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METHODS FOR SYNTHESIZING TABLES OF MULTIVARIABLE GIC_N IMMITTANCE CONVERSION

The paper proposes methods for synthesizing tables of multivariable GIC_N immittance conversion. Problems of synthesis are analyzed only partially in literature, which points to the current importance of further development of the above-mentioned methods.

Key words: immittance, generalized immittance converter (GIC), field-effect transistor, unijunction transistor.

Introduction

As one-crystal generalized immittance converters (GIC_N) transistor structures having three and more (N)-electrodes are used: bipolar (BT), one-gate and dual-gate field-effect transistors (FET); unijunction (UT) and injection transit-time (ITTT) transistors. All GIC_N can be divided into one-parameter and multivariable ones. Methods for synthesizing informational devices (ID) on the basis of one-parameter GIC_N with the application of immittance conversion tables are substantiated in works [1, 2]. In work [3] ID synthesis issues are covered only partially, which points to the current importance of further development of the methods for synthesizing tables of multivariable GIC_N immittance conversion.

Goal of the work

The work is aimed at the development of the basic generalized methods for synthesizing tables of multivariable GIC_N immittance conversion with their further application to such GIC_N tables that use three- and four-electrode transistor structures.

Methods of synthesizing immittance conversion tables for two-parameter grounded GIC_N based on an independent tripole

Principles of constructing one-parameter GIC_N conversion tables and their implementation in the cases of different transistor structures are substantiated in work [1].

When an independent tripole, is used three variants of two-parameter GIC_N construction are possible (fig. 1.)

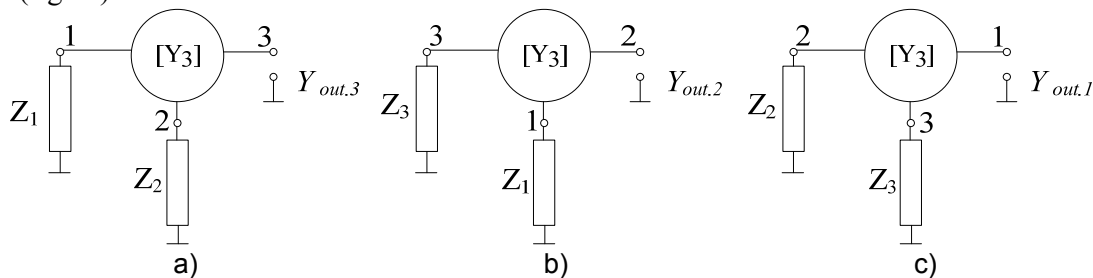


Fig. 1. Variants of constructing two-parameter GIC_N on the basis of an independent tripole

Converted conductivity Y_{out} of such GIC_N is function F of resistances Z_i to be converted and of the parameters of the tripole indefinite matrix $[Y_3]$:

$$\left. \begin{aligned} Y_{out.1} &= F_1(Z_2, Z_3, [Y_3]); \\ Y_{out.2} &= F_2(Z_1, Z_3, [Y_3]); \\ Y_{out.3} &= F_3(Z_1, Z_2, [Y_3]). \end{aligned} \right\} \quad (1)$$

Specifying the character and values of the resistances $Z_1 - Z_3$ to be converted and conversion frequency Ω_m , provided that elements of matrix $[Y_3]$ are known, the character of the converted conductivity $Y_{out.i}$ can be determined for each variant of GIC₃ construction by solving equation set (1) where $i = 1, 2, 3 \dots m$ – the pole number.

If an independent tripole is used, this problem has a unique analytical solution. E.g. for the circuit (fig. 1a)

$$Y_{out.3} = \frac{I}{k} \left[y_{22} + Z_2 \Delta y - \frac{(y_{11} - Z_2 \Delta y)(y_{21} - Z_2 \Delta y)}{y_{11} + Z_2 \Delta y + k y_1} \right],$$

where $k = I + Z_2 \Delta y$;

$\Sigma y = y_{11} + y_{12} + y_{21} + y_{22}$;

$\Delta y = y_{11} y_{22} - y_{21} y_{12}$;

$y_1 = I/Z_1$;

$y_{11}, y_{12}, y_{21}, y_{22}$ – parameters for the conductivity matrix of the dependent quadripole formed using a tripole with electrode 2, common for input and output, for $Z_2 = 0$.

This makes it possible to determine the character of the converted conductivity $Y_{out.i}$ for different variants of GIC₃ construction. Calculations results are presented as immittance conversion tables for each variant of GIC₃ construction and the tripole used. In the case where BT, FET, UT and ITTT are used 12 immittance conversion tables are obtained. Table 1 presents an example of such synthesis for the case of UT application where resistances to be converted are connected between the emitter – Z_1 (polar № 1), the collector – Z_2 (polar № 2) (fig. 1a) and the common bus.

