THE MULTI-CHANNEL CAPACITANCE UNIT FOR THE INTERFACE LEVEL AND FLOW SENSORS SENSITIVE TO ELECTROMAGNETIC INTERFERENCES

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Summary: The paper presents new, industry version of the multi-channel capacitance measurement unit for the liquid interface level and liquid flow. The measurement unit was designed to use with capacitive probe consisting up to 32 electrodes. The device has special features allowing to connect the probe by means of long coaxial cables (up to 10 meters) where cable length has a very little effect on measurements stability and accuracy. The influence of EMI was reduced by using a new generation electronic circuits and special microcontroller and computer software eliminating errorneous measurements.

Keywords: capacitance measurement unit, interface and flow sensors, electromagnetic interferences

1. Introduction

In the petrochemical industry one of the most important problems is oil flow measurement and detection of different forms of liquids within horizontal oil-water separators such as oil, water, gas as well as various mixtures composed of the described above. The mixtures may appear in a form of foam and emulsion. The basic approach is to utilize special sensors that have to meet many requirements which include working safety (petrochemical industry), long-term reliability and measurements stability (extreme hard industrial conditions), ease of use, ease of installation, controlling and maintenance as well as low cost. The non-contact working principle these sensors is the main advantage of this technology but the capacitance sensors are sensitive to electromagnetic disturbances.

A working principle of such kinds of capacitive sensors seems to be a simple thing. It leads to measuring capacitance of many identical sensor elements which act as capacitors placed along the probe [1]. The capacitance change is caused by a change of dielectric characteristics of material that fills the space between the electrodes. However, realizing such measurements is not simple, especially in the industrial conditions and, at the current stage, it requires new techniques concerning the making of the probe and the use of a proper one.

2. Description of multi-channel capacitance units

In this paper is presented industry version of the two prototypes of capacitance units. Besides, without going into a complexity of physical phenomenon one can come to the conclusion that a multi-channel measurement (32 channels) of very many capacitances in the range of fractions of picofarads up to a few picofarads is a next problem that at the current stage requires a new metrological approach. An additional difficulty is the fact of existing parasitic capacitances coming from external and internal probe wiring system.

A simplified circuit which realize the idea of "charge transfer method" [2,3] for the measuring low capacitances (for one channel) in the existence of high parasitic capacitances is shown in Fig. 1.

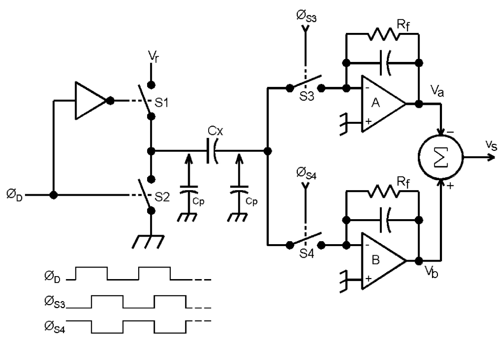

Fig. 1. Simplified schematic of "charge-discharge" electronic circuit with self-cancellation of the parasitic capacitors *Cp* due to cabling [3].

The multi-channel capacitance measurement unit was designed to use with multi-channel capacitive probe consisting up to 32 electrodes. The device has special features allowing to connect the probe by means of long coaxial cables (up to 10 meters) where cable length has a very little effect on measurements stability and accuracy. The device is wholly controlled by *WinCap* software installed on host computer [Fig. 2].

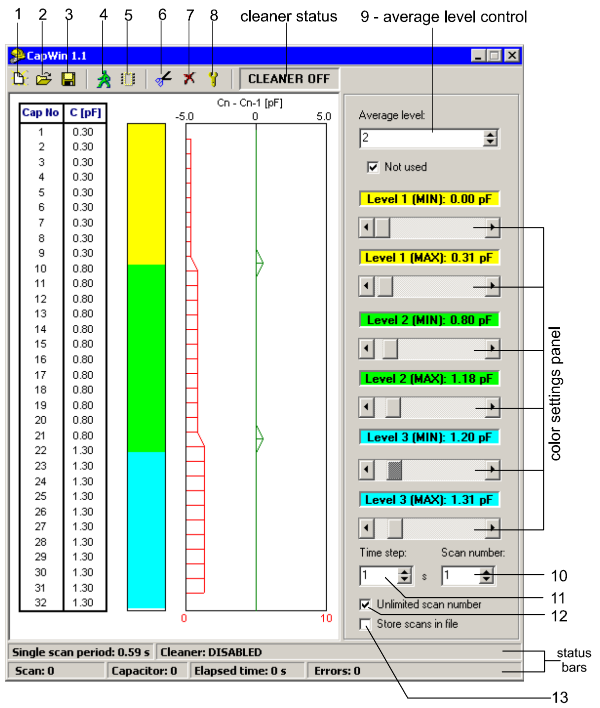

Fig. 2. The main window of the software.

