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Optoimmittance logic elements

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ABSTRACT

Justification of optoimmittance logic and conception of construction of optoimmittance logic elements is developed, the system of their classification is grounded, basic parameters are certain, formulated requirements and the analysis of possible ways of their technical realization is conducted. Proposed in the concept of building immittance logic allows you to create high-frequency logic elements on the active components operating in quasi-linear mode, which partially overcomes the above mentioned disadvantages and to develop the logic elements formed by optical emitters and receivers in combination with generalized immittance converters - optoimmittance logic elements. By combining to set the logic level, optical and immittance parameters is possible to realize a large number of optoimmittance logic elements.

Keywords: immittance, optoimmittance, optoimmittance logic, optoimmittance logic elements

1. INTRODUCTION

Logical elements play a crucial role in computing. With the development of information technologies there are new requirements for speed, noise immunity, energy efficiency, size of logic elements, and so on. The implementation of these requirements is not always possible on the basis of video-pulse logic elements. Therefore researches for new principles of logic elements that meet certain specific requirements are constantly carry out. An example of such research is the development of optoimmittance logic elements, which use the character of immittance or immittance value as the information parameter. Using immittance enables to significantly improve the energy efficiency and noise immunity of the logic element.

2. FORMULATION OF THE PROBLEM

The presence of large video streams requiring appropriate processing, has led to optoelectronic gates [1,2,3]. They generally are a combination of logic elements and a video pulse of optical emitters and receivers. These gates have two significant disadvantages. Firstly, these cells are used in the video-keys operate in a nonlinear mode, which limits their performance. Second, the successful interaction of the optical elements and video pulse requires a relatively high energy costs associated with the need to change the operating point of the key scheme. As a result, quality factor $Q = p\tau$ of such optoelectronic gates remains low.

3. MAIN RESEARCH MATERIAL

Proposed [4] in the concept of building immittance logic allows you to create high-frequency logic elements on the active components operating in quasi-linear mode, which partially overcomes the above mentioned disadvantages and to develop the logic elements formed by optical emitters and receivers in combination with generalized immittance converters - optoimmittance logic elements (OLE) [4, 5].

The optoimmittance logic gates logic level is defined by the presence (absence) of an optical signal *F* (input or output of the circuit) and the appropriate nature of immittance *W*, as the input or output circuit. On this basis, the basic structure of the optoimmittance logic elements can be represented as shown in Fig. 1.

OLE, depending on the physical nature of the input and output parameter information, divided into 8 groups:

1. With the optical input and immittance outputs (Fig. 1a).
2. With immittance input and optical outputs (Fig. 1b).
3. With the optical input and output (Fig. 1c).
4. With combined (optical and immittance) inputs and immittance outputs (Fig. 1d).

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5. With the combined input and optical outputs (Fig. 1e).
6. With the optical input and combined outputs (Fig. 1f).
7. With immittance input and combined outputs (fig. 1g).
8. With the combined inputs and outputs (Fig. 1h).

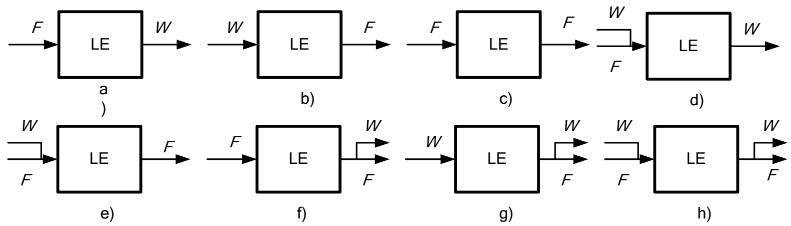


Figure 1. Variations of optoimmittance gates depending on the nature of the information signal at its input and output

Such an optical signal LE – F can influence directly on the SPR (Fig. 2a) or being converted immittance W_g (Fig. 2b), or simultaneously on PGI and W_g (Fig. 2c).

The OLE immittance with the optical output signal from the output of the SPR is supplied to the converter Π immittance into an optical signal (Fig. 2d) or optical signal comes directly from the output of the SPR (Fig. 2e), implemented on light transistor.

