International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075, Volume-2, Issue-4, March 2013

Seat Occupancy Detection Based on Impedance Measurement

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Abstract— ***Improved automotive safety depends on the sensing of the occupancy of the seat. Capacitive sensors are one of the most attractive sensor technologies that are used in seat occupancy detection. With the help of capacitive sensing methods the presence of an object or a person can be detected. This information can be used in vehicles for triggering safety devices, like airbag, only in the case when the seat is occupied by a human. A method for identifying human proximity in a seat by sensing the electric field and by measuring the impedance is introduced in this paper.***

Keywords— ***capacitive sensing principle, electrodes, electric field sensing, impedance measurement, integrated circuit.***

I. INTRODUCTION

Seat occupancy detection is an application of capacitive sensing principle. In vehicles, information about the presence of the passengers or an object can help to improve automotive safety. Airbag can be deployed when a vehicle is collided, in order to prevent the collision of the passenger sitting on the seat with an instrument panel of the vehicle. But while traveling, there can be a state of unoccupancy of the seats other than the driver seat. In such cases the occupancy detection system can provide the information to a control unit so that the air bag is deployed only if the seat is occupied by the passengers. An inductive [2] and capacitive [3] proximity sensing principle is used to detect the presence of an occupant.

In this paper the seat occupancy detection by measuring the impedance value is described. Impedance to digital converter IC (AD5933) is used to convert the impedance value of the person or object to a digital value [4], [6], [7]. Then the state of occupancy of the seat is determined according to the measured impedance.

II. OVERVIEW

Body impedance depends on the volume of different tissues or fluids in the body [6]. In this paper the occupancy of the seat is detected regarding the impedance value. Electrical impedance of a material is the opposition that the material offers to the flow of electrical charges through it. The impedance which varies as the function of frequency [1] is used for detecting the occupancy of the seat.

Manuscript received on March, 2013.

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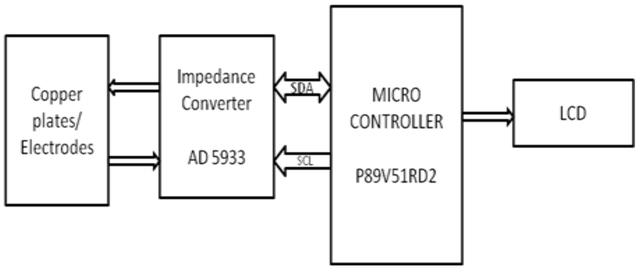

Fig. 1. Overall block diagram of seat occupancy detection

Fig 1 shows the block diagram of the seat occupancy detection which consists of two electrodes/copper plates that are to be placed on the sitting area of the chair. Electrical signal is given to one of the electrodes, from AD5933 impedance converter. The electrode to which the electrical signal was given, act as a transmitter and the other electrode act as a receiver. Now, electric field gets generated between the two plates and the field strength is high. When the load (human being/object) is placed, the field between the electrodes gets shielded. Due to that obviously the current in the electrode varies. The current from the receiver electrode is given to the impedance to digital converter IC (AD5933). Inside the AD5933, the magnitude of the impedance is calculated using the DFT process. Through I²C the impedance value is given to the microcontroller. In the microcontroller, the impedance value is checked according to the threshold value. And then, in the LCD the occupancy state of the seat will be displayed.

A. *Impedance converter*

Fig 2 shows the block diagram of AD5933 which is a high precision impedance converter system solution that combines an on-board frequency generator with a 12-bit, 1 MSPS, analog-to-digital converter (ADC).

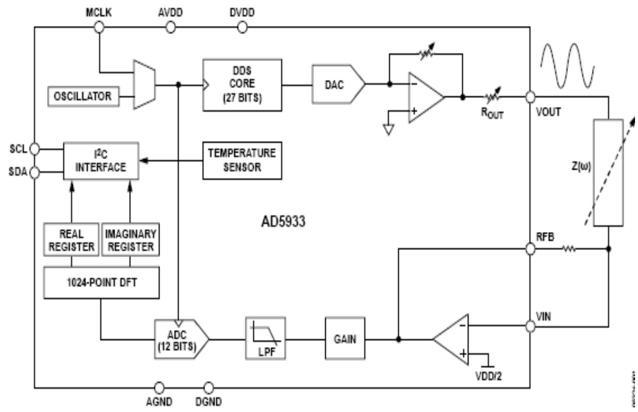

Fig. 2. Functional block diagram of AD5933

The on-chip frequency generator allows an external complex impedance to be excited with a known frequency. The system allows the user to program a 2V peak to peak sinusoidal signal as excitation to an external load. The response signal from the impedance is sampled by the on-board analog to digital converter (ADC) and a discrete Fourier transform (DFT) is processed by an on-board DSP engine. The DFT algorithm returns a real (R) and imaginary (I) data-word at the real and imaginary register contents, which can be read from the serial I²C interface.

