LOW-COST CAPACITIVE PERSONNEL DETECTOR

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A low-cost capacitive personnel detector has been implemented. It can detect relative position of a person as well as its direction movement. Furthermore, the detector system can be calibrated for different sensitivity depends on the final application. The principle of the detector is based on the measurement of changes of capacitances between electrodes that are affected by the location of a human-body.

1. INTRODUCTION

Personnel detectors are used in many public places for security reasons or entrance counting. Usually, those systems are based on double light switches that enable the detection of the direction of passing persons [1]. Those systems can be easy recognized by delinquents and be destroyed. However, the detector presented in this paper can easily be camouflaged by decorations as carpets, painting frames, and mural paper. Furthermore, such a detection system could be very suited for application in interactive artwork [2].

In this paper a design of a low-cost capacitive personnel detector is presented. A model for the capacitance changes is derived and measurement results are presented. Even though the capacitance changes are in the order of only 0.001 pF the electronic circuit is able to detect and bring reliable information at very low-cost. The capacitance changes are measured by using a first-order relaxation oscillator [3,4,5], which has been connected to a microcontroller.

2. BASIC PRINCIPLE

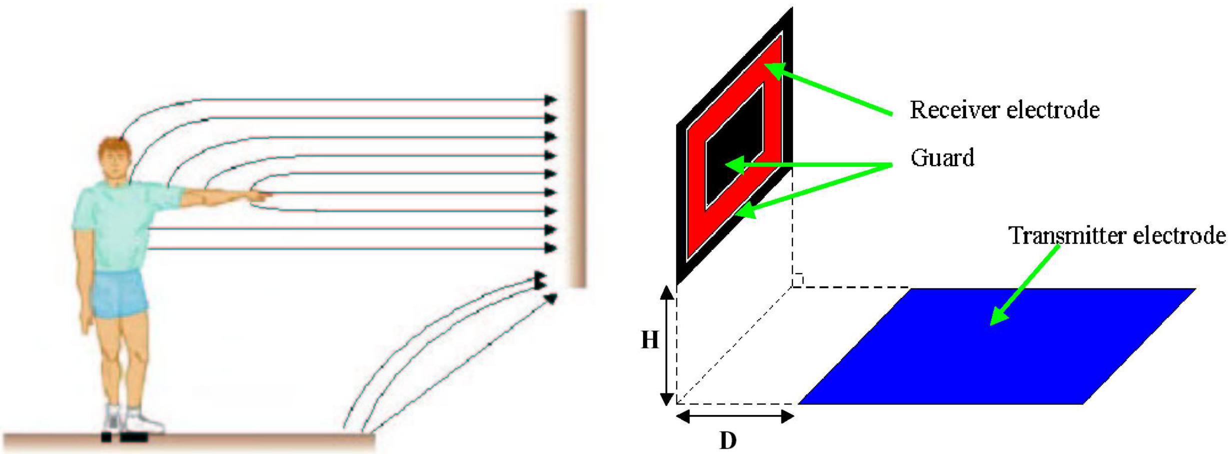

Fig. 1. (a) Electrodes configuration and its electric field, (b) Layout of the personnel detector

The electrode structure consists of two electrodes located at 90 degrees with respect to each other (Fig.1.a). This system is capable to detect the presence of a person located on the laid electrode and to estimate its relative movements. The principle is based on the fact that the human body for a large percentage consists of water. Thus, the human body can be considered as a conductor that moves between the electrodes. The person's shoes are assumed to isolate his body from the electrode placed on the floor; nevertheless it is not a necessary requirement.

The practical implementation of this system has been depicted in figure 1(b). Several electrodes are used. The transmitter electrode is placed on the floor, where the requirement is to be isolated from the environment. A guard electrode surrounds the receiver electrode [6]. This guard electrode allows the system to be least sensitive to electrical field from noise sources as e.g. power lines and electronic equipments. A simplified electrical model of the system is depicted in fig. 2. The capacitances C_{1p} and C_{2p} are the parasitic capacitances adding to the system by cable connections. The capacitance formed between the receiver electrode and the guard electrode will increase the capacitance represented by C_{2p}. If a shielding electrode is added under the transmitter electrode, its capacitance value will increase the capacitance represented by C_{1p}. The model element C_{feet} represents the capacitance of the person's feet to the transmitter electrode; C_{air} is the parasitic capacitance from the transmitting electrode to the receiving electrode and C_x is the capacitance formed from the person to the receiving electrode, which is the sensing capacitance.

The effect of parasitic capacitances C_{1p} and C_{2p} is reduced by applying the so-called "two-port technique" [7]. Using this technique the effect of the parasitic capacitances C_{1p} and C_{2p} is minimized by using a low-impedance voltage source V and a low-impedance current meter for the detection of I_m.

