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Ternopil Ivan Puluj National Technical University

Faculty of Applied Information Technologies and Electrical Engineering
(full name of faculty)
Department of Electrical Engineering
(full name of department)

QUALIFYING PAPER

For the degree of

bachelor
(degree name)

topic: **DEVELOPMENT OF POWER SUPPLY FOR LED LIGHT SOURCES**

Submitted by: fourth year student 4 , group IEE -42
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ASSIGNMENT
FOR QUALIFYING PAPER

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(surname, name, patronymic)

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2. Calculation and research section.
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1. Improving the efficiency of a switching power supply.
2. Serial discharge of capacitors Cs, C1 and C2 without delay of the discharge of the capacitor Cs
3. Comparison of semiconductor switches of the old and new sample during operation of the circuit of a switching power supply
4. Comparison of diodes of the old and new sample in operation of the circuit of the switching power supply

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Chapter	Advisor's surname, initials and position	Signature, date	
		assignment was given by	assignment was received by
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situations			
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2	Preparation of the «CALCULATION AND RESEARCH	21.01.22 – 20.02.22	
	SECTION»		
3	Preparation of the «PROJECT DESIGNING SECTION»	21.02.22 – 30.03.22	
4	Preparation of the «LABOUR OCCUPATIONAL	01.04.22 – 20.04.22	
	SAFETY AND SECURITY IN EMERGENCY		
	SITUATIONS»		
5	Preparation of introduction, conclusions,	20.04.22 – 05.05.22	
	Content and summary.		
6	Preparation, execution and printing graphic material	05.05.22 – 10.06.22	
7	Design of the graphic part.	11.06.22 – 30.06.22	
	And drafting a report for the bachelor defense.		

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ABSTRACT

Bachelor's thesis. Ternopil National Technical University named after Ivan Pulyuy. Faculty of Applied Information Technologies and Electrical Engineering. Department of Electrical Engineering, IEE-42 group . - T.: TNTU, 2022.

P.65; Fig.65; table7; drawings 15; sources 17; applications . _

The qualifying work of the bachelor was performed on the basis of the task on the topic: " Development of power supply for led light sources ".

The aim of the work is to increase the efficiency of the switching power supply.

The review of known circuit solutions of different types of switching power supplies is carried out, and their parameters are compared with each other. As a result , for research was selected diode bridge with C- filter , as the most common circuit design solution . As _ inverters were selected DC voltage pulse converter (DCVC) and pulse boost voltage converter (PBVC) .

Schematic solutions are presented to improve the characteristics of switching power supplies, namely the series discharge of capacitors in the input unit

Keywords: DC voltage pulse converter, pulse width modulation, voltage rectifier.

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INTRODUCTION

There are two types of power supplies that convert mains voltage to DC voltage of the desired magnitude for the consumer.

These are analog and switching power supplies. Switching power supplies are diverse in terms of circuitry. Therefore, in general, they have better quality indicators in contrast to analog.

Switching power supplies have the following main parameters:

1) efficiency;

2) dimensions;

3) cost;

4) output parameters (voltage, current, power);

5) pulsation frequency;

6) amplitude pulsations weekend voltage , current; etc.

As a rule, in switching power supplies operating at high frequencies, small passive components are used, which leads to an increase in switching losses in the hard switching mode. To reduce switching losses when operating at high switching frequencies, special soft switching methods have been developed. Among them, the most common are resonant methods and zero voltage switching methods.

Resonance methods use the characteristic features of resonance in capacitors and inductors throughout the switching period, which leads to the fact that the switching frequency begins to change depending on the input voltage and load current. Changing the switching frequency, ie frequency -pulse modulation, complicates the development of switching power supplies, which include input filters. Because the filters do not have an output coil

inductance, the voltage at the output rectifier diodes does not emit, which allows developers to choose low-voltage diodes. However, with increasing output current , the lack of an inductor leads to an increase in the load on the output capacitors, so resonant methods are not suitable for circuits with high load currents and low output voltages.

On the other hand, zero-voltage switching methods use resonant phenomena that occur between the parasitic components of the circuits during the on / off of power switches, ie during transients. The use of parasitic components, such as the scattering inductance of the main transformer and the output capacitance of the switches, is one of the main advantages of such methods, as they do not require additional external components to implement soft switching. In addition, these methods are based on pulse -width modulation (PWM), so the circuits operate with a fixed switching frequency. Thus, systems implemented on this principle are easier to understand, analyze and design than resonant methods.

Improving the efficiency of a switching power supply is the goal of qualification work, the task of which is to:

1) Review and comparison switching power supplies, as well as ranking their parameters;

2) Search for methods to improve the efficiency of parameters: circuitry and parameters of transistors and diodes;

3) Modeling of operation of the pulse converter of direct voltage at change of parameters of elements (power transistors and diodes);

4) Modeling of the proposed circuitry of the C-filter

1. ANALYTICAL SECTION

The structure of the switching power supply is as follows (Figure 1.1):

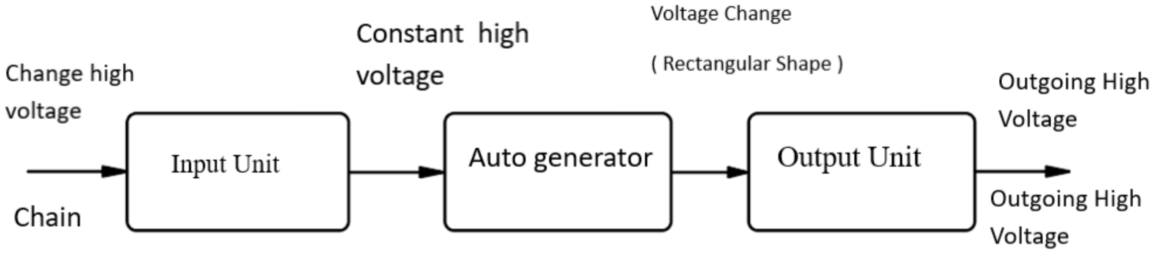

Figure 1.1 - Typical circuit of switching power supply

Switching power supply consists of three main units that convert voltage from one state to another, as shown in Figure 1. The input unit converts mains voltage to DC and includes (Figure 1.2):

1) Filter interference filter

2) Rectifier

3) Smoothing filter

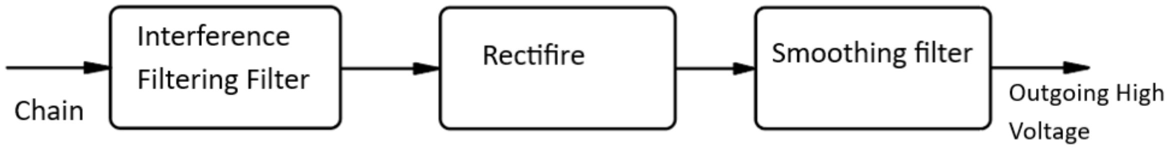

Figure 1.2 - Switching power supply input unit

The main feature of the autogenerator is the presence of a semiconductor key, through which the conversion takes place

DC voltage after rectification into a rectangular high frequency voltage. The number of keys can be more than one, it all depends on the scheme.

The output filter has the same structure as the input unit, only the filter element is at the output of the source. The peculiarity of this unit is that due to the sufficiently high frequency of the pulsating voltage, the values of the elements of the output filter will be smaller than in the input.

Analysis of the element base of each unit on the parameters of the switching power supply and analysis of promising circuit solutions is one of the main tasks of this thesis. To select a circuit for research, a review of known circuit design solutions was performed. Selected schemes can be more than one.

1.1 Single-phase network filter

These elements are low-pass filters. They can suppress interference from both the source and the network input.

One of the variants of the filter element is a single-phase network filter (Figure 1.3).

