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VIRTUAL INSTRUMENT FOR DIELECTRIC MEASUREMENT

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Abstract: A PC-based bridge for measurement of parameters of a capacitor and from this the two component of the relative complex permittivity is described. The ac bridge method used is the quasi-balanced bridge method, where a multiplying digital-to-analog converter functions as a resistive potentiometer. It is presented the block scheme of the instrument, the flow chart of the software and some results obtained for the real and imaginar part of the relative complex permittivity, over the frequency range of 1-10kHz programable from the PC.

Key words: bridge method, permittivity, virtual instrument.

1. INTRODUCTION

The measurement of dielectric constant is in generally made at high frequencies for materials with electronic polarization. The most insulated materials used in electrotehnics (PVC, polietilen, prespan) are inhomogen. These materials have their resonant frequencies at lower values. From this reason they must be studied in a frequency domain including the resonant frequencies. It is important to know the behaviour of these materials, the variation of the two component of the relative complex permittivity, to use them correctly [6].

For measuring the variation of the relative permittivity we used the bridge measurement method, in witch the studied dielectric material is in a plan paralell capacitor (measurement cell) put in one arm of the bridge. In the other arm of the bridge is a resistor with a known value. The other two arms of the bridge are a resistor-net used as multiplying-digital-analog converter. The measurement follows in two steps, and each time we memorize the position of the resistor-net. With these values and with the value of the fix resistor we calculate the capacitance and the conductance of the measurement cell. It is folowed by the calculation of the two components ε' and ε'' of the relative complex permittivity.

The measurements are made in a frequency range of 100Hz-10kHz which is varieted by a frequency-generator.

In this paper is presented a virtual instrument in CVI, wich is able to measure and calculate the two components ε' and ε'' of the relative complex permittivity. The instrument has two parts: the hardware, witch includes the circuits needed for measurement and circuits to interface the measurement part to the PC (adressing and data flow).

2. PRINCIPLE OF MEASUREMENT

In [4] is presented a bridge made with the unknown impedance Z, a known high precision resistance R, and a resistive potentiometer having a total resistance P (fig. 1.).

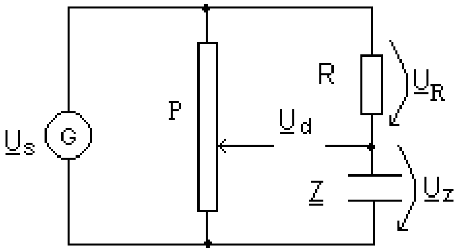

Fig. 1. The measurement bridge.

The bridge is excited by a sinusoidal voltage U_S. The output of the bridge U_d is taken between the node formed by the resistance R and the impedance Z and the variable point of the potentiometer P. The parameters of the unknown impedance Z are obtained using R and the position of the variable point of the potentiometer P named x.

By dielectric measurement the unknown impedance is a measurement cell including the dielectric. The measurement cell is a plan parallel capacitor. The parameters of the capacitor are the conductance G and the reactance X_c.Thise are determinated using the parallel equivalent circuit for the measurement cell.

$$\underline{Y} = G + j\omega C \tag{1}$$

The measurement follows two steps: the variable point of the potentiometer is moved so than the output voltage U_d is in the quadrature with the excitation voltage U_S in this case the actual position of the potentiometer is x=n. In the second step the position of the potentiometer is varied until the the output voltage U_d is in the quadrature with the voltage across the capacitor U_Z the actual position of the potentiometer is x=m.

The parameters of the measurement cell are obtained from the following relations:

$$\omega C = \frac{1}{R} \cdot \frac{1}{1-m} \cdot \sqrt{\frac{n-m}{1-n}}$$

$$G = \frac{1}{R} \cdot \frac{m}{1-m} \tag{2}$$

The admitance of the measurement cell can be writen in an other way too, which expresses also that a dielectric material is present:

$$\underline{Y} = j\omega \underline{C} = j\omega C_0 (\varepsilon' - j\varepsilon'') = \omega\varepsilon'' C_0 + j\omega\varepsilon' C_0 \tag{3}$$

According relation (3) to the relation (1) the two components of the relative complex permittivity can be written:

$$G = \omega\varepsilon'' C_0 \qquad\qquad C = \varepsilon' C_0 \tag{4}$$

The conductance G and the capacitance C are obtained with measurements, so the component of the relative complex permittivity can be calculated from:

$$\varepsilon'' = \frac{1}{\omega C_0} \cdot \frac{1}{R} \cdot \frac{m}{1-m}$$

$$\varepsilon' = \frac{1}{\omega C_0} \cdot \frac{1}{R} \cdot \frac{1}{1-m} \cdot \sqrt{\frac{n-m}{1-n}} \tag{5}$$

As we see the real and imaginar component of the relative complex permittivity can be obtained with two measurements and depends on frequency of the excitation voltage, from the high precision resistance R, and the two positions of the potentimeter P. The precision of the measurement and calculation depends also from these terms.

