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MODELLING OF RECTANGULAR PULSE OSCILLATOR OF ELECTRICAL TONAL RAIL CIRCUIT

Introduction

Modern automation systems must comply with the safety requirements in rail transport; have a minimal negative influence on staff. At the same time, stricter economic conditions of existence of the automated control systems. So actual is the updating and improvement of equipment based on the use of more modern or economically reasonable element base. In the implementation of high-speed traffic as the input sensor of the rolling stock at stations and tracks used electrical tonal rail circuit [1]. With the improvement of the equipment is considered an oscillator of amplitude-manipulated signals of low frequency band of rail circuit of tone frequency [2, 3].

Purpose

The ultimate objective is to select the rectangular pulse oscillator circuit of the electrical tonal rail circuit, for this:

– considered the most cost-effective circuit of oscillating a rectangular signal on the basis of integrated circuits;

– for selected circuits performed mathematical simulation in a software environment NI MultiSim [4, 5];

– executed a study of developed mathematical models of oscillators;

– performed the physical modelling and analysis of the work of oscillators.

The choice of schemes for oscillator development

When considering the most actual of technical circuits for implementing selection based on the use of least elements quantities and their final cost. As a result, the oscillator circuit selected on the basis of integrated circuits [6] with 2-3 logical elements (LE) of basic oscillator [7, 8]. The base oscillator is represented by primary frequencies oscillator and the oscillator of modulation frequencies. Oscillator circuit for further simulation are shown in fig. 1.

At fig. 1 signed elements:

– D1–D3 – logical elements AND-NOT or OR-NOT type;

– R1, R2, C1, C2 – variable elements for frequencies installing;

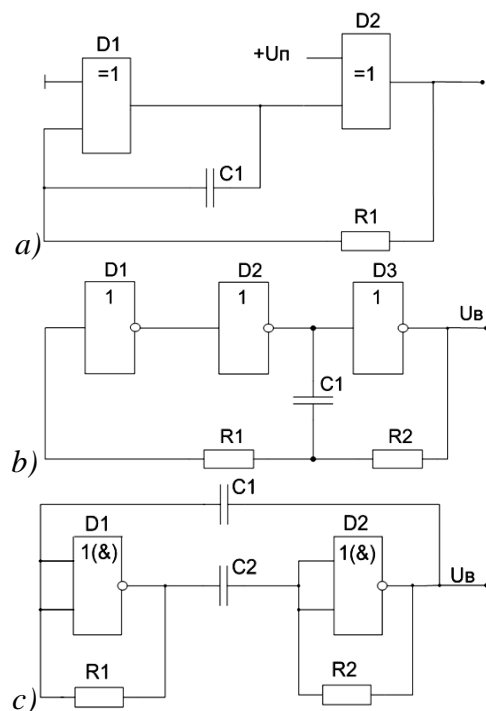– Uп –positive pole voltage power circuit (negative lead is not showed);

Fig. 1. Oscillator scheme with two *(a)*, three *(b)*, and two logic elements with loopback *(c)*

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– Uв – the pole of output voltage of oscillator (electrical output of scheme).

These schemes have different numbers of elements. In Scheme A (fig. 1 *a*) elements R1 and C1 is set only the value of the output frequency rectangular pulses, which positively affects its cost and ease of construction. In schemes B (fig. 1 *b*), and C (fig. 1 *c*), by the values of resistance and capacitance additionally changes the value of pulse duration and interval in loop signal. These additional features can complicate the process of reconfiguring the track oscillator of electrical tonal rail circuit (ETRC) with rectangular pulses according to the need to simultaneously change of R and C values.

In the schemes at fig. 1 all considered elements have two inputs. This is due to the necessity of using the identical elements, including the final element of the signal modulation.

Oscillator of primary frequencies and modulation frequencies simulation

Development of the rectangular pulse oscillator model is made by the NI Multisim software. As researched oscillator frequencies used 420 Hz primary and 8 Hz modulation frequencies. The result is a rectangular pulse oscillator simulation is shown in fig. 2.