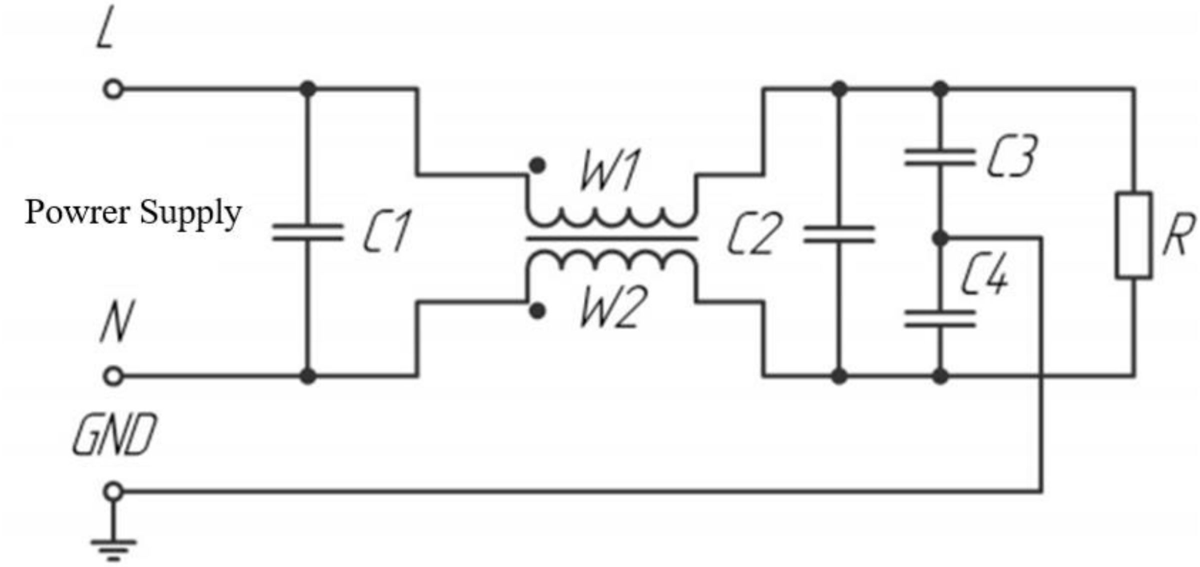

Figure 1.3 - Single-phase network filter

This scheme is used quite often, and contains a fairly small number of components. The principle of operation is as follows: a sinusoidal input signal is fed to the input of the winding W1, and a sinusoidal output signal is fed to W2. Since the magnetic fluxes created by the choke windings are in antiphase, the same signal inductance of the coil will be zero. If the signal at W2 is distorted, the magnetic flux compensation will not be in full and the inductor will form an inductor that will not pass in-phase interference to the network. Capacitor C2 compensates for low-frequency differential interference from the unit to the network. Capacitors C3 and C4 compensate for the differential interference of the high part. C3 and C4 are included in parallel with C2. Capacitor C1 suppresses differential interference from the network.

1.2 Analysis of voltage rectifiers

In order to get rid of the negative half-waves of the sine wave, it is necessary to put a rectifier in the input filter, a large number of circuit solutions for this unit.

1.2.1 One-and-a-half-cycle rectifier of voltage change

One of the simplest rectifiers can be considered a one-and-a-half-cycle rectifier, which is shown in Figure 1.4.

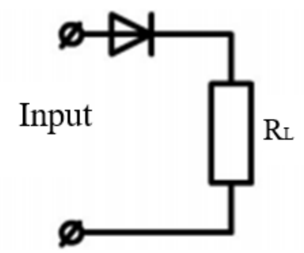

Figure 1.4 - One-and-a-half-cycle rectifier

This rectifier converts alternating voltage into pulsating, but the rectification occurs only one half-cycle as shown in Figure 1.5, the rest of the conversion time the voltage is zero. The obvious disadvantage of this scheme is that to filter the low-frequency voltage you need to use a filter of sufficiently large values, which will negatively affect the mass and dimensions of the source. Therefore, this type of rectifier is often used in the output filter, where the voltage frequency is quite high and its parameters will be much smaller.

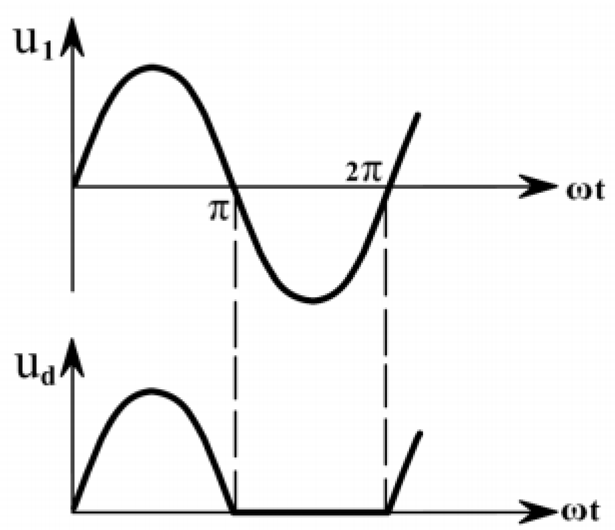

Figure 1.5 - Voltage before and after the one-and-a-half-cycle rectifier

The advantages of this scheme can undoubtedly be considered low cost, simplicity of the scheme, a minimum of losses on the elements.

1.2.2 Two-and-a-half-cycle transformer rectifier with midpoint

This type of rectifier is shown in Figure 1.6.

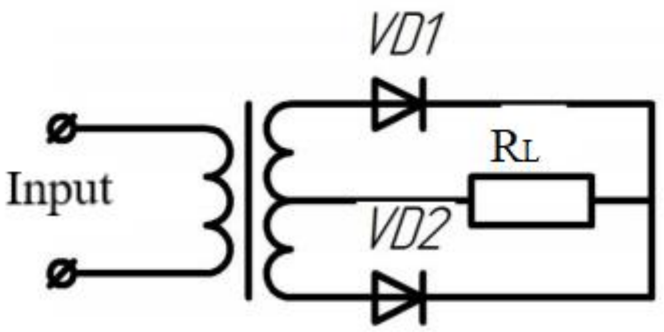

Figure 1.6 - Two-and-a-half-cycle transformer rectifier with midpoint

This rectifier, in contrast to the first case, rectifies the voltage throughout the sine wave period, therefore, the ripple at the output of the rectifier will be less (Figure 1.7).

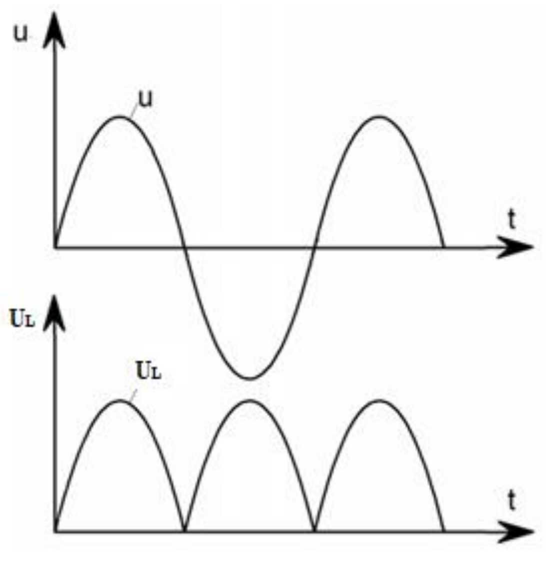

Figure 1.7 - Voltage before and after the two-and-a-half-period rectifier

This factor will have a positive effect on the mass and dimensions of the filter. However, the presence of a transformer and an additional diode will negatively affect the cost and efficiency of the rectifier, as well as the dimensions of the rectifier.

