensor to the monitor, and the potential signal output of the sensor due to antenna size constraints and battery

power limitations. In situations where additional power is utilized for increasing signal transmission strength, battery life is reduced. Also, prior art stem mounted pressure sensors are unreliable due to pressure leakage. In addition, prior art pressure monitoring systems are difficult to install and operate, particularly when a large number of pressurized objects (such as tires of a truck or RV) are being monitored. Prior art system typically limited to operating within specific temperature ranges and providing warnings only at predetermined pressure values that are not adjustable based upon different operating pressures, or when adjustable, such adjustment is difficult to accomplish, usually requiring mechanical manipulations. These and other disadvantages are solved or reduced using the invention instant invention.

Summary of the Invention

[0006] The present invention comprises a tire pressure monitoring system, apparatuses and methods of monitoring pressure in pressurized objects.

[0007] The pressure monitoring system includes a pressure sensor assembly for measuring a pressure in a pressurized object and a monitor assembly for receiving a transmission from the pressure sensor assembly. The pressure sensor assembly includes a pressure sensor connected to an input of a microcontroller, and a radio frequency transmitter connected to an output of the microcontroller. The monitor assembly includes a radio frequency receiver connected to an input of a microcontroller, and an output for the microcontroller. In a preferred embodiment, the sensor assembly is constructed to include a triple-safe mechanism to minimize pressure leakage and to be easily manufactured. In another embodiment a bit pair transmission protocol is used to transmit signals from the pressure sensor assembly to the monitor assembly to reduce transmission time and thus increase battery life. In another embodiment, the sensor assembly includes a Folded Inverted F type antenna to increase transmission signal integrity. In

yet another embodiment, the pressure sensor assembly includes a symmetrical valve stem seal to minimize pressure leakage and for ease of assembly.

[0008] In a preferred embodiment, the pressure monitoring system of the instant invention monitors a plurality of pressurized objects at a single time, including options for temporarily disabling the monitoring of selected objects. The pressure monitoring system includes a missing sensor alert and special sensor installation signal. Monitored pressure levels are automatically programmed in the pressure sensor upon installation, and a plurality of alerts are triggered based upon the installation pressure.

[0009] The foregoing and other objects are intended to be illustrative of the invention and are not meant in a limiting sense. Many possible embodiments of the invention may be made and will be readily evident upon a study of the following specification and accompanying drawings comprising a part thereof. Various features and subcombinations of invention may be employed without reference to other features and subcombinations. Other objects and advantages of this invention will become apparent from the following description taken in connection with the accompanying drawings, wherein is set forth by way of illustration and example, an embodiment of this invention and various features thereof.

Brief Description of the Drawings

[0010] A preferred embodiment of the invention, illustrative of the best mode in which the applicant has contemplated applying the principles, is set forth in the following description and is shown in the drawings and is particularly and distinctly pointed out and set forth in the appended claims.

[0011] Fig. 1 is an exploded perspective view of a pressure sensor assembly of the instant invention.

[0012] Fig. 2 is a section view of the sensor assembly of Fig. 1.

[0013] Figs. 3a through 3c are perspective views of a lower housing portion of the sensor assembly of Fig. 1 showing installation of a printed circuit board (PCB).

[0014] Fig. 4 is a table comparing transmission times of the prior art to those of the transmission protocol of the instant invention.

[0015] Fig. 5a is a front elevation view of an antenna for the pressure sensor of Fig. 1.

[0016] Fig. 5b is a top plan view of the antenna of Fig. 5a.

[0017] Fig. 6a is a perspective view of a valve stem seal of the pressure sensor of Fig. 1.

[0018] Fig. 6b is an exploded perspective view of the pressure sensor of Fig. 1 and the valve stem seal of Fig. 6a, showing the installation of the valve stem into the pressure sensor.

[0019] Fig. 7 is a block diagram of the pressure monitoring system of the instant invention.

[0020] Figs. 8a through 8c are front plan views of various face plates for a monitor assembly of the instant invention.

[0021] Fig. 9 is an exploded view of a monitor assembly of the instant invention.

[0022] Fig. 10 is a rear plan view of the monitor assembly of Fig. 9.

Detailed Description of a Preferred Embodiment

[0023] As required, a detailed embodiment of the present inventions is disclosed herein; however, it is to be understood that the disclosed embodiment is merely exemplary of the principles of the invention, which may be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure.

[0024] Referring to Fig. 7, the basic components of the pressure monitoring system of the instant invention include pressure sensor assembly 10 and monitor (or receiver) assembly 20. Sensor assembly includes pressure sensor 30 that connects to the valve stem of a tire or other pressurized object (such as an air shaft). Pressure sensor 30 is connected to an input for microcontroller 40, which includes common components such as an analog digital converter, an oscillator, a watchdog timer, internal timers, a reset circuit, ROM/RAM/EEPROM. Additional inputs on microcontroller 40 connect to battery 32, a temperature sensor, vibration switch (to activate assembly 10 upon movement) and a hall-effect switch (to activate assembly 10 by magnet). The analog digital converter converts the analog input from pressure sensor 30 and the temperature sensor to digital format for utilization by microcontroller 40. The microcontroller uses the converted data to calculate a value for the pressure within the object to which assembly 10 is connected. Microcontroller 40 then transmits the digital pressure value to monitor 20 using an RF transmitter that is connected to an output of microcontroller 40. Antenna 34 is connected to the RF transmitter to optimize signal integrity. The RF transmitter is manufactured in a manner known in the art, and includes an oscillator, a volt controlled oscillator (VCO) and an adjustable power amplifier (for boosting transmission power of the transmitter).

[0025] Monitor **20** includes a pair of extendible antenna **22** connected to a receiver for receiving the signal transmitted by pressure sensor assembly **10**. The receiver is manufactured in a manner known in the art and includes a VCO, an intermediate frequency stage (IF stage), and an adjustable low noise amplifier (LNA). The receiver is connected to an input of microcontroller **45** of monitor **20**. Microcontroller **45** includes the same or similar components to those of microcontroller **40** for pressure sensor assembly **10**. Control switches, such as membrane switches located on the face plate of monitor **20**, are connected to inputs of microcontroller **45**. A battery and a received signal strength indicator (RSSI) can also be connected to inputs of microcontroller **45**. Microcontroller **45** receives and processes the data from pressure sensor assembly **10** and activates various output devices based upon the particular signal received. Outputs of microcontroller **45** include an audible alarm output, digital pressure LCD display **24** (displays actual tire pressure), tire location LEDs **26**, low battery indicator **27**, and monitor power indicator LED **28**. Outputs for additional optional alarms, such as external alarms, or outputs **25** for connecting to a PDA or other computer devices (such as via RS-232, USB mini B 5 pin or other connection for live data readings) are also included. Output **25** can also be used as an input for a 12V DC power source for monitor assembly **20**.