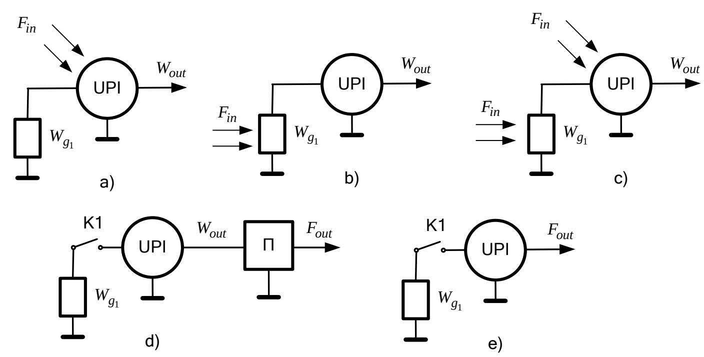


Figure 2. Varieties OLE on the basis of one-parameter GIC depending on the photodetector (a, b, c) and the type of optical converter (d, e)

Using multiparameter GIC_N [6,7,8] reduces the number of components in the implementation of OLE. Generalized block diagram of the LE with a combined optical and inputs are shown in Fig. 3.

The OLE logic level is characterized by the presence of ($F \neq 0$) or lack of $(F = 0)$ the optical signal (see Table 1).

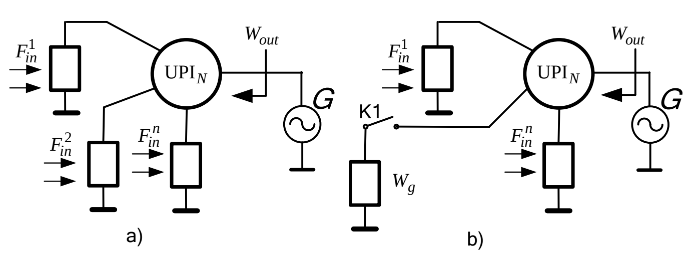


Figure 3. Generalized block diagrams OLE on multiparameter GICN

As it follows from [9,10,11,12], immittance when implementing logic circuits may use both positive and negative immittance and combinations thereof. As a result, there may be combinations of these seven options immittances, which are recommended to display the appropriate logic level. The eighth embodiment shown by way for example, is due to the difficulties of realization, unpromising.

Table 1. Options for presenting logical levels of the optical signal.

Positive logic		Negative logic	
Logic level	Optical level	Logic level	Optical level
0	$F = 0$	0	$F \neq 0$
1	$F \neq 0$	1	$F = 0$

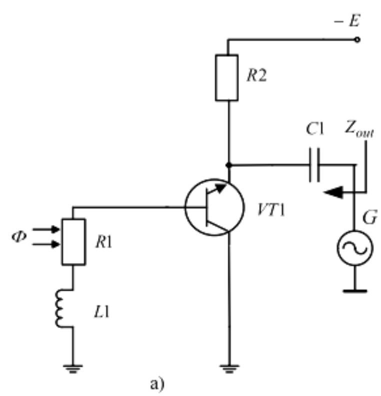
By combining, to set the logic level, optical and immittance parameters is possible to realize a large number of OLE. For example, each of the considered simplest LE (Fig. 1a, b) 32 is an embodiment of a combination of logic levels.

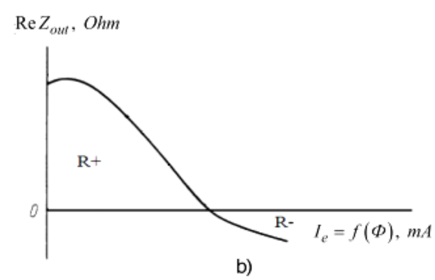
4. TECHNICAL REALIZATION

The most promising is the realization of immittance LE-based single-chip PGI, using bipolar and field-transistor structure, capable of operating at frequencies in the tens or even hundreds of GHz. On this basis, the implementation of OLE is also advisable to carry out on the basis of the SPR [13].

For example, to implement a logic "NOT" function in the luminous flux is used as an input parameter information *F*. Logical unit "1" corresponds to the presence of the luminous flux, ie, $F \neq 0$, logical zero "0" - no light flux $F = 0$. As an output parameter information used by the active component of impedance values Z_{out}. Then, the positive value of the active component of impedance $\mathrm{Re}\,Z_{out} > 0$. It corresponds to a logic one "1", and a negative value $\mathrm{Re}\,Z_{out} < 0$ – logical zero "0".