1.3 Analysis of smoothing filters

To smooth the voltage after the rectifier in the circuit must be present smoothing filter. For the devices to work well, the ripples must be less than the allowable value. Different devices have different values. There are three types of ripple factor F_R:

1. Small (if F_R less than 0.1%)
2. Average (if F_R is in the range from 0.1% to 1%)
3. Large (if F_R more than 1%)

The power loss on the filter must be minimal. The filter must not affect the operation of the device by negative factors. Due to low frequency, denominations filter will be rather large parameters.

1.3.1 C- filter

A capacitive filter is the simplest solution for smoothing ripples (Figure 1.8).

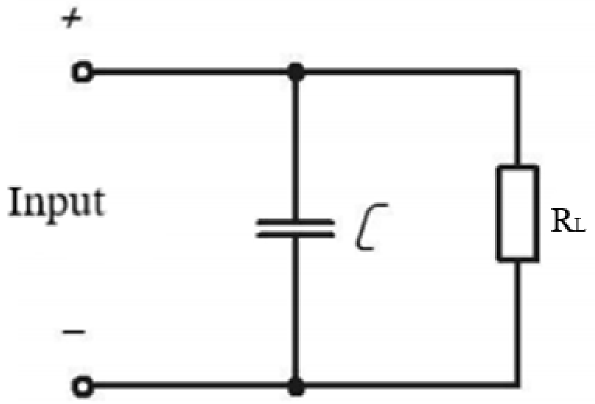

Figure 1.8 - C-filter

Capacitor C is placed parallel to the resistor R_L(load resistance). At maximum voltage values after the rectifier U_I , the capacitor C is charged, and when the rectified voltage decreases and becomes less than the voltage on the capacitor, it is discharged to the resistor R_L. At the input of the filter charge, a significant part of the current flows in a circle through the capacitor, charging the capacitor and limiting the maximum ripple voltage of the rectifier.

When the capacitor is discharged, it gives R_L energy that was accumulated earlier, thus maintaining the voltage at R_L. The voltage on the load changes much less, thus the ripple factor also becomes lower. This filter is often used in low power rectifiers. The simplicity of the device is the main advantage of this filter. The main disadvantage is that the rectifier must use diodes that can withstand large values of the amplitude of direct current.

If you use this filter at low frequencies, the capacitance of the capacitor will have a large enough capacity, which will negatively affect the dimensional parameters of the input unit.

1.3.2 RC filter

The RC filter is shown in Figure 1.9.

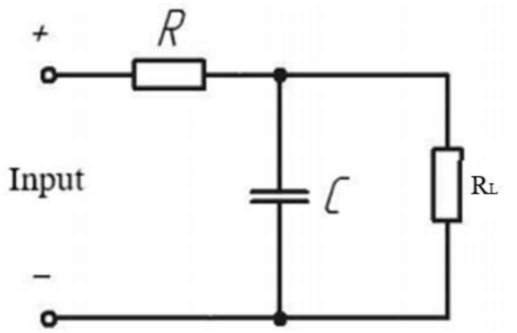

Figure 1.9 - RC filter

This filter is used in medium power rectifiers with a load resistance of kOhm.

To obtain a large smoothing coefficient it is necessary that R_L>> X_c and R_f >> X_c . The main disadvantage of this filter is the loss of the resistor, which directly affects the efficiency .

1.3.3 L-filter

The inductive filter is shown in Figure 1.10.

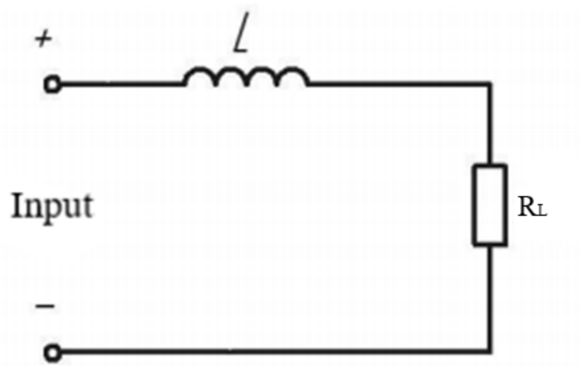

Figure 1.10 - L-filter

The L-filter is nothing but an L choke, which is connected in series with RL. The current after the rectifier has a variable component, it creates a magnetic flux in the magnetic circuit L. The magnetic flux induces the counteraction of EMF in the winding L. This setting does not change the current in the circuit, resulting in reduced voltage ripple . To increase the coefficient of the smoothing filter, you need to increase the number of phases and inductance L. Therefore, the L-filter is best used in multiphase high-power rectifiers. Factors such as: small power losses, weak dependence of U_{vyh} on the change of R_L, as well as the simplicity of the filter circuit - are the advantages of the inductive filter. Minus the circuit, the following: if you abruptly change the load or turn it off altogether, then overvoltages are possible. This factor occurs due to the appearance of EMF self-induction L with a rapid change in current R_L.

1.3.4 LC filter

The inductive capacitive filter is shown in Figure 1.11.

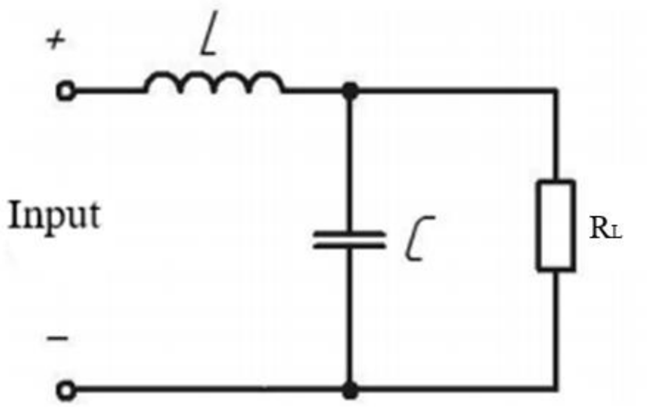

Figure 1.11 - LC filter

All the above examples of filters do not provide the input unit with a high coefficient of smoothing ripple. That is why the LC filter is often used, which contains both the choke L and the capacitor C. This scheme allows you to improve the smoothing parameters of the filter. The resistance of the circuit is minimal, so the alternating component of the rectified current flowing through the coil increases. This leads to a drop in voltage on it, which reduces the variable component of the load voltage. The energy reserve in the magnetic field of the choke is greater than in the electric field of the capacitor, which will have a positive effect on the mass and dimensions. The disadvantage is that the chokes are not standardized and, if necessary, will have to wind the coil, which will take several hours.

1.4 Analysis of autogenerator circuits

Autogenerators or inverters play a very important role in the circuit of a switching power supply. This unit converts DC voltage after the input unit into AC voltage of rectangular shape. An important part of the inverter is the presence of one or more key elements due to which this transformation takes place. Most often, a transistor is used as a key, which can operate at fairly high frequencies. Switching power supplies are divided into transformer and non-transformer.

The next point is considered without transformer switching power supplies. The energy storage in these circuits is a choke.

1.4.1 Switching DC voltage converter (SDCVC) -1

Pulse step-down voltage converter or PSDVC-1 is shown in Figure 1.12.

