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RESEARCH OF GENERALIZED CONVERTER OF IMMITANCE ON THE BASE OF ONE-JUNCTION TRANSISTOR FROM PARAMETERS OF ITS PHYSICAL EQUIVALENT CIRCUIT

In the article the mathematical model of GCI was developed on a base of OT, which takes into account dependence of its regenerate immitans from OT physical parameters, and also was researched the dependences of regenerate immitans of W_{in} (W_{out}), which is conducted of physical parameters of OT and range of workings frequencies.

Key words: *one-junction transistor, generalized transformer of immitans.*

Introduction

The one-junction transistors (OJT) got wide application as low-powered keys of different impulsive devices [1-3]. Presence in their active mode of coefficient of transmission on the current of $h_{21} > 1$ [4] makes it as a perspective component of the generalized transformer of immitance (GCI) for operation on frequencies of several hundreds of MHZ [5]. In this case, from the practical point of view, there is a problem of requirements forming to the physical parameters of OJT, that ensure the receipt of necessary values of regenerated immitaces W_{in} (W_{out}).

Task setting

Determination of optimal values of OJT physical parameters, which ensure the receipt of the required values of the transforming emmitance Win (Wout), when it is used as GCI, that is, the receipt of maximum values of negative real emmitances and inductive regenerated immitances, requires the solution of the following rasks:

– to develop the mathematical model of GCI on the base of OT, which takes into account dependence of its regenerated immitance of OT physical parameters;

– to conduct research of dependence regenerated immitance of Win (Wout) of OT physical parameters and range of working frequencies.

Development of mathematical model

Generalized transformer of immitance on the OJT base is a quadripole which is formed on OJT, switched according to the circuit with the general base (b1). An immitance W_g , that is transformed, is connected to the quadripole input, and to the output – W_n (fig.1). Thus immitance which is transformed, $W_{in} = f(W_n)$, and $W_{out} = f(W_g)$.

To build the mathematical model construction of such GCI_{b1}, which takes into account OJT physical parameters, we use its physical equivalent circuit, presented on fig. 2a. There are many such equivalent charts of different complication level. But, on practice, complication of equivalent circuit does not provide for the substantial increase in calculations accuracy, since parameters determination accuracy of its elements is low. That’s why it is better to choose the simple physical equivalent circuit of transistor (fig. 2a), which parameters may be adjusted to more exact experimental characteristics [6].

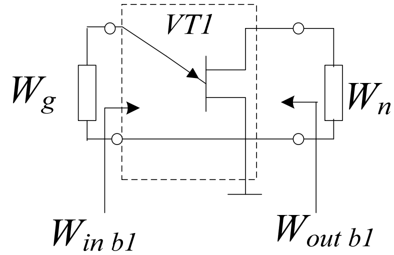


Fig. 1. High-frequency part of GCI circuit on basis of one-junction transistor with a general base 1

There used a simplified physical equivalent diagram without consideration of interferring elements, since the researches are conducted on relatively low frequencies. The physical equivalent circuit parameters are determined according to [6] with the use of experimental equipment, described in the patent [7].

On the circuit h_{21} is coefficient of transistor transfer on current; R_{b1}, R_{b2} ohmic base resistance 1 and 2; C_e and R_e are barrier capacity and differential resistance of emitter transition; C_{b1} - diffusive capacity of base 1.

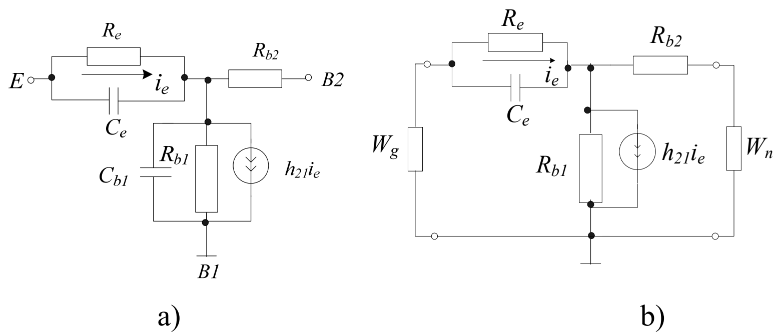


Fig. 2. Equivalent circuit of OJT (a) and GCI$_{b1}$ (b) on base of one-junction transistor

Replacing the transistor *VT1* on fig. 1 with its physical equivalent circuit (fig. 2a), we receive physical equivalent circuit of GCI$_{b1}$ (fig. of 2b).

