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OPTOELECTRONIC DEVICES FOR INFORMATION TRANSMISSION OVER SHORT DISTANCES

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Abstract: The advantage of optical information transmission devices is shown, since optical radiation does not create interference and spreads in limited spaces, providing the necessary secrecy of information transmission.

The principles of the formation of optical radiation during the transmission of both analog and digital information are considered.

To study the distortion of the photoelectric signal shape, an experimental method was selected and an experimental setup was developed.

Analysis of the results shows that the shape of the pulses is largely influenced by the parameters of the photoreceiving circuit and the duration of the pulses, and the influence of the emitting diode current is insignificant.

A principle is proposed for the formation of short pulses corresponding to the falling and rising sections of transmitted digital signals over short distances.

Keywords: optoelectronics, LED, photodiode, optical radiation, photoelectric signal shapes, pulse duration, information transmission over short distances.

Introduction. Introduction. The basis of optoelectronic devices based on semiconductor emitters is the presence of an LED and a photodetector optically connected to it through a medium.

The radiation created by the LED, passing through a controlled environment, is perceived by a photodetector. Optoelectronic devices based on semiconductor emitters use optical radiation as an information carrier, which does not create electromagnetic interference and is not affected by this interference [1]. The presence of such a feature and the simplicity of instrumental implementation create the prerequisites for the research and development of various optoelectronic devices based on semiconductor emitters based on the use of IR radiation.

Solving the problem of creating and analyzing optoelectronic devices based on semiconductor emitters includes the following steps [2]:

• analysis of measurement (control) conditions and choice of measurement principle;

• drawing up a block diagram of optoelectronic devices based on semiconductor emitters;

• mathematical description of the functional transformation performed by an optoelectronic device;

• determination of the main characteristics of optoelectronic devices based on semiconductor emitters;

• analysis of errors and determination of the accuracy of optoelectronic devices based on semiconductor emitters;

• assessment of accuracy and information characteristics;

• basic block diagram of optoelectronic devices based on semiconductor emitters.

The essence of converting a controlled parameter into a photoelectric signal comes down to the fact that the controlled object is irradiated with a radiation flux of a certain spectral composition, receives a fraction of the radiation after interaction and converts it into a photoelectric signal [4-5].

Methods for studying photoelectric signal waveform distortions

When transmitting digital information, the optical signal is first converted into current. This current, flowing through a semiconductor emitter, is converted into an optical signal, the intensity of which is determined by the radiation power proportional to the flowing current.

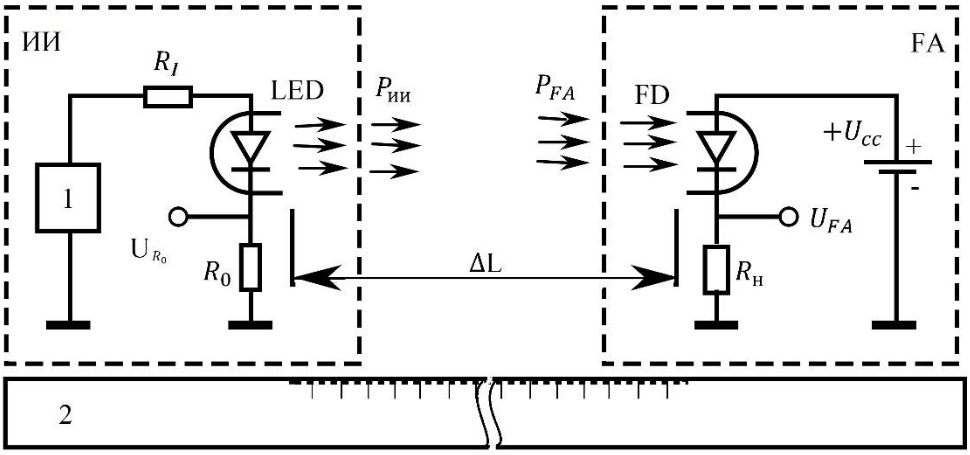

Fig. 1. Experimental setup for studying photoelectric signal waveform distortions.

