The Research Results of Capacity Converter with Voltage Negative Impedance Converter

Ventseslav D. Draganov[1] , Zlatko D. Stanchev[2], Ilya T. Tanchev[3]

Abstract - **The problem of increasing the frequency output relative sensitivity of the capacity converter and decreasing of the influence of the parasitic capacities is solved by connecting the Negative Impedance Converter (NIC) to the converter.**

The research results of a real capacity converter with Voltage Negative Impedance Converter (VNIC) are presented, which show the extent of compensation of the parasitic capacities. The experimental results confirm the derived theoretical relation-ships and the simulation results with program product to a considerable extent.

Keywords – **Voltage Negative Impedance Converter, compensation of parasitic capacities, stray-immune capacity converter**

I. Introduction

Measurement of small capacities is accompanied by the main difficulty, which caused by the effect of parasitic capacitances. In practice the three-terminal sensor has a grounded screen of its electrodes to protect it from external sources and of the influence of the parasitic capacities [1].

Circuit solutions for capacitance measurement, which can provide compensation of the parasitic capacitances and the electrodes of the unknown capacitance C_x are ungrounded are known [2, 3, 4, 5, 6]. The methods for compensation used in them do not enable their application in circuit solutions for measurement of the capacity of converter with one grounded electrode.

When developing the capacity converters for measuring of non-electrical quantities a necessity to design converter circuits for registering very small capacities with reduced influence of the parasitic capacities arises.

A converter "capacity – DC voltage" is developed [7]. It is capable of compensating the parasitic capacity of the connected primary capacity converter to a certain extent. This solution provides comparatively low sensitivity (a few pF).

A solution enabling the increasing of the output relative sensitivity of *capacity converter* when it is needed the comparatively large parasitic capacity (over 10÷20 pF) to be compensated – by connecting Negative Impedance Converter (NIC) is suggested [8].

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Scheme applications for improving the sensitivity of the capacity converters are known [9] [10]. The final result of the both cases is higher frequency output relative sensitivity.

The study of this circuit solution is carried out without taking into account the influence of the parasitic capacities as well as of the input capacity of the used operational amplifier.

The adding of the Voltage Negative Impedance Converter (VNIC) to the converter "capacitance – time interval" [11] decreases the equivalent capacity to a considerable degree and the bigger change is at the lower values of the unknown capacity $\boldsymbol{C_x}$. This method, which uses the equivalent negative capacity of VNIC, enables decreasing of the assembly parasitic capacitances several times due to the decreasing of the correlation between the value of the measured capacity and this one of the parasitic capacitances.

II. Exposition

A. Negative Impedance Converter (NIC)

The Negative Impedance Converter (NIC) represents a four-pole [12], and there are two separate boundary cases - the Current Negative Impedance Converter (CNIC) and the Voltage Negative Impedance Converter (VNIC). The VNIC is shown in *Fig.1*, for which the dependence (1) is valid.

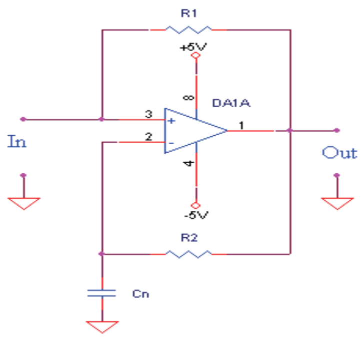

Fig.1. Voltage Negative Impedance Converter (VNIC)

$$C_i = -\frac{R_2}{R_1}.C_n \,. \qquad (1)$$

When synthesizing the VNIC the stability have to be taken into consideration as the negative capacity can exist only in relation to other elements [12].

The choice of the element values in the negative impedance realization is usually based on the following general design consideration:

$$R_0 << (R_1, R_2, X_{C_n}) << R_{id} \qquad (2)$$

where [13]:

R_0 - output resistance of the used operational amplifier,
R_{id} – its input differential resistance.

The maximum useful frequency can be increased by making $R_1 = R_2$ [13].