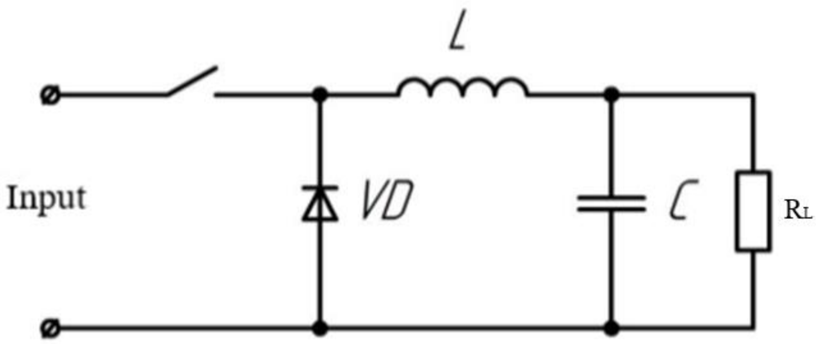

Figure 1.12 - Pulse step-down voltage converter

PSDVC of the 1st kind works as follows: first the key is closed, the current will flow in a circle: source U input - key - choke L - load resistance R_L- source U_{input} . Due to the voltage drop across the choke L, there is no instantaneous increase in current in R_L. Therefore, the voltage at R_L increases smoothly and at the moment when it exceeds the allowable value, the key opens. The voltage across the choke changes polarity. The current will flow in a circle: choke L - load R_L- diode VD - choke L. The voltage on R_L gradually decreases and when it decreases to a certain value, the switch closes and the voltage on RLbegins to increase again. Capacitor C smoothes U_{out} . The circuit can work both with a continuous choke current and with an intermittent one.

1.4.2 Pulse boost voltage converter (PBVC) -2

The principle of operation of the pulse step-up voltage converter (Figure 1.13) is as follows: at the beginning the key is closed, the current will flow in a circle: source U_I - L_{choke} - key - source $U_{I.}$ The current of the choke L increases, therefore, the energy of the choke L. also increases . The value obtained is applied through VD to R_L . The current will flow in a circle: source U_I - L_{choke} - diode VD - load resistance R_L - source $U_{I.}$ The inductive element L gives energy in R_L. Energy accumulates on the capacitive element C and when the key is opened again, the capacitor C will maintain a voltage of R_L. Diode VD is required so that the capacitor can not be discharged when the key is closed.R_L

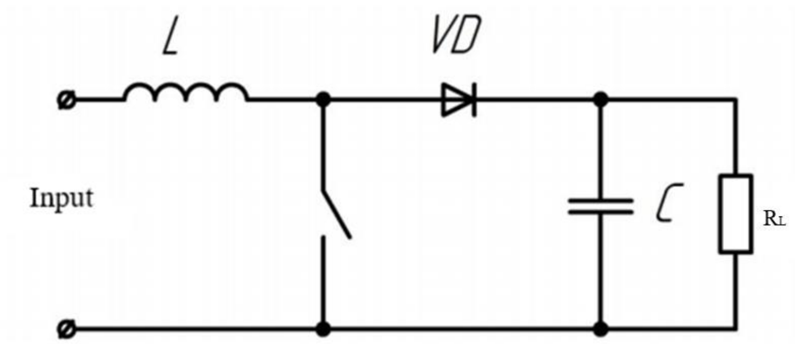

Figure 1.13 - Pulse boost voltage converter

2. DESIGN AND CONSTRUCTION SECTION

2.1 Variants of circuits of alternating discharge of capacitors in the C-filter

Having considered the circuit variants of all switching power supply units, a diode bridge with a C-filter was selected for the study as the most common circuit design solutions. SDCVC and PBVC were selected for the inverter. The main elements of the inverter in a switching power supply are a semiconductor switch and diodes. Therefore, it makes no sense to study the element base on all inverter circuits.

Almost always the smoothing filter is a dimensional part of the input unit. This is due to the fact that most switching power supplies use a standard C-filter (Figure 2.1) that operates at a network frequency of 50Hz. Therefore, for high-quality smoothing with the smallest pulsation amplitude, you need a capacitor of sufficiently large capacity, which directly affects the dimensions of the unit.

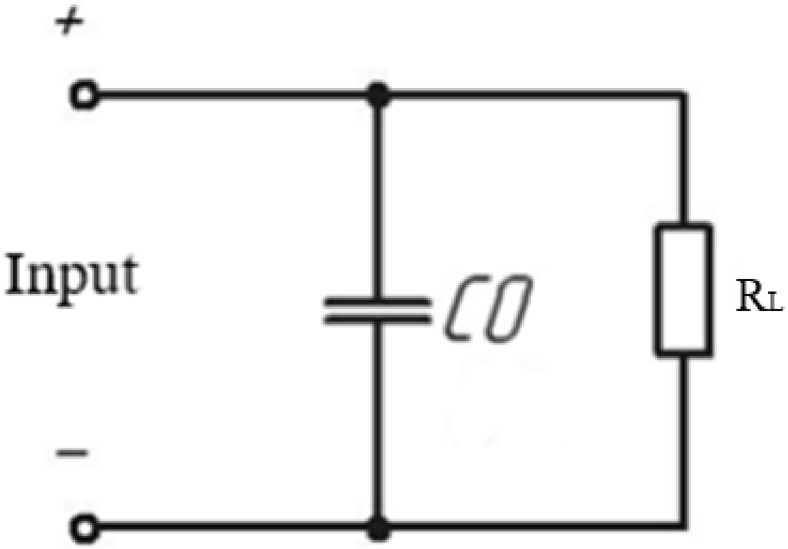

Figure 2.1 - C-filter

Solution schemes have been developed that reduce the size of the filter without compromising its parameters. This solution is shown in Figure 2.2.

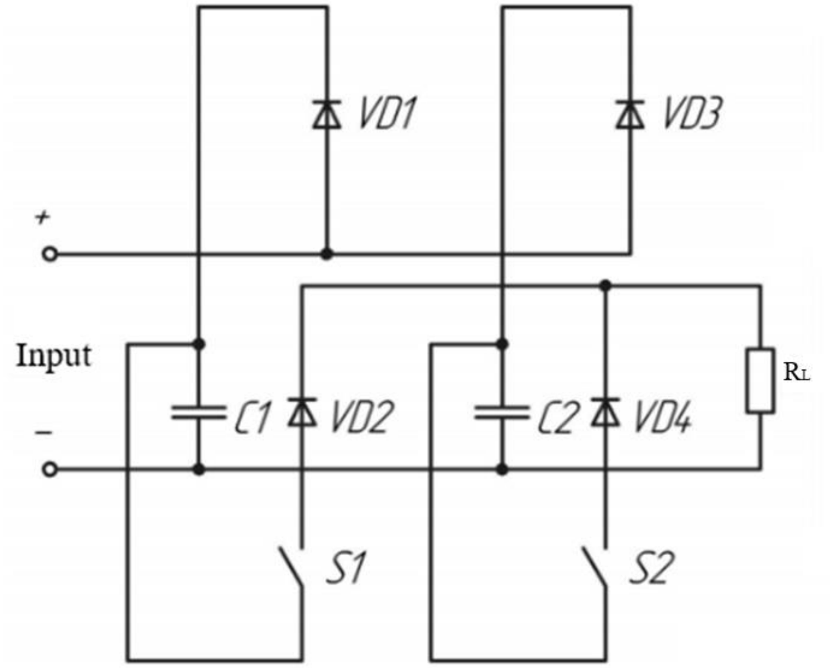

Figure 2.2 - Scheme of alternating discharge of the capacitor

The filter capacitor C0 (Figure 2.1) is divided into two capacitors C1 and C2 (Figure 2.2) with denominations equal to half the value of one capacitor. You can use a larger number of capacitors, then the nominal value of each capacitor will be equal to the ratio of C0 to the number of capacitors.

Each capacitor has its own charge circuit and discharge circuit. The charge circuits provide a simultaneous charge of the capacitors at a positive voltage half-wave after the diode bridge. Discharge circuits allow you to sequentially discharge capacitors under load R_L. In other words, first the capacitor C1 is discharged, and then the capacitor C2. Next, three cases of diode bridge operation with a filter were considered as research work:

1. Standard operation of the C-filter (Figure 2.3)

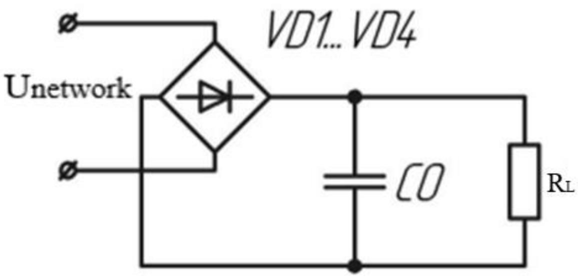

Figure 2.3 - Standard view of the diode bridge and C-filter

2. Serial discharge of filter capacitors without delay of the discharge of the first capacitor C_s. This capacitor operates in standard mode, and the following capacitors will actively work charge and discharge circuits (Figure 2.4).