The "*WinCap*" software is intended to use with *Multichannel Capacitance Measurtement Unit*. All the functions of the device are controlled by the software which can work in three different modes:

- observation only mode: measurements results are shown in the chart only, no data is stored
- observation with storing unlimited number of scan into a file
- observation with storing limited number of scan into a file

Important function of the software is zero trimming. The aim of this function is to remove parasitic capacitances that exist in the measurement circuits and probe cables. Zero trimming is performed by measuring all the 32 capacitances on each probe channel (with the main electrode on channel 33 disconnected). The measured parasitic capacitances are then subtracted from every measured capacitance during normal operation. To activate the function is necessary to disconnect channel 33 cable (main electrode) and select *zero trimming* button (6) and follow the messages displayed.

Communication with the device takes place through RS485 interface. It is possible to connect up to 32 devices in parallel to the RS485 communication cable thus allowing to control many probes simultaneously. Installation is a simple process and requires only of connecting probe coaxial cables, power supply voltage and RS485 cable. To connect RS485 cable to the host computer (to RS232 or USB) additional RS232/RS485 or USB/RS485 converted is required which is supplied along with the device.

The analog circuit used to measure all the capacitances drives each electrodes pair with a signal (square wave of amplitude 5.0 V) at a frequency of about 40kHz. The signal is applied by a special low-capacitance multiplexer to each electrodes pair (only one electrodes pair is handled at a time) (Fig. 3).

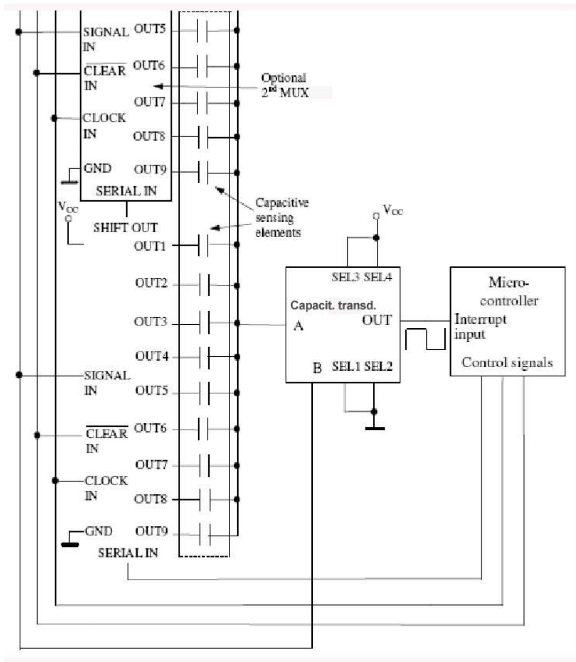

Fig. 3. A diagram for the application of the multiplexer in a multiple-capacitance measurement.

However, the measured capacitance is converted to another square wave signal (by a special customized chip) which frequency depends on capacitance which is being measured. For the range of 0..10 pF the frequency changes from 27 to about 50 Hz (the higher the capacitance the lower the frequency). This frequency is directly measured by a microcontroller (in fact, the period is measured) and, using appropriate mathematical formula it is recalculated to capacitance read by the computer through RS485 interface. Thus, the maximum time which is needed to measure one capacitance (one electrodes pair) equals to 1/17 Hz = 37 ms. As the probe consists 16 electrode pairs the overall time required to measure all the capacitances equals to 16 * 37 = 0.59 s (approximately). So, about 0.6 second is needed to "handle" one 16-channel probe. If the probe consisted 32 electrode pairs it would be 1.2 s.

It is possible to decrease the overall time required to measure all the capacitances. The chip can also work in "high speed mode" which make it possible to make the measurement process a few times faster. However, there were concerns about affecting the accuracy of the probe so in the current version it was not used. Anyway, it will be taken into account in the next improved versions. The first version of multi-channel capacitance unit is shown in Fig. 4.