To implement the SPR LE uses a bipolar transistor (Fig. 4a), included in the circuit with common collector.





Input		Otput		
$F = 0$	0	$\mathrm{Re}\,Z_{out} > 0$	$R^{(+)}$	1
$F \neq 0$	1	$\mathrm{Re}\,Z_{out} < 0$	$R^{(-)}$	0

c)

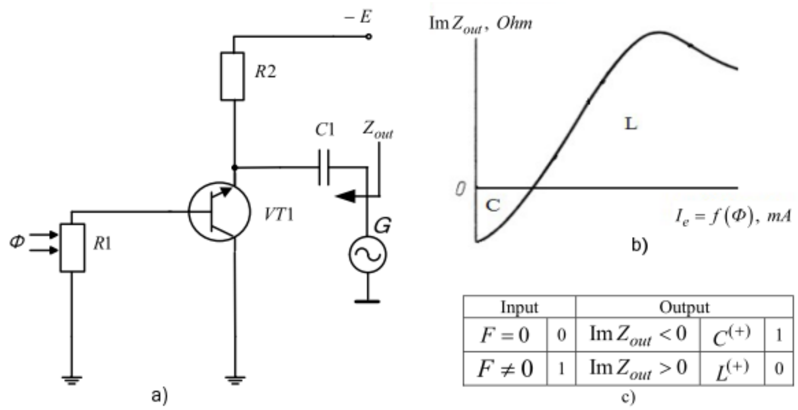
Figure 4. Optoimmittance R-gate "NOT": a) the concept; b) dependence of the real component of the converted impedance on input light intensity; c) truth table.

This element is immittance converter [13, 14]. PGI is converted impedance serial connection photoresist R1 and inductor L1. The transformed impedance Z_{out}. It depends on the presence or absence of an optical signal *F*, supplied to photoresistor *R1*. The dependence of the real component $\mathrm{Re}\,Z_{out}$ transformed by the emitter impedance of transistor current which is proportional to the intensity of optical radiation, shown in Fig. 4b. If no optical signal at the input photoresistor *R1* ($F = 0$), that corresponds to a logical "0", the output device is a positive value of the real component of the impedance of the transformed $(\mathrm{Re}\,Z_{out} > 0)$, which corresponds to a logical "1". If the optical signal is fed to *R1* photoresistor ($F \neq 0$), that corresponds to a logical "1" at the output is a negative value of the real component of the impedance of the transformed $(\mathrm{Re}\,Z_{out} < 0)$, that corresponds to a logical "0". Thus, the implemented function "NOT." The truth table considered optoimmittance R-logical element "NOT" have the form shown in Fig. 4c.

Similarly, the above discussed embodiments are implemented LC-gate "NOT" circuit diagram is shown in Fig. 5a. As the output of the information parameter value is the reactive component $\mathrm{Im}\,Z_{out}$ converted impedance. The inductive nature of the reactive component of the impedance $\mathrm{Im}\,Z_{out} > 0$ It corresponds to a logical "0", and capacitive $\mathrm{Im}\,Z_{out} < 0$

– a logical "1". The converted immittance PGI is the resistance of the photoresistor *R1*. The converted immittance is dependent on the presence or absence of optical radiation on photoresistor *R1*. If *R1* photoresistor does not apply radiation $F = 0$, that corresponds to a logical "0", the emitter current $I_e = 0$ and the device output will be transformed impedance with capacitive character of reactive component $\operatorname{Im} Z_{out} < 0$, that corresponds to a logical "1".

If *R1* photoresistor optical signal acts on the input device $(F \neq 0)$, that corresponds to a logical "1", the emitter current $I_e > 0$ and the output impedance of the PE will be converted to the inductive nature of the reactive component $\operatorname{Im} Z_{out} > 0$, that corresponds to a logical "0". Thus, the implemented function "NOT." The truth table optoimmittance LC-logical element "NOT" have the form shown in Fig. 5. When connecting multiple logic elements "NOT" (Fig. 5) alternating current to the total load is realized LC-gate "AND-NOT" (Fig. 6) [15,16,17].