The switching speed of semiconductor emitters is very high, and, therefore, the radiation flux pulse will repeat the current pulse. Next, the generated pulsed radiation flux passes through the medium and, with some attenuation, usually according to the law of squared distances, is attenuated and hits the photosensitive surface of the photodetector:

$$P_{FA} = \frac{P_L}{L^2} \qquad (1)$$

An experimental method was chosen to study the distortion of the photoelectric signal shape. To conduct research, an experimental setup has been developed, the block diagram of which is shown in Fig. 1.

As a radiation source, an emitting diode of the LD-274 type and a photodetector of the SFH-205 type were used [6-7].

To evaluate the shape of the photoelectric signal, the integral reproducibility criterion was applied:

$$K_F = \frac{\int |U_{FA}(t) - SF_0(t)| dt}{S\int F_0(t)dt} \quad (2)$$

where U_FA is the photoelectric signal; F_0(t) is an optical signal whose shape follows the current of the emitting diode.

Photoelectric signal distortions lead to output errors:

$$\delta_c(t) = U_{FA}(t) - SF_0(t) \quad (3)$$

Errors brought to the system input

$$\delta_g(t) = F_0(t) - \frac{1}{S}U_{FA}(t) \quad (4)$$

There is a relationship between the errors given to the input and the output errors:

$$\delta_g(t) = \frac{1}{S}\delta_c(t) \quad (5)$$

Here S is the sensitivity of the photodetector.

Research results.

The studies were carried out for three cases, and the shape coefficients of the pulse were determined

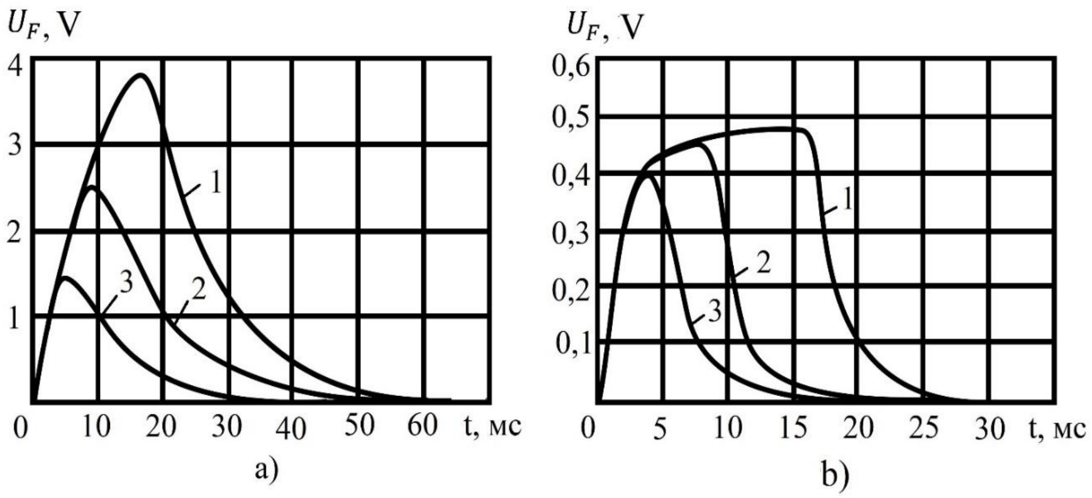

Fig. 2. Forms of photoelectric signals: a – for $R_l = 120\ kOM$; b – for $R_l = 12\ kOM$; 1 - t_D=16,4 ms; $K_F = 2.25152$; 2 - t_D=8.6 ms; $K_F = 1.6687$; 3 - t_D=4,6 ms; $K_F = 0.9017$.