B. Capacity converter with VNIC, connected into the measured capacity

The capacity converter (*Fig.2*) includes relaxing generator, which is realized by the operational amplifier *DA2*, the resistors R_3, R_4, R_5 and the unknown capacity C_x on the primary capacity converter [9]. VNIC, which is realized by the operational amplifier *DA1*, the C_n capacitor and the resistors R_1 and R_2 is connected to the primary capacity converter in parallel.

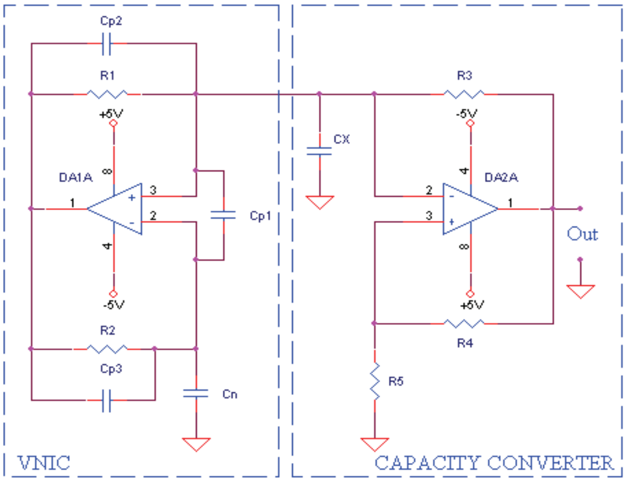

Fig.2. Capacity converter with VNIC, connected into the measured capacity C_x

The period of generated oscillations is defined by the expression [8]:

$$T = N.R_3.(C_x - C_i) = N.R_3.\left(C_x - \frac{R_2}{R_1}.C_n\right) \qquad (3)$$

where: the coefficient N is defined by values of the resistors R_4 and R_5 as well as of the supply voltage.

The period of the generated signal is decreased proportionally to the values of the capacity C_n and the resistor R_2 and conversely proportionally - to the value of the resistor R_1 in the circuitry of VNIC.

The equivalent capacity to the unknown capacity C_x and the VNIC's input capacity C_i, which are connected in parallel, is defined by the expression [9]:

$$C_{eq} = C_x - C_i \qquad (4)$$

The equivalent capacity relative alternation δ_c is defined by the expression:

$$\delta_c = \frac{C_{eq}}{C_X}.100, [\%] \qquad (5)$$

C. Graphic representation of the dependences $C_{eq} = \varphi(C_n)$ and $\delta_c = \varphi(C_n)$

The dependence of the change of the equivalent capacity C_{eq} on the capacity C_n, with C_X = const, is shown graphically in *Fig.3*.

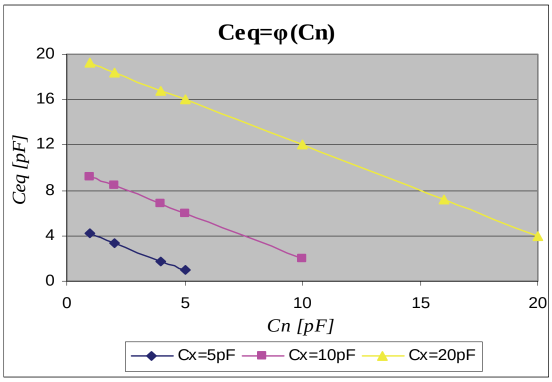

Fig.3. Dependencies $C_{eq} = \varphi(C_n)$

The dependence of the change of the equivalent capacity δ_c on the capacity C_n, with C_X = const, is shown graphically in *Fig.4*.

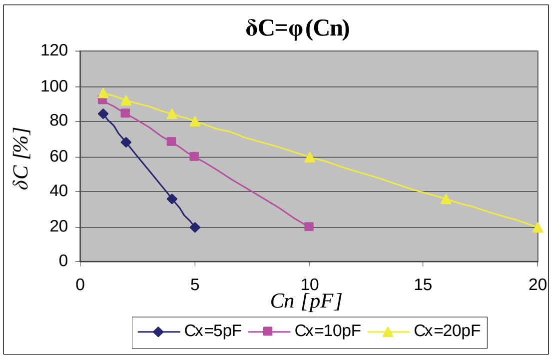

Fig.4. Dependencies $\delta_C = \varphi(C_n)$

D. The validity of the dependence $T = \varphi(C_n)$ and influence of the parasitic capacities on the period of generated oscillations in VNIC circuit

The dependence of the period of generated oscillations on the value of the capacity C_n corresponds to this formula from (3) to a considerable degree when the value of the capacity $C_n < C_x$ [8].