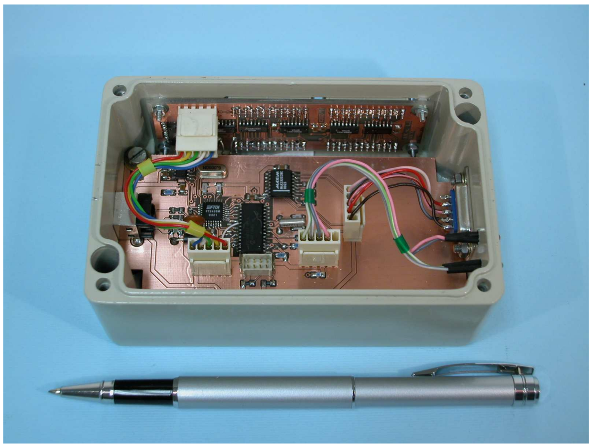

Fig. 4. The first version of capacitance unit (inside view)

The next (improved), industry version of capacitance unit is shown in Fig. 5 and Fig. 6.

Fig. 5. Multi-channel capacitance unit (front view)

Fig. 6. Multi-channel capacitance unit (rear view)

3. Testing of multi-channel capacitance unit

The capacitance multi-channel unit was tested in the industry condition. The metrology parameters are very satisfied for flow measurement and detection of the interface between the oil, foam and water. The capacitances were measured for 16 channel industry version of capacitance probe with the resolution for each channel 10 femtofarad (0.01 pF). Long-term stability is comparable with the tests in the laboratory condition. Because of improved of electronic circuits and PCB design, influence of electromagnetic interferences was minimized. All kinds of standard techniques was applied such as the use of shielded boxes around the measurement circuits, shielded cables, net filters. The remaining interferences was filtered out by measurement microcontroller and computer system.
The chosen results for the long term capacitance measurement is shown in Fig. 7a and Fig. 7b.

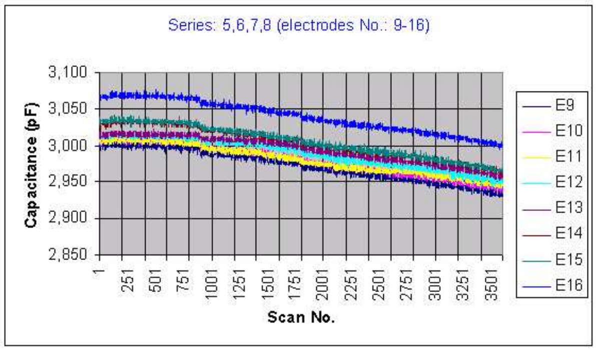

Fig. 7a. The chosen results for the long-term capacitance measurement

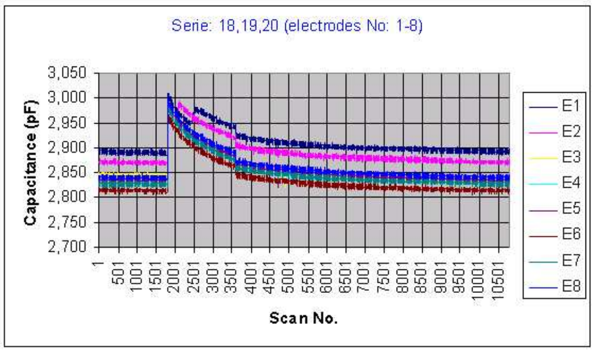

Fig. 7b. The chosen results for the long-term capacitance measurement

4. Conclusion

The newly designed industrial version of multi-channel unit for the interface liquid level and flow sensors can give accurate and stable measurement of flow and interface level in petrochemical industry. The measurement of very small capacitances requires a use of very sensitive electronic circuits. Interfering electromagnetic signals can easily deteriorate the accuracy and the resolution of the measurement system or prevent the system from functioning at all, at higher levels of interferences. The prevention of electromagnetic interference (EMI) therefore plays an important role. The electromagnetic disturbances were practically eliminated not only in the laboratory version of the capacitance unit but also was improved in the industry prototype. The parasitic capacitances of the cables (10 meters length) were eliminated by using modified measurements circuits and measurement procedure.

5. References

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