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MULTIVIBRATOR INVESTIGATION WITH ACCOUNT FOR THE DIODE OPENING VOLTAGE

Introduction. We investigate the well-known non-symmetric multivibrator circuit [1, 2] which contains a capacitor, an operational amplifier, two silicon diodes and several resistors, see Fig. 1. For example, this circuit is a part of the electronics course for the students of telecommunication specialty. The diode CVC is considered to be an ideal one, see Fig. 2. As far as we know, in literature this circuit is described without taking into account the diode opening voltage which is equal to 0.7V, see, for example, [1, 2]. In this paper we propose the mathematical description of the circuit under consideration with account for the diode opening voltage.

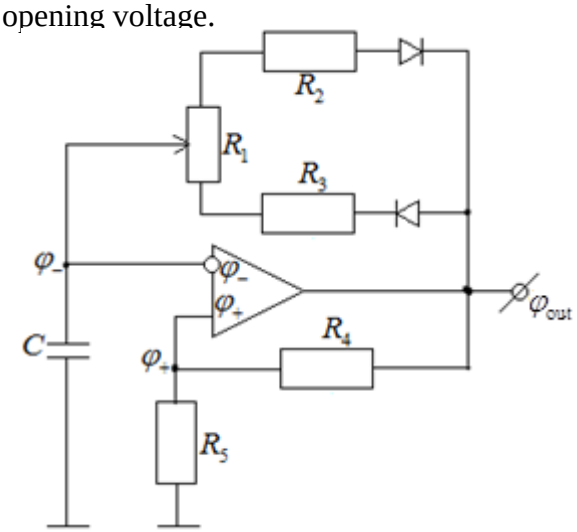

Figure 1 – Circuit under consideration

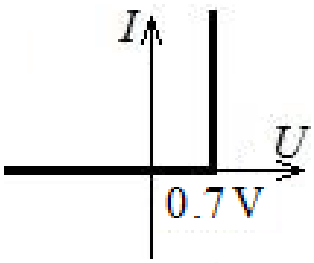

Figure 2 – Diode CVC

Circuit description. In the circuit under consideration the operation amplifier works as a comparator:

$$\varphi_{\text{out}} = \begin{cases} +\varphi_{\max}, \varphi_+ > \varphi_- \\ -\varphi_{\max}, \varphi_+ < \varphi_- \end{cases}. \quad (1)$$