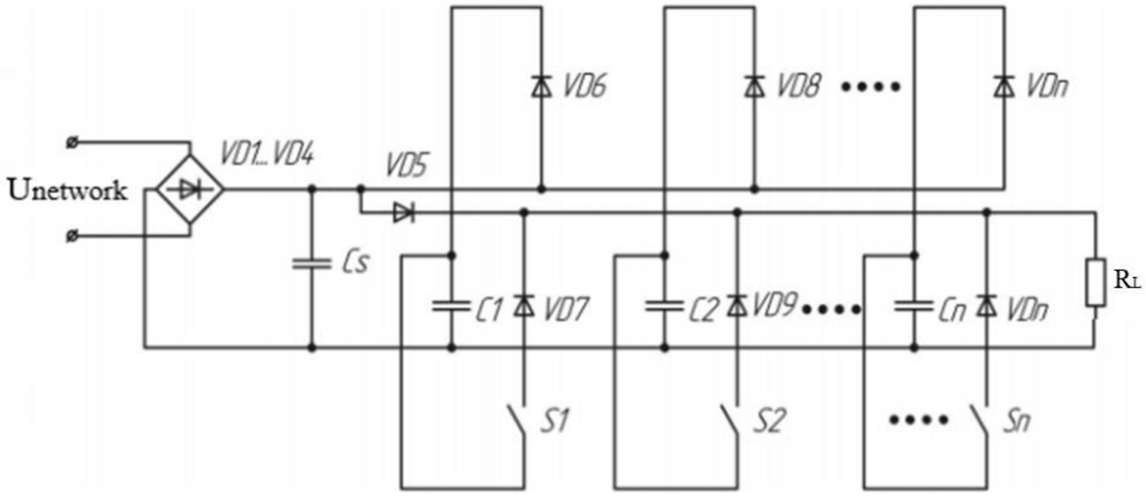

Figure 2.4 - Scheme of alternating discharge of C-filter capacitors without delay in the discharge time of the first capacitor Cs

3. Serial discharge of the filter capacitors with a delay of the discharge of the capacitor C1 in time. There is no capacitor in the circuit that operates in standard mode (Figure 2.5).

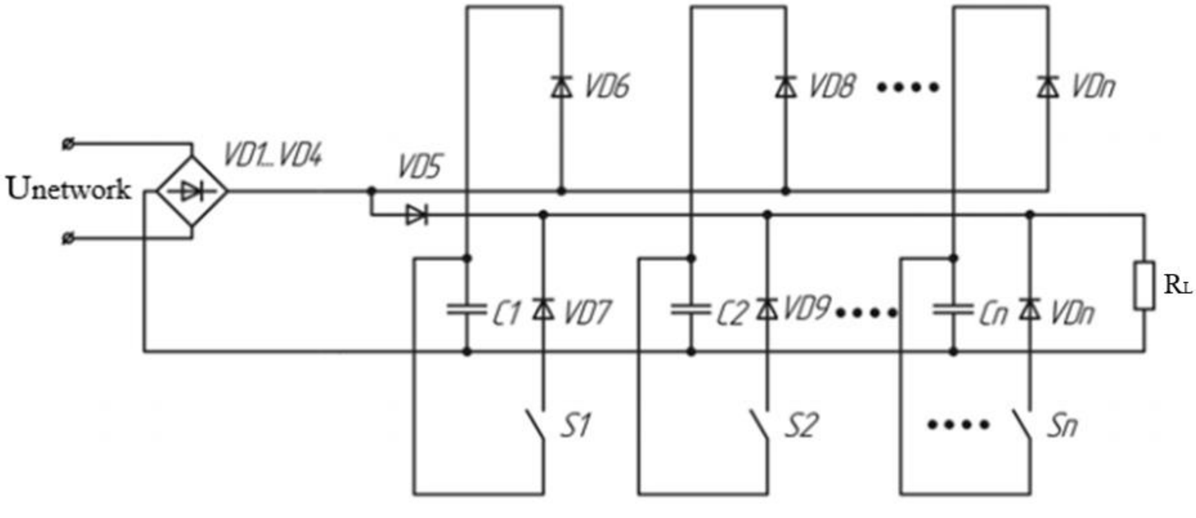

Figure 2.5 - Scheme of alternating discharge of filter capacitors with a delay of the discharge of the capacitor C1 in time

The total capacity for all three cases is maintained. It is equal to 6 μf. Oscillograms will be taken at three different load resistances: R_L= 500 Ohms, R_L= 100 Ohms, R_L= 1000 Ohms. This is necessary in order to understand how the load affects the operation of the filters. Let's take a closer look at each case of the filter.

2.1.1 Standard operation of the C - filter

Figure 2.6 shows a diagram of a standard C-filter modeled in the Micro-cap 9 software. The capacitance of the capacitor (C0 = 6μF) was selected so that the ripple at the output was as large as possible. This was necessary in order to better see the difference in all cases of filters. Load resistance R_L= 500Ohm. The Vs source simulates a 220V network.

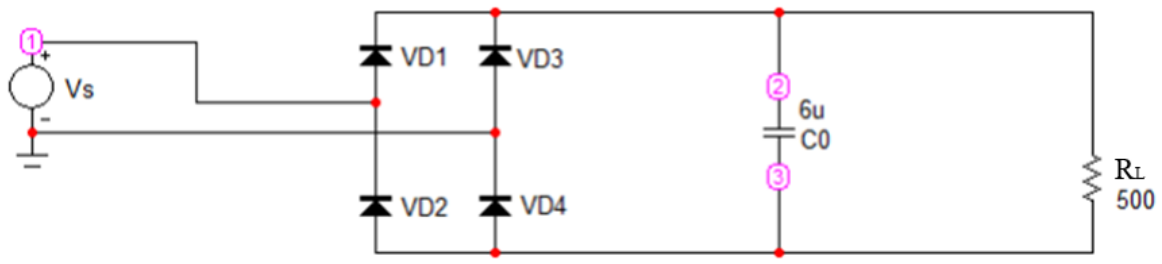

Figure 2.6 - Standard C-filter scheme in Micro-cap

Figure 2.7 shows the oscillogram of the output voltage of the standard operation of the C-filter with one filter capacitor.

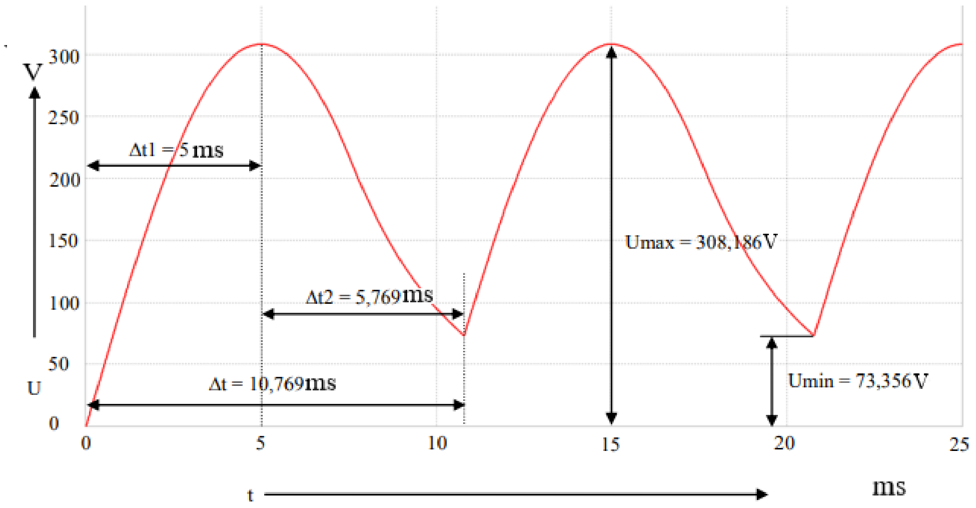

Figure 2.7 - Oscillogram of the output voltage of a standard C-filter at R_L= 500 Ohms

Next, to remove similar characteristics, only at load resistances R_L= 100 Ohms and RL= 1000 Ohms.

