The outlook for multivibrator application in the present day electronic systems

N Yu Savvin¹, D D Garbuzov², R S Singatulin¹ and P V Roshchubkin¹

¹Department of Electric Power Engineering and Automation, Belgorod State Technological University named after V.G. Shukhov, Kostyukov St., 46, Belgorod, 308012, Russia
²Department of Energy Engineering of Heat Technology, Belgorod State Technological University named after V.G. Shukhov, Kostyukov St., 46, Belgorod, 308012, Russia

E-mail: n-savvin@mail.ru

Abstract. The paper discusses challenges that the present-day electronic industry of the Russian Federation faces today, analyses reasons for lagging in this sector in volume and production scale of the finished products in comparison to the leading in this area countries, suggests ways for reaching a new level in this industry by implementing a nationwide digitalization, reviews a place of digital signals in modern-day electronic, their types, creation methods, main characteristics, devices for generation and processing. The method of digital signals forming using the multivibrator was suggested in this paper. Different multivibrator types were reviewed, including the multivibrator with AND-NOT gates, its advantages were considered in comparison with the transistor stage multivibrators, parameters of the electronic circuit elements in the AND-NOT gate multivibrator for generating a signal with the required characteristics were calculated, then the multivibrator was assembled and the output signal parameters were taken down. The output signal parameters and the calculated parameters were identical. The conclusion was made about the possibility of the suggested AND-NOT gate multivibrator application in the complex automatic control circuits and electronic systems indication circuits as a device that generates signals with the required parameters.

1. Introduction

Advancement and progress in the electronic industry are some of the key elements for economic growth in developed countries. Currently, this industry sector is a leading scientific sector [1] and its main purpose is to develop, produce, and implement electronic equipment in all areas of life. The level of electronics development in any country has a direct impact on people’s quality of life, volume, and complexity of product output, sovereignty, and integrity of the state. The electronic industry is critical for providing all aspects of sovereignty, security, and progress in any country, and also for national policy towards implementation of the economy’s digital transformation. Electronic industry development in Russia is the most crucial task at the moment and demands close attention.

The reason that keeps Russia behind in electronic production, in comparison with the USA and China, is the fact that this industry was practically built from nothing, which is the result of degradation during the ’90s. In this context, the state plays an active role in supporting and developing the national electronic industry, implementing programs that allow significantly increase electronic devices sales at the world’s markets within a short period of time.
A notable example of such programs is the «Development strategy of the electronic industry of the Russian Federation until 2030», the framework of which outlines the main directions of the state policy for the national electronic industry development. The strategy specifies a complex solution for nine key areas: «Scientific and technological development», «Means of production», «Industry standards», «Staff», «Management», «Cooperation», «Industrial data environment», «Markets and products», «Economic efficiency». Implementation and progressive realization of this program require close attention to the area of training and qualification of professionals. This demands the promotion of a specific sector as well as science in general.

2. Materials and Methods

2.1. Materials

Trends in electronics development entail its full digitalization. The function of modern electronic equipment involves digital signal processing in real-time. Fuzzy logic controller development is one such example of fuzzy rules application for automatic control systems architecting. Electrical signals are commonly used for electronic equipment control.

An important issue in the development of circuits, which are based on the multivibrators, is the task of providing precise parameters of the circuit elements that give maximum reliability and precision of the device functioning. This issue was discussed in the paper «Choice of tolerance limits for multivibrator components» by A.A. Kazakov and E.G. Prugov. The examined in this paper program allows us to determine tolerance limits for the components of the circuit in development based on the required precision of the objective function. This is especially important for the circuits with components that have nonlinear parameters.

Insufficient front slope of the generated pulses is one of the shortcomings in traditional multivibrator design. This issue was resolved by using a solution suggested in the patent «Multivibrator» by I.M. Zhovtis. The patent describes a design when blocking oscillator and multivibrator are combined in one stage. This design uses an additional retroactive circuit.

2.2. Methods

The main purpose of the multivibrator is the creation of a square-wave pulse with predetermined parameters which allows us to use it in an indicating system of different electronic devices. The inventor’s certificate «Device for output of information from electronic counters to the display» by Leshchinsky A.S., Zelenin A.N., Vasilyev V.M. analyzed a possibility of functional capability enhancement by way of information readout from several sources. This invention can be useful in devices where single display use creates difficulties of information output from several sources and allows the output of information in a certain sequence with predetermined time duration.

The development of the multivibrator circuits based on logic gates has been discussed in scientific publications many times. The inventor’s certificate «One-shot multivibrator» by Bizyaev V.A., Zharkov L.K. Voronov V.I. reviewed the multivibrator circuit which allows us to increase the output signal stability substantially. For this purpose, an inverter was introduced into the device’s circuit which is based on the fourth AND-NOT gate.