The influence of the parasitic capacity C_{p1}, connected to the input capacity of the operational amplifier *DA1* (*Fig.2*), on the dependence (3) is studied. For the values of the capacity $C_n < C_x$, current through the input capacity of the operational amplifier *DA1* practically does not flow, the voltage between the input terminals is near to zero and the capacities C_{in} and C_{p1} has not an effect on the validity of the dependence (3) [8].

When the capacity $C_n < C_x$ in the circuitry of VNIC, the parasitic capacities C_{p2} and C_{p3} have noticeable effect just only on values over (5 ÷ 10) pF, which are greater than the real ones [8].

The aim of the present work is to show in what degree the parasitic capacities in real capacity converters can be reduced as well as measurement of capacities, which are smaller than the value of the real parasitic capacities.

III. Experimental Research

The capacity converter, with *VNIC* connected to the measured capacity, is studied by simulation with the program product *Electronics Workbench 5.12* as well as through experimental studies on a real experimental treatment.

The validity of the dependence (3) for the values of the capacity $C_X = 5, 10, 20\ pF$, which are near to the real values of the parasitic capacities, with the capacity values $C_n = 1, 2, 4, 5, 10, 16, 20\ pF$ is studied.

1. Results from the experiments, obtained through simulation with software

The summary results from the investigations of the dependences $T = \varphi\ (C_n)$, through simulation, are shown graphically in *Fig.5*.

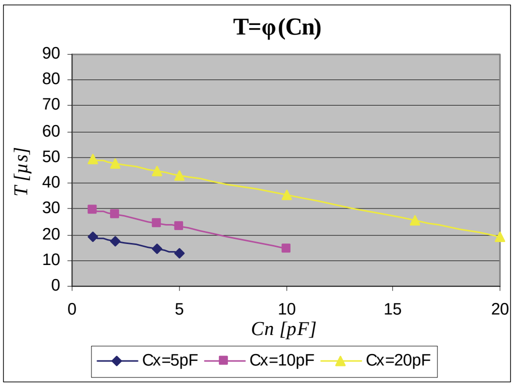

Fig.5. Summary results for the dependences T = φ (C_n), through simulation

Conclusion: The period of the generated signal is decreased proportionally to the change of the capacity C_n in a linear law, with values $C_n < C_X$.

2. Results from the experiments, obtained through on a real experimental treatment

The summary results from the investigations of the dependences $T = \varphi\ (C_n)$, on a real experimental treatment, are shown graphically in *Fig.6*.

Conclusion: The experimental results correspond to this through simulation.

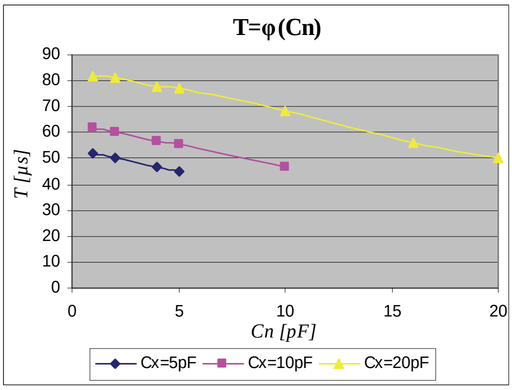

Fig.6. Summary results for the dependences T = φ (C_n), through a real experimental treatment

3. Comparison of the investigations results, obtained through simulation and a real experimental treatment for the dependence (3)

The comparison results for the dependence $T = \varphi\ (C_n)$, obtained through simulation and a real experimental treatment, with the values of the capacity $C_X = 5, 10, 20\ pF$ are shown graphically in *Fig.7*, *Fig.8* and *Fig.9* respectively.