[0026] Referring to Fig. 1, pressure sensor assembly **10** is shown, including injection molded upper case (upper housing portion) **36** and injection molded lower case (housing portion) **38**, printed circuit board assembly **37**, webbed gasket (sensor seal) **31** and valve seal **33**. Pressure sensor **30**, antenna **34**, battery **32**, microcontroller **40**, and the RF transmitter are all mounted on printed circuit board assembly **37**. Assembly **10** attaches to a valve stem, such as on a tire, by threaded insert **35**.

[0027] Referring to Figs. 2 and 3, pressure sensor assembly **10** is constructed to provide a

triple seal mechanism to minimize pressure loss from the pressurized object (such as a tire) on which sensor assembly **10** is attached. The primary and secondary seal interfaces are accomplished by gasket **31**, which is a molded elastomer including o-ring section **31a**, and outer section **31b**. The primary seal interface is accomplished by compressing o-ring section **31a** between inside diameter of the brass insert **35**, which is molded into lower case **38**, and the outside wall of cylinder **39** that protrudes from (or connects or feeds to) pressure sensor **30**. The secondary seal interface is accomplished by compressing outer section **31b** of webbed gasket **31** between the lower surface of circuit board assembly **37**, and the inner surface of lower case **38**. The secondary seal (**31b**) resembles another o-ring and acts against the circuit board assembly **37** at a ninety degree angle to the primary seal (**31a**). Indentations in lower case **38** match up with protrusions in secondary seal **31b** to provides increases sealing and prevent the seal from rolling during assembly. The primary and secondary seals work together to prevent leakage up to the maximum burst pressure for assembly **10**. A tertiary seal interface, **31c**, is accomplished by ultrasonic welding together lower portion **38** to upper portion **36** of the housing for assembly **10**. This provides an air-tight bond at the end of the manufacturing process and adds to the strength of the housing, increasing durability in rugged environments, such as outside a tire.

[0028] The primary and secondary seals are compressed together by attaching circuit board assembly **37** lower case **38**. Referring to Figs. 3a through 3c, the method of attaching circuit board assembly **37** lower case **38** is discussed which compress gasket **31** (particularly secondary seal **31b**) and simplifies production assembly by eliminating components, such as screws, and creating a one-step assembly process. Lower portion **38** of the sensor assembly housing includes three vertical risers **38a** which include horizontal shelves **38b** and **38c** protruding inwardly. Shelves **38b** and **38c** are aligned with mating tabs **37a** protruding

outwardly from circuit board assembly 37. Once all of the components (i.e. pressure sensor, antenna, microprocessor, etc.) have been attached (such as by soldering) to circuit board assembly 37, the circuit board assembly is inserted and pressed downward into lower case 38 such that tabs 37a of assembly 37 are next to shelves 38b and 38c, as is shown in Fig. 3b. Circuit board assembly 37 is then rotated clockwise until tabs 37a are located between upper shelf 38c and lower shelf 38b, as is shown in Fig. 3c. Shelves 38b and 38c hold assembly 37 in place and maintain compression of secondary seal 31b, without utilizing screws, glue or other fasteners, reducing space consumption, weight and assembly time.

[0029] Referring to Figs. 6a and 6b, valve seal 33 of the instant invention is discussed. Seal 33 is made of an elastomer material and includes a main body in the form of a disc, and rectangular protrusions 33a located on opposing sides/faces of the disc. Seal 33 is pressed into brass insert 35 during assembly to provide an airtight seal between the end of a valve stem on which pressure sensor assembly 10 is attached and the inside of brass insert 35. Protrusions 33a depress the dill valve in the valve stem to release air pressure into pressure sensor assembly 10. Openings 33b through the disc allow a metered amount of air to flow from the valve stem to pressure sensor 30. The disc prevents air from escaping out of the tire (or other pressurized object) through the valve stem threads. Because protrusions 33a are located on both sides of seal 33 (i.e. the seal is symmetrical), seal 33 can be installed during manufacturing without any concern for proper orientation. In addition, if seal 33 is missing or removed from sensor assembly 10, non air will escape from the tire, as the dill valve cannot be depressed. Holes/openings 33b minimize the amount of air entering sensor assembly 10 and reaching pressure sensor 30, preventing contaminants from reaching pressure sensor 30 and minimizing the amount of “rushing” air that could disrupt the gel in the sensing element of pressure sensor

30.

[0030] Referring to Figs. 5a and 5b, antenna **34** of pressure assembly **10** of the instant invention is discussed which efficiently transmits the signal (energy) from pressure sensor assembly **10** to monitor assembly **20** while minimizing sensor size. Antenna **34** is a secondary circuit board that includes coil image **34a** that acts as a radiating element. Antenna **34** is configured as a Folded Inverted F type antenna in which the RF feed point is located a fixed distance from the ground point. The distance between the feed point and the ground point is based on the tuning characteristics relating to the particular transmit frequency and the physical characteristics of adjacent components, such as battery **32** and sensor housing (**36**, **38**). The bottom layer of the circuit board of antenna **34** makes up a solid “ground plane” that is common with the positive terminal of battery **32**. Although the circuit board mounts above battery **32**, and that reference plane exists, the circuit board plane is used to minimize inconsistencies that may occur due to manufacturing variability. A key feature of antenna **34** of the instant invention is the omni-directional radiation pattern that is achieved on the same plane as the circuit board. When pressure sensor assembly **10** is installed on a vehicle tire, the signal is radiated effectively forward and backward down the length of the vehicle in a consistent pattern in which tire rotation does not dramatically affect the signal integrity. In addition, the radiation pattern inward, toward the tire where it is not needed, is very weak, preserving unnecessary energy usage and maximizing signal integrity in the direction that best increases the chances of reception by monitor assembly **20**.

[0031] Referring to Fig. 4, the transmission protocol to transmit data from pressure sensor assembly **10** to monitor **20** of the instant invention is discussed. Data is transmitted from pressure sensor assembly **10** to monitor **20** for display and notification across an radio frequency

(RF) link in a digital format. Each pressure sensor assembly **10** that is monitored by monitor **20** includes a unique header byte, three bytes of serial number unique to each sensor assembly **10** (allows for more than 16 million unique sensor identification codes), pressure data, temperature data, status data (i.e. reason for transmission such as alarm, timed interval etc., low battery warning, etc.), and checksum data to verify that the data was received correctly.

[0032] In transmission methods of the prior art, each bit being transmitted has a unique pattern which differentiates itself from other bits. This allows the monitor/receiver to identify each bit in succession for recreation of the original digital sequence. The transmission protocol of the instant invention utilizes a unique pattern for sequential pairs of bits, as opposed to for each bit. As a byte is composed of 8 bits, each transmission of the instant invention includes 4 patterns instead of the typical 8.

[0033] Given two bits per pattern, 4 possible patterns exist including 00, 01, **10**, and 11 in binary representation. Each of these patterns is assigned a unique timing width so that it can be identified on the receiving end. The timing widths of the patterns of the instant invention and the timing widths of the prior art are compared in the chart shown in Fig. 4. As can be seen the timing width for the first two possible patterns of bit pairs of the instant invention are identical to the timing widths for the two possible bit values for a single bit of the prior art.