The use of programmable multivibrators can be helpful in circuits of the automatic control devices. This type of multivibrator, which was reviewed in the inventor’s certificate «Programmable multivibrator» by Petrovsky A.K., Antonov V.V., allows us to control frequency, relative duration, and pulse number in series. The function of this multivibrator type is based on a comparison of the program and ramp voltage values, which form pulse width and pauses in series, that were generated by the integrated into the device trigger flip-flop.

Signals can be continuous or discrete. The continuous (analog) signal differs from discrete in a way that the information parameter, which such signal carries, can take any instantaneous value within the preset limits. Discrete signal, on the contrary, has only two states: high and low level of the information parameter. Discrete square-wave signals and meander are of special interest for use in the con-
Meanders and square-wave signals are the basic signals, which comprise the backbone of the entire electronics. Meander is a voltage that switches between fixed levels at equal intervals. Usually, these signals are used for amplifier testing which should process rapid transitions between two levels of voltage. Meander is an ideal clock frequency signal for digital systems – computers, wireless communication devices, high-definition TV, and many others. Square-wave signal has characteristics that are similar to meander with the exception that intervals of high and low levels are not equal against each other.

To generate square-wave electrical pulses with preset parameters a device called a multivibrator is used. The purpose of the multivibrator is to generate signals that are close to a square shape. This type of signal is essentially a sum of a large number of harmonics, and each of them is multiple of the main oscillation frequency. In electronic devices multivibrators have a support function, therefore, there are no strict requirements for stability of time characteristic of the generated output signal.

3. Results

3.1. Pulse generation

There are several variants of how multivibrators can be constructed. One of them is transistor based (Figure 1). In this case, the multivibrator is a two-stage amplifier with a retroactive circuit (RC) [5]. At the same time, the output of the second transistor stage is connected to the input of the first transistor stage through the capacitor, which through charging and discharging takes part in the pulse generation. In this way, the function of pulse generation is implemented using the amplifier.

![Figure 1. Multivibrator circuit with transistor stages.](image)

In this circuit resistances of each resistor are equal, i.e. R1 = R2 = R3 = R4, also capacitor’s capacitances are equal C1 = C2, and the oscillogram of the output signal (Figure 2) is a square-wave signal with equal pause time and pulse duration [6].

According to equation (1) pulse frequency of the symmetrical multivibrator is:

\[
f = \frac{700}{(C1 \times R2)}
\]

where: C1= C2 – capacitance of the capacitors in stages, R1= R2 – resistance of the resistors in the multivibrator’s arms.
Figure 2. Output signal oscillogram of the symmetrical multivibrator.

The multivibrator is characterized by parameters such as frequency $f$, Hz, pulse duration $t_i$, ms, output signal amplitude $U$, V, relative duration $(T/t_i)$.

The multivibrator, which is based on logic gates, presents some features of interest [7]. This circuit is free from shortcomings of the transistor circuit because of the low current drain and it is not locked to the power supply of +5V.

3.2. Circuits
Presented in Figure 3 circuit is considered a classic circuit of multivibrator which is based on logic gates. In this circuit, three logic gates are generating pulses, and the fourth is improving an output signal waveform [8]. The circuit is characterized by two quasi-stable states. In the first state LG1 (logic gate) is open, LG2 and LG3 are closed. While the capacitor is charging the voltage at the LG3 input becomes higher than the threshold which makes it open [9]. The regenerative process initiates circuit switching. In the second state LG2 and LG3 are open, LG1 is closed.

Figure 3. Multivibrator circuit based on AND-NOT gates.

To assemble the multivibrator on logic gates it is suggested to use two SN54LS22 microchips [10]. The microchip of this type consists of two AND-NOT gates and has 10 input legs, two output legs, and power supply legs.
It is necessary to test the logic gates of the microchip for defects before the assembly. In order to do that the inputs of every logic gate should be connected by energizing it with a high/low level signal and then take down the signal from the output. If a signal of a certain level doesn’t disrupt AND-NOT gate logic functioning then it means that the logic gate is working properly.

4. Discussion

Microchip based multivibrator generates square-wave signal parameters of which can be changed by way of resistor’s resistance and capacitor’s capacitance change in the multivibrator circuit [11]. Pause duration time of the pulse is calculated by the equation (2):

\[ t_{u1} \approx (R_1 + R_2) \times C \times \ln \left( \frac{2 \times R_2}{R_1 + R_2} + \frac{1.5 \times R_2}{4 + R_2} \right) \]  

(2)

where: 
- \( R_1 \) – resistance of the resistor between LG1 and LG2, 
- \( R_2 \) – resistance of the resistor between LG2 and LG3, 
- \( C \) – capacitance of the capacitor in the feedback circuit [12].