B. *Magnitude Calculation*

The first step in impedance calculation for each frequency point is to calculate the magnitude of the DFT at that point. The DFT magnitude is given by

$$\text{Magnitude}=\sqrt{R2+I2} \quad (1)$$

R is the real number stored at Register Address 0x94 and Register Address 0x95 and the Imaginary number (I) is stored at Register Address 0x96 and Register Address 0x97.

To convert the number into impedance, it must be multiplied by a scaling factor called the gain factor. The gain factor is calculated during the calibration of the system with known impedance connected between the VOUT and VIN pins.

Once the gain factor has been calculated, it can be used in the calculation of any unknown impedance between the VOUT and VIN pins of the impedance converter chip.

C. *Impedance Calculation*

The gain factor is determined by placing known impedance between Vin/Vout pins of the AD5933 and by measuring the resulting magnitude. The AD5933 system gain settings need to be chosen to place the excitation signal in the linear region of the on-board ADC. The gain factor must be recalculated if any one of the parameters like current to voltage gain setting resister or output excitation voltage is changed.

The gain factor can be calc1ulated using the below formula,

$$\text{Gain Factor} = \frac{1}{knownimpedance * magnitude} \quad (2)$$

The calculated gain factor derived previously is used to measure the unknown impedance. The magnitude of the impedance is therefore given by the following formula,

$$\text{Impedance}= \frac{1}{gain\,factor * magnitude} \quad (3)$$

III. RESULTS

The observed impedance value for both the occupied seat and the unoccupied seat is given in the table below. Here, the term occupied seat refers to the seat which was occupied by humans and the term unoccupied seat refers to the seat which was occupied by any objects and the state of unoccupancy or empty seat.

Seat Occupied By Human

Person 1 Impedance (kohm)	Person 2 Impedance (kohm)	Person 3 Impedance (kohm)
13	10	11
07	06	06
11	07	07
13	11	11
12	12	06
08	11	08
12	08	06
Range 7-13 (kohm)	Range 6-12 (kohm)	Range 6-11 (kohm)

From the obtained readings which are mentioned in the above table, it is obvious that a threshold value of 13 kohm is fixed to determine the state of occupancy. When the load is placed, if the impedance value is below the threshold value, then it can be identified as the seat is occupied by the human. If the impedance value is greater than the threshold value, then it can be stated that the seat is not occupied by the human. The weight of the humans whose impedance value was measured lies between 50-55kg.

The experimental readings in the table shown below shows clearly that, when the seat is empty or when it is occupied by objects the impedance value does not falls on the range of occupancy of the seat. The laptop used is dell inspiron and its weight is 2.5kg.

Seat Unoccupied

Laptop Impedance (kohm)	Empty Impedance (kohm)
23	80
18	81
30	100
28	72
19	92
30	124
22	115
19	109
18	76
23	73
Range 18-30 (kohm)	Range 72-124 (kohm)

Fig 3 shows the experimental setup of the seat occupancy detection system based on the impedance measurement which has two copper plates each of 37cm in length and 17cm in breadth that are stitched on a cloth and placed on the sitting area of the chair beside each other with a small space between them.

The position of the human on the seat does not affect the obtained range of impedance, for the electrode setup used in this paper. If one electrode is placed on the sitting area and the other electrode is placed on the back resting surface [1] of the seat, then the impedance values falls in the range of unoccupancy when the human being is bent forward.

The number of electrodes used to detect the occupancy of the seat in this paper is two. Whereas increase in number of electrodes [5] increases the circuit complexity.

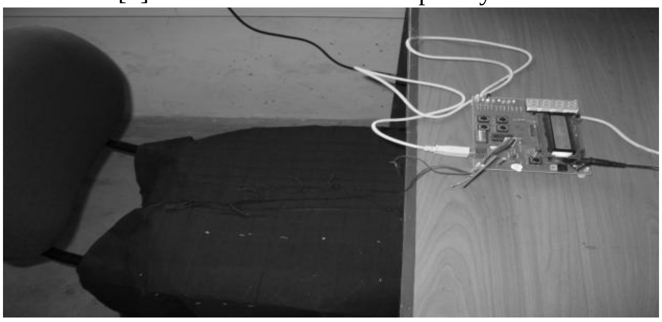

Fig. 3. Experimental setup

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IV. CONCLUSION

This system is a microcontroller based, high precision and low power device which uses only two electrodes for capacitive sensing technology. Due to the simple structure, it can be made as a portable impedance measurement device, which is used in a lot of scientific and industrial fields such as bioelectrical impedance analysis. In this paper we have used the impedance converter to detect the occupancy of the seat, which provides an accurate low cost solution to impedance measurement.

ACKNOWLEDGMENT

We wish to acknowledge staff, management and the professors of Karunya University for supporting us in providing the infrastructure and support for the completion of this paper.

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