Input		Output		
$F = 0$	0	$\operatorname{Im} Z_{out} < 0$	$C^{(+)}$	1
$F \neq 0$	1	$\operatorname{Im} Z_{out} > 0$	$L^{(+)}$	0

c)

Figure 5. Optoimmittance LC-gate "NOT": a) the concept; b) dependence of the imaginary component of the converted impedance on input light intensity; c) truth table.

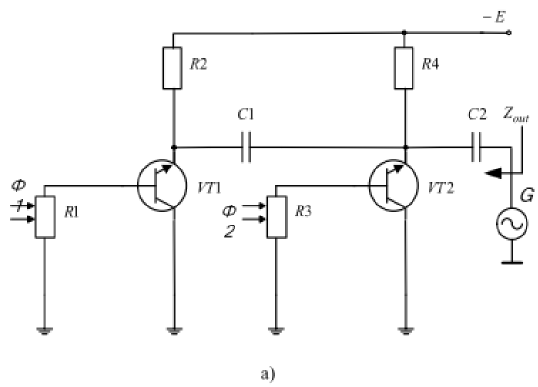
In the scheme of inductive reactive component of the output impedance $\operatorname{Im} Z_{out} > 0$ It corresponds to a logical "0", and capacitive $\operatorname{Im} Z_{out} < 0$ - A logical "1". The circuit operates at a frequency above f_0, where f_0 – the resonant frequency of the parallel circuit formed by the capacitive and inductive impedance components of converted output transistors VT1 and VT2. Converted impedance PGI implemented using bipolar transistors VT1 and VT2, it is the resistance of the photoconductive *R1* and *R3*. The converted immittance impedance opto LE depends on the presence or absence of an optical signal on photoresistors *R1* and *R3*.

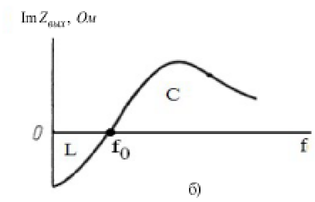
If photoresistor optical signal is not valid $(F = 0)$, that corresponds to a logical "0", between the emitter and collector of the transistor will be turned impedance capacitive reactive component (Fig. 5b), which corresponds to a logical "1". If the optical signal affects the photoresistor $(F \neq 0)$, which corresponds to a logical "1" increases the emitter current I_e and between the emitter and collector of the bipolar transistor becomes turned inductive impedance that corresponds to a logical "0". Each stage separately implements the "NOT" function. Thus, it is possible the combination of synchronous and separate irradiation of photoresists *R1* and *R3*, in which the function is implemented "AND-NOT", which corresponds to the truth table (Fig. 6).

The disadvantage of this optoimmitance logic element is the need to use at each input transistor operating in the active mode, which deteriorates the energy characteristics of the logic element. This disadvantage is absent in optoimmitance LC-gates, electrical circuits which are shown in Fig. 7 [15,16,17].

In the circuit in Fig. 7a transformed impedance of optoimmittance logical element depends on the presence or absence of optical radiation to the resistor *R1-R3*. So if at all there is no radiation photoconductive $F = 0$, which corresponds to a logical "0", between the emitter and collector of the bipolar transistor VT1 will be transformed impedance of capacitive reactive component that is responsible as a logical "0". If one of the photoconductive act, optical radiation, which corresponds to a logical unit "1" on one of the inputs (eg $F1 \neq 0$, $F2 = 0$, $F3 = 0$), the resistance of irradiated photoresistor *R1* decrease, but since the photoresistor connected in series, the total resistance of three photoconductive

R1-*R3* is great because transformed impedance logic element will wear the capacitive nature of the reactive component that is consistent logical "0". If the exposure will be valid for two photoresistor *R1* and *R2* (*F1 ≠ 0 ≠ 0 F2, F3 = 0*), the support illuminated photoconductive *R1* and *R2* will drop, but unclarified photoresistor resistance *R3* is several orders of magnitude greater resistance photoconductive lit *R1* and *R2*. Therefore transformed impedance logic element will also carry capacitive nature that correspond to logical "0". Only in case of simultaneous lighting of three converted photoconductors element impedance becomes inductive logic that meet the logical unit "1" [18,19,20].