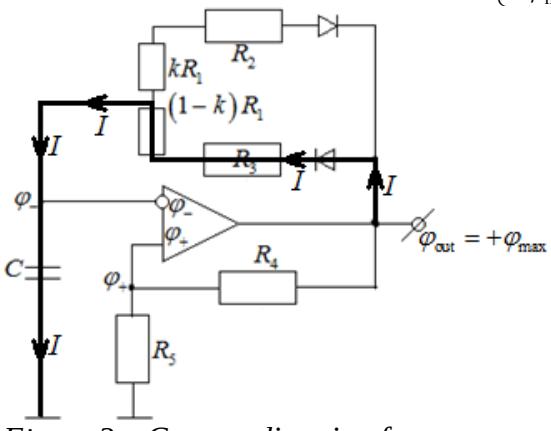

Figure 3 – Current direction for stages with odd numbers

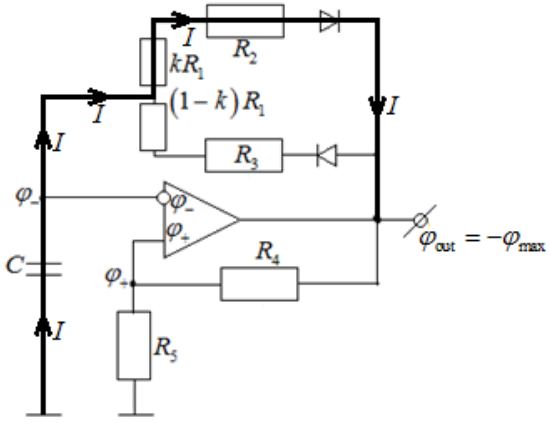

Figure 4 – Current direction for stages with even numbers

Let us suppose that due to weak noise $\varphi_+ > \varphi_-$ at the initial moment. Then at the first stage the current direction is that as shown on Fig. 3 and in fact the capacitor charges from zero voltage to the voltage equal to $\varphi_{\max} R_5/(R_5+R_4)$. At the end of the first stage the potential φ_- becomes greater than φ_+ and the second stage begins. During the second stage the current direction is that as shown on Fig. 4 and the capacitor discharges from the voltage equal to $\varphi_{\max} R_5/(R_5+R_4)$ to the voltage equal to $-\varphi_{\max} R_5/(R_5+R_4)$. At the end of the second stage the potential φ_+ becomes greater than φ_- and the third stage begins. During the third stage the current direction is that as shown on Fig. 3 and the capacitor charges from the voltage equal to $-\varphi_{\max} R_5/(R_5+R_4)$ to the voltage equal to $\varphi_{\max} R_5/(R_5+R_4)$. At the end of the third stage the potential φ_- becomes greater than φ_+ and the fourth stage begins and so on. The obtained graphs are given on Fig. 5.

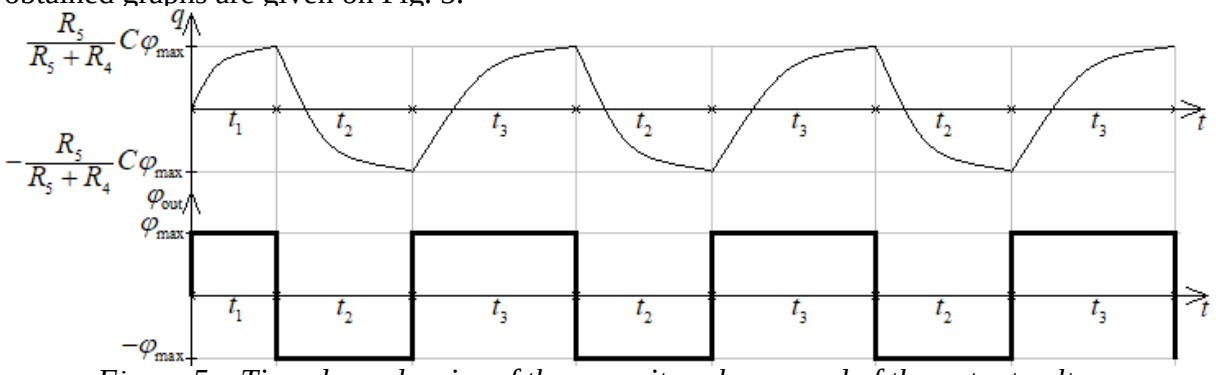

Figure 5 – Time dependencies of the capacitor charge and of the output voltage

The following result for the period of the output voltage is obtained:

$$T = t_2 + t_3 = (R_1 + R_2 + R_3) C \cdot \ln\left(\frac{\varphi_{\max}(2R_5 + R_4) - U_{07}(R_5 + R_4)}{\varphi_{\max} R_4 - U_{07}(R_5 + R_4)}\right) \quad (2)$$

where the blue terms are our corrections to the result [1, 2] which are calculated with taking into account the diode opening voltage equal to $U_{07} = 0.7\text{V}$. In order to check the obtained result, the circuit is modeled in the Multisim package. The results of the modeling are shown in Table 1.

Table 1. The results for R_1=4 kΩ, R_2=1 kΩ, R_3= R_4=2 kΩ, C=1μF, $\varphi_{\max}$=12V

k	T,s [1,2]	T,s (2)	T,s Multisim	k	T,s [1,2]	T,s (2)	T,s Multisim
0	4.852	5.180	5.153	0.6	4.852	5.180	5.164
0.1	4.852	5.180	5.157	0.7	4.852	5.180	5.164
0.2	4.852	5.180	5.160	0.8	4.852	5.180	5.162
0.3	4.852	5.180	5.161	0.9	4.852	5.180	5.163
0.4	4.852	5.180	5.163	1	4.852	5.180	5.161
0.5	4.852	5.180	5.164				

As can be seen, for the numerical data under investigation, our result (2) is approximately 5.5% more accurate than the result [1, 2] which is widely used in literature.

Conclusions. The corrections to the non-symmetric multivibtator period are obtained on the basis of taking into account the diode opening voltage. In particular, obtained results may be introduced to the educational process for the students of the Dnipro University of Technology.

References

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2. Dnipro University of Technology, laboratory work dedicated to Op Amp generators, https://physics.nmu.org.ua/ua/To_students/Day_mode_of_study/Methodical_instructions_to_laboratory_works/Electronics%20and%20circuitry/6_EaC.pdf (in Ukrainian).