Symbols used at fig. 2:

– D1, D2, U1A, U2A, U3A, U4A – logical elements (inverters), which is assembled the scheme;

– R1, R2, C1, C2 – resistances and capacitance of timing circuits of schemes;

– V1 – power supply circuits.

Fig. 2 shows the scheme of the rectangular pulse oscillator, tuned to the frequency modulating oscillations 8 Hz. To avoid repetitions are not presented the oscillators of rectangular pulses of the primary frequency of 420 Hz. The difference in the schemes consists in the value parameter of tuning elements.

As a result of the formation of the amplitude-manipulated signal oscillator, which is based on the primary oscillator (see fig. 2), are formed full functional scheme from the above oscillator (fig. 1 *a–c*). They are shown at fig. 3.

Shown in Fig. 3 schemes of manipulated signal oscillators are the starting point for further technical implementation. The possibility of establishing an output voltage and power are not covered. Although the output voltage of the scheme is set to the supply voltage of the projected scheme.

For further analysis, and selection one of the final implementation of the scheme is necessary to study the mathematical model oscillator.
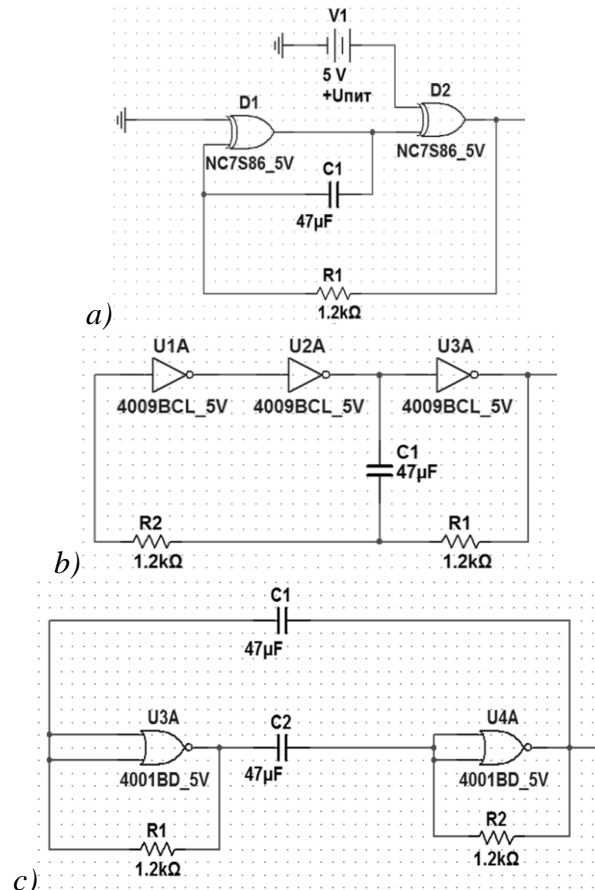

Fig. 2. Window program NI Multisim of the unmodulated frequency oscillator with two *(a)*, three *(b)*, and two elements with loopback *(c)*

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Research of mathematical model work of oscillator in Multisim

During the research of the mathematical model (fig. 3) the analysis of the output voltage of the oscillator done.

At 8 Hz and 420 Hz (fig. 4) as the result of the research are shown output voltage waveforms of oscillator.

Common X-scale in fig. 4 is 50 ms/Div and 2 ms/Div respectively, Y-scale is 2 V/Div.

In fig. 4 graphs are identical for all oscillators shown in fig. 1. The output non-modulated signal graphs are shown for the scheme with two logical elements (fig. 1 *a*).

The ideal characteristics of the model do not take into account the actual conditions of real work schemes. The output signal has no distortion at the front and down of signal. The pulse amplitude is the same throughout the duration of, the interval contains no noise.

The modulated signal of output voltage oscillators (fig. 3) is similar like for non-modulated formed oscillators schemes. It is shown in the program window at fig. 5.

X-scale in fig. 5 is 20 ms/Div, Y-scale is 5 V/Div.

Proceeding from results, shown in the oscilloscope, obtained following periods of signals:

− non-modulated primary − 123.976 ms (actual frequency of 8.066 Hz);

− modulated frequency signal − 2.383 ms (actual frequency of 419.64 Hz);

− modulated signal − 123.902 ms (actual frequency of 8.07 Hz).