3. VIRTUAL INSTRUMENT

3.1. Hardware

Based on this measurement principle has been made a virtual instrument. The hardware of the instrument consist two parts. The first part includes the circuits needed for measuring: instrumentation amplifier (AI), analog multiplexer (MUX), analog multiplier (X), low-pass-filter (FTJ) and analog-digital converter (A/D). The second part includes the circuits needed for interfacing the measurement part to the PC: bus amplifier, bus transceivers, buffers and adress selection circuits. The instrument comunicates with the PC through the ISA Bus. The bloc diagram of the virtual instrument is presented on figure 2.

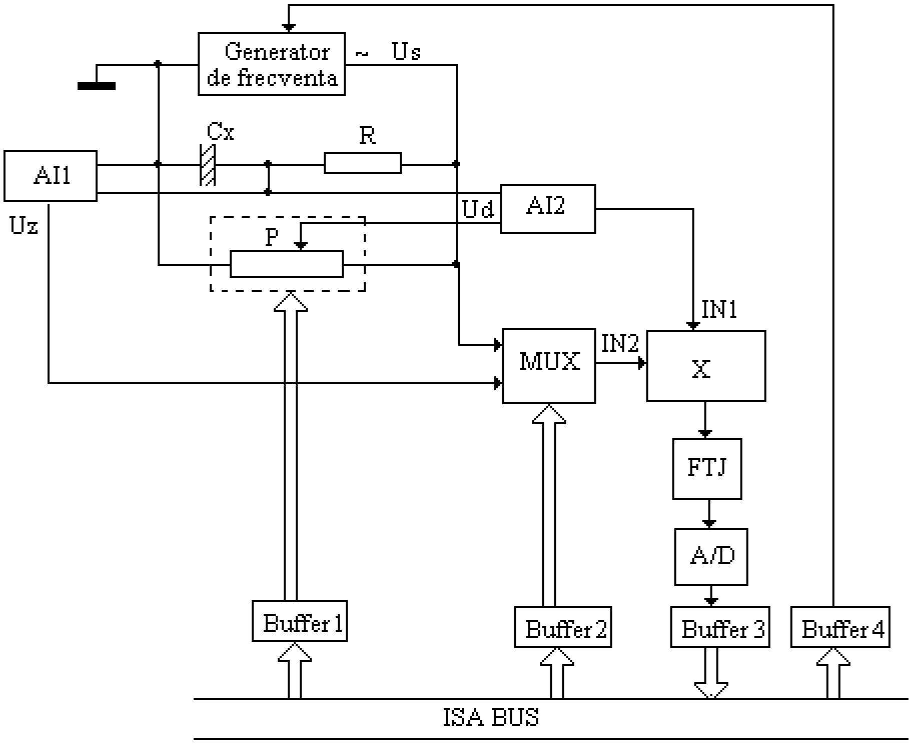

Fig. 2. The bloc diagram of the virtual instrument

The resistive potentiometer P, which forms the half part of the bridge, is a multiplying digital-to-analog converter (AD7520). The variable point of the potentiometer is set by the number sent through the data bus and Buffer1. Two instrumentation amplifiers INA128 are used, AI2 converts the output voltage of the bridge U_d, and AI1 converts the voltage across the capacitor U_Z to single-ended outputs.

With the MUX (4051) is connected to the second input IN2 of the analog multiplier (X) the two voltages U_S and U_Z consecutive.

The analog multiplier circuit (AD633) is used as phase-sensitive detector. At IN1 is applied the output voltage of the bridge U_d and at the IN2 U_S or U_Z. The transfer function for AD633 is:

$$W = \frac{(X_1 - X_2)(Y_1 - Y_2)}{10V} + Z \qquad (6)$$

For the miltiplier function $X_1 = \underline{U_d}$, $X_2 = \underline{U_S}$ (or $X_2 = \underline{U_Z}$) and X_2 Y_2 and Z are zero. The output voltage becomes:

$$W = \frac{U_d U_S}{20}\left[\cos\alpha - \cos(2\omega t + \alpha)\right] \qquad (7)$$

This voltage has a dc component wich depends on the phase-difference between the two input voltage. If the phase-difference is α=90° the two input voltages are in quadrature, the dc component becomes zero (cos90=0). The ac component with duble frequency is eliminated through a low-pass-filter.

The amplitude of this dc voltage is measured with an A/D converter AD0804 type. The result of the convertion is read by the PC through buffer 3 and data bus.