Large emitter currents $R_e \to 0$, and $Z_{b1} = 1/j\omega C_{b1}$. With use of the program «*Snap*» we receive mathematical expressions of Z-parameters of the presented equivalent circuit:

$$Z_{11} = \frac{R_{b1} \cdot (1 - h_{21})}{1 + j \cdot \omega \cdot C_{b1} \cdot R_{b1}}; \qquad Z_{12} = \frac{R_{b1}}{1 + j \cdot \omega \cdot C_{b1} \cdot R_{b1}};$$

$$Z_{21} = \frac{R_{b1} \cdot (1 - h_{21})}{1 + j \cdot \omega \cdot C_{b1} \cdot R_{b1}}; \qquad Z_{22} = \frac{R_{b2} + R_{b1} + j \cdot \omega \cdot C_{b1} \cdot R_{b1} \cdot R_{b2}}{1 + j \cdot \omega \cdot C_{b1} \cdot R_{b1}};$$

The resistance matrix of this circuit will look as:

$$[Z_{b1}] = \begin{bmatrix} \dfrac{R_{b1} \cdot (1 - h_{21})}{1 + j \cdot \omega \cdot C_{b1} \cdot R_{b1}} & \dfrac{R_{b1}}{1 + j \cdot \omega \cdot C_{b1} \cdot R_{b1}} \\ \dfrac{R_{b1} \cdot (1 - h_{21})}{1 + j \cdot \omega \cdot C_{b1} \cdot R_{b1}} & \dfrac{R_{b2} + R_{b1} + j \cdot \omega \cdot C_{b1} \cdot R_{b1} \cdot R_{b2}}{1 + j \cdot \omega \cdot C_{b1} \cdot R_{b1}} \end{bmatrix} \tag{1}$$

The matrix determinant $\Delta Z_{b1} \neq 0$, as a result of it the input transformed resistance will be

$$Z_{in.b1} = Z_{11} - Z_{12} \cdot Z_{21} / (Z_{22} + Z_n), \tag{2}$$

accordingly the output resistance will be equal

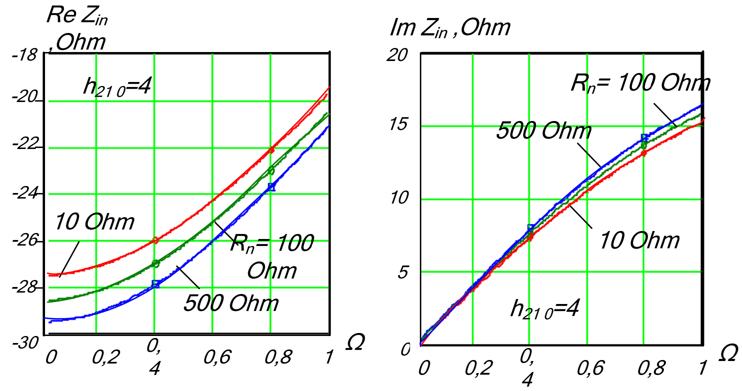
$$Z_{out.b1} = Z_{22} - Z_{12} \cdot Z_{21} / (Z_{11} + Z_g), \tag{3}$$

where Z_n та Z_g –resistances, which are being transformed.