Applying the two-port technique, the measured capacitance C_m is:

$$C_m = C_{air} + \frac{C_{feet} C_x}{C_{feet} + C_x} \quad (1)$$

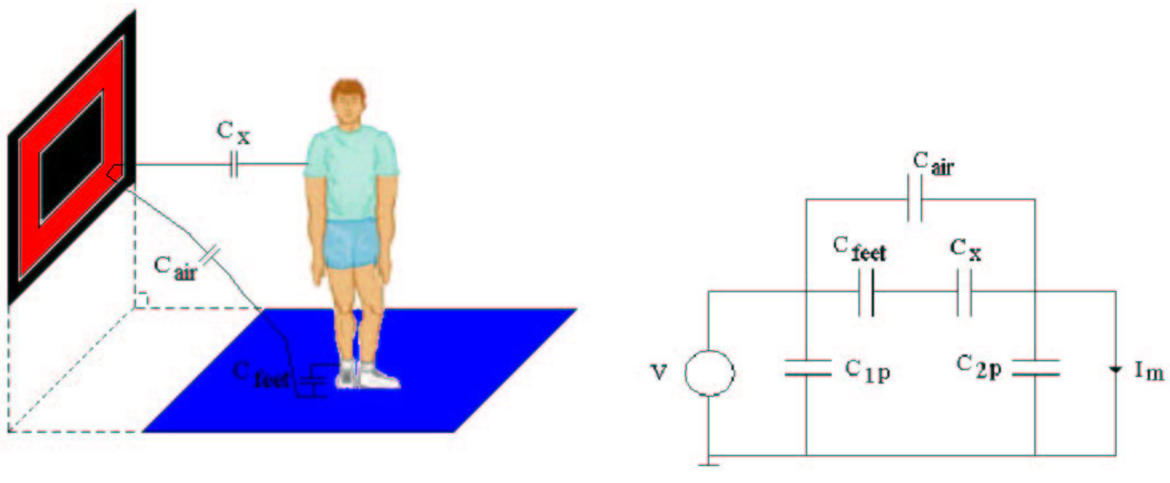

Fig. 2. (a) Capacitances distribution, (b) Simple electrical model of the structure

The capacitances are connected to the first-order capacitance-dependent oscillator called modified Martin oscillator [7] implemented in Smartec's universal interface transducer UTI[5]. This interface chip has also a built-in multiplexer, which enables the measurement of the capacitances in comparison with respect a reference capacitor. The period of the oscillator signal is measured by a microcontroller. Applying the three-signal autocalibration technique eliminates the effect of offset and unknown gain parameters in the system. Thus, the C_m capacitance can be estimated as

$$\frac{C_m}{C_{ref}} = \frac{T_m - T_{offset}}{T_{ref} - T_{offset}} \qquad (2)$$

where T_m, T_{offset} and T_{ref} represent the time-modulated output signals of the UTI [5].

3. NONIDEALITIES

Several non-idealities result from the measurement system such as air capacitance dependency, shunt-capacitance effects, unknown size and type of shoes, unknown size and shape of the person, incomplete modeling and other unknown parameters.

3.1. Air capacitance dependency

Humidity changes slightly affect the permittivity of air. Permittivity changes influence the capacitances C_{air} and C_x [6],[8]. This small effect can be compensated by using a reference air-dependent capacitor and applying the threesignal technique. Unfortunately, the feet capacitance is not an air-dependent capacitor. Thus the capacitance ratio C_m/C_{ref} is affected by humidity changes.

3.2. Shunt - capacitance effect

The element C_x represents the measurand (the capacitor to be measured). However, this capacitance cannot be measured accurately in the presence of shunting capacitances (see Fig. 2 (b)). The capacitance C_{air} works as an offset in the system decreasing the accuracy of the measurement (see Eq. (1)).

The air capacitance C_{air} can be measure in absence of a person on the transmitter electrode. However, when a person is located between the electrodes, the air capacitor C_{air} will also be affected. So there is interaction between the values of the capacitances C_{air} and C_x. Fortunately, it concerns only a small effect, and the simplified model of Fig. 2 (b) is still useful to estimate the changes in the measurand C_x.

In the structure of our capacitive sensor the electrical fields are rather complex and there is a lot of interaction when moving a person is moving. Therefore this simplied model only can give a first idea of what happens.

3.3. Unknown size and type of shoes

The feet capacitance C_{feet} depends on the area of the feet base, the thickness of the shoes sole and the kind of material of the soles. Usually, this information is unknown and cannot be estimated for a person passing by. Fortunately, the capacitance C_{feet} is in the order of 0.06 nF, which is much larger than the capacitance C_x. Thus, the total capacitance formed by the serial capacitors $C_{fee}t$ and C_x is dominated by the capacitance C_x. Experimentally it can be noted that when a person walks on the detector without shoes, that the sensitivity is improved.

