Smart Sensor Technology and Measurement System

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Abstract— This paper revels the introduction and information regarding smart sensors and their measuring devices. This are used for sensing comfort, air quality, occupancy assessment like air temperature, air velocity, humidity, CO2, odors, sound motion etc. sensors like Traditional Integrated Sensors used to sense element and further signal conditioning and processing which leads to microprocessor. Smart sensor possesses several functional layers: signal detection from discrete sensing elements, signal processing, data validation and interpretation and signal transmission along with display. A smart sensor system will require energy to support and operate all components. If the sensor element and communication both have low power designs and are compatible, the total energy for system is correspondingly low. Monolithic integrated chip is low powered BiCMOS signal processor chip can amplify, filter and time – division which multiplex the signals that are transmitted via an RF link contained within packages to an external radio receiver. In the last decade few industries have been impacted by rapid advancement in technology. 88% smart sensors are used in personal computers and laptops, 79% in smartphones, 47% in tablets, 35% in games and smart televisions, 14%in smart home appliances, 11% in smart watch, 10% in smart wristbands and 2% in remaining devices. The presented partial implementation of the system measures the temperature at several locations in the soil profile in field conditions and communicates with the host PC computer in wireless way. The developed hardware and software is intended to be adapted to more complex monitoring systems working in compliance with IEEE 1451 smart transducer interface standard and covering large areas as an element of air-borne or satellite remote sensing and serve for ground reference measurements.

Key words: Smart Sensors, Occupancy Assessment, Signal Processing, Monolithic Chip Etc

I. INTRODUCTION

The design, fabrication, and construction of smart structures are one of the ultimate challenges to engineering researchers today. Because they form the essence of system intelligence, one of the cores of smart structures technology centers around innovative sensors and sensor systems. Structural health monitoring (SHM) represents one of the primary applications for new sensor technologies. Indeed, much attention has been focused in recent years on the declining state of the aging infrastructure in the U.S., as well as to the limitation of their responses during extreme events (such as wind and earthquakes). These concerns apply not only to civil engineering structures, such as the nation's bridges, highways, and buildings, but also to other types of structures, such as the aging fleet of aircraft currently in use by domestic and foreign airlines. The ability to detect damage at an early stage can reduce the costs and down-time associated with repair of critical damage. Observing and/or predicting the onset of dangerous structural behavior, such as flutter in bridges, can allow for advance warning of such comportment and commencement of removal of the structure from service for the protection of human life. In addition to monitoring long term degradation, assessment of structural integrity after catastrophic events, such as earthquakes, hurricanes, tornados, or fires, is vital[1]. In contrast to smart sensors, primitive sensors are devices or materials that have some electrical property that changes with some physical phenomenon. With the right circuit and program, microcontroller light measurements are possible. Other examples of common primitive sensors are current/voltage output temperature sensors, microphone transducers, and even the potentiometer, which is a rotational position sensor. Inside every smart sensor is one or more primitive sensors and support circuitry. The thing that makes a smart sensor "smart" is the additional, built-in electronics [2].

II. SMART SENSORS

"Smart" sensors with embedded microprocessors and wireless communication links have the potential to fundamentally change the way civil infrastructure systems are monitored, controlled, and maintained. Sensors and sensor systems are vital to our awareness of our surroundings and provide safety, security, and surveillance, as well as enable monitoring of our health and environment. A transformative advance in the field of sensor technology has been the development of smart sensor systems. The definition of a smart sensor may vary, but typically at a minimum a smart sensor is the combination of a sensing element with processing capabilities provided by a microprocessor. That is, smart sensors are basic sensing elements with embedded intelligence. The sensor signal is fed to the microprocessor, which processes the data and provides an informative output to an external user. A more expansive view of a smart sensor system. The fundamental idea of a smart sensor is that the integration of silicon microprocessors with sensor technology can not only provide interpretive power and customized outputs, but also significantly improve sensor system performance and capabilities. The smart sensor possesses several functional layers: signal detection from discrete sensing elements, signal processing, data validation and interpretation, and signal transmission and display. Multiple sensors can be included in a single smart sensor system whose operating properties, such as bias voltage or temperature; can be set by the microprocessor.