[0034] As all receivers have a limited minimum pulse width at which they will work reliably and with good sensitivity, the minimum bit time for the two bit patterns of the instant invention is equivalent to that of a single bit of the prior art. The instant invention provides the advantage that, for the majority of byte values, the overall time is less than if composed of eight unique timing widths. By reducing the transmission time, battery life is prolonged and the statistical probability of multiple pressure sensor assemblies **10** sending transmissions at the

same time is minimized increasing the likelihood that a transmission will not be interrupted.

[0035] Referring to Figs. 8a through 8c, several alternative front face plates **20a** for monitor assembly **20** of the instant invention are shown. Each of the alternate face plates **20a** shown in Figs. 8a through 8c can be installed on the same housing assembly **20c** of monitor assembly **20**, such that the primary components (i.e. microprocessor, inputs, LCD display, etc.), which are contained in housing assembly **20c** may be manufactured in the same manner regardless of the specific face plate used. Each face plate is for monitoring different types of vehicles or pressurized objects, and while most of the operations for each vehicles type are the same, several variations will be discussed below. Fig. 8a shows face plate **20a** for a pressure monitoring system for a vehicle that has either 4 or 6 tire locations to be monitored. Six clear windows are located in the position of tire location LEDs **26** located on housing assembly **20c**, and a clear plastic window is located over LCD display **24**. Button membranes **21a**, **21b**, and **21c** are located over buttons **61a**, **61b** and **61c** of housing **20c**. Clear windows are also included in the locations of low battery LED **27** and power indicator LED **28**. As can be seen in Fig. 9, additional tire location LEDs **26** are available on housing **20c** for use with other face plates that allow for monitoring of additional tire locations (such as those of Figs. 8b and 8c). In addition, button **63** is also located on housing **20c** that provides additional control for other face plates in which extra tire locations are included, but which is not utilized in the face plate of Fig. 8a. As is shown in Figs. 8b and 8c, front/back button membrane **23** is located on face plate **20a** for activating front back button **63**. Activation of front back button **63** allows monitor assembly **20** to temporarily discontinue monitoring of certain pressure sensors that have been programmed into the memory of monitor assembly **20**. This allows the user to disconnect a trailer or car carrier that is monitored using the face plate of Fig. 8b, or a tractor trailer that is monitored using

the face plate of Fig. 8c and continue monitoring a portion of the sensors, without receiving a missing sensor alert for the disconnected sensors. The user can monitor either tire locations **26a** of the front portion of the vehicle combination (i.e. an RV or truck tractor), tire locations **26b** of the back portion of the vehicle combination, or both **26a** and **26b**. This feature is controlled by the programming of microcontroller **45**.

[0036] Figure 9 shows the assembly of face plate **20a** to housing **20c**. Face plate **20a** is attached to the surface of housing **20c** by a double-side adhesive panel **20b** cut in the shape on monitor **20** and including cutouts **20b'** for the LEDs and buttons.

[0037] Figure 10 shows a rear view of housing **20c** of monitor assembly **20**. As is shown, housing **20c** includes notches **70** including notch tabs **72**. Notches **70** create openings to internal channels **72** through the back of housing **20c**. Visor clip **80** is engaged between tabs **72** of notches **70** and the bottom surfaces of notches **70**. Clip **80** extends below finger **76** and engages with a protrusion located on the inner surface of housing **20c** at hole **82**. Finger **76** can be depressed to push down clip **80** and release hole **82** from the protrusion. Notch **84** of clip is used to mount a suction cup to clip **80**, if desired. Velcro (hook and pile fasteners) may also be used to mount housing **20** is a desired location.

[0038] As is discussed above, monitor **20** of the instant invention can be programmed to monitor a plurality of tire locations. In operation a pressure sensor **10**, having a unique identification code, is stored in the memory of the microprocessor **45** by placing the microprocessor in "program" mode. This is accomplished by holding down program button **21c** for a set period of time, i.e. 5 seconds and selecting a tire location to be programmed, in the manner discussed in U.S. Patent No. 6,453,737. The sensor is then placed on a valve stem and pressurization of the sensor causes the sensor to transmit a special "installation" code that is

received by the monitor and tells the monitor processor that the sensor is intended to be programmed into the memory of the monitor. This installation code may also be activated by holding a magnet to a sensor. The installation code is transmitted along with the ID code for the sensor. This allows multiple systems to be installed in the same proximity without accidentally programming the wrong sensors and without worrying about crosstalk from other sensors as the monitor will only program in sensors that are transmitting the special installation code and not sensors that are merely transmitting pressure data. In addition, once a sensor is stored in the monitor, that sensor cannot be stored in a second tire location in the same monitor, as the microprocessor will exclude that sensor ID from being programmed again. Thus, if a sensor is to be moved to another tire location, it must be deleted from its current tire location. Powering off does not remove any sensors from memory.

[0039] The monitor on the instant invention reports tire pressures with no danger of picking up other sensors signals as the monitor stores and only reports on the specific sensor IDs programmed.

[0040] Another aspect of the instant invention is that the monitor alerts the user by an audible alarm and by displaying the tire location by lighting the appropriate LED to dropped signal condition and corrects then itself (resets) when signal gets through. Each pressure sensor assembly 10 transmits an update and check-in signal on a recurring timeframe. This signal is separate from a pressure signal. If the monitor does not receive this signal, it will display a missing sensor alert to notify the user that a sensor may be missing or malfunctioning. This is a short millisecond signal that is sent based upon a timer in the microprocessor 40 of the sensor assembly 10. The missing sensor signal differs from low pressure alerts so user can tell the difference between a low pressure alert and a missed signal alert

[0041] When a pressure sensor assembly of the instant invention is pressurized, or activated by a magnet, the pressure measurement will be recorded in the memory of the pressure sensor as the appropriate operating pressure. If the pressure sensor is fully depressurized for a predetermined time period without being repressurized, the memory will reset to the new pressure once the sensor is finally repressurized. This allows the sensors assemblies of the instant invention to be utilized on a variety of pressurized objects regardless of operating pressure. Low pressure alarms are calculated by the microprocessor of the pressure sensor assembly based upon the installation pressure. In a preferred embodiment of the invention a first low pressure alarm is sent by sensor assembly 10 if the pressure drops 12.5% below the installation pressure, and a second alarm is sent if the pressure drops 25% below the installation pressure. Each pressure sensor assembly 10 polls the pressure of the object to which it is installed every seven seconds and transmits pressure data to the monitor every five minutes unless immediately activated by a magnet, or if a low pressure level is detected by the sensor (i.e. 12.5 or 25% pressure reduction). Such time-lapsed transmission minimizes draw on the battery, extending battery life.