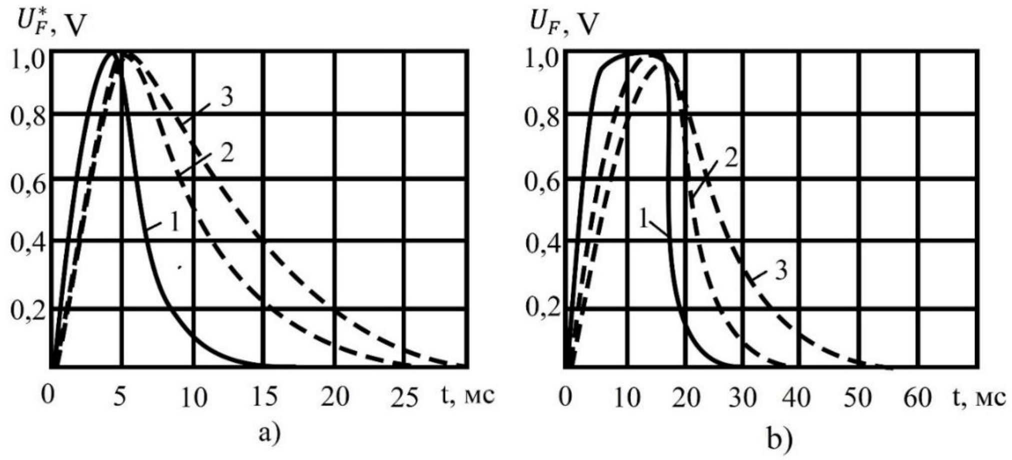

Fig. 3. Signal graphs for pulse durations: a - t_{D1}=4,6 ms; b - t_{D3}=16,4 ms; 1 - R_l = 12 kOM; $K_F = 0.8468$; 2 - R_l = 56 kOM; $K_F = 1.9282$; 3 - R_l = 120 kOM; $K_F = 2.5152$.

First case: keep the amplitude value of the emitting diode current constant ($I_L = 35\ mA$)and for the load resistances of the photodetector $R_l = 120\ kOM$ и $R_l = 12\ kOM$ and pulse durations $t_{D1} = 4{,}6\ ms$, $t_{D2} = 8{,}6\ ms$, $t_{D3} = 16{,}4\ ms$**.** On an experimental setup, using an oscilloscope, we record the shape of the photoelectric signal and determine the shape coefficients of these signals using a calculation method. In Fig. 2 shows signal graphs for the first case.

In the second case, the current amplitude is constant for pulse durations $t_{D1} = 4{,}6\ ms$, $t_{D3} = 16{,}4ms$ and for load resistor resistances $R_l = 12\ kOM$, $R_l = 56\ kOM$ и $R_l = 12\ kOM$ we record the forms of photoelectric signals. In Fig. 3 shows graphs for the second case.

The third case - separately for the pulse duration $t_{D1} = 4{,}6\ ms$ and load resistor $R_l = 12\ kOM$ and for pulse duration $t_{D3} = 16{,}4\ ms$ and load resistor $R_l = 12\ kOM$. In Fig. 4 shows the graphs for this case.

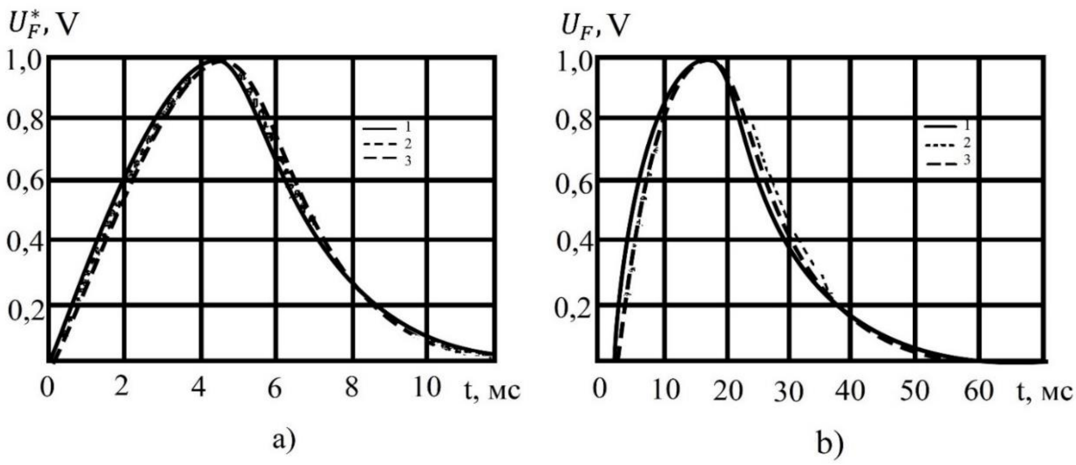

Fig. 4. Signal graphs for the third case: a - R_l = 12 kOM; $t_D = 4{,}6\ ms$; б - R_l = 120 kOM; $t_D = 16{,}4\ ms$; 1 - I_L = 40 mA; $K_F = 0.8861$; 1 - I_L = 20 mA; $K_F = 0.9430$; 1 - I_L = 10 mA; $K_F = 0.9655$

Table 1. Dependences of the pulse shape factor on the parameters of the photodetector circuit and pulse duration R_y.

