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Wireless Sensor and Display Unit for Tank Level Monitoring

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2008100552 10 Jul 2009

ABSTRACT

The disclosed wireless sensor and corresponding display unit provides visual information for monitoring of material level within a vessel such as a water tank. The function of the invention is to provide statistical and predictive values that facilitate improved management and reduced consumption of the material held in the vessel. A key value displayed by the invention is the predicted time capacity remaining, displayed as the number of days of remaining material. A further feature of the invention is the ability to display the volume of material inflows to the vessel and the time since the last inflow, typically the volume of rainfall received into the tank and the number of days since the rainfall occurred. The wireless sensor uses ultrasonic transducers to determine the level of water from the top of the tank by measuring the time of flight of pulses of sound reflected from the water surface. Signals received by the ultrasonic transducer are sampled and digitized by a high-speed analog to digital converter. The time of flight, indicating the measured distance, is determined by numerical interpolation of the digitized waveform to find the zero crossing point, or intercept of the pulse. Air temperature within the tank is measured by the sensor to allow for temperature correction of the time of flight. The sensor is of low power design and battery powered with an integral wireless communication capability for transmission of information from multiple wireless sensors to one display unit. The display unit may include an integral display or may take the form of a computer device such as a computer, PDA or mobile phone. Information received from the wireless sensors is stored as historical values within the display unit allowing the historical values to be displayed and used to compute time-based statistics and to predict the remaining time capacity of material based on consumption history.

2008100552 10 Jul 2009

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COMPLETE SPECIFICATION

INNOVATION PATENT

WIRELESS SENSOR AND DISPLAY UNIT FOR TANK LEVEL MONITORING

The following statement is a full description of this invention, including the best method of performing it known to me:

2008100552 10 Jul 2009

WIRELESS SENSOR AND DISPLAY UNIT FOR TANK LEVEL MONITORING

Water usage within Australia has become a critical issue in the past few years and awareness has grown within the community for better management and utilisation of water within domestic, commercial and industrial premises. Although this increased awareness has resulted in reduced water consumption from the water grid, the reduction has been largely achieved by restrictive measures prescribed by water authorities. The need to perform regular domestic and commercial activities in times of water restrictions has resulted in a dramatic increase in the number of water tank installations, which have been subject to government rebates and promotion as a means of demand management by water authorities. Further savings and improved water management without mandatory restrictions require that consumers have timely, concise and relevant information to enable decision making and improved self regulation.

The invention described herein relates to the above mentioned issues by providing the water consumer with detailed information relating to the consumption of water from domestic or commercial water tanks or wells. It comprises two physically separate portions that are interconnected using wireless information transmission. The first portion is a wireless level sensor and the second portion is a wireless display unit. The wireless level sensor measures the level of water within a tank and regularly transmits the value of the level measurement to the wireless display unit. Batteries and optionally a solar panel may be used to power the wireless level sensor which includes transducers for distance measurement and a low power radio transceiver.

The wireless display unit includes a radio transceiver and is powered from either internal batteries or a power supply. One wireless display unit can receive and interpret signals from a plurality of wireless level sensors. The wireless display unit receives the information from one or more wireless sensors and stores the information as historical values. The historical values are then used to compute and display statistical and predicted values relating to water consumption, including the time capacity of remaining liquid and may include visual display of the usage rate and time patterns of usage.

The wireless display unit is typically located indoors for easy and frequent inspection. The preferred embodiment of the display unit is a compact unit with buttons and an LCD display and an optional computer interface. Alternately the display unit may be a computer, computer peripheral, personal digital assistant (PDA) or mobile phone with suitable wireless interface such as Bluetooth to communicate directly with wireless level sensors.

The wireless level sensor transmits digital information including the measured distance and variance of measured distance. It also transmits ancillary information, including a serial number, unique identification number, checksum information, communications status and other status information such as inflow detection, and low battery indication.

The quantity of water remaining in the tank is computed from the measured level of water from the top of the tank. An embodiment of the level sensor may use optical or ultrasonic transducers to measure the said level. Alternately pressure measurement at the bottom of the tank may be used to determine the said water quantity. The preferred embodiment uses one or two ultrasonic transducers, one emitting pulses of ultrasonic sound in bursts and the same, or a second transducer dedicated to receiving, is used to detect the echo. The transmitted ultrasonic pulses are of a plurality of ultrasonic frequencies to improve the accuracy of measurement by compensating for the effects of standing waves within the tank and constructive/destructive summation of the waveforms as the sound reflects from the surfaces within the tank.

