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DESIGN OF EMBEDDED SYSTEM BASED RAPID SENSING AC ELECRICAL CAPACITANCE TOMOGRAPHY

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ABSTRACT

An electrical capacitance tomography (ECT) sensor consists of eight electrodes, usually mounted outside on insulating pipe. The principle difficulties to predict the real time data from the ECT sensor are permittivity distribution between the plate and capacitance is nonlinear; the electric field is distorted by the material present and is also sensitive to measurement errors and noise. This paper describes rapid sensing an AC ECT system and interface has been developed with embedded system. The combinational electrodes are fast switching by programming in the embedded system. The development of new method of this system is to increase the measurement accuracy, signal processing speed and reduce the signal-to-noise ratio.

KEYWORDS – *ELECTRICAL CAPACITANCE TOMOGRAPHY, ELCTRODES, EMBEDDED SYSTEM, REAL TIME SYSTEM, PERMITTIVITY.*

1. INTRODUCTION

An ECT sensor consists of multiple electrodes, usually mounted outside an insulating pipe, the capacitance measured from the multiple electrode sensors. The changes in capacitance based on the presence of permittivity distribution, which in turn maps the material distribution in the process [1]. ECT is one of the imaging techniques most likely to provide quantitative flow visualization flow rate information in industrial flows. It has particularly used in two-phase oil/gas and gas/solid flows typical of petroleum and process industry [3-5]. The ECT can be obtained the internal information is valuable for understanding complicated process, verifying computational fluid dynamic models, measurement and control can be compared with other industrial tomography models. ECT offer more advantages of rapid response, no radiation, non-intrusive and non-invasive, withstanding high temperature and pressure and low cost. This technique is also used for biomedical field applications instead of CT and X-rays, because the ray has more radiation [6-8]. It has been used for many industrial applications such as gas, oil, water flows in wet gas separators, oil pipelines, pneumatic conveyors, cyclone separators and fluidized beds. This is used to oil field industries for monitoring the bubbles in oil flow based on the difference in their dielectric processes. In the fluidized beds, pharmaceutical industry is operated by trial and error, because of the lack of online measurement tools. The operation of the pharmaceutical fluidized beds cannot be optimized; the low operation efficiency and product quality cannot be guranteed.ECT has been used in pharmaceutical fluidized beds successfully [9-12]. The technique is capable of monitoring, both continuously and simultaneously, the local and global dynamic behavior of the gas bubbles and the solid particles in a noninvasive manner Electrical capacitance tomography (ECT) has prospective uses for applications to real chemical processes, since mostly they are using organic liquids, which are nonconductive, rather than widely used water as model liquid in laboratory [15].

In this paper, discusses about the voltage flow in the ECT system. The most commonly used data predicted from ECT system are micro processor or microcontroller based system. But the response time for the single measurement is approximately 10.4-μ sec. the time to reconstruct one image was measured was to be approximately 8.48 msec. This paper describes an intelligent interface has been developed with vital role of embedded system. The in-homogeneity of sensors sensitivity distribution and medium distribution are fully considered. The sensor is designed and constructed based on ac triangle wave as input signal with 20 kHz. The sensitivity of the measurement is up to 0.3 femto farads the minimum speed of measurement is brought to 1500 frames per second.

2. PRINCIPLE OF AC ECT SYSTEM

The AC ECT system sensor is mounted equally around the cross-section of the pipe, with an earthed screen outside the electrode to reject external noise. The number and size of the capacitance electrodes used depends on the application. A larger number of electrodes will give a higher resolution image but the measurement sensitivity will be low. The sensitivity can be increased by using longer electrodes but this will lower the axial resolution. If high axial resolution is required, a small number of short electrodes can be used together with separately excited axial guard electrodes, which prevent the electric field from spreading excessively at each end of the sensor electrodes. The sensor with N-measuring electrodes, there are N (N-1)/2 electrode pairs and thus N (N-1)/2 independent capacitances are measured. These measurements for 8 electrodes are suitable, so the sensor is connected in excitation signal and suddenly started the current flow in the electrodes. The current flow is dependent on distance between two electrodes and permittivity of the medium inside the tube.

The parameters of ECT sensors can be summarized as follows [2]:

1. Thickness and the material of the wall between the electrodes and the sensing zone.
2. Thickness and the material of the wall between the electrodes and the screen.
3. Size of the electrodes.