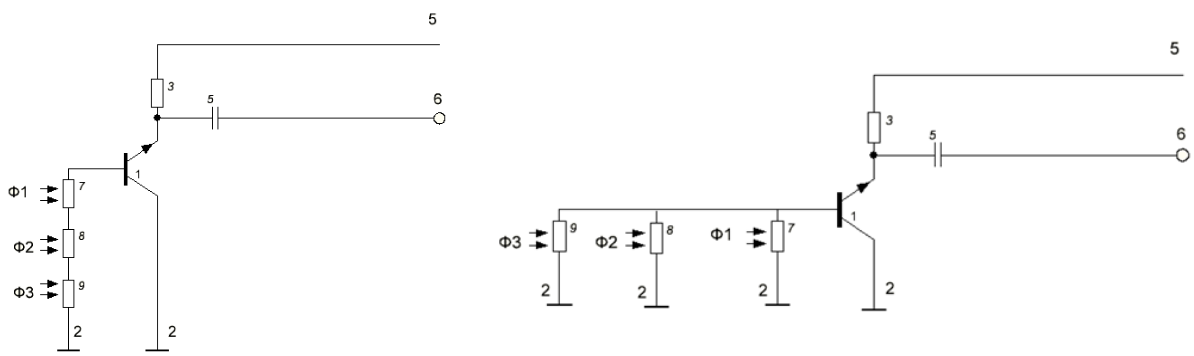




Input		Otput	
F1	F2		
0	0	$\mathrm{Im}\, Z_{out} < 0$	1
0	1	$\mathrm{Im}\, Z_{out} < 0$	1
1	0	$\mathrm{Im}\, Z_{out} < 0$	1
1	1	$\mathrm{Im}\, Z_{out} > 0$	0

c)

Figure 6. Optoimmittance LC-gate "AND-NOT": a) the concept; b) the frequency dependence of converted immittance at: $F_1 \neq 0$, $F_2 = 0$, $F_1 = 0$, $F_2 \neq 0$; c) truth table.



a) b)

Figure 7. One-transistor optoimmittance RLC-gates "AND" (a), and "OR" (b).

Such combinations of simultaneous and separate radiation photoconductors optoimmittance logic element ensure the implementation of logical functions "AND", which corresponds to the truth table shown in Table 2.

Table 2.The truth table of optoimmitance LC-logical element "AND".

Input			Output	ImZ *out*
F1	F2	F3		
0	0	0	0	$\mathrm{Im}Z_{out} < 0$
0	0	1	0	$\mathrm{Im}Z_{out} < 0$
0	1	0	0	$\mathrm{Im}Z_{out} < 0$
0	1	1	0	$\mathrm{Im}Z_{out} < 0$
1	0	0	0	$\mathrm{Im}Z_{out} < 0$
1	0	1	0	$\mathrm{Im}Z_{out} < 0$
1	1	0	0	$\mathrm{Im}Z_{out} < 0$
1	1	1	1	$\mathrm{Im}Z_{out} > 0$

In the circuit in Fig. 7b transformed impedance of optoimmittance logical element depends on the presence or absence of optical radiation to the resistor *R1-R3*, in parallel. If all of photoresistor no radiation ($F = 0$), which corresponds to a logical "0" at the three entrances of the device, between the emitter and collector of the bipolar transistor VT1 will be transformed impedance of capacitive reactive component that is responsible as a logical "0". If one of the photoconductive act, optical radiation, which corresponds to a logical unit "1" on one of the inputs (eg $F1 \neq 0$, $F2 = 0$, $F3 = 0$), the resistance of irradiated photoresistor R1 is reduced, and since the photoresistor connected in parallel, the total resistance of three photoconductive be small. Therefore transformed impedance will be inductive logic element nature reactive component that is responsible logical "1". If the exposure will be valid for two photoresistors ($F1 \neq 0$, $F2 \neq 0$, $F3 = 0$), the support illuminated photoconductive *R1* and *R2* will be reduced and converted impedance logic element will also be wearing inductive nature that meet a logical "1". This condition is fulfilled and when illuminated photoconductive *R1 - R3* simultaneously [21,22].