Impittance conversion table construction usually involves the problem of choosing the relative frequency of calculations $\Omega_m = f_0 / f_m$, where f_m – limiting frequency of the active multipole. Taking into account that acceptable values of the noise factor F_n (one of the defining ID parameters) are observed at frequencies $\Omega_m < 0,5$, we choose the value of $\Omega_m = 0,25$, which ensures acceptable F_n and provides ID realization at relatively high frequencies including the microwave range where they are most efficient.

Table 1

Impittance conversion table for two-parameter GIC_3 connected according to the circuit of fig.1a.

Number of the variant	Z_1	Z_2	$Y_{out.3}$
1.1	R_1	R_2	
1.2		L_2	
1.3		C_2	
1.4	C_1	R_2	
1.5		L_2	
1.6	C_2		
1.7	L_1	R_2	
1.8		L_2	
1.9		C_2	

Methods of synthesizing impittance conversion tables for two-parameter GIC_N on the basis of an independent quadripole

For independent quadripole application two variants of two-parameter GIC_4 of the grounded type can be realized (their structural diagrams are partially presented in fig.2) and 18 variants of three-parameter GIC_4 (their structural diagrams are partially presented in fig. 5). In the diagrams (fig. 2) digital index of $Y_{out.i}$ indicates the following: i – the output pole; j – the grounded pole number. Possible variants of such 12 combinations are presented in table 2.

Table 2

Variants of the combinations of poles and converted resistances for the independent quadripole, which are used as a basis for two-parameter GIC₄ construction

State of the poles				i	j
1	2	3	4		
1	2	Z ₃	Z ₄	1	2
1	Z ₂	3	Z ₄	1	3
1	Z ₂	Z ₃	4	1	4
Z ₁	2	3	Z ₄	2	3
Z ₁	2	Z ₃	4	2	4
1	2	Z ₃	Z ₄	2	1
1	Z ₂	3	Z ₄	3	1
Z ₁	2	3	Z ₄	3	2
Z ₁	Z ₂	3	4	3	4
1	Z ₁	Z ₂	4	4	1
Z ₁	2	Z ₂	4	4	2
Z ₁	Z ₂	3	4	4	3

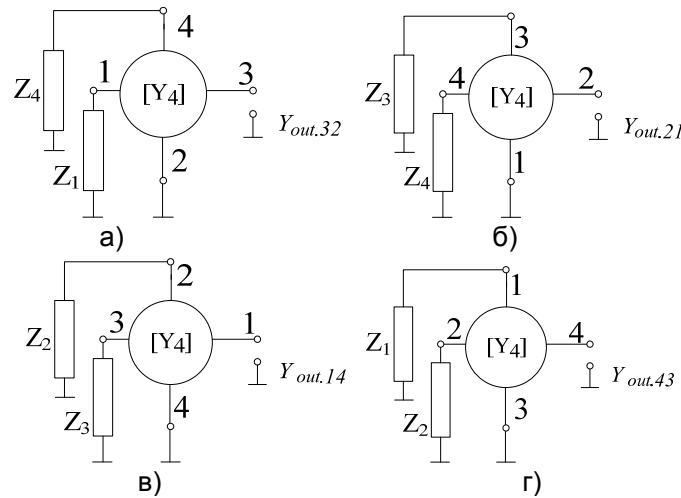


Fig. 2. Some variants for the construction of a two-parameter GIC₄ based on the independent quadripole

The converted conductance $Y_{out,i}$ is a function of F_{ij} of the converted resistances Z_i and parameters of the indefinite matrix $[Y_4]$ of the independent quadripole.

$$\left. \begin{aligned} Y_{out.12} &= F_{12}(Z_3, Z_4, [Y_4]); \\ Y_{out.13} &= F_{13}(Z_2, Z_4, [Y_4]); \\ &\dots\dots\dots \\ Y_{out.43} &= F_{43}(Z_1, Z_2, [Y_4]). \end{aligned} \right\} \quad (2)$$

Specifying the character and the value of the converted resistances $[Z_1 - Z_4]$ and conversion frequency Ω_m , provided that the elements of matrix $[Y_4]$ are known, the character and the value of the converted conductance $Y_{out,i}$ can be determined for each GIC₄ construction variant by solving equations (2). However, analytical solutions of this problem are rather cumbersome and in a number of cases it has no explicit solution. A simpler variant is a numerical solution represented in the form of three-dimensional plots. Their examples are shown in fig. 3.