[0042] In a preferred embodiment of the invention low pressure alerts continue until a user does something to correct the fault, such as increase tire pressure or reset the sensor by removing the sensor for the predetermined time period and reinstalling to automatically set new pressure and the target "installation" pressure. When a sensor "reprograms" automatically to new pressure levels (i.e. by remove sensor from tire for 30 seconds) and the sensor is screwed back on the valve stem and new pressure is accepted, it will also calculate and reset the 12.5% & 25% low alarms based upon the new pressure. By automatically reprogramming, the sensors are generic. In a preferred embodiment the sensors may be installed on any tire position at any

pressure from 5psi to 150psi.

[0043] In a preferred embodiment, the monitor can be placed into “reminder mode” allowing the audible alert to be minimized and still alert of low pressure conditions with an audible alarm every two minutes and a visual alarm by flashing the LED of the tire location in which an alarm is active. In another preferred embodiment the monitor allows for multiple low pressure alerts at a time indicating 1 or more tires as low by both audible and visual (LED flashing) alarms. In another preferred embodiment, the microcontroller for a pressure sensor assembly is programmed to time out after 15 hrs of no movement (detected by vibration sensor or motion sensor) during a 25% low alert when vehicle is in storage to save battery life. In yet another preferred embodiment, the monitor can be set to display sensors serial numbers for ID'ing a specific sensor.

[0044] In another preferred embodiment, a signal repeater can be installed in a vehicle or other location to receive a signal transmitted from a sensor and echo or repeat or regenerate the same data message using an amplified signal.

[0045] In the foregoing description, certain terms have been used for brevity, clearness and understanding; but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art, because such terms are used for descriptive purposes and are intended to be broadly construed. Moreover, the description and illustration of the inventions is by way of example, and the scope of the inventions is not limited to the exact details shown or described.

[0046] Although the foregoing detailed description of the present invention has been described by reference to an exemplary embodiment, and the best mode contemplated for carrying out the present invention has been shown and described, it will be understood that

certain changes, modification or variations may be made in embodying the above invention, and in the construction thereof, other than those specifically set forth herein, may be achieved by those skilled in the art without departing from the spirit and scope of the invention, and that such changes, modification or variations are to be considered as being within the overall scope of the present invention. Therefore, it is contemplated to cover the present invention and any and all changes, modifications, variations, or equivalents that fall within the true spirit and scope of the underlying principles disclosed and claimed herein. Consequently, the scope of the present invention is intended to be limited only by the attached claims, all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

[0047] Having now described the features, discoveries and principles of the invention, the manner in which the invention is constructed and used, the characteristics of the construction, and advantageous, new and useful results obtained; the new and useful structures, devices, elements, arrangements, parts and combinations, are set forth in the appended claims.

[0048] It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

CLAIMS

What is claimed is:

1. A pressure monitoring system comprising:
a pressure sensor assembly for measuring a pressure in a pressurized object including a pressure sensor connected to an input of a microcontroller, and a radio frequency transmitter connected to an output of said microcontroller; and
a monitor assembly including a radio frequency receiver for receiving a transmission from said pressure sensor assembly, said receiver connected to an input of a microcontroller, and said microcontroller including an output.
2. The pressure monitoring system as claimed in claim 1 wherein said pressure sensor assembly is attached to a threaded valve stem of the pressurized object.
3. The pressure monitoring system as claimed in claim 2 wherein said pressurized object is a tire.
4. The pressure monitoring system as claimed in claim 2 wherein said pressure sensor assembly further comprises a threaded insert for engagement with threads of said valve stem.
5. The pressure monitoring system as claimed in claim 4 wherein said pressure sensor assembly further comprises a valve stem seal.
6. The pressure monitoring system as claimed in claim 5 wherein said valve stem seal comprises a disc that fits within said insert and a protrusion extending from a surface of said disc capable of depressing a dill valve of said valve stem when said insert is threaded to said valve

stem.

7. The pressure monitoring system as claimed in claim 6 wherein said valve stem seal further comprises a second protrusion extending from an opposing surface of said protrusion.

8. The pressure monitoring system as claimed in claim 5 wherein said valve stem seal includes an opening to meter an amount of air passing from said pressurized object to said pressure sensor.

9. The pressure monitoring system as claimed in claim 1 wherein said output of said microcontroller of said monitor is connected to a visual display, an audible alarm, a PDA, and/or a computer.

10. The pressure monitoring system as claimed in claim 1 wherein said pressure sensor assembly further comprises:

a housing surrounding said pressure sensor, said microcontroller and said transmitter; and

a webbed o-ring gasket including a primary seal interface and a secondary seal interface

between said housing and an exterior of said pressure sensor.

11. The pressure monitoring system as claimed in claim 10 wherein said exterior of said pressure sensor comprises a printed circuit board to which said pressure sensor is attached.

12. The pressure monitoring system as claimed in claim 10 wherein said housing comprises an upper housing portion and a lower housing portion bonded to said upper housing portion through an ultrasonic weld.

13. The pressure monitoring system as claimed in claim 1 wherein said pressure sensor

assembly further comprises a housing surrounding said pressure sensor, said microcontroller and said transmitter, said housing comprising an upper housing portion and a lower housing portion bonded to said upper housing portion through an ultrasonic weld.

14. The pressure monitoring system as claimed in claim 1 further comprising:
 - a support for said pressure sensor, said microcontroller and said transmitter;
 - a housing surrounding said pressure sensor, said microcontroller and said transmitter; and
 - a receptacle in said housing for engagement with said support.
15. The pressure monitoring system as claimed in claim 14 wherein said receptacle comprises vertical risers and horizontal shelves.
16. The pressure monitoring system as claimed in claim 15 wherein said support includes protruding tabs that fit within said receptacle.
17. The pressure monitoring system as claimed in claim 14 wherein said support is rotated into engagement with said receptacle.
18. The pressure monitoring system as claimed in claim 14 wherein said support is a printed circuit board.
19. The pressure monitoring system as claimed in claim 1 wherein said transmission between said pressure sensor assembly and said monitor assembly comprises bit pairs.
20. The pressure monitoring system as claimed in claim 19 wherein each of said bit pairs include a predetermined timing width based upon a pair pattern.
21. The pressure monitoring system as claimed in claim 1 further comprising a low noise

amplifier connected to said receiver.

22. The pressure monitoring system as claimed in claim 1 further comprising a folded inverted F type antenna connected to said transmitter.

23. The pressure monitoring system as claimed in claim 22 wherein said antenna comprises a circuit board and a coil image radiating element on said circuit board.

24. The pressure monitoring system as claimed in claim 1 wherein said transmission includes a pressure value.

25. The pressure monitoring system as claimed in claim 1 wherein said transmission includes an installation signal.

26. The pressure monitoring system as claimed in claim 25 wherein said installation signal is separate from a pressure signal.

27. The pressure monitoring system as claimed in claim 25 wherein said installation signal is initiated upon an initial pressurization of said pressure sensor.