The excitation voltage is obtained from a frequency generator based on circuit MAX038. The MAX038 is a high-frequency, precision function generator producing accurate high-frequency triangle, sine square and pulse waveforms with a minimum of external components. The output frequency can be controlled over a frequency range of 0.1Hz to 20MHz by an external resistor and capacitor. Sine, square, or triangle waveforms can be selected at the output by setting the appropiate code at two TTL-compatible select pins. The output signal for all waveforms is a $2V_{p-p}$ signal that is symmetrical around ground. Frequency and duty cycle can be independently controlled by programing the current, voltage or resistance. The frequency domain in which the measurements are made is varieted in this case from 100Hz to 10kHz. To change the frequency in this domain we have to connect more capacitors and resistances to the MAX038 through analog multiplexers.The comunication between the PC and frequency generator it is realised through buffer 4 and data bus. The variation of the frequency (through the variation of the capacitors and resistance) can be made in very small steps.

3.2. Software

The all hardware of the virtual instrument is controlled by a software which has its flow chart on figure 3 and is made in LabWindows/CVI.

The soft permits the variation of the frequency in three ways: automatic 1 (varieted from 100Hz to 10kHz in small steps), automatic 2 (the measurements are made only at a few frequencies) and manual (fixed from the front panel of the instrument). On the front panel is displayed the frequency, the value of the capacitance C and conductance G of the measurement cell, and the two components of the relative complex permittivity.

4. CONCLUSIONS

It was made a virtual instrument for dielectric material. The advantage consist in determination of the real and imaginar part of the relative complex permittivity for a solid insulated material at the wished frequency, or the variation of these with frequency, in short time and in two measurement steps.

The hardware can be modified to reduce the errors of the measurement, by increasing the binary number of the MDAC. The value of the resistor R determins the domain of the measurement cell capacitor.

The software can be modified to calculate more values from these measurements, for example the tgδ, and/or for dielectric recognition.

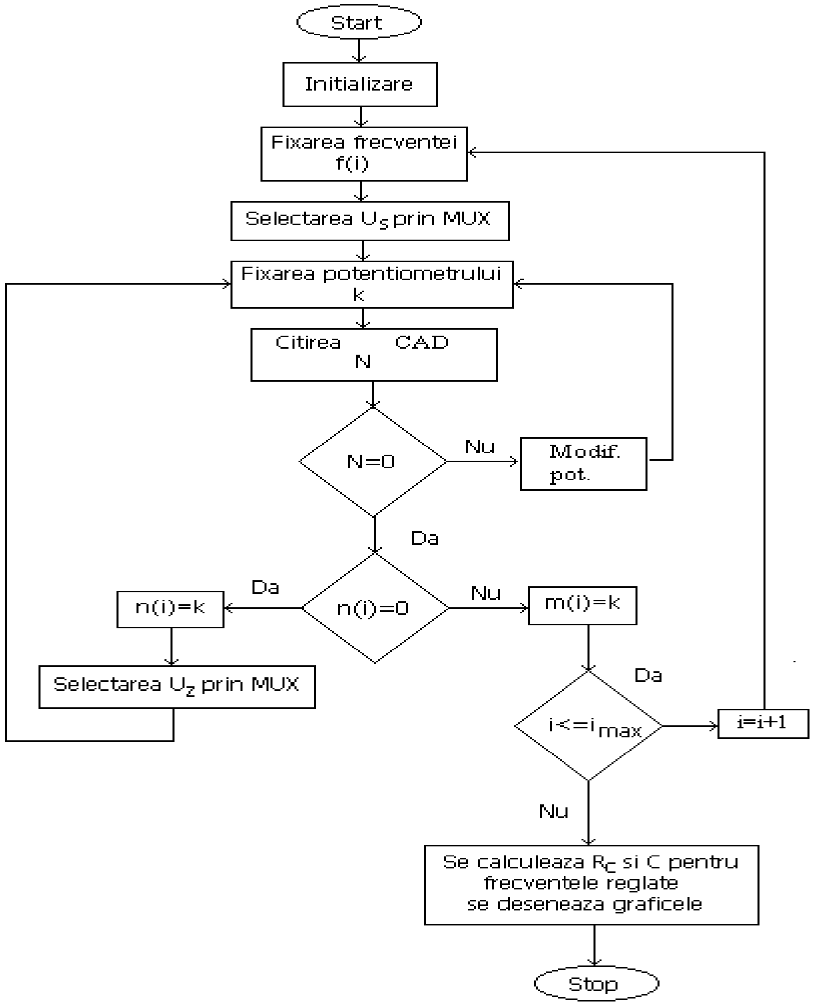

Fig. 3. The flow chart of the measurement.

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