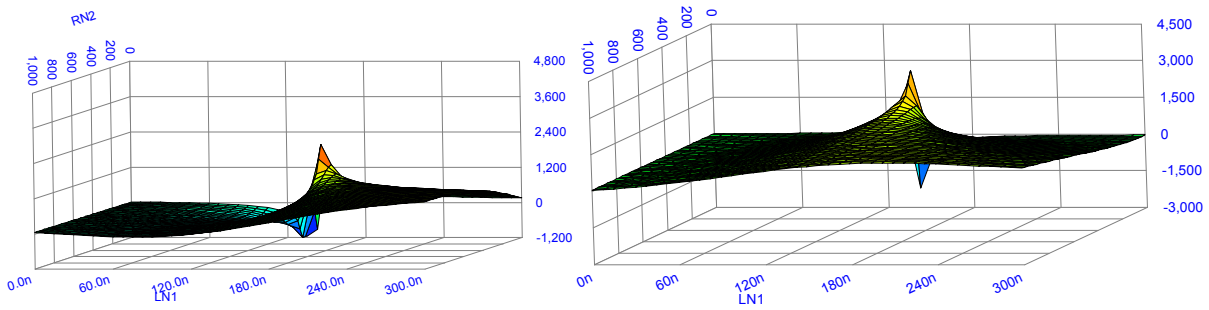


Fig. 3. Dependencies of the converted conductance $Y_{out.32}$ components for GIC_4 , the structural diagram of which is shown in fig. 2a

The calculations were performed for a dual-gate FET of the 2N4456 type where the converted resistances Z_1 i Z_4 are connected between the second gate (pole №1), the sink (pole № 4) and the common gate to which the source of FET is connected (pole № 2). In this case an uncertainty exists as to the choice of the value range for the converted resistances Z_i . There has not been found any unique solution for this uncertainty elimination. A strong probability of its elimination can be achieved while analyzing 3D plots (fig. 3) or by choosing the values of the resistances to be converted on the basis of the relationships [2]: $1/Z_i \ll Y_{ii}$ – in the case of realizing the converting properties of the conductance conversion channel; $1/Z_i \gg Y_{ii}$ in the case of realizing the inverting properties of the conductance conversion channel.

Analysis of the plots (fig. 3) makes it possible to reveal the character of converted frequency $Y_{out.32}$ depending on the values of converted resistances R_1 and R_4 . The results of such analysis are presented in the form of the immittance conversion table similar to table 1. Similarly, immittance conversion tables can be constructed on the basis of other independent quadripoles provided that Y parameters of the indefinite GIC_4 matrix are determined. Using different voltage polarity combinations on the gates of the dual-gate FET, two variants of its indefinite matrix can be obtained. This makes it possible to receive 48 variants of such GIC_4 on the basis of two-gate FET, which requires, therefore, the construction of 48 immittance conversion tables.

For two-parameter GIC_N on the basis of two-gate FET a more simple method could be applied for immittance conversion table construction using one-parameter GIC_N immittance conversion tables. This method is based on the possibility to represent two-gate FET in the form of two one-gate FET [4] as it is shown in fig.4.

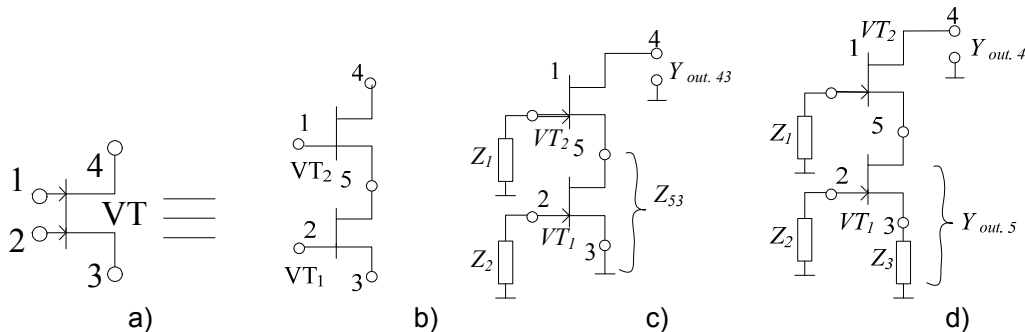


Рис. 4. Representation of a two-gate FET (a) in the form of two one-gate FET (b) and one of the variants of constructing a two-parameter (c) and a three-parameter (d) GIC_N on its basis

Using the tables of immittance conversion on the basis of one-parameter GIC , realized on a field-effect transistor [1], we find the character of the converted conductance $Y_{out.53} = 1/Z_{53}$, that determines the second converted resistance Z_{53} of the two-parameter GIC_3 , realized on transistor VT_2 . Taking into account the character of resistances Z_1 and Z_{53} , with the help of table 1 for the circuit 1a we can find the character of the converted conductance $Y_{out.43} = Y_{out.4}$. After performing similar operations for all 48 variants, the tables of two-parameter GIC_4 on the basis of the dual-gate Наукові праці БНТУ, 2011, № 1

FET are determined for different polarities of voltage at its gate.