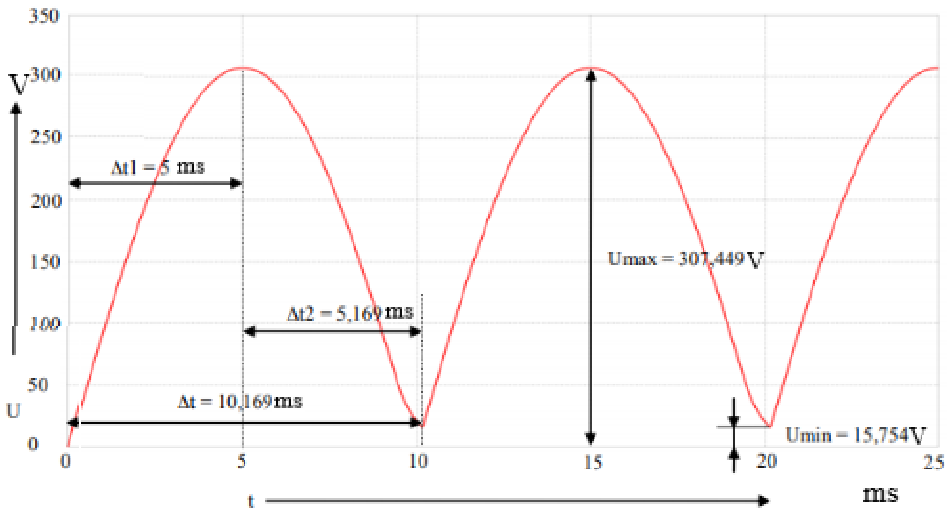

Figure 2.8 - Oscillogram of the output voltage of a standard C-filter at R_L= 100 Ohms

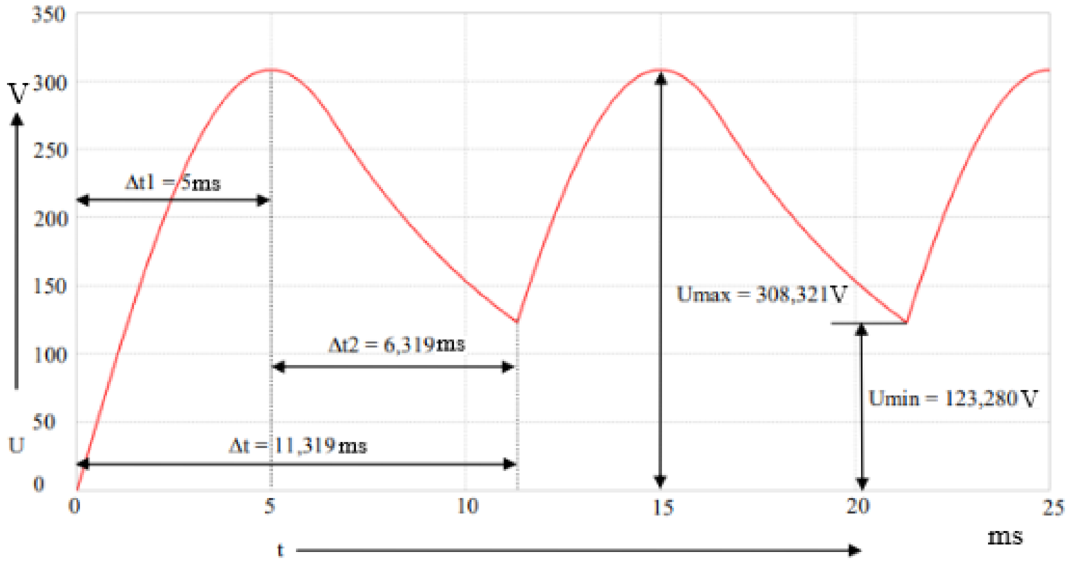

Figure 2.9 - Oscillogram of the output voltage of a standard C-filter at R_L= 1000 Ohms

The results of the study are shown in table 2.1.

Table 2.1 - The result of the study of the standard operation of the C-filter

	U_{max} (V)	U_{min} (V)	ΔU (V)	Δt1 (ms)	Δt2 (ms)	Δt (ms)
C0=6μF at R_L=100Ω	307.449	15.754	291.695	5	5.169	10.169
C0=6μF at R_L=500Ω	308.186	73.356	234.83	5	5.769	10.769
C0=6μF at R_L=100Ω	308.321	123.280	185.041	5	6.319	11.319

The maximum threshold of the pulsating voltage U_{max} at all load resistances is almost the same. The minimum threshold of the pulsating voltage U_{mix} changes significantly when changing R_L. The greater the load resistance RL, the slower the capacitor C0 is discharged in the circuit, therefore, the capacitor begins to exhibit its smoothing properties earlier, which directly affects the parameter U_{mix} . The amplitude of the ripple ΔU is equal to the difference between the maximum and minimum voltage thresholds, therefore, ΔU decreases with decreasing load current. Capacitor C0 is charged during Δt1 = 5 ms, at any load. The time Δt2 directly depends on R_L, as this is the discharge time of the capacitor C0. The better the smoothing properties of the filter, the longer the capacitor C0 will be discharged. Based on the change in time Δt2, the total cycle time Δt will also increase with decreasing load current.

2.2 Serial discharge of capacitors Cs and C1 without delay of the discharge capacitor Cs

The next step is to model the circuit (Figure 2.10) of the alternating discharge of capacitors with the standard operation of the capacitor Cs. Capacitor C1 has a charge circuit (node 2 - diode VD6 - node 4) and discharge circuit (node 4 - key S1 - diode VD7 - load R_L- node 3). Capacitor Cs has only a discharge circuit (Node 2 - diode VD5 - R_L- node 3). The capacitance of the capacitors is 3μF.

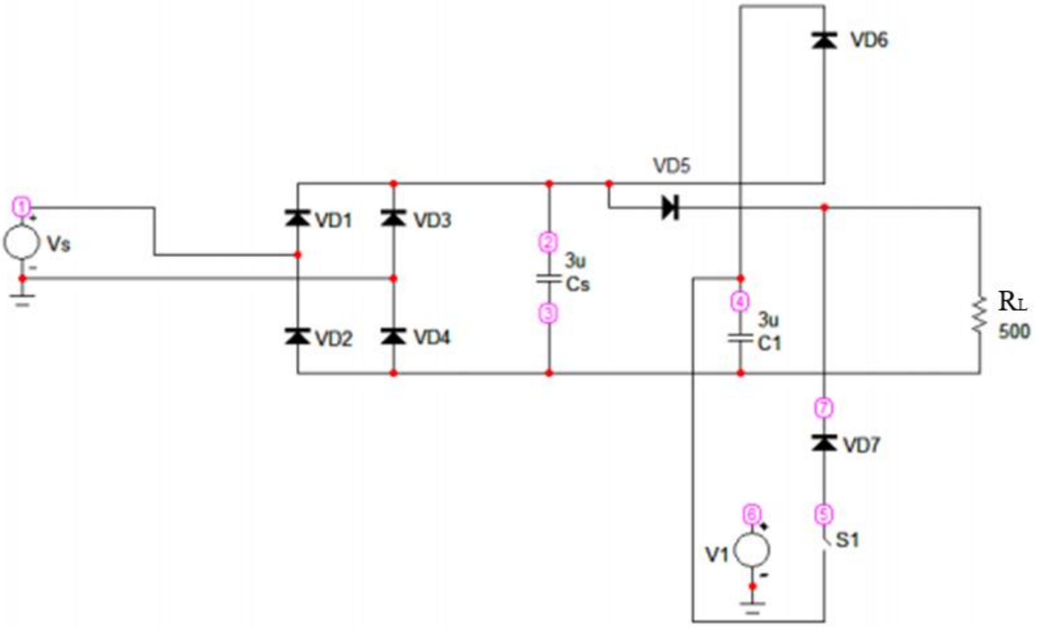

Figure 2.10 - Scheme of alternating discharge of capacitors Cs and C1 without delay of the discharge of the capacitor Cs