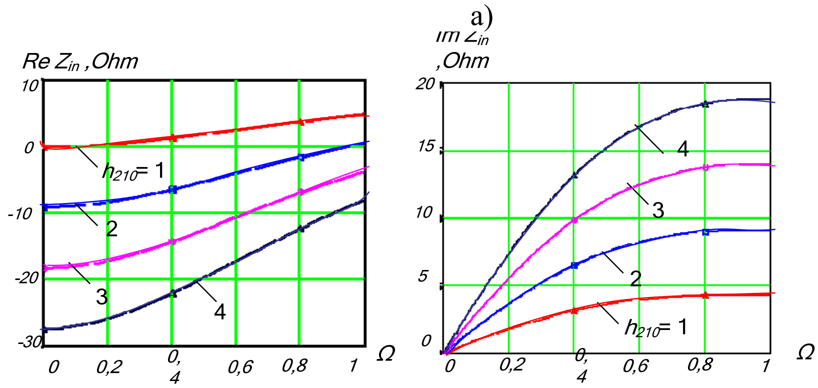
The equations system (1) - (3) forms the GCI$_{b1}$ mathematical model and allows to conduct research of transformed resistances dependencies of the of $Z_{in\ b1}$ and $Z_{out\ b1}$ on the physical OT equivalent circuit parameters.

Research results

Let us determine the dependencies of input and output impedance on the basic physical parameters of circuit, namely: resistances of base 1 (R_{b1}) and base 2 (R_{b2}), diffusive capacity of base 1 (C_{b1}), current transmission coefficient of transistor h_{21}, maximum frequency of transistor ft, as well as the resistance of load of Z_n for the input W_{in} parameters, and resistance of generator (Z_g) for output W_{out} parameters. The results of numeral calculations of input impedance are presented on fig. 3 and 4.



a)



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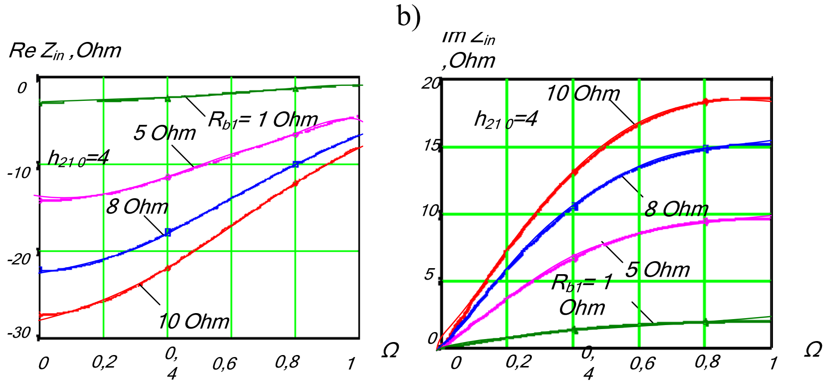
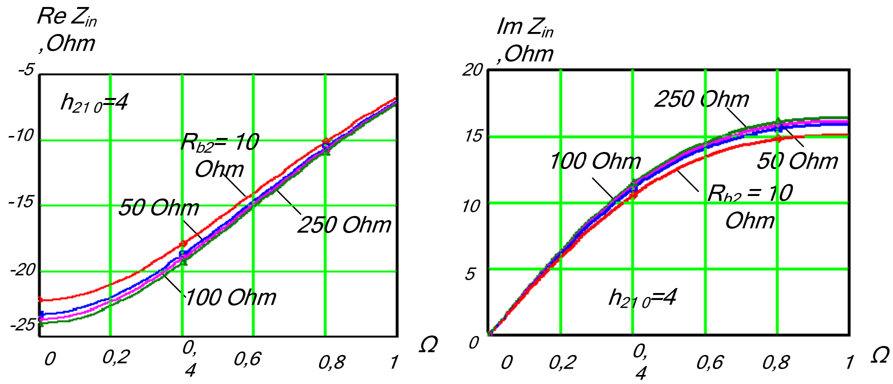