Formed frequencies signal uncertainties of mathematical model determined by needed proximity of resistance R and the capacitance C to their standard value. These uncertainties are 0.825 %, 0.08 % and 0.875 %, respectively. Despite this, the primary and modulation frequencies included in bandpass width of filter of ETRC receiver:

− 1.2 Hz and 1.6 Hz for the modulating frequencies 8 and 12 Hz;

− 24 Hz for the primary frequencies [9].

Because it was impossible to implement selection of one of the oscillator circuits (as shown in fig. 1), the physical simulation is performed for each of these schemes.
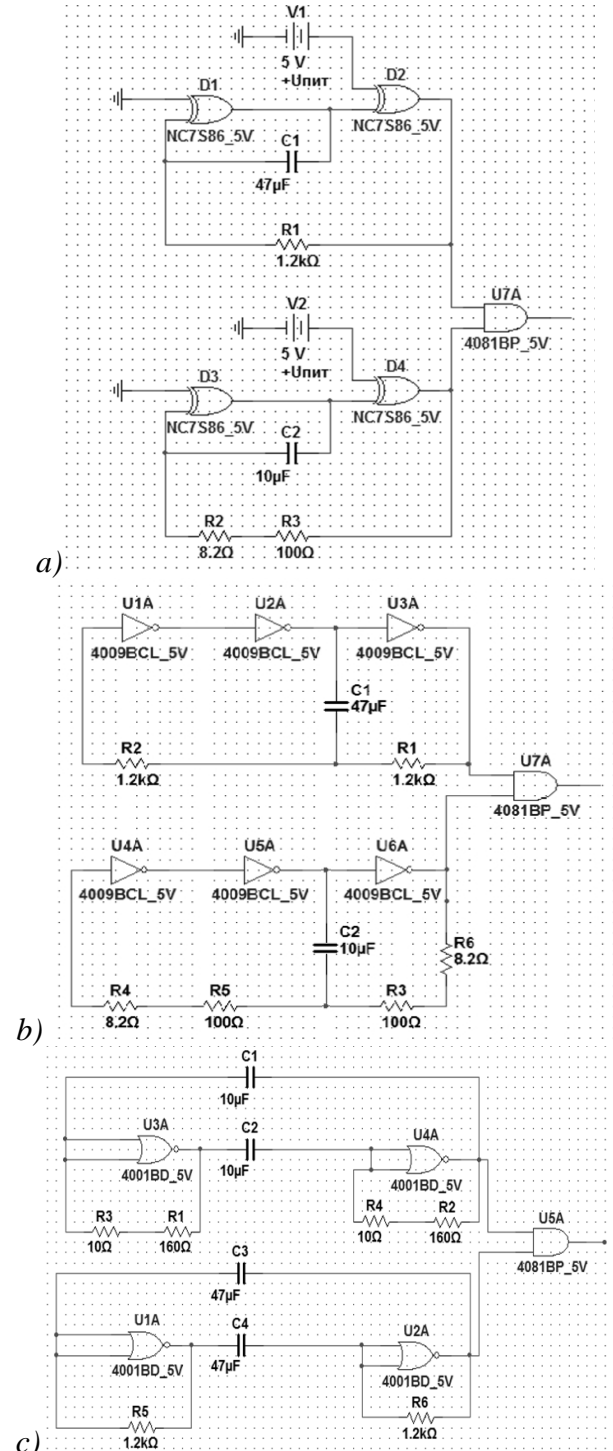

Fig. 3. The oscillator schemes of amplitude-manipulated signals as a result of computer modelling of three initial schemes

Analysis of the physical simulation of oscillator

To form and analyze oscillators based on schemes shown in fig. 1, used the following elements:

– RC elements of timing (value is shown in the diagrams in fig. 1–3);

– logical elements – on-chip type CD4011BE [10];

– USB digital oscilloscope BM8020 [11];

– stabilized power supply (in the scheme not shown).

The scheme implemented on the base of the prototyping board. [12] The output voltage of each of the simulated schemes analyzed in the firmware of a digital oscilloscope. Time dependence of the output voltage for simulated oscillator with two logic elements shown in fig. 6.