Figure 2.11 shows the oscillogram of the voltage across the resistor R_L= 500 Ohms with alternating discharge capacitors Cs and C1.

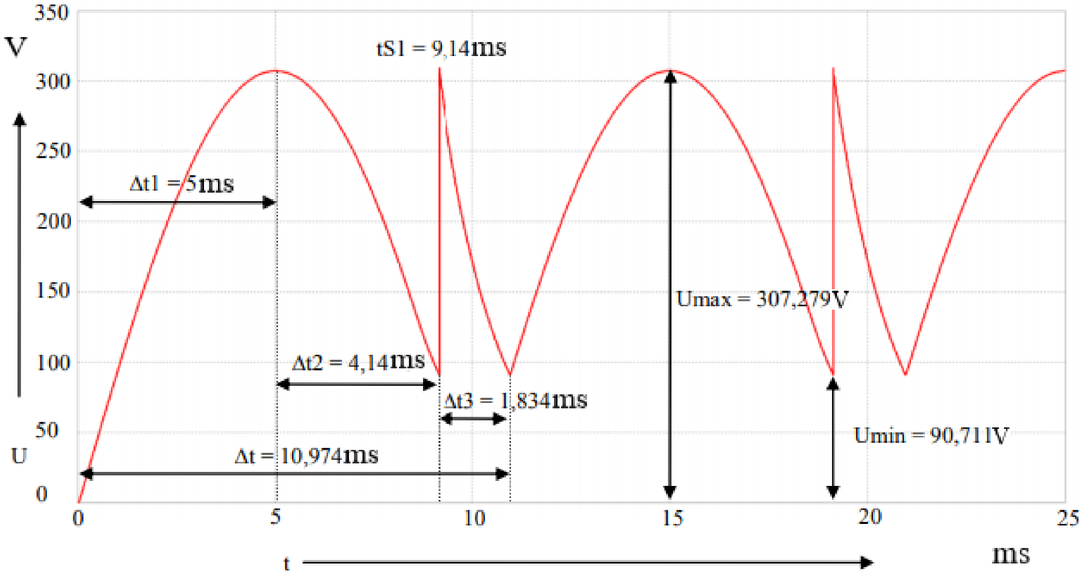

Figure 2.11 - Oscillogram of the output voltage of the filter with alternating discharge capacitors Cs and C1 with standard operation of the capacitor Cs at R_L= 500 Ohms

Figure 2.12 shows the voltage on the capacitors Cs and C1 in this mode.

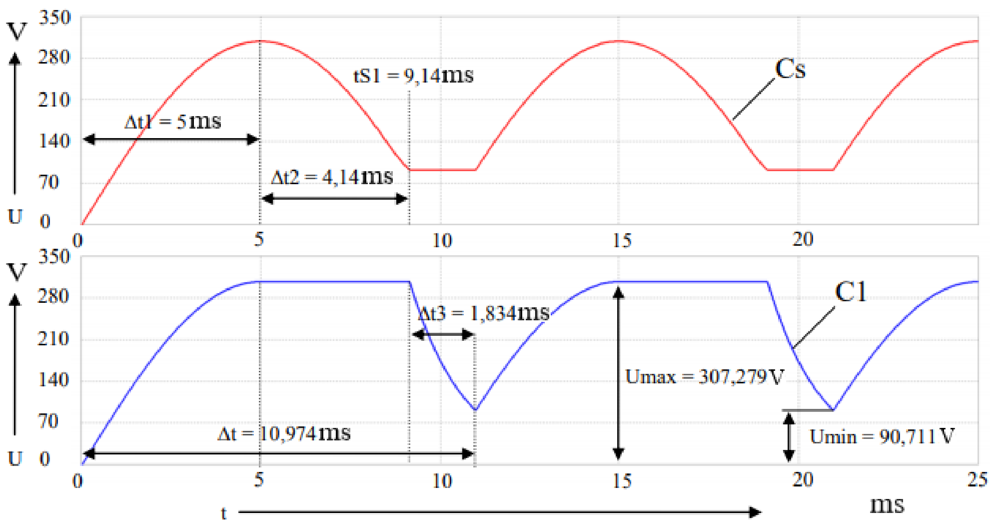

Figure 2.12 - Voltage on the capacitors Cs and C1 in alternating discharge without delay of the discharge of the capacitor Cs at R_L= 500 Ohms

The control system of the key S1 was configured so that the minimum voltage level was the same after the discharge of each capacitor. The minimum voltage U_{min} in this method is 90.711 V.

It is seen that both capacitors are charged Δt1 = 5m s until the voltage after the diode bridge reaches its amplitude value. During the time period Δt2 is discharged on the load only Cs. Capacitor C1 remains charged because switch S1 is open and diode VD6 prevents C1 from discharging back into the circuit. After Δt2 = 4.14 ms, at time tS1 = 9.14 ms, the key S1 is closed and the capacitor C1 begins to discharge to a load R_L. Diode VD5 does not allow C1 to discharge on Cs. Capacitor C1 is discharged at time Δt3 = 1,834 ms. The capacitor Cs at this time can not be discharged through its discharge circuit, as the voltage at the cathode of the diode VD5 will be greater than the residual in Cs, therefore, VD5 will be closed. At the end of the time period Δt3, the charge of both capacitors begins again. The total operating time of one cycle is equal to Δt = 10,974 ms.

In this method of operation, it is important that the switch S1 is turned on at a time when the minimum voltage levels of both capacitors are the same. This will allow you to get the maximum level of minimum voltage, which will have a positive effect on the amplitude of the ripple of the smoothed voltage ΔU, as this parameter will be smaller.

Based on the above, the dependences of the minimum voltage levels after each discharge of the capacitor on the time of inclusion of the key in the circuit of the discharge of the capacitor C1 were removed. The characteristic is shown in Figure 2.13. The switching time of the key tS1 varied from 6 ms to 10 ms. When the lower voltage levels collide, it will mean that at this point in time these voltage values are at the same level, so the minimum voltage level will be higher. This level is equal to 90.711 V at the time of inclusion of the key tS1 equal to 9.14 V, which is confirmed by the graph in Figure 2.13. The experiment was performed at R_L= 500 Ohms.