28. The pressure monitoring system as claimed in claim 25 wherein said installation signal is initiated upon activation by a magnet.

29. The pressure monitoring system as claimed in claim 1 wherein said transmission includes a check-in signal.

30. The pressure monitoring system as claimed in claim 29 wherein said check-in signal is separate from a pressure signal.

31. The pressure monitoring system as claimed in claim 1 wherein said microprocessor stores an installation pressure upon obtaining an initial pressure measurement for said pressurized object.
32. The pressure monitoring system as claimed in claim 31 wherein said microprocessor resets said installation pressure upon full depressurization for a predetermined time period.
33. The pressure monitoring system as claimed in claim 31 wherein said microprocessor initiates an first low pressure alert upon a pressure of said pressurized object falling below a first percentage of said installation pressure.
34. The pressure monitoring system as claimed in claim 33 wherein said microprocessor initiates a second low pressure alert upon a pressure of said pressurized object falling below a second percentage of said installation pressure.
35. The pressure monitoring system as claimed in claim 1 wherein said monitor assembly includes a visor clip removably connected to a housing of said monitor assembly.
36. The pressure monitoring system as claimed in claim 35 wherein further comprising a suction cup removably connected to said visor clip.
37. The pressure monitoring system as claimed in claim 1 further comprising a user interface for said monitor assembly.
38. The pressure monitoring system as claimed in claim 37 wherein said monitor receives transmissions from a plurality of pressure sensor assemblies, and wherein said microprocessor of said monitor outputs a missing sensor warning when a transmission for one of said plurality of

sensor assemblies is not received within a predetermined time period.

39. The pressure monitoring system as claimed in claim 38 wherein said user interface includes a control for selectively disengaging said missing sensor warning for a portion of said plurality of sensor assemblies.

40. The pressure monitoring system as claimed in claim 1 wherein said monitor assembly includes a housing for said receiver and said microcontroller.

41. The pressure monitoring system as claimed in claim 40 further comprising a face plate for attaching to said housing.

42. The pressure monitoring system as claimed in claim 41 wherein said face plate utilizes a portion of standard input and/or output components of said housing.

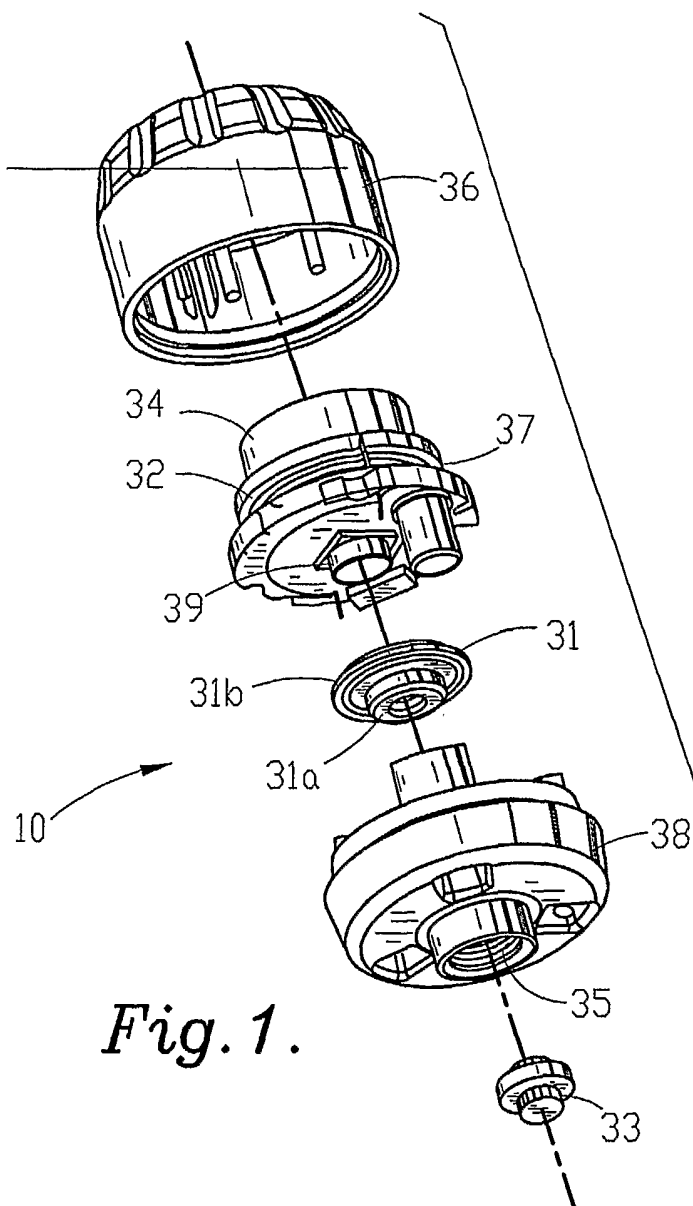


Fig. 1.

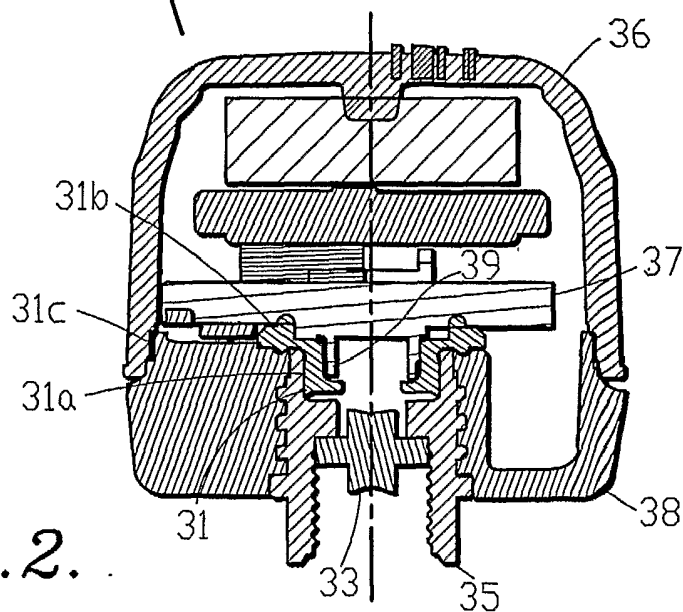
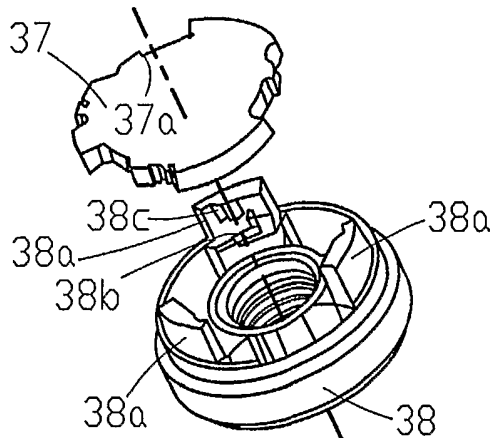
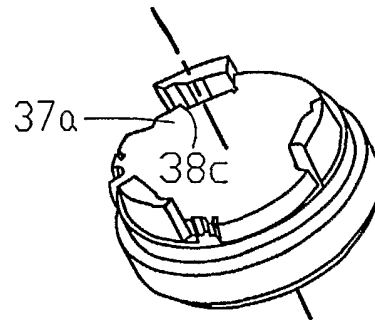
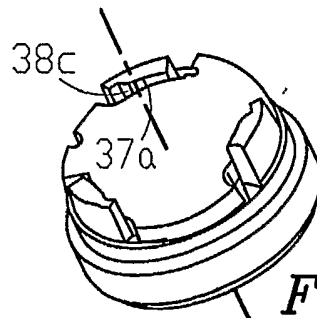


Fig. 2.