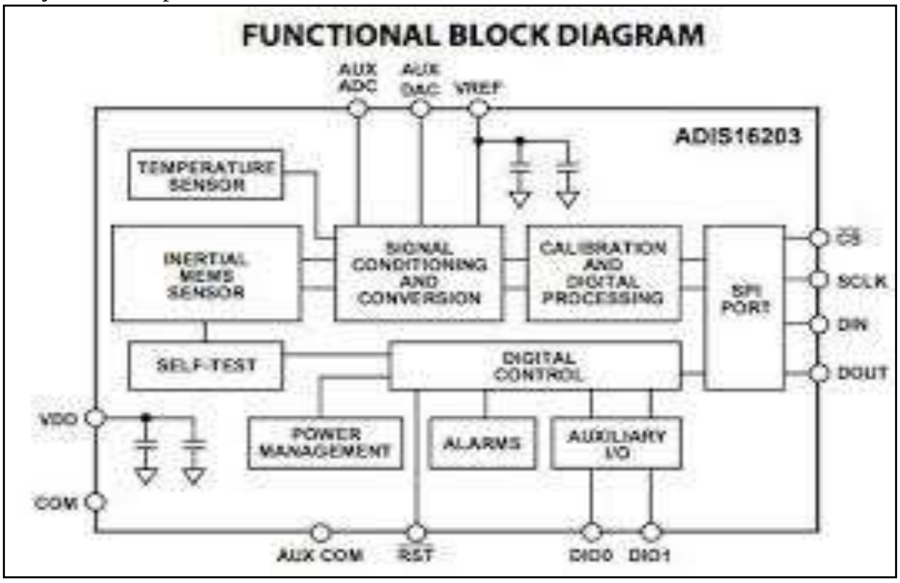

Fig. 1: Block Diagram of Smart Sensor [4]

The sensor elements interface to signal control and conditioning stages that will provide both excitation and signal data logging and conditioning. The data acquisition layer will convert the signal from analog to digital and acquire additional parameters of interest to provide compensation when needed for thermal drift, long term drift, etc. The embedded intelligence will continuously monitor the discrete sensor elements, validate the engineering data being provided, and periodically verify sensor calibration and health. The processed data becomes information and can then be transmitted to external users. The user can choose the complexity of the data transmitted: from a single reading to a complete download of the sensor system's parameters. The size of smart sensors has been decreasing with time. The use of MEMS has made possible the dream of having ubiquitous sensing and in particular small "smart" sensing. MEMS devices are manufactured using vary large scale integration technology (VLSI) and can embody both mechanical and electrical functions. MEMS can be used in an environment to both sense and actuate. Sensing requires that a physical or chemical phenomenon be converted to an electrical signal for display, processing, transmission, and/or recording. Actuation reverses this flow and converts an electrical signal to a physical or chemical change in the environment. The main advantage brought by this technology and its design paradigm to applications is miniaturization. MEMS features are typically on the scale of microns (10–6 m). MEMS devices can be found in a wide-range of applications from accelerometers for airbag deployment to electronic particle detector that helps for nuclear, biological, and chemical inspection [3].

A. Components of Smart Sensors

The components of a smart sensor system as depicted in Fig. 1 include sensors, power, communication, and signal processing typically provided by a microprocessor. The description of advances in microprocessor technology is beyond the scope of this article, but recent advances are enabling sensor systems to function remotely on very little power. There are many examples of technology advancements in sensors, power, and communications that can enable future smart sensor systems. The ideal goal is to have a self contained smart sensor system that is cost-effective, reliable, self-monitoring, reconfigurable, and can operate indefinitely. Simply put, just as micro fabrication approaches are enabling the revolution in microprocessor technology and MEMS sensor elements, micro fabrication and nanotechnology will play a notable role in the development of smart sensor systems. Below are examples of several potentially enabling technologies for smart sensor system [3].