3.4. Unknown size and shape of the person

The capacitance C_x that represents the capacitance from the human-body to the receiver electrode is the measurand of the detector. This capacitance does not only depend on the person's position. The capacitance C_x also depends on the person's size and the person's shape. All these unknown values cannot be estimated for each person. However, if the absolute value of the capacitance C_x is rather low (approx. 40 timer lower) than C_{feet}, the measured capacitance C_m is strongly dependent on the person's position.

Figure 3 shows an estimation of the non-linear behavior of C_m. The response sensitivity is high when the ratio C_{feet}/C_x is high and decrease when the ratio C_{feet}/C_x is decreasing.

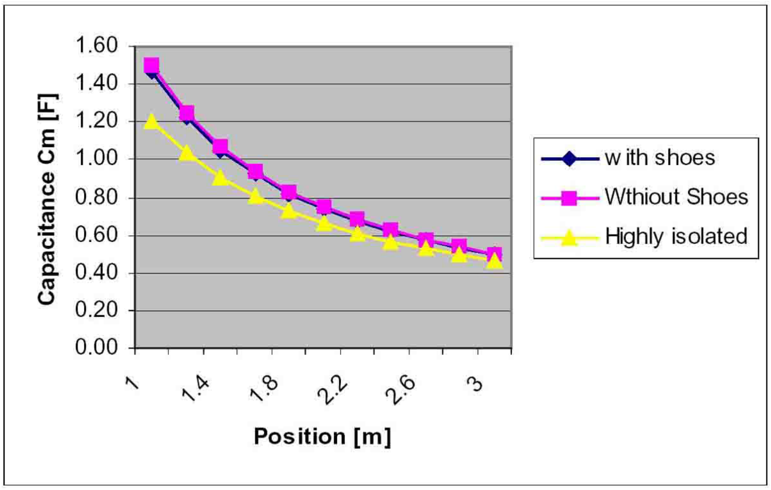

Fig. 3. An estimation of *Cm* as a function of the person's position on the floor electrode

4. EXPERIMENTAL RESULTS

The personnel detector consists basically of one transmitter electrode and one receiver electrode (see fig. 1(b)). The transmitter electrode has a width of 1 m wide and a length of 2 m. The receiver has a rectangular pattern with outer dimensions of 82 cm x 90 cm and a width of 16 cm. Guard electrode surround the receiver electrode and also the backside has been shielded. The receiver structure was located at 73 cm above the floor. The transmitter electrode was located approximately at 1 m from the front direction. The resulting capacitance of this configuration is about 0.5 pF.

The capacitances are connected to a Universal Transducer Interface (UTI) that consists of a capacitance controlled oscillator and a built-in multiplexer. The output of the UTI is connected to a PIC16F876 microcontroller that measures the oscillation period with a 0.2 μs resolution. The total measurement time is about 100 ms.. The measured capacitance C_m is computed in the microcontroller. A display is used to show in real-time the capacitance value C_m (fig. 4).

In the implementation the electrodes have been connected to line drivers (LT1030CN) in order to achieve ± 15 volts excitation signals. The standard deviation of the detector amounts to 0.001 pF. Figure 5 shows the capacitive value C_m as function of person's position. The maximum capacitance change was 1.3 pF for a position range of 2 meters.

Fig. 4. (a) Overview of the person detector system, (b) Display and electronics box contains the electronics

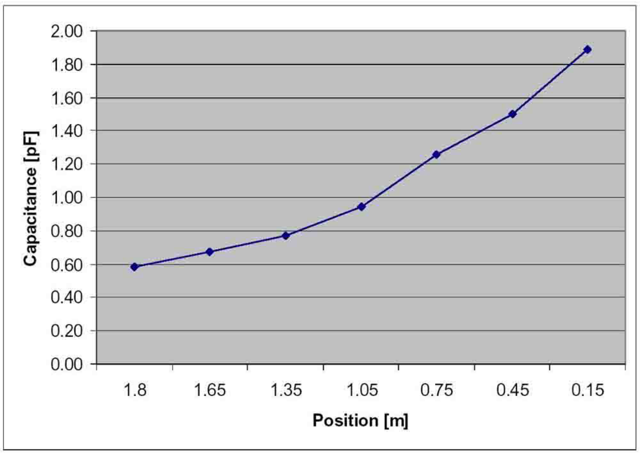

Fig. 5. Practical results using the presented implementation

4. CONCLUSION

A low-cost capacitive personnel detector system has been developed. The system is able to estimate the presence of a person and its relative position on the transmitter electrode. The personnel detector is very suited to be used for interactive artwork. Furthermore, the detector can be used for protection and safety purposes.

The detector can easily be camouflaged in a natural environment.

Acknowledgement

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