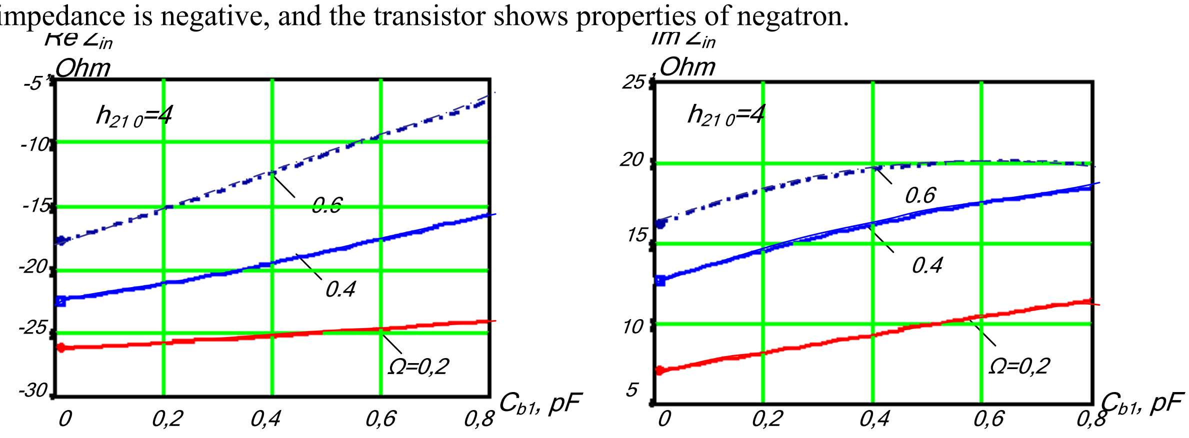
c)



d)

Fig. 3. Input impedance dependence on the resulted frequency $\Omega = f/f_T$ with different resistances of load R_n (a); current transmission coefficient of transistor h_{21} (b); resistance values of base 1(c); resistance values of base 2(d)

The received dependences have common tendences: non-linearity of characteristics and increase on the module for all parameters. The real part of impedance lies in area of negative values, that proves that the device is a negatron. Imaginary part is of inductive character. It confirms the possibility of the use of this transistor as an equivalent of an inductive soil. When $h_{21\,0} \leq 1$ (fig. 3 б)) real part of input impedance becomes positive and with increase $\Omega = f/f_T$ increases proportionally with the slope of S = 0,65 *Ohm/MHz.* With all values of $h_{21} > 1$ a real part of input impedance is negative, and the transistor shows properties of negatron.



a) b)

Fig. 4. Dependence of input resistance on C_{b1} with different values Ω

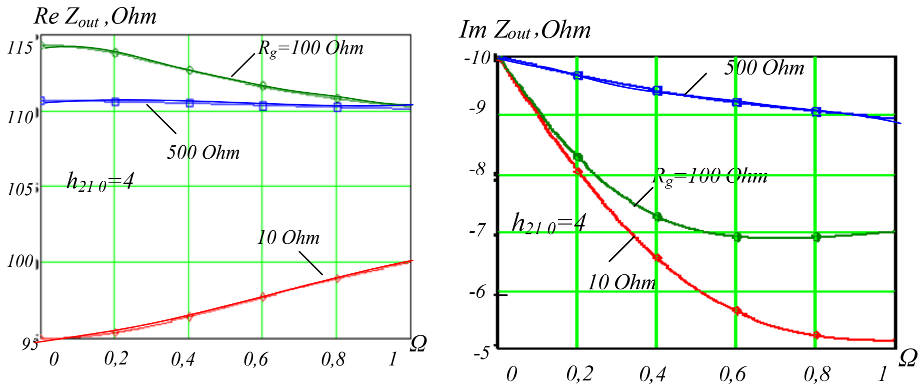
Analyzing dependence of impedance on the input of circuit on the capacity of base 1 (fig.4), it is possible to draw conclusions, that with capacities to 0,8 *pF* the dependence of the real part of input impedance is practically linear, increasing and lies in area of negative values. Imaginary part in the same range of capacities is nonlinear, growing and has certain rejections with a value Ω= 0,6, that are expressed in stopping of growth of input impedance with the capacity of base 1 $C_{b1} \geq 0{,}45$ *pF*.