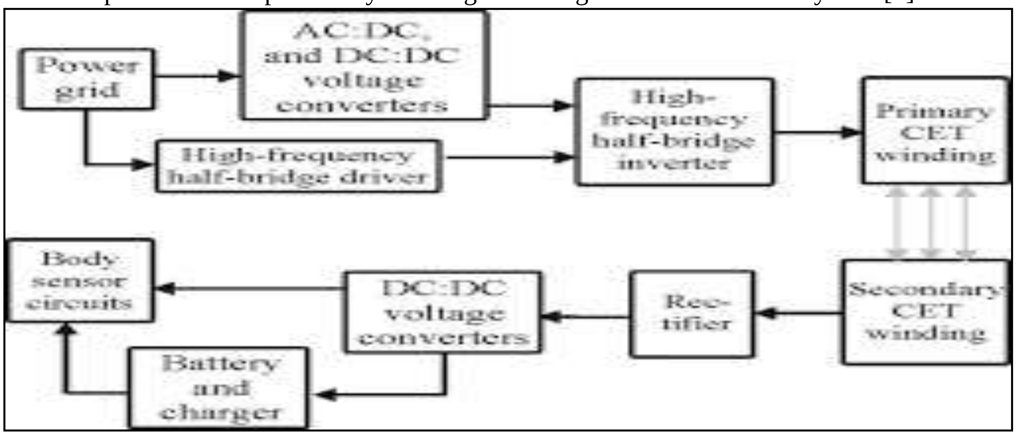

Fig. 2: Components of Smart Sensor [5]

III. MEASURING DEVICES

The popularity of smart phones and the development of mobile Internet, the demands for accurate indoor positioning have grown rapidly in recent years. Previous indoor positioning methods focused on plane locations on a floor and did not provide accurate floor positioning. Traditionally, barometers are used outdoors to measure altitude and meet positioning needs.

McLellan presented a method that combined a barometric altimeter and GPS to improve the GPS accuracy and prevent the influence of environment. To date, micro-electromechanical system (MEMS) pressure sensors can achieve a relatively high accuracy. Massé even used MEMS pressure sensors to study human action (the achieved relative accuracy was 0.53 m). Because of the sensitivity of barometric sensors to vertical movements, a number of researchers have used these sensors to detect vertical motions of a human body, such as standing up, sitting down, and falling. With the miniaturization and decreasing cost of MEMS barometric sensors, they are now installed in a number of portable intelligent devices. MEMS barometric sensors have launched in a number of Android phones such as the Galaxy Nexus, Galaxy SIII, Galaxy Note 2, and other similar devices. Recent studies on the use of MEMS barometers to increase the accuracy of satellite/inertial navigation system vertical channel are presented in. These papers showed that MEMS barometers can be successfully integrated with all types of sensors. In a sensor fusion method is presented to track vertical velocity and height based on inertial and barometric altimeter measurements [6].

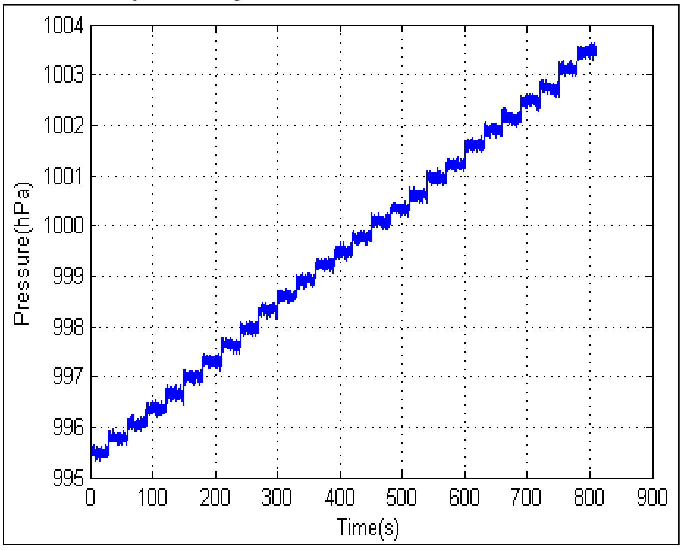

Fig. 3: Barometric-pressure distribution of a 25-story building (with two basements).