In Fig. 6 given output voltage dependence is similar for the other two considered schemes, therefore results in the future will not be. To select the oscillator circuit in the following analysis considered the amplitude-frequency characteristics (AFC) of simulated schemes. For shown in fig. 1 AFC shown in fig. 7–9.

Based from the above in fig. 7–9 AFC can make a preliminary conclusion that the maximum efficiency of power from output voltage of oscillator scheme with three logical elements.

As the numerical characteristics are represented the values of the AC voltage amplitudes; DC voltages; voltages at the primary and modulating frequencies in table 1.
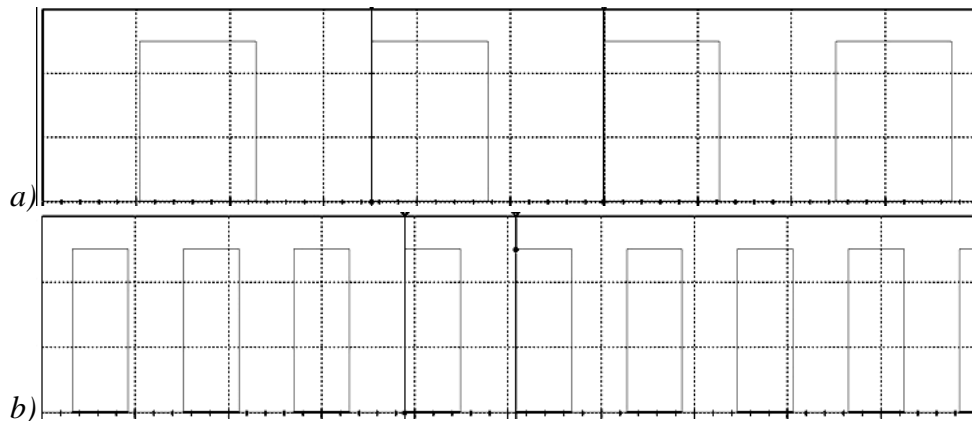

Fig. 4. Oscilloscope display with primary *(a)* and
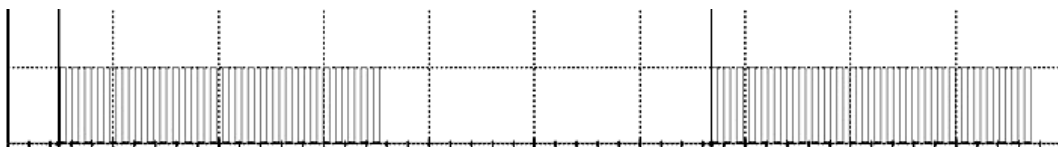a modulating signal *(b)* of rectangular pulses

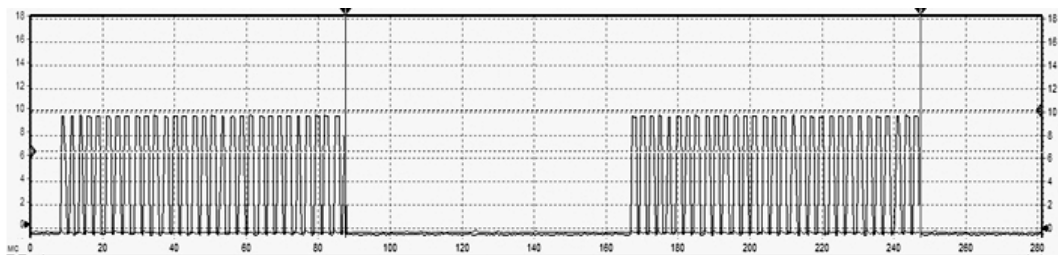Fig. 5. Oscilloscope screen with modulated signal 420/8 Hz

Fig. 6. The voltage generated at the oscillator output based on two logical elements

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According table 1 data most output power, and respectively efficiency at the same input DC power supply 9 V, is presented at scheme with 3 LE. At more detailed analysis coefficients of output voltage ratio is considered, which are summarized in table 2.