Results of many calculations of output impedance, depending on physical parameters OJT are presented on a fig. 5. Frequency descriptions of output impedance, depending on load resistance take the opposite character (fig.5): when R_g=10 *Ohm* the increase of frequency causes the growth of of *Re* Z_{out}; when R_g=100 *Ohm* there observed the descending character of dependence and when R_g =500 *Ohm*, output resistance of *Re* Z_{out} remains practically permanent.

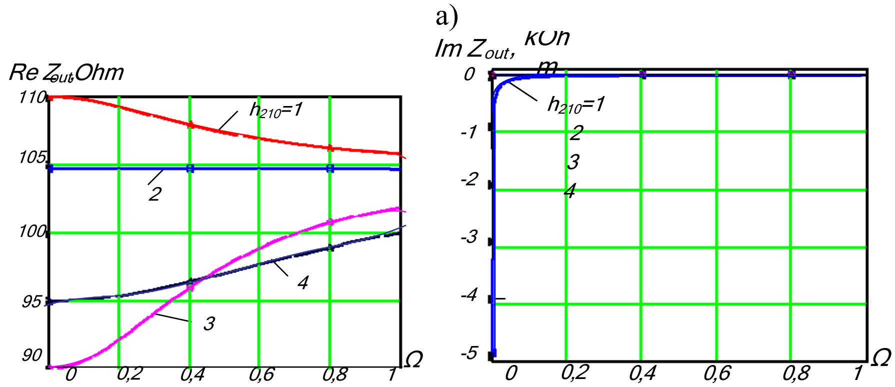
The real part of frequency dependence of Z_{out} is also of contradictory character with the different values of $h_{21\,0}$, namely: when $h_{21\,0}$ = 1– decreases, when $h_{21\,0}$ = 2 – remains permanent and when $h_{21\,0} > 2$ – has growing character. Imaginary part of frequency description of initial impedance depends on the size of size of $h_{21\,0}$ only on very low frequencies (fig. 5).

As is shown on fig. 5, the real part of output impedance with different values of base resistance $R_{б1}$ descends on the whole renge of frequencies which is researched. For this circuit of switching the one-junction transistor, the frequency Ω_{opt} = 0,5 (intersection point of all received dependences) is the optimum one.

The same graph shows that on the same frequency with R_{b1}=5 *Ohm* the observed the least value of imaginary component of initial resistance. On imaginary part with R_{b1}=5 *Ohm* is the point of bend Ω = 0,3, in which character of dependence changes from descending to growing one.



a)



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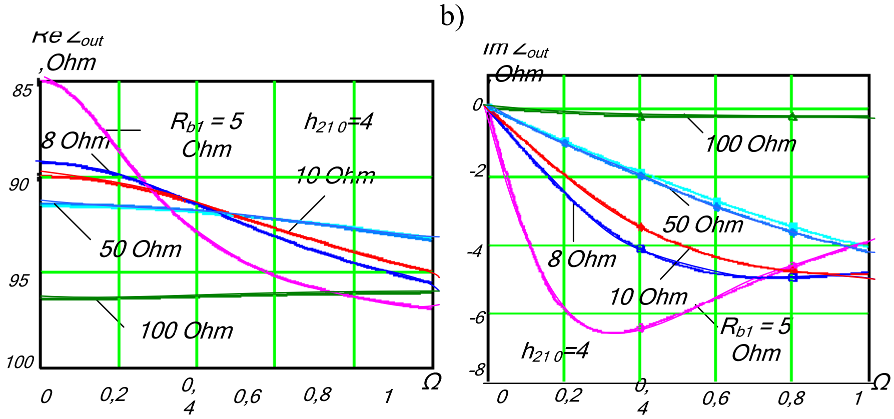