R_y	$t_D = 4{,}6\ ms$	$t_D = 8{,}6\ ms$	$t_D = 16{,}4\ ms$
120	2.5152	1.6687	0.9017
56	1.9282	1.1494	0.6590
12	0.8468	0.5146	0.2841

Table 2. Dependence of the pulse shape factor on the emitter current and pulse duration.

I_L, mA	$t_D = 4{,}6\ ms$ $R_y = 12\ kOM$	$t_D = 8{,}6\ ms$ $R_y = 56\ kOM$	$t_D = 16{,}4\ ms$ $R_y = 120\ kOM$
10	0.9655	0.7726	1.1831
20	0.9430	0.7482	1.1657
40	0.8861	0.7081	1.1595

The oscilloscope used in the research was a Philips oscilloscope type PM3365A with memory. Operating frequency 100 MHz.

In table 1 and 2 show the values of pulse shape coefficients for various currents, load resistors and emitting diode currents.

Analysis of the above results shows that the shape of the pulses is largely influenced by the parameters of the photodetector circuit and the duration of the pulses. The influence of the emitting diode current is negligible.

In general, the conversion process in information transmission systems can be depicted by timing diagrams shown in Fig. 5.

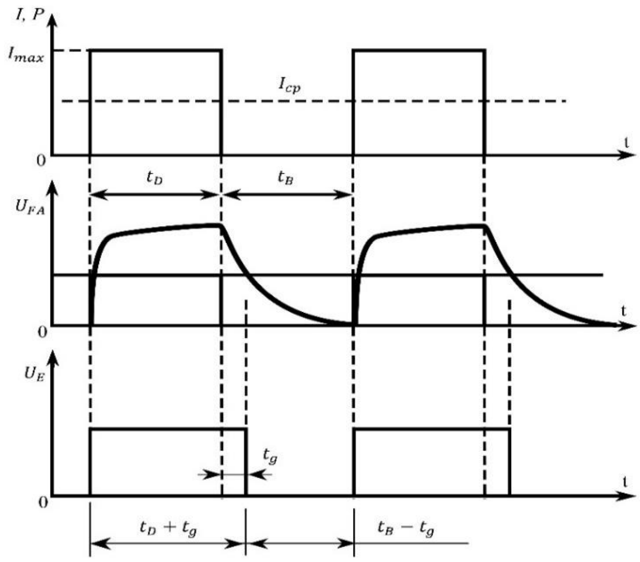

Fig. 5. Timing diagrams of the signal conversion process in information transmission systems.

Analysis of timing diagrams shows that errors occur

$$\delta_D = \frac{(t_D + t_g) - t_D}{t_D} \cdot 100 = \frac{t_g}{t_D} \cdot 100 \qquad (6)$$

associated with delay. Here t_g is the delay time. Average current flowing through a semiconductor emitter

$$I_{cp} = I_{max} D = I_{max} \frac{t_D}{t_D + t_B} \qquad (7)$$

The maximum permissible current (assuming that $I_{cp} = I_N$)

$$I_{max} = \frac{I_N}{D} = I_N \frac{t_D + t_B}{t_D} \qquad (8)$$

The pulse duration is usually selected from the condition $t_D = 3\tau_{FA}$, где τ_{FA} photodetector time constant.

The discussion of the results

In Fig. 6 shows timing diagrams that explain the principle of forming short pulses along decreasing and increasing sections.