The received ultrasonic pulses are amplified and pre-filtered using analog circuitry before being sampled by a low-cost microcontroller with in-built high-speed analog to digital converter capable of sampling at approximately 100,000 samples per second. The return signal is processed digitally to determine the time of flight, by means of interpolating the slope of the return pulse to find the zero intercept. This method reduces the effect of amplitude of the return pulse and improves the accuracy and range of measurement over methods where the return pulse is compared to a fixed threshold value. The said microcontroller also computes the variance of the time of flight, over a number of successive measurements to detect disturbances at the water surface such as those caused by rainfall or other inflows entering from the top of the tank. In the presence of water disturbance the accuracy of the measurement is reduced. By detecting the disturbance the data is known to be less reliable. It allows corrective adjustments to be made to calculated values once the water disturbance has ceased.

Coded information unique to each sensor and/or by transmitting the information on separate radio frequencies is used to allow a number of wireless level sensors to be installed within the same physical area and be connected to one only designated display unit.

The wireless level sensor operates in sampled mode to prolong battery life. Sampled mode may involve transmitting data only on a detected change of level or at regular timed intervals, or preferentially a combination of both. The radio-frequency (RF) transmit power may also be fixed or adjustable: the benefit of reducing power would be to prolong battery life at the expense of radio range.

A wireless display unit in accordance with this invention has the capability of displaying information received and calculated from a plurality of wireless level sensors. The digital information received from the wireless level sensors is accumulated over specified time periods to determine water consumption, peak flow rate, water demand and other flow and consumption statistics.

This information and statistics displayed includes but is not limited to: total tank capacity, water level, current water capacity (volume), current percentage of capacity, individual and averaged daily totals of water consumption, weekly and quarterly totals of water consumption, occurrence of rainfall, estimates of inflow volume, current draw-down rate, and predicted time capacity of remaining liquid (for example, number of days of water remaining). The display unit also has the capability of providing visual and/or audible alarms for various user programmable scenarios including low level alarm, falling rate alarm, rising rate alarm and high level alarm.

This information contained within the wireless display unit can be transmitted over wires, for example by USB, or by a secondary wireless connection, such as Bluetooth, to a computer device capable of displaying, recording and possibly re-transmitting the flow information to other locations, such as a central office. The computer device may be a personal computer, personal digital assistant (PDA), mobile phone or similar item. Alternately and possible concurrently, the information transmitted by the wireless level sensors may be received directly by a computer device.

2008100552 10 Jul 2009

A plastic or plastic/metallic enclosure is used to house the sensor with a required degree of environmental protection from dust and moisture ingress. A means is provided to replace the battery in the sensor detector and where required to access potentiometers, buttons, miniature switches and any other interfaces required to configure and to test the sensor.

The invention is illustrated in the attached figures which are explained as follows. Figure one shows the wireless level sensor 1 and the wireless display unit 6 separated by a distance and interconnected by radio frequency (RF) transmission 5. The wireless level sensor is mounted on a water tank 2 and emits and detects ultrasonic pulses 3 and measures the time of flight of reflections from surface of the water in the tank 4. An optional computer interface 7 allows data to be gathered and further stored, displayed and retransmitted by a computer device or computer network.

Figure two shows a possible embodiment of the wireless detector circuitry. An ultrasonic transducer 8 is pulsed by voltage signals from pulse generator 9. The number, frequency and timing of each burst of pulses are controlled by microcontroller 11. Immediately after transmission of the pulses the microcontroller 11 begins to digitally sample the incoming echo signal which is received by ultrasonic transducer 10 and electrically amplified and filtered by circuitry in 7 before reaching the microcontroller. The circuitry in 7 may also contain a discriminator circuit to provide digital indication of faults and out-of-range warning to the microcontroller. A further option within circuitry 7 is adjustable amplifier gain whereby the amount of amplification can be increased as the time of flight increases. The gain may be controlled from within 7 and synchronised by microcontroller 11, or may be controlled directly by signals from the microcontroller. The time of flight of ultrasonic pulses is dependent on air temperature and so the sensor includes a temperature transducer 13 to measure the air temperature within the tank. This allows the microcontroller to apply corrections to the measured time of flight to correct for temperature variations and thus provide a more accurate result.