Pulse working time is given by equation (3):

\[ t_{u2} \approx (R_1 + R_2) \times C \times \ln(2.5 + \frac{3 \times R_1}{R_1 + R_2}) \]  

(3)

The period of oscillation is given by equation (4):

\[ T = t_{u1} + t_{u2} = 10.1 \text{ ms} \]  

(4)

The oscillation frequency is calculated according to equation (5):

\[ f = \frac{1}{T} \]  

(5)

Relative pulse duration is calculated using the equation (6):

\[ Q = \frac{T}{t_{u2}} = 1 + \frac{t_{u1}}{t_{u2}} \]  

(6)

When the necessary values of resistance and capacitance in the multivibrator circuit are determined, it is time to wire the elements according to Figure 4.

When the device is assembled it is necessary to test it with the oscillograph by taking down parameters of the output signal from the fourth logic gate’s output [13].

The output signal parameters testing requires voltage supply to the inputs +5V and GND, the fourth logic gate output should be connected to the input of the oscillograph [14]. The received oscillogram (Figure 5) allows us to estimate the output signal parameters and observe their change while resistances \( R_1, R_2 \), and capacitances \( C \) are changing [15].

The received output signal parameters should be compared with the calculated to make sure that the multivibrator works properly [16]. The presented AND-NOT gate based multivibrator can be used in circuits of devices that automatically control load for operation mode indication control, and also to generate controlling pulses for the operation of other devices which use the square-wave signal as a controlling signal.
5. Conclusion
The results of the conducted experiment allow us to conclude that an AND-NOT gate based multivibrator has good prospects in industrial automation as an indication instruments control device and in devices that are controlled by way of square-wave signal sequence with preset parameters. The circuit, which is realized during the experiment, provides output signal parameters that are high in accuracy when compared to the calculated parameters, and that allows us to use it as an integral part of complex control devices and automation.

6. Acknowledgments
The work is realized in the framework of the Program of flagship university development on the base of the Belgorod State Technological University named after V.G. Shukhov, using equipment of High Technology Center at BSTU named after V.G. Shukhov.
References
[1] Krokhin O N and Lebedev P N 2007 Quantum electronics 50th jubilee Proceedings of SPIE 6595 659502
[2] He R and Yun H 2020 Electronic Differential Control of Rear-Wheel Independent-Drive Electric Vehicle SAE Int. J. Veh. Dyn., Stab., and NVH 4(1) 49-65
[3] Haseda Y, Bonefacino J, Tam H-Y, Chino S, Koyama S and Ishizawa H 2019 Measurement of pulse wave signals and blood pressure by a plastic optical fiber FBG sensor Sensors 19(23) 5088
[4] Nanda M A, Seminar K B, Nandika D and Maddu A 2019 Development of termite detection system based on acoustic and temperature signals Measurement 147 106902
[5] Hardiyanto D, Priyambodo S, Kristiyana S and Enrico C A R 2020 Automatic Broadcast Transmission Control with 8 Relay Channels Based on Arduino IOP Conf. Ser.: Mater. Sci. Eng. 846 012047
[6] Getting I A 1938 Multivibrator geiger counter circuit Physical Review J. Archive 53 103
[7] Watanabe Y 1930 Some remarks on the multivibrator Proceedings of the Institute of Radio Engineers 18(2) 327-35
[8] Ma P, Gao L, Ginzburg P and Noskov R E 2020 Nonlinear Nanophotonic Circuitry: Tristable and Astable Multivibrators and Chaos Generator Laser and Photonics Reviews 14(3) 1900304
[9] Vlasov A I, Prisyazhnuk S P and Zhalnin V P 2020 Analysis of memristor modules as an element base of microprocessor control systems: Contradictions and prospects Int. Conf. on Industrial Eng. Applications and Manufacturing (Sochi: IEEE) 9111917
[10] Rajput D S and Singh R 2015 Timer circuit using OTRA and its application as astable and Monostable multivibrator 2nd Int. Conf. on Electronics and Communication Systems (Coimbatore: IEEE) pp 1047-50
[11] Hu W T, Zhang Y X, Sun Y, Liu W S and Zhang L Z 2014 Research on small-capacity capacitor type sensor detection method Advanced Materials Research 981 594-7
[12] Filanovsky I M, Jarvenhaara J and Tchamov N T 2013 Push-pull RC-oscillator/multivibrator 56th Int. Midwest Symp. on Circuits and Systems (Columbus: IEEE) pp 141-4
[13] Shaa P, Sun H J, Zhou W L, Xu X H, Zhang J J, Wang Q, Hu C Y, Yan P and Miao X S 2012 Programmable frequency Multivibrator based on memristor Information Optoelectronics, Nanofabrication and Testing (Wuhan: OSA Publishing) IF5A.4
[14] Abrams Z R and Zhang X 2011 Signals and circuits in the Purkinje neuro Front. Neural Circuits 5 11
[15] Mitra N and Mukhopadhyay S 2011 A method of developing all-optical mono-stable multivibrator system exploiting the Kerr non-linearity of medium Optik 122(2) 92-4
[16] Khentov V Ya and Semchenko V V 2018 On the connection of the physical properties of metal elements with the temperature of decay Chemical Bulletin 1(2) 19-23