Such combinations of simultaneous and separate radiation photoconductive *R1 - R3* optoimmitance LC-logic element ensuring realization of logical function "OR" corresponding to the truth table shown in Table 3.

Table 3.The truth table of optoimmitance logic element "OR".

Input			Output	ImZ_{out}
F1	F2	F3		
0	0	0	0	$ImZ_{out} < 0$
0	0	1	1	$ImZ_{out} > 0$
0	1	0	1	$ImZ_{out} > 0$
0	1	1	1	$ImZ_{out} > 0$
1	0	0	1	$ImZ_{out} > 0$
1	0	1	1	$ImZ_{out} > 0$
1	1	0	1	$ImZ_{out} > 0$
1	1	1	1	$ImZ_{out} > 0$

5. RESEARCH RESULTS

In the above optoimmittance transistor LE, used as GIC, operates in active mode, providing high speed circuit. In general, the switch is OLE

$$\tau_{OI} = \tau_{in} + \tau_{UPI} + \tau_{out}, \quad (1)$$

where τ_{in} – converting the optical signal F_{in} in conversion immittance W_g; τ_{UPI} – time of converting the converted immittance W_g converted into immittance W_{out}; τ_{out} – time converting immittance W_{out} the output optical signal F_{out}.

As an input optical signal converter in conversion immitance possible to use different types of photodetectors, the conversion of which is shown in the Table 4.

Table 4. The main types of photodetectors and their inertia.

Type of sensor	τ_{in}, s
Photoresistor	$10^{-5} - 10^{-6}$
Silicon photodiode	10^{-7}
P-i-n diode	$10^{-9} - 10^{-10}$
Schottky Diode	$10^{-10} - 10^{-11}$
Bipolar phototransistor	$10^{-7} - 10^{-8}$
Field phototransistor of p-n transistor	$10^{-5} - 10^{-8}$
Thyristor	$10^{-5} - 10^{-8}$
Phototransistor with the Schottky transistor	$10^{-10} - 10^{-11}$

Parameters of such photodetectors relatively optoelectronic LE, analyzed in detail in [17,23,24]. In optoimmittance less than the speed of transformation is also an important character immittance of the receiver and its manufacturability. As the Table 4, in terms of adaptability to OLES working in the microwave range, preferred to use the structure Schottky photodetectors, which provide $\tau_{in} \approx \left(10^{-10} - 10^{-11}\right)s$.

Time of converting the converted immittance W_g to a converted immittance W_{out} depending on the type of GIC. Most are single-chip high-speed GIC, implemented bipolar and field effect transistor structures. The minimum conversion time such structures immittance

$$\tau_{UPI} = 1/2\pi f_T ,$$

where f_T – cutoff frequency of transistor structure.

Given that the present structure transistor designed with the utmost speed of more than 100 GHz, have $\tau_{UPI.\min} \geq 10^{-12} s$.

Time of converting conversion immittance W_{out} the output optical signal conversion depends on the scheme *П*. In the extreme case, its minimum value determined source inertia flux. In OLE incoherent appropriate use of semiconductor light sources - LEDs, the speed of which the implementation on the basis of heterostructures is $\tau_{out} \approx \left(10^{-9} - 10^{-12}\right)s$.

In view of the analysis can predict the potential performance OLE amount to order $\left(10^{-10} - 10^{-11}\right)s$ and depends on the nature of the information signal at its input and output. The research of the main parameters was carried out in [25–27].

6. CONCLUSIONS

Justification of optoimmittance logic and conception of construction of optoimmittance logic elements is developed, the system of their classification is grounded, basic parameters are certain, formulated requirements and the analysis of possible ways of their technical realization is conducted. Proposed in the concept of building immittance logic allows you to create high-frequency logic elements on the active components operating in quasi-linear mode, which partially overcomes the above mentioned disadvantages and to develop the logic elements formed by optical emitters and receivers in combination with generalized immittance converters - optoimmittance logic elements. By combining to set the logic level, optical and immittance parameters is possible to realize a large number of optoimmittance logic elements. Considered optoimmittance gates can serve as the basis for the construction of the input devices of optical information in immittance logic. To implement the reverse process in such schemes are optoimmittance converters.

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