An important operational aspect of the invention is to prolong the life of the battery supply 14 and hence minimize required maintenance. Two schemes may be used to reduce power and are available for selection by the user. The first is where the distance is sampled at regular intervals, for example once per minute, and the results always transmitted by 12 to the wireless display unit. The second scheme involves regular sampling of the distance in the same fashion as the first scheme but transmitting the information only when a change in level is detected. In either scheme the electronics is put into a state of minimum power consumption when measurements and data transmission are not occurring. The preferred scheme is a combination of the above, whereby information is transmitted upon a detected change in level or at a nominal maximum period between transmissions. As an example, the measurement circuit checks the level every minute; if there is no detected change in state then a transmission would occur only once every ten minutes to ensure that the wireless display unit is regularly but less frequently updated with status information (eg low battery warning). If the level has changed over the minute then the information is sent.

Figure three shows a possible embodiment of the wireless display unit. Radio frequency (RF) signals from one or more wireless level sensors are received by the antenna 15 and RF receiver 16 which demodulates the radio signals into a serial digital bit-stream. The serial bit stream is decoded by a microcontroller or computer device 17 which interprets the data and displays the information on the LCD display or computer screen 18. An input device such as a keypad, computer keyboard and/or mouse may be used to select windows or pages of information and to configure the display unit with user settings and add new wireless level sensors. A power supply and/or battery pack 19 provides power to the other circuitry.

The information displayed by 18 comprises graphical displays, numerical data and text. Light emitting diodes and/or output circuits may also be used for status indication (for example low battery or communications error).

Outputs from the wireless display unit may include serial communications such as USB or Firewire. Or there may be a second wireless connection, such as Bluetooth to allow information transfer from the display unit to another system, such as a computer or communications networking device.

Optionally the display unit can be in the form of a personal computer, personal digital assistant (PDA) or mobile phone with appropriate wireless interface (eg Bluetooth) and with application software to perform the functions of receiving, accumulating and performing computations on the information received from one or more wireless sensors. The application software includes the ability to provide visual displays of the information and to store the data for historical reference and graphical historical display. It also generates visual and audible alarms and is capable of retransmitting the information to computer or mobile phone networks.

The display unit has the ability to check the information from the sensor which contains a unique identification number matching a number stored within the display unit to ensure that the information transmitted from a specific wireless sensor is intended for reception by a specific display unit. This is required for situations where a number of wireless sensors and corresponding display units are installed within the same vicinity. The sensor and display unit has the capability to store information in non-volatile memory for the purpose of unique identification, serial number and user settings. User settings include the mode of operation, sampling interval and alarm settings.

In the presence of radio frequency interference the above embodiment may suffer some problems in that transmission of information may be corrupted. This is likely in environments where spurious electromagnetic noise is significant. Two methods can be used to alleviate this situation. In the first method the sensor/transmitter sends the same information a number of times. Each successive transmission is known as a 'retry'. The display unit thus has more than one chance of faithfully receiving the information. The number of retries could be fixed, or set by the user with the setting determined by the anticipated severity of electromagnetic noise and on other factors, such as the negative effect on battery life.

In the second method, both the wireless level sensor and wireless display unit include radio transceivers with the capability for bi-directional communications. Upon reception and decoding of information, the wireless display unit sends an acknowledgement message back to the wireless level sensor. Such messages indicate to the wireless level sensor that information was properly received and that no further retry is required. And in the event that the display unit did not receive a valid reply then the wireless sensor would automatically retransmit the data, within a limited maximum number of retries.

2008100552 10 Jul 2009

In the case where bi-directional radio communications are used there is a further possible method of prolonging battery life. The RF transmit level is automatically adjusted to achieve reliable error free communications using the minimum transmit power.

2008100552 10 Jul 2009

The claims defining the invention are as follows:

1. A wireless sensor and corresponding display unit for monitoring of liquid level within a vessel whereby information from one or more wireless sensors is received by a single display unit capable of visually displaying the level of material, remaining volume, and computed statistics and predicted values associated with material consumption, including but not limited to, the time period of remaining material and volume and time of material inflows, determined from historical values of the said information.

2. A wireless sensor as claimed in Claim 1 that uses one or more ultrasonic transducers to measure at a plurality of ultrasonic frequencies the distance to the material surface, based on the time of flight for pulses of ultrasonic sound, or alternately that uses an optical transmitter and receiver to determine distance to the surface by means of reflection and triangulation from the surface of the material, or as a further alternative, that uses a combination of ultrasonic and optical sensors to determine the distance to the material surface.

3. A wireless sensor and corresponding display unit as claimed in Claim 1 whereby regularly occurring measurements from one or more wireless level sensors are received by the display unit and are used to display information including, but not limited to: remaining tank capacity (remaining volume), water level (height), current water capacity (volume), remaining percentage of total capacity, averaged totals of water consumption for a variety of time frames, weekly and quarterly totals of water consumption and rainfall, estimated inflow volume, consumption draw-down rate, and predicted time capacity of remaining liquid (for example, number of days of water remaining), and where the said information may be displayed for individual vessels, and as consolidated figures for a combination of vessels.