Methods for synthesizing immittance conversion tables for three-parameter GIC_N on the basis of the independent quadripole

On the basis of independent the quadripole four variants of three-parameter GIC_N are realized (fig. 5).

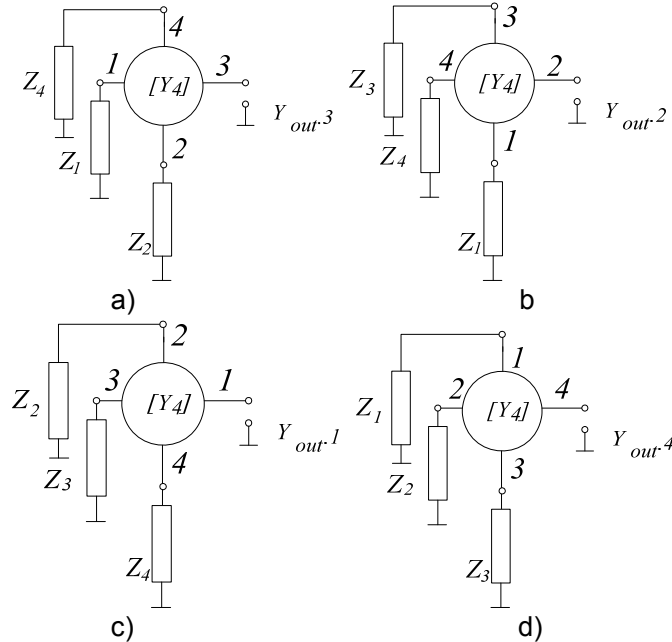


Fig. 5. Variants of the three-parameter GIC_4 on the basis of an independent quadripole

Taking into account that:

$$\left. \begin{aligned} Y_{out.1} &= F_1(Z_2, Z_3, Z_4, [Y_4]); \\ Y_{out.2} &= F_2(Z_1, Z_3, Z_4, [Y_4]); \\ Y_{out.3} &= F_3(Z_1, Z_2, Z_4, [Y_4]); \\ Y_{out.4} &= F_4(Z_1, Z_2, Z_3, [Y_4]). \end{aligned} \right\} \quad (3)$$

and specifying the character and the values of converted resistances ($Z_1 - Z_4$) and conversion frequency Ω_m , provided that $[Y_4]$ matrix elements are known, the character and the value of the converted conductance $Y_{out.i}$ can be determined for each variant of the three-parameter GIC_4 construction. Taking into account that analytical solutions are cumbersome and the fact that sometimes they are absent, we recommend using the above-described semigraphical method that provides the construction of three-parameter GIC immittance conversion tables. If a real active quadripole (e.g. on the basis of a two-gate FET) is used, the number of GIC_N construction variants increases to 16. Therefore, it is necessary to construct 16 variants of immittance conversion tables. However, in this particular case the problem solution is simplified by a two-gate FET representation in the form of two one-gate FET. For this case a three-parameter GIC_4 is presented in fig. 4d. Using the tables of two-parameter GIC_3 conversion (tables 1), we find the character of the converted conductance of GIC_3 realized on the transistor VT_1 ($Y_{out.5}$). Taking into account that it reflects the character of the second converted resistance of the two-parameter GIC_3 , realized on VT_1 transistor, we determine the character of the converted conductance $Y_{out.4}$ using table 1. After performing similar operations for all 16 variants of three-parameter GIC_N on the basis of two-parameter FET, we obtain their immittance conversion tables.

Similarly, immittance conversion tables can be obtained for multiparameter GIC_N on the basis of multipoles having $N > 4$, but they do not have any practical application today.

Conclusions

1. An advantage of the developed methods of synthesizing immittance conversion tables for multipole GIC_N consists in the application of the qualitative (rather than quantitative) parameters such as active, capacitive and inductive character of GIC_N immittances that are to be converted and of those already converted, which excludes restriction on the frequency for the proposed synthesis procedure application.
2. Two procedures are possible for synthesizing immittance conversion tables of multiparameter GIC_N :
 - direct analytical solution;
 - application of immittance conversion tables for two-parameter GIC_N .

The complexity of the first procedure increases with the growth of N and in the majority of cases any explicit solution exists.

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