FIG. 4 is a block diagram illustrating how a plurality of Smart Modules may be configured in two-way communication with one another, as Smart End Devices or as a Smart Module Coordinator.

## DETAILED DESCRIPTION OF THE INVENTION

The following description and Figures describe the overall features of the smart module of the present invention. More detailed description of the invention may be found in the Appendices of Provisional U.S. Patent Application No. 61/921,298 filed on Dec. 27, 2013, and incorporated herein by reference. Appendix I contains the System Design Description for the Smart module of the present invention, while Appendix II includes the schematic diagrams for the Smart module of the present invention. Appendix III includes the source code for the software operating in the present invention. All three Appendices are incorporated herein by reference. Appendix III is also provided as an Appendix I to the present application.

FIG. **1** is an exploded view of one embodiment of the apparatus of the present invention. Referring to FIG. **1**, the present invention comprises a satellite transceiver **160**, circuit board **120** including a GPS receiver, antenna **110**, mass data storage device, short range wireless radio, and battery pack **150**. Custom circuit board **120** includes a very low power processor, real time operating system, and custom application firmware. The components are enclosed in watertight enclosure **130** with connections **140**, **145** for external power and sensors.

Most of the components illustrated in FIG. **1** are commonly available parts, except the custom circuit board **120** and application firmware. The circuit board **120** is what ties the common components together into a system. The application firmware is created by commonly available software development tools. Appendix III includes a copy of the application firmware. The specific function of the application will depend on the intended purpose for the module. Some government applications that have been completed are a converter of analog signals to calibrated digital signals, data logger, asset position reporter, and environmental data message transmitter.

The device components, including the antenna **110**, are enclosed in a NEMA 6P rated enclosure **130** to resist harsh open ocean environments. The device is small and lightweight, which makes it less susceptible to damage from the ocean environment. FIG. **3**A is a perspective view of the smart sensor module, illustrating installation on an existing weather data buoy. As illustrated in FIG. **3**A, the device of the present invention (in detail B) may be readily mounted to a weather data buoy **310** without disturbing existing sensors **350** or other hardware. Watertight enclosure **130** may be mounted to a buoy mast using fasteners or even wire ties and the like. An external sensor may be connected to the buoy via connections **140**, **145**, and power supplied via connection **145**. Power may be provided from battery pack **330** and/or solar panels **320**.

FIG. **3**B illustrates the smart module of the present invention as mounted to the data buoy of FIG. **3**A. In this application of the smart module of the present invention, an AIRMAR sensor wind speed sensor **340** manufactured by AIRMAR Technology Corporation of Milford, N.H., is being tested against a standard propeller-type anemometer **350** on Buoy **310**. AIRMAR sensor **340** measures wind speed and direction, temperature and barometric pressure. Normally there are two propeller-type anemometers **350** on the buoy **310** (two for redundancy). In this case, one anemometer has been removed and a smart module **130** and AIRMAR sensor **340** combination mounted in that spot. This installation illustrates how a new sensor can be substituted for an existing sensor, or used to augment existing sensors, without disturbing the underlying electronics for the existing sensor system.

The smart module of the present invention may be also used by private companies conducting commercial activities at sea in a similar manner. These may include oil and gas exploration companies. However, a commercial (rather than government) Iridium gateway may have to be used which may add to communications costs.

The present invention provides a small, very low power system building block to use in multiple ways in remote data acquisition and reporting systems. It provides a unique combination of commercially available functions needed to acquire, process, store, and report data economically. It makes testing of new sensors or processing methods, easier and with less risk to operational systems. Thus changes, or additions, to existing more complicated systems can be made faster, more economically, and with less risk to operational systems.

FIG. **2** is a block diagram illustrating the major components in one embodiment of the present invention. Referring to FIG. **2**, smart module enclosure **130** includes the smart module custom board **120**, which is provided with an MSP430 processor **240**, manufactured by Texas Instruments, of Dallas, Tex. Built around a 16-bit CPU, the MSP430 is designed for low cost and, specifically, low power consumption embedded applications. The MSP430 processor **240** may include an onboard A/D converter **250**, counter **260**, and battery backed real-time clock (RTC) **295**.

The smart module of the present invention is provided with advanced calibration firmware, which may be used to calibrate both the smart module of the present invention and the sensor as one unit. Within user menus and under user control, the smart module of the present invention automatically computes a second order calibration and stores the calibration coefficients in non-volatile memory, such as flash card **290**. The calibration coefficients are later applied to acquired data. Thus, the smart module of the present invention can increase the accuracy of a sensor. The smart module of the present invention may also have the capability to store data internally.

The software may run a Real-Time Operating System (RTOS) known as Salvo, provided by Pumpkin, Inc., of San Francisco, Calif. The RTOS greatly simplifies coding of the system and eases control of timing. For example, normally code for switching back and forth from high power and low power modes would be sprinkled through the overall code. Also, waking up from low-power mode would have to be done many times. The application becomes complex because of going to low power mode and waking up has to be carefully planned. With Salvo, going into low-power mode and waking up is done in one location in the code. The Salvo scheduler handles all aspects of timing and low-power cycling.

Wet mate plug **140** may be used to interface with various sensors or other smart modules. Inputs from sensors may include three channels of sensor data and one channel of counter data, which may be fed to analog signal conditioning circuit **210**, which in turn is tied to the A/D input **250** and counter input **260** in MSP430 processor **240**. Power to external sensors may be fed through wet made plug **140** as well. Sensor data or user interface data in serial form may be fed through serial RS232 interface **220**, which in turn may transmit data to MSP430 processor **240**.

In a wired mode, the smart module of the present invention measures an analog input signal fed through wet mate plug **140**, averages the values in analog signal conditioning circuit **210** (or digitally in MSP 430 processor **240**), and then formats