The horizontal axis represents the sampling time (s), and the vertical axis represents the Barometric-pressure value (hPa). The data collection order is from the top floor to the basements.[6]

IV. APPLICATIONS

Sensors are input devices of the measurement system while actuators are output devices translating electrical signals into usually mechanical actions. Transducers are defined as devices that convert one type of energy to another, for example temperature to an electrical signal. A sensible distinction is to use 'sensor' for the sensing element itself and 'transducer' for the sensing element plus any associated circuitry. All transducers would thus contain a sensor and most (though not all) sensors would also be transducers. Smart transducers must incorporate some element of control, computation or decision-making. They enhance functionality, performance or cost of the measurement system. Sensors and actuators are everywhere: at home appliances, in the office, in factories etc., and they are intended to increase the control of human environment, increase production efficiency and enhance our security. Because of the inherent intelligence smart sensors implementation would give many advantages as compared to standard sensors. The driving forces that develop smart sensor technology are mainly: aerospace, automotive and military industries, industrial control and automation, building automation, security and also environmental monitoring. Currently there are two ways for the development of smart sensing technologies (WICZER 2001). The first one represents basic physical and (bio) chemical research in sensor's conversion phenomena: thermoelectric, photoelectric, photomagnetic, electromagnetic, thermooptic, etc. in the context of integrating the sensing element with microelectronic-based "smart" capabilities. The problems facing researchers in this field concern selectivity, materials compatibility and integration of different technologies. The example of technology and material incompatibility is a thermocouple operating at temperatures 300 ° C to 50° C enhanced by "smart" microelectronic element. The most microelectronics circuits do not work at temperatures above 150 ° C and the materials used to manufacture thermocouples are generally not compatible with high purity conditions of silicon based microelectronics fabrication process. Other example is the Micro-Electro-Mechanical System (MEMS) that integrate mechanical elements, sensors, actuators, and electronics on a common silicon substrate through micro-fabrication technology. The successful applications of MEMS sensors are: pressure transducers integrated with analog signal processing circuits and digital interfacing circuits, accelerometers available in the form of integrated circuits. Apart from technical obstacles there are also economical reasons that hamper the wide implementation of integrated smart sensors, i.e. users and producers implementation costs as well as the lack of widely accepted standards. Soil physical parameters change continuously for climatic reasons and human activity. Mineral composition, grain distribution and humus content are practically not affected by spatial and temporal change. Human activity: organic and chemical fertilization, as well as mechanical influence modify the variable parameters of the soil solid phase including: organic matter content, aggregate distribution and soil compaction. The basic quantities describing the soil physical status in the quantitative way are: soil water content and potential, soil temperature, mechanical properties (texture and porosity porosity), gas diffusion, salt concentration and ions activity [7].