While designing the electrodes, the electrodes the insulation lining between the electrodes is the greater importance. The area and distance between the plates are constant. In these technique the current values will detected in the system. It will depend on the permittivity value of the material located between the electrodes. The figure1 shows the block diagram AC ECT system.

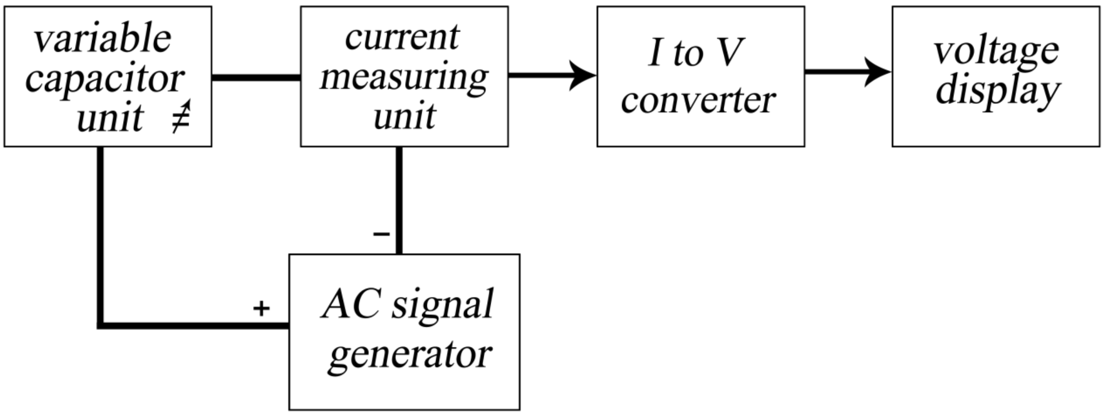

Figure 1. Block diagram of AC ECT system

3. METHODOLOGY

3.1 CAPACITANCE MEASUREMENT

The resolution of the ECT system depends upon the how fast the transducer senses the small change in capacitance with higher degree of accuracy and the number of electrode plates used in the system. The number of sensor electrodes that can be used depends on the range of values of inter-electrode capacitances and the upper and lower measurement limits of the capacitance measurement circuit. The pulse generator provides required excitation (pulse with well- defined fall and raise times) signal to the active differentiator capacitance transducer. At the output of the active differentiator a positive and a negative peak result. These peaks are separated using a peak-to-peak detector and are summed by a differential amplifier. The micro controller generates control signals to control of CMOS switches to select the excitation and detection electrodes, control of the multiplexer to select the DC signals, in turn, from the capacitance measuring circuit; and control the gain of the amplifier to make full use of the measurement range of the ADC and stores all the inter- electrode capacitances which will be used for image reconstruction. The time during which the capacitor charges from 1/3 V_{cc} to 2/3 V_{cc} is equal to the time the output is high and is given by

$$T_C = 0.69(R_A+R_B)\,C \qquad (1)$$

Similarly, the time during which the capacitor discharges from 2/3 V_{cc} to *1/3* V_{cc} is equal to the time the output is low and is given by

$$T_D = 0.69\,R_B C \qquad (2)$$

Thus the total period of the output waveform is

$$T = 0.69(R_A + 2\,R_B)\,C \qquad (3)$$

This in turn, gives frequency of oscillation as

$$F_O = 1/T = 1.45/\,(R_A+2R_B)\,C \qquad (4)$$

Thus varying RA, RB and C can vary the frequency of the pulse generator. Varying RA and C can vary the pulse width.

3.2 DESIGNING OF EMBEDDED SYSTEM FOR FAST SWITCHING

The word ‘tomography’ represents image slicing. The image is obtained by rotating the detector and the source in such a way that points outside the plane give a blurred image.

Electrical capacitance tomography is a very high-speed technique to capture the real time data of the turbulent fluctuation in the flow field. So the charging and discharging of the electrodes are should be fast, which can be done by CMOS switches. The CMOS switches should be controlled fast, that can be done by the micro controller. When a pair of electrodes is selected, one of them is known as the active electrode is continuously charged and discharged by the multiplexer's switches. The active electrode is charged to voltage Vc, and to the input of the current detector potential via the multiplexer's switches. The micro controller controlled the selection of the source electrode and the detecting electrode. The microcontroller ports can control the 0 and 1 pins in the multiplexers. The two ports from the micro controller are used for this purpose. The micro controller sends the control signals to the multiplexers at the micro second ranges. The design of driving circuit is shown in figure2.