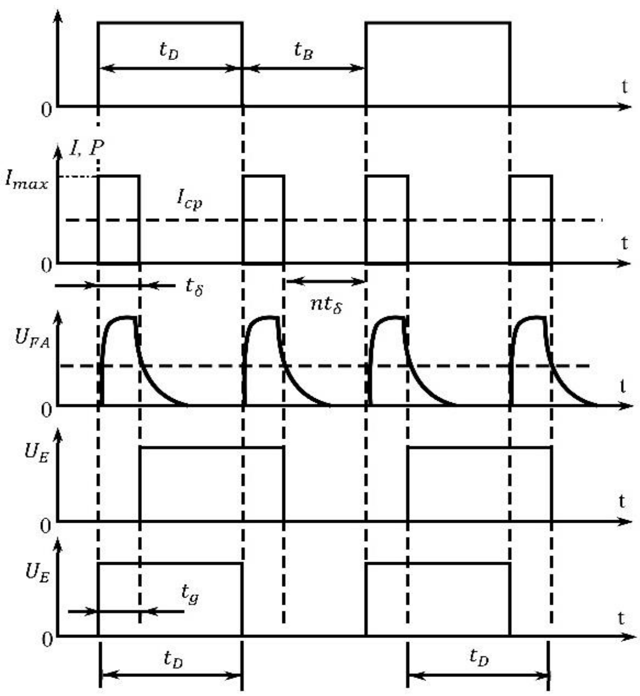

Fig. 6. Timing diagrams explaining the principle of short pulse formation.

In this case, the pulse current flowing through the semiconductor emitter

$$I_{max} = I_N \frac{nt_\delta + t_B}{2t_\delta} \qquad (9)$$

where t_δ is the duration of a short pulse formed from the leading and trailing edges of the transmitted pulse. Accordingly, the radiation power in this case will be increased and determined as

$$P^*(t) = K_L I(t) = K_L I_N \frac{nt_\delta + t_B}{2t_\delta} \qquad (10)$$

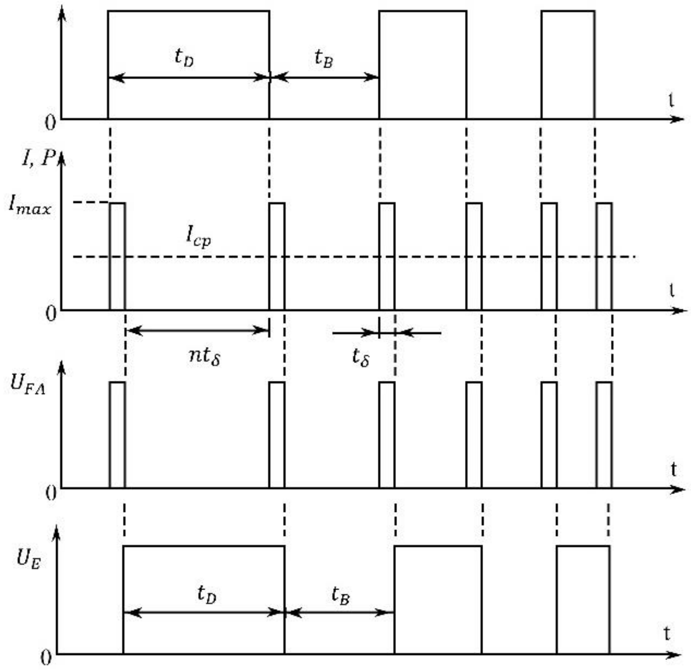

Fig. 7. Timing diagrams explaining the application of the principle of forming short pulses when transmitting an analog signal, previously converted to frequency.

where K_L - coefficient of conversion of current into radiation power. The influence of the pulse shape is also excluded here, since the pulse duration is unchanged, although the duration of the transmitted pulses varies over a wide range.

After processing the photoelectric signal, the original pulse shape is restored (see Fig. 6, UE). The only difference here is that there is a delay with a maximum value t_g between the input and reconstructed pulses. This principle can be successfully applied to transmit an analog signal that has been previously converted to frequency (see Fig. 7).

Conclusion. When developing information transmission systems, the need arises to transmit pulses with a duration varying within a wide range. Fluctuations in pulse duration over a wide range complicate the choice of power supply modes for semiconductor pulses and do not allow taking into account the influence of pulse shape distortion. For this purpose, a principle is proposed for the formation of short pulses corresponding to the falling and rising sections of the transmitted digital signals. In this case, regardless of the duration of the transmitted pulses, pulses of a fixed duration flow through the semiconductor emitter, which allows you to select the required operating mode of the semiconductor emitter.

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