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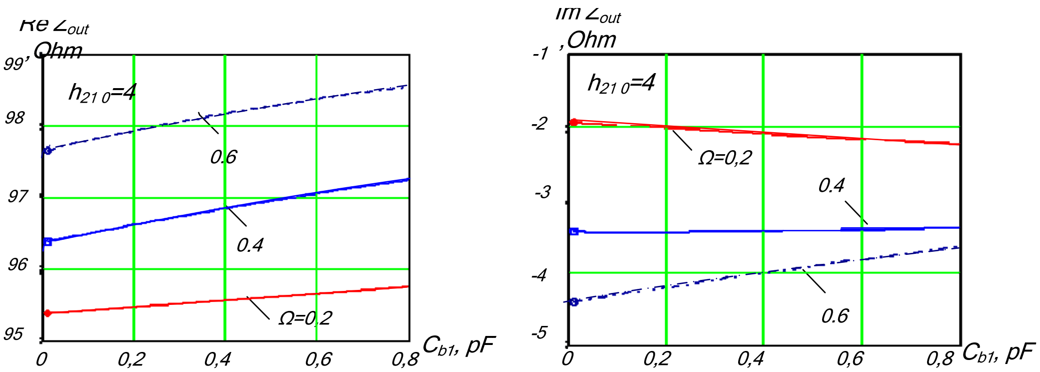

d)

Fig. 5. Dependence of output impedance on $\Omega = f/f_T$ at: different generator resistances R_g (a), current transmission coefficients of transistor h_{21} (b), resistances of base 1(c), and capacities of C_{b1} (d)

The real part of frequency characteristics of output impedance with the capacity increase C_{b1} is growing. Imaginary part of Z_{out} behaves contradictorily: when Ω = 0,2 it falls; when Ω = 0,4 initial resistance remains constant during all range of capacities and when Ω = 0,6 – dependence is of growing character.

Conclusion

The conducted research showed the sensitivity of the regenerated impedance of the one-junction transistor to the parameters change of its physical equivalent circuit. It shows the possibility of controlling over the size of transistor impedance with direct and reverse transformation of impedance by the change of R_{b1}, R_n and $h_{21\,0}$.

1. For the input impedance the real part has the most negative character, and imaginary part has the most inductive character with the following values: R_{b1} = 10 Ohm, $h_{21\,0}$ = 4, R_{b2} = 250 *Ohm*.

2. For the output resistance the real part is the most positive, and imaginary part is the most inductive at R_{b1} = 5 *Ohm*, $h_{21\,0}$ = 3, R_n = 10 *Ohm*.

REFERENCES

1. Ленк Дж. Электронные схемы. Практическое руководство / Ленк Дж. – М.: Мир, 1985. – 344 с.

2. Ерофеева И. А. Импульсные устройства на однопереходном транзисторе / И. А. Ерофеева – М.: Связь, 1974. – 72 с.

3. Ольсевич А. Е. Двухбазовые диоды в автоматике / А. Е.Ольсевич, В. В.Михайлов, В. И. Беличенко – М.: Энергия, 1972. – 72 с.

4. Стафаев В. И. Теоретические и экспериментальные исследования двухбазового диода / В. И. Стафаев, А. П. Штагер. – Рига: Знание, 1986. – 525 с.

5. Філинюк М. А. Аналіз і синтез інформаційних пристроїв на базі потенційно нестійких узагальнених перетворювачів імітанса / М. А. Філинюк – Вінниця: ВДТУ, 1998. – 85 с.

6. Ліщинська Л. Б. Експериментальний метод визначення параметрів одно перехідного транзистора. В кн. «Контроль і управління в складних системах» / Л. Б. Ліщинська, А. Г. Швидюк, М. А. Філинюк – КУСС, 2008. – 137 с.

7. Пат. 41314 України на корисну модель. МПК[8] G 01 R 27/28. Установка для вимірювання граничної частоти одноперехідного транзистора / Ліщинська Л. Б., Шведюк А. Г., Філинюк М. А., заявник та патентовласник Вінницький нац. техн. ун-т. – №u200900490; Заявл. 23.01.2009; Опубл. 12.05.2009, Бюл. №9.

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