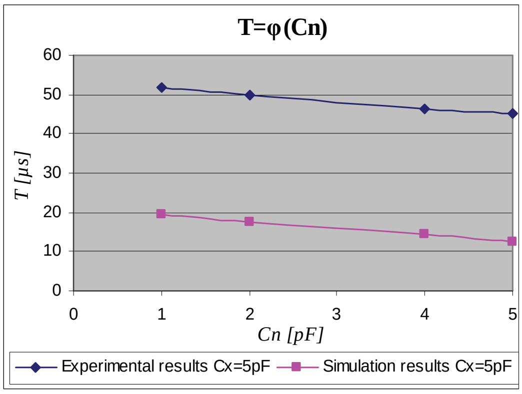

Fig.7. Dependence T = φ (C_n), with C_x = 5 pF

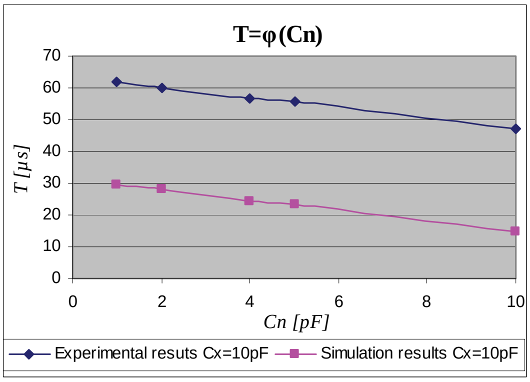

Fig.8. Dependence T = φ (C_n), with C_x = 10 pF

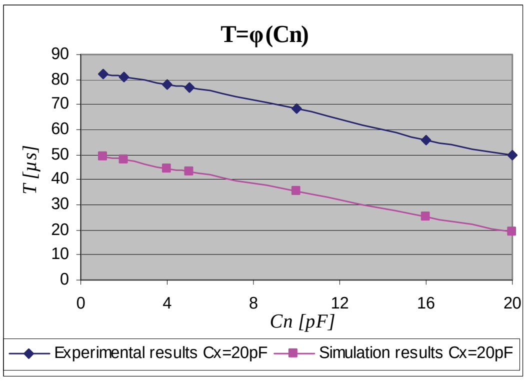

Fig.9. Dependence T = φ (C_n), with C_x = 20 pF

Conclusions:

1.When the values of the C_n capacitor increase ($C_n < C_x$), the period of generated oscillations decrease proportionally to the decrease of the equivalent capacity of the measured capacity and the VNIC's capacity, connected in parallel. The dependence $T = \varphi (C_n)$ is comparatively linear.

2. The relative decrease of the actual parasitic capacity increase with the augmentation of the value of the measured capacity.

3. From the data comparison the value of the parasitic capacity in the real experimental treatment – in the order of 30 pF can be determined.

IV. Conclusion

From the made investigations of the capacity converter, with voltage negative impedance converter connected to it, one comes to the following important conclusions:

1. The dependence $T = \varphi (C_n)$ corresponds to the one from formula (3) to a considerable degree when the values of the capacity $C_n < C_x$. The dependence was comparatively linear in this range.

2. The parasitic capacity, connected to the unknown capacity C_x, can be decreased, but no more than five times.

3. In the studied range $C_n < C_x$, the dependences $C_{eq} = \varphi (C_n)$ and $C_{eq} = \varphi (C_x)$ are linear functions.

The experimental results are analogous to the simulation results and correspond to the derived theoretical relationships for the effect of the VNIC capacity variation within a certain range on the period of generated oscillations.

By using the Voltage Negative Impedance Converter (VNIC) the output relative sensitivity of the capacity converter, constructed on the basis of relaxing generator with connected to it primary capacity converter is increased. This is due to decreasing of the initial capacity of the primary capacity converter as well as to lessening the effect of the parasitic capacity of the conductors connecting the primary capacity converter.

In case of necessity to decrease the effect of the parasitic capacities in measuring circuits, the VNIC can be used to increase their sensitivity.

The prepositional decision can be used for a limited decrease of the parasitic capacities in linear capacity converters with one grounded electrode, for the purpose of increase their sensitivity.

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