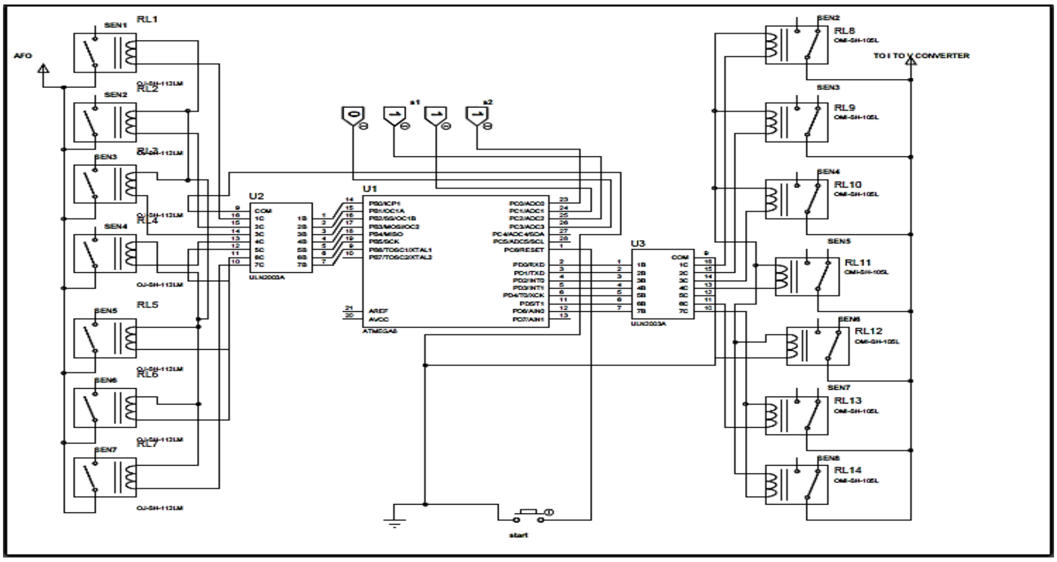

Figure 2. Circuit Diagram for Driving Circuit

4. EXPRIMENTAL RESULTS

The pulse generating circuit is designed for 1 micro second pulse width and 400 nanosecond rise and fall time. The outputs are obtained through embedded system with necessary supporting circuits. The output signal of the differentiator output for different capacitance is measured. The output shows that differentiating output having the noise with the amplitude of 0.2v. The practical output results for programmable gain amplifier are taken for the 3.9 Pf, and the corresponding output voltage is 1V. The results and the response for programmable gain amplifier are shown in the figure 3 and in the experimental setup figure 4.

The circuit for the driving circuit is constructed as per the design. The performance is demonstrated with ECT sensor with full air medium and for different switching signals. Thus the sequence observed at low frequency switching pulses validates the logic used for driving the electrode status. The gain selection for the programmable gain amplifier is checked.

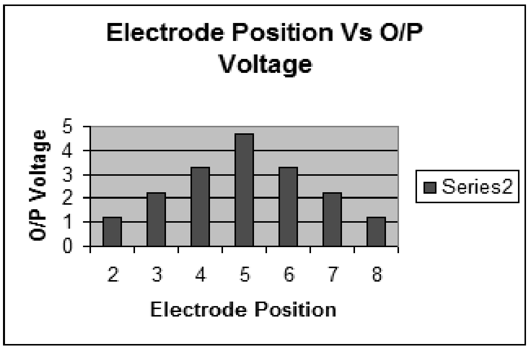

Figure 3. Programmable Gain amplifier response

Figure 4. Experimental work

CONCLUSIONS

In this paper we present high-speed data processing system for AC ECT sensor. This concept is analyzed, considering sensing speed, noise level and accuracy. A signal conditioning circuits can be able to measure a small inter-electrode capacitance in the presence of large stray capacitances giving good stray immunity. The output voltage of the differentiator mainly depends on the unknown capacitance, feedback resistor and excitation voltage. The analog multiplexers can be switched by using interface with programming. The multiplexers are operated with very high speed according to the channel selection by the controller. The embedded system can be operated in the nanoseconds range.

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