*Fig. 3.a**Fig. 3.b**Fig. 3.c***Traditional Method:**

Symbol Bit Value	Symbol Width (usec)
0	72
1	98

Implemented Method:

Symbol Bit Pattern	Symbol Width (usec)
00	72
01	98
10	126
11	156

Average symbol width: 85 usec
 Average byte width: 680 usec
 Maximum byte width: 784 usec

Average symbol width:	113.0 usec	% Improvement
Average byte width:	452 usec	33.5%
Maximum byte width:	624 usec	20.4%

Fig. 4

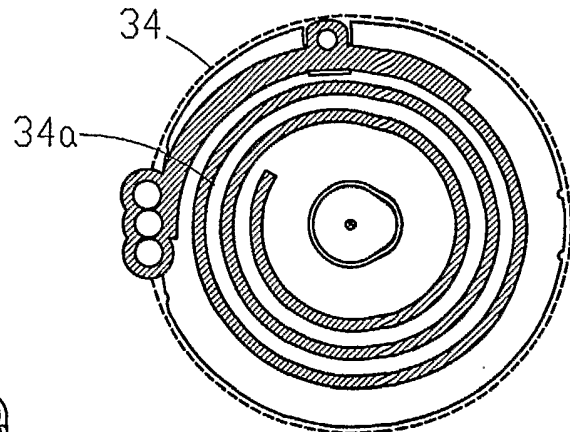
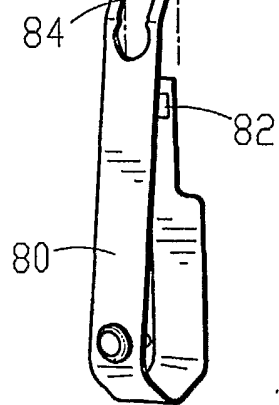
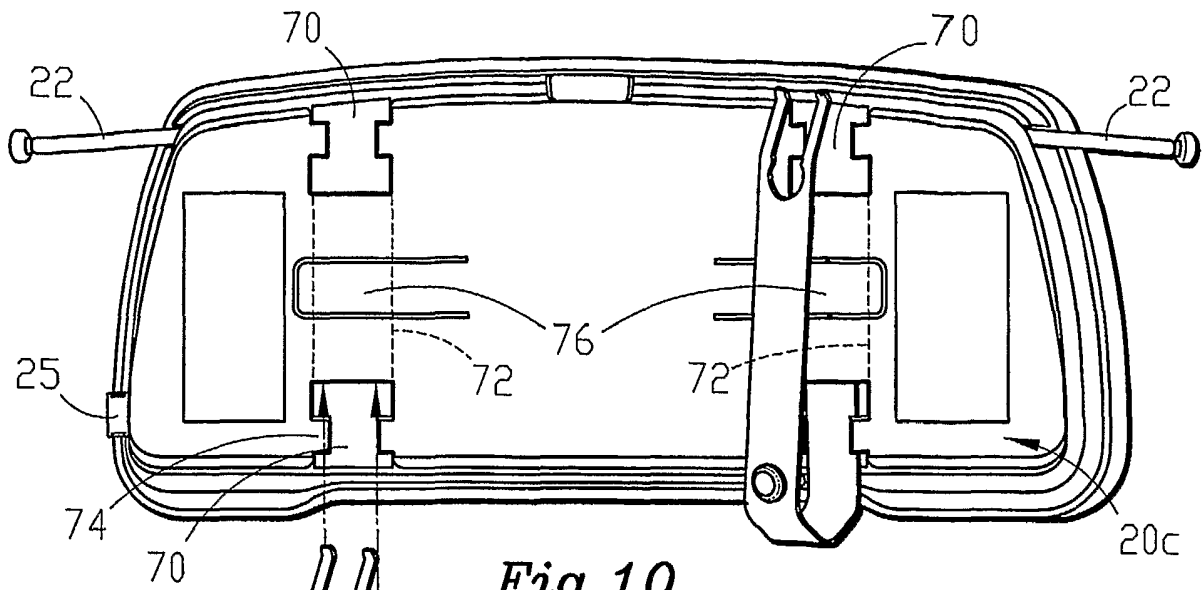
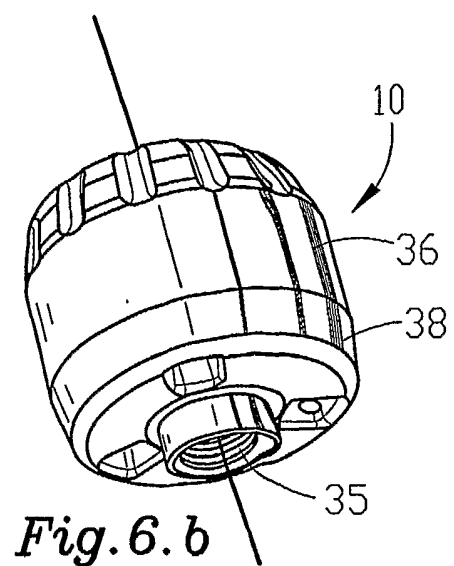
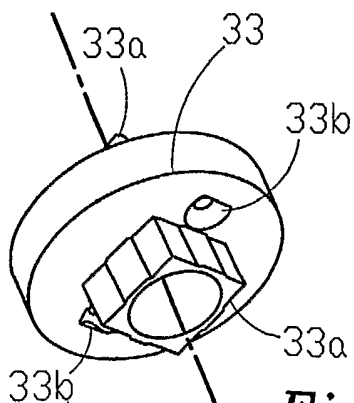
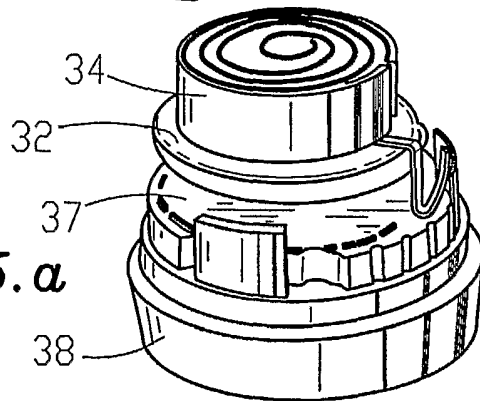