V. ADVANCEMENT IN SMART SENSOR

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All integrated circuits employ silicon technology. A smart sensor is made with the same technology as integrated circuits. A smart sensor utilizes the transduction properties of one class of materials and electronic properties of silicon (GaAs). A transduction element either includes thin metal films, zinc oxide and polymeric films. Integrating electronics circuits on the sensor chip makes it possible to have single chip solution. Integrated sensors provide significant advantages in terms of overall size and the ability to use small signals from the transduction element. The IC industry will get involved in smart sensor if a very large market can be captured and the production of smart sensor does not require non-standard processing steps [8]. The sensors and sensing technology plays a crucial role in our day-to-day life. Sensors and associated measuring instrumentation circuits pose a challenge towards the development of a low-cost intelligent sensing system. Sensors are a significant part of complex and sophisticated systems of modern technology. It will be difficult to achieve the purpose of any modern system or process control without use of any forms of sensors. In recent times, a significant amount of research work is undertaken to develop smart and intelligent sensor system for different novel applications. J. Schmalzel et. al. (Schmalzel, Figueroa, & Morris, 2005) have reported an implementation of a prototype intelligent rocket facility, the results of which established a basis for future advanced development and validation using the rocket test stand facilities at Stennis Space Center. In health management systems, smart sensor components play key roles in providing the distributed intelligence needed to perform diagnosis of overall health of the people. A wireless visual sensor comprising of a low-cost greyscale camera as the sensing hardware and BlueTooth (BT) 100-m slave module as the transmission hardware has been reported in (Ferrigno, Pietrosanto, & Paciello, 2006). The sensor is quite efficient in terms of cost, energy saving and bandwidth for image transfer. Usually the camera based sensor systems are not able to provide internal characteristics of the system though in recent times depth camera has now been reported. A low-cost, high performance displacement sensor has been presented in (Toth & Meijer, 1992). The system has been implemented with simple electrodes, an inexpensive microcontroller and linear capacitance-to-period converter. For the sensing system sometime excitation for the sensors pose design challenges. The excitation part of the sensor as reported in (Toth et al., 1992) is not very clearly explained as this can be challenging in many applications. A low-cost, smart capacitive angular-position sensor with simple, stable and reliable characteristics has been reported in(Li & Meijer, 1995), (Li, Meijer, de Jong, & Spronck, 1996) and (Li, Meijer, & de Jong, 1997). Interfacing the sensors signals to a microprocessor or to a microcontroller pose a challenge. A novel smart interface for voltage-generating sensors has been reported in (Li, Meijer, & Schnitger, 1998). A smart and accurate interface for resistive sensors has been reported in (Li & Meijer, 2001). If the sensors provide DC signals as in for thermocouple types, the problem of interfacing is not so severe. It is important that the signal from the sensors should also have the condition signals, which provide rudimentary information necessary for fault detection and isolation in sensor systems (Amadi-Echendu & Zhu, 1994). Such rudimentary information should be very significant in the development of an intelligent measurement system. An interface circuit for a differential capacitance transducer has been described in Mochizuki, Masuda, & Watanabe (1998) which allows high-accuracy signal processing with standard components. In Patra, Kot, & Panda (2000), a scheme of an intelligent capacitive pressure sensor using an artificial neural network has been proposed. A complete solution to connect an IEEE 802.11-based sensor with a wireless network has been presented in (Ferrari, Flamini, Marioli, & Taroni, 2006). An overview of significant development of methods, structures, manufacturing technologies, and signal processing characterizing today's sensors and sensing systems has been presented in (Kanoun & Trankler, 2004). Most of the common magnetic sensing methods have been described and the underlying principles governing their operation have been highlighted in (Lenz & Edelstein, 2006) [9].

VI. CONCLUSION

So, in conclusion the introduction and information regarding smart sensors and their measuring devices. This are used for sensing comfort, air quality, occupancy assessment like air temperature, air velocity, humidity, CO2, odors, sound motion etc. sensors like Traditional Integrated Sensors used to sense element and further signal conditioning and processing which leads to micro processor. Smart sensor possesses several functional layers: signal detection from discrete sensing elements, signal processing, data validation and interpretation and signal transmission along with display. A smart sensor system will require energy to support and operate all components. If the sensor element and communication both have low power designs and are compatible, the total energy for system is correspondingly low. Monolithic integrated chip is low powered BiCMOS signal processor chip can amplify, filter and time – division which multiplex the signals that are transmitted via an RF link contained within packages to an external radio receiver. In the last decade few industries have been impacted by rapid advancement in technology. 88% smart sensors are used in personal computers and laptops, 79% in smartphones, 47% in tablets, 35% in games and smart televisions, 14%in smart home appliances, 11% in smart watch, 10% in smart wristbands and 2% in remaining devices. The presented partial implementation of the system measures the temperature at several locations in the soil profile in field conditions and communicates with the host PC computer in wireless way.

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