Table 2 shows the coefficients:

− Kov – output voltage coefficient: the ratio of the AC output voltage to DC output voltage;

− Kop – AC output power coefficient: a square of AC output voltage to the input voltage ratio;

− Kpf – the coefficient of the primary frequency: the ratio of the output voltage of the primary frequency to the AC output voltage;

− Kmf – coefficient of modulating frequency: the ratio of the output voltage of the modulating frequency to the output AC voltage.
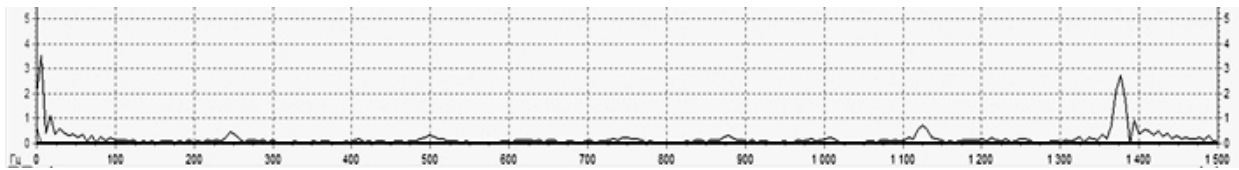

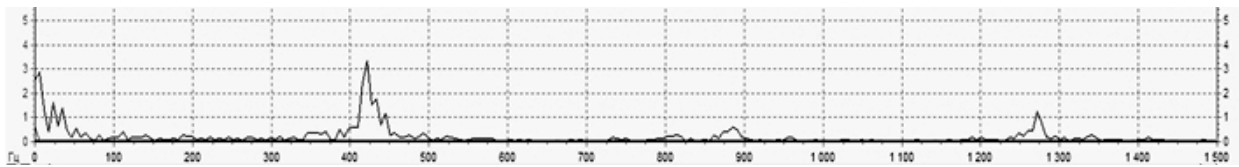Fig. 7. Amplitude-frequency characteristics of the assembled oscillator with two logic elements

Fig. 8. Amplitude-frequency characteristics of the assembled oscillator with three logic elements
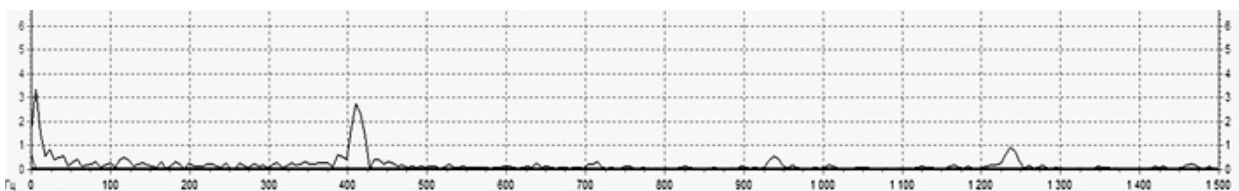

Fig. 9. Amplitude-frequency characteristics of the assembled oscillator
with two logic gates and loopback

Table 1

Analysis results of output voltage of oscillators

Scheme	Output DC voltage, V	Output AC voltage, V	Amplitude of primary frequency voltage, V	Amplitude of modulated frequency voltage, V
With 2 LE	2,05	4,38	0,8	3,5
With 3 LE	2,55	5,0	3,4	2,9
With 2 LE and loopback	1,68	4,61	2,7	3,3

Table 2

Results analysis of scheme oscillator

Scheme	Kov	Kop	Kpf	Kmf
With 2 LE	2,14	0,24	0,18	0,8
With 3 LE	1,96	0,31	0,68	0,58
With 2 LE and loopback	2,74	0,26	0,59	0,72

As a result of general analysis of parameters of output circuits (table. 1) and the ratio parameters (table 2) can be concluded that the primary for implementing scheme is consisted two LE and loopback. As the main features highlighted:

1) the lowest DC output voltage;

2) the highest efficiency produced output power AC;

3) the usage of two elements.

Conclusions

At this work executed the virtual and physical modelling of amplitude-manipulated signals oscillators for electrical tonal rail circuits, selected type of schemes which implemented to further increase the functionality. It is necessary to be considered the possibility of tuning of the oscillator at different primary and modulating frequencies, the output voltage regulation.

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