Fig. 5.a



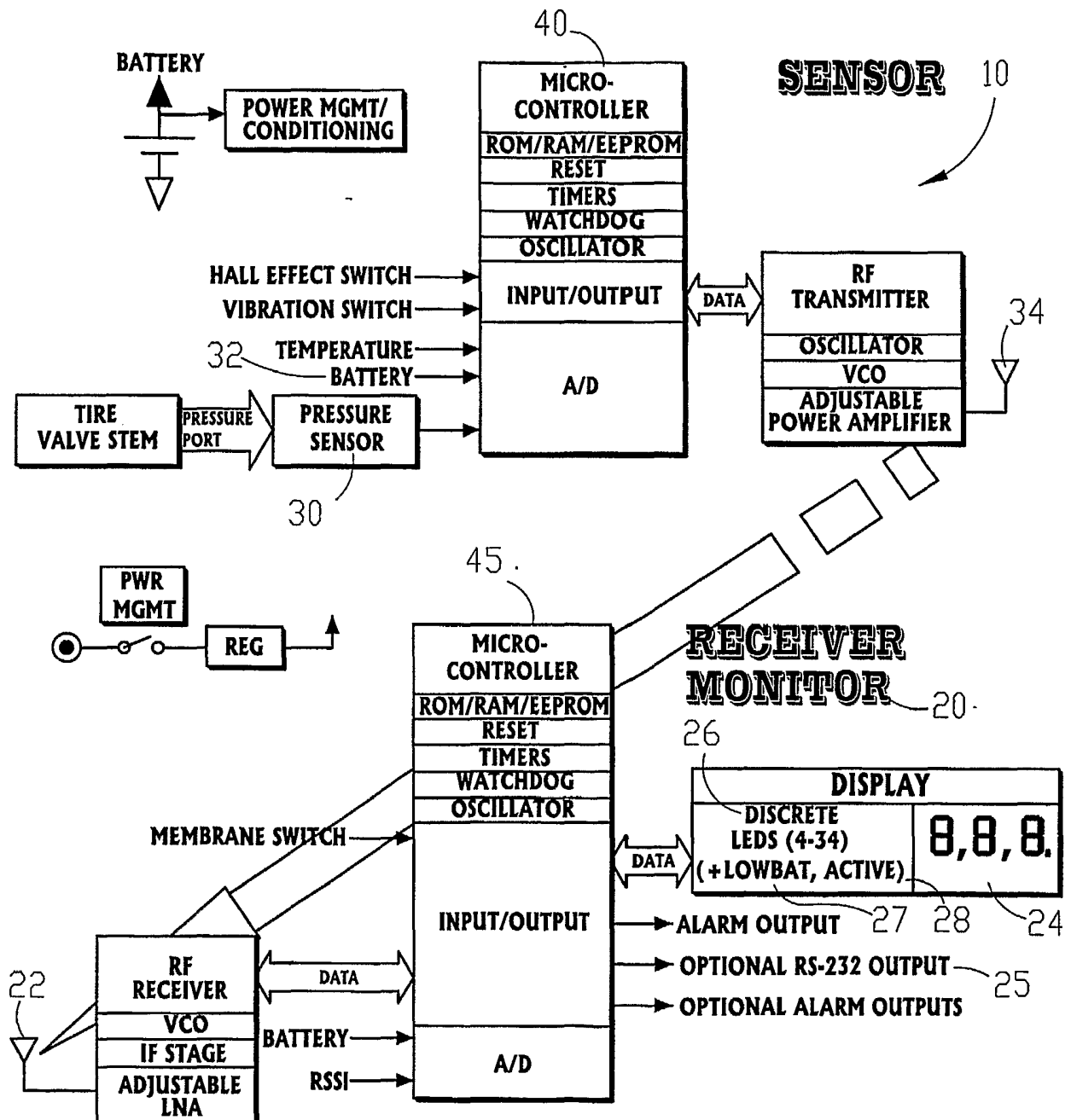
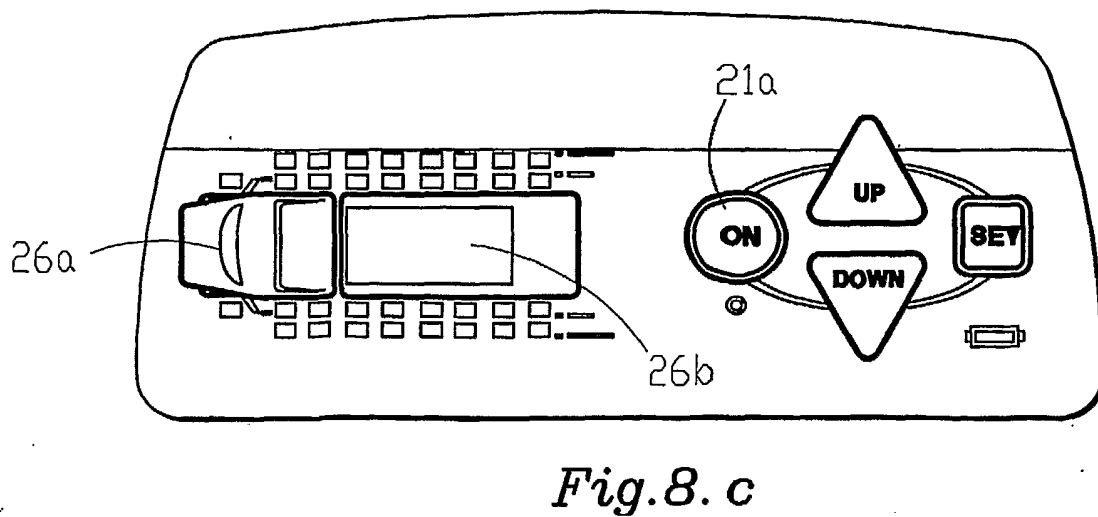
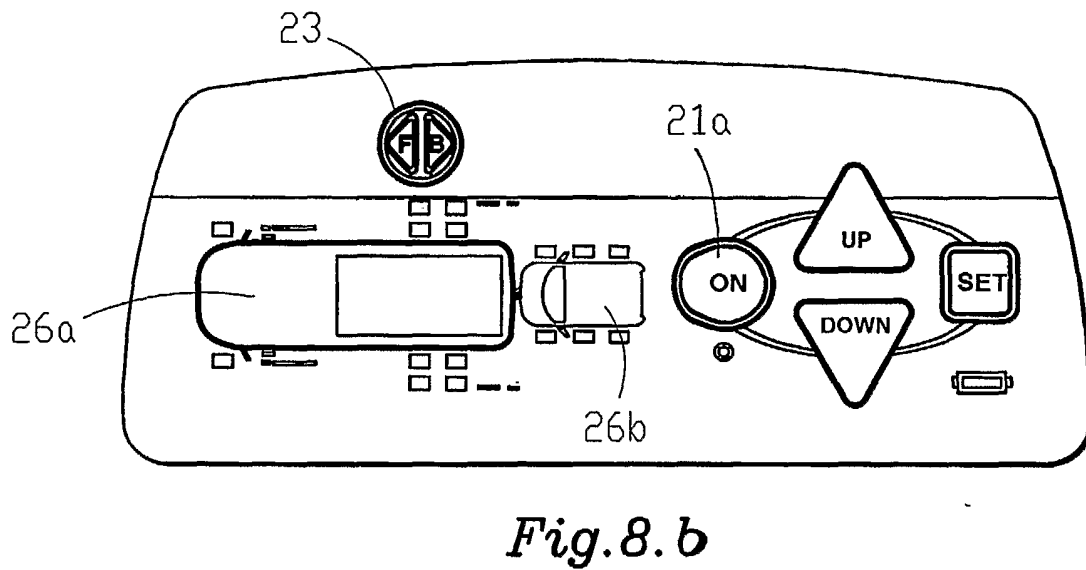