4. A wireless sensor and corresponding display unit as claimed in Claim 1 where the display unit is capable of displaying information in numerical, graphical and/or textual format, and having an optional capability of providing visual and/or audible alarms, and may be in a physical form of a compact unit with a liquid crystal display, keypad, computer interface and optional optoelectronic indicators, or in the physical form of a

computer device such as a computer, PDA or mobile phone with a capability to communicate with the said wireless sensors.

5. A system substantially as described herein with reference to figures 1 to 3 of the accompanying drawings.

Andrew James Stewart 13 June 2008

2008100552 13 Jun 2008

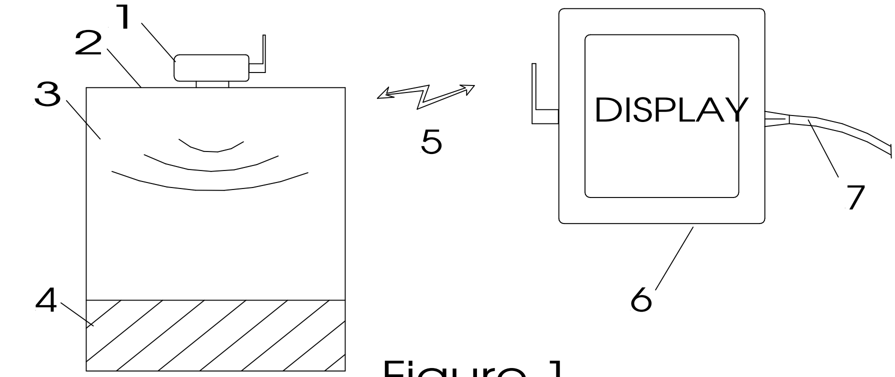

Figure 1.

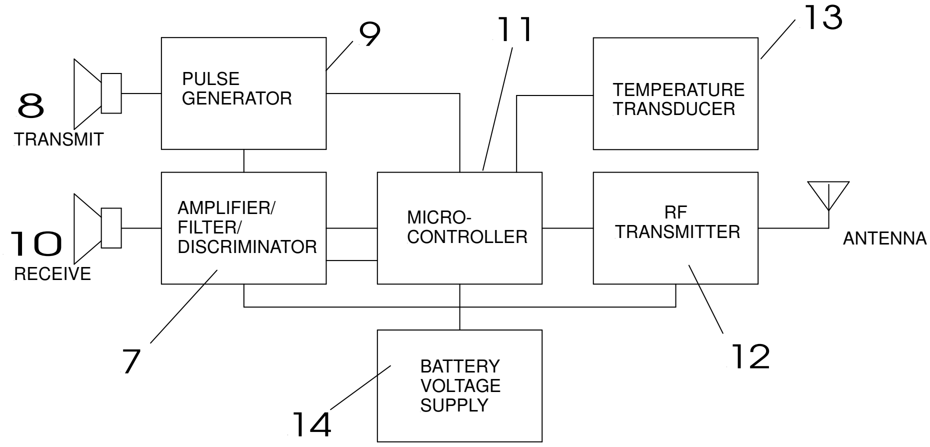

Figure 2.

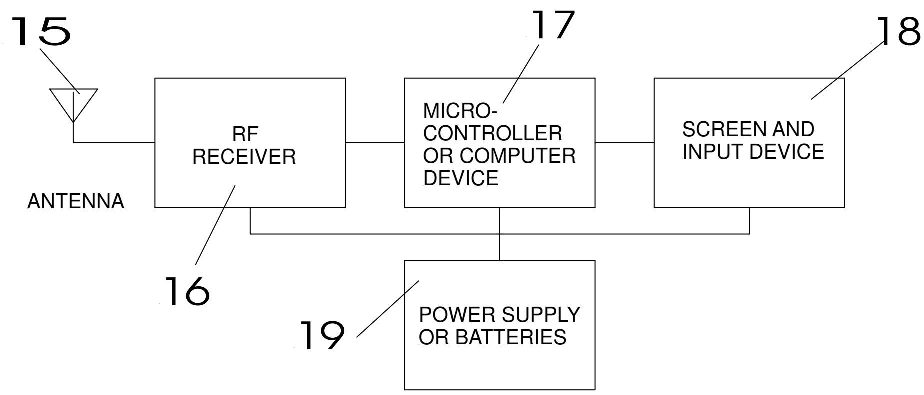

Figure 3.