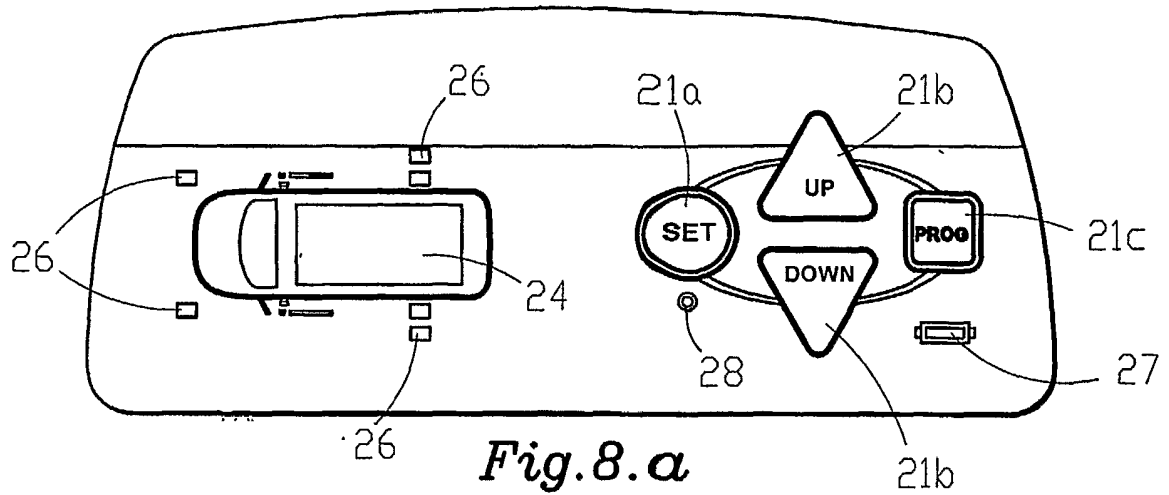
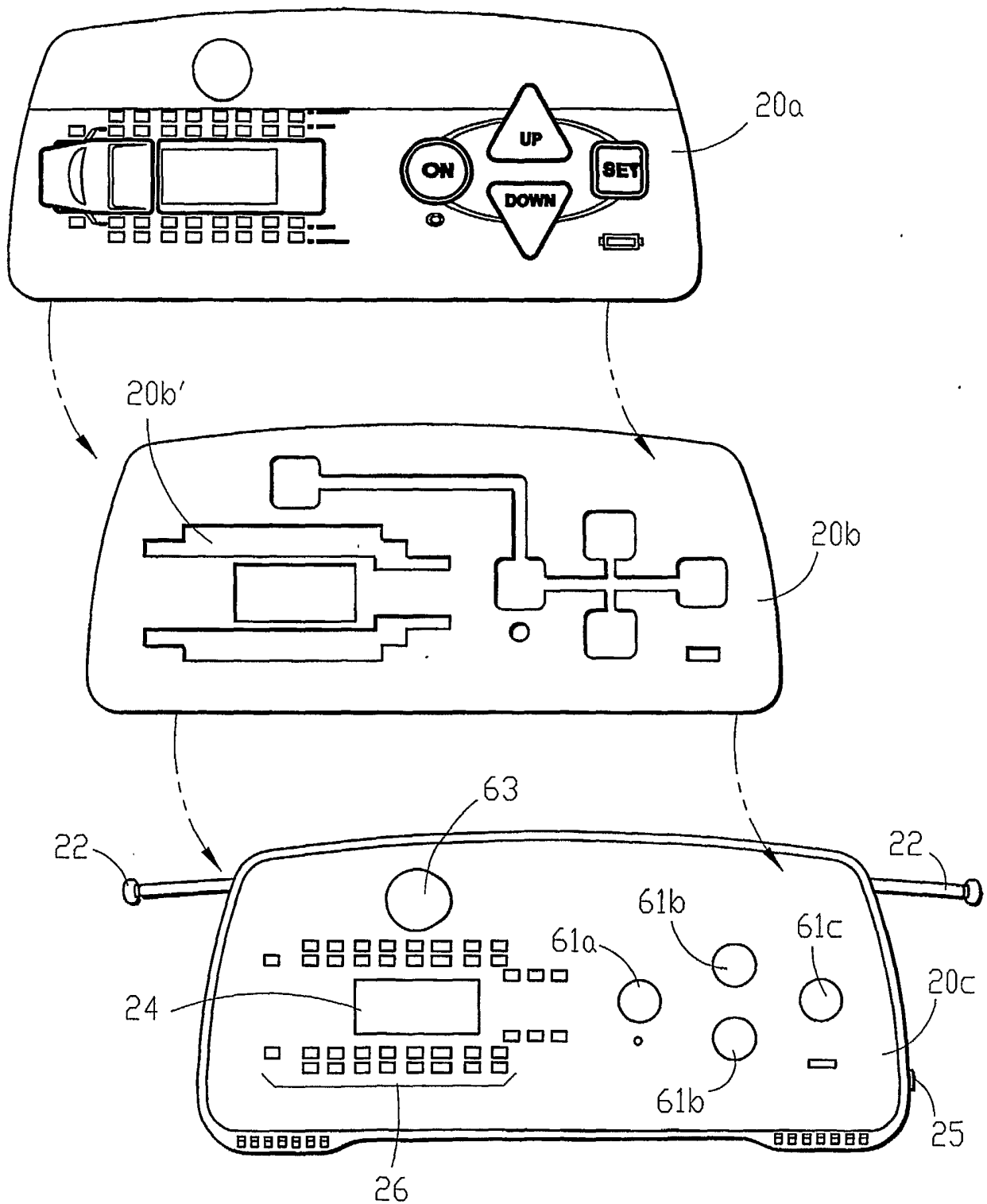


Fig. 7.



*Fig. 9.*