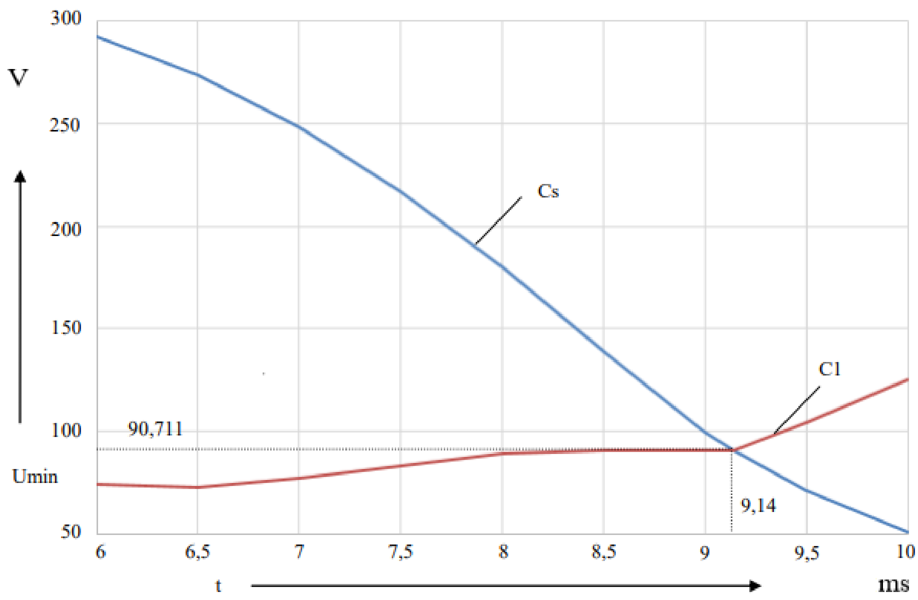

Figure 2.13 - Dependences of the minimum voltage levels after the discharge of capacitors from the time of inclusion of the key in the circuit of the discharge C1

The following shows the oscillograms of the output voltage at R_L= 100 Ohms and R_L= 1000 Ohms. The results are shown in Figures 2.14 and 2.15 , respectively.

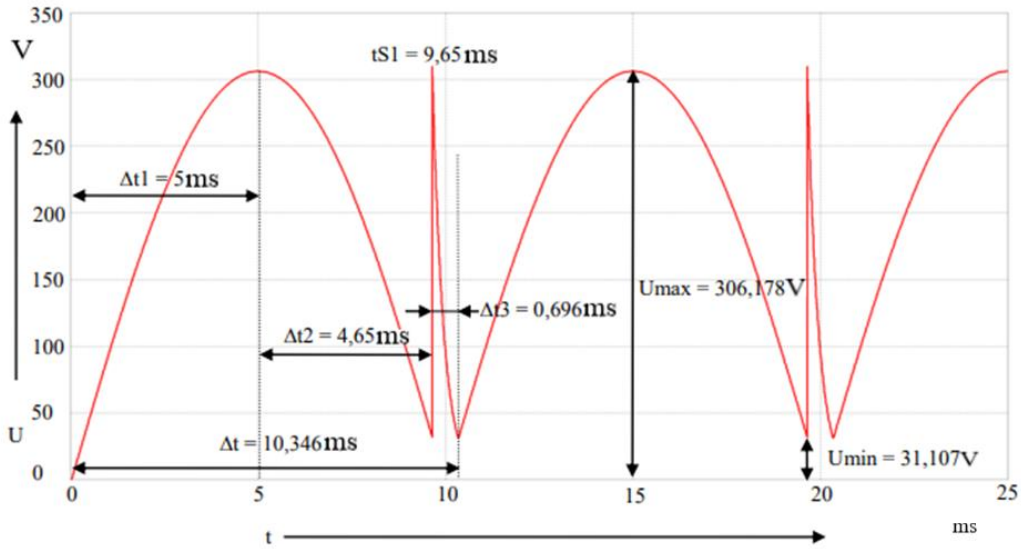

Figure 2.14 - Oscillogram of the output voltage of the filter with alternating discharge of capacitors Cs and C1 without delay of the discharge of the capacitor Cs at R_L= 100 Ohms

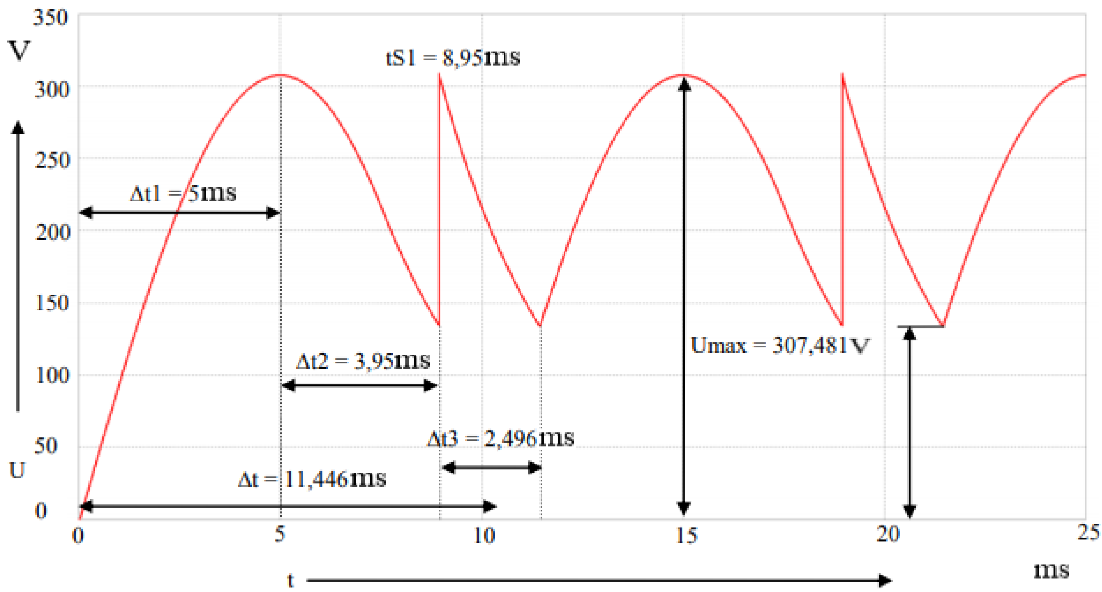

Figure 2.15 - Oscillogram of the output voltage of the filter with alternating discharge capacitors Cs and C1 without delay the discharge of the capacitor Cs at R_L= 1000 Ohm

The results of the study of successive discharges of the capacitors Cs and C1 of the filter during standard operation of the first capacitor Cs are shown in table 2.2.

Table 2.2 - The result of the study of successive discharges of the capacitors Cs and C1 filter during standard operation of the first capacitor Cs

	U_{max} (V)	U_{min} (V)	ΔU (V)	tS1 (ms)	Δt1 (ms)	Δt2 (ms)	Δt3 (ms)	Δt (ms)
C_S=C1=3μF at R_L=100Ω	306.178	31.107	275.075	9.65	5	4.65	0.696	10.346
C_S=C1=3μF at R_L=500Ω	307.279	90.711	216.568	9.14	5	4.14	1.834	10.974
C_S=C1=3μF at R_L=100Ω	307.481	133.920	173.561	8.95	5	3.95	2.296	11.446

Analyzing table 2.2, it is seen that at R_L= 100 Ohms, the capacitors Cs and C1 discharge faster on the load and therefore begins to show its smoothing properties much later than at R_L= 500 Ohms.

The minimum voltage is 31.107 V, which is much lower than at higher load resistance. The maximum level remained almost unchanged. The turn-on time of the tS1 key was 9.65 ms, so it can be concluded that the filter exhibits its smoothing properties later. At R_L= 1000 Ohms, the situation is mirror image. The minimum smoothed voltage is 133.990 V, which is the best of all loads. The key activation time tS1 is 8.95 ms.

Filter smoothing is more efficient. The charge time of capacitors Δt1 is the same for any load, the time Δt2 is different. The greater the load resistance, the smaller the range Δt2 due to the fact that the switch S1 is turned on earlier, due to better filter performance. It should be noted that the discharge time of the second capacitor Δt3 increases with increasing load resistance. This is due to the fact that, as in the case of capacitor Cs, capacitor C1 discharges more slowly at R_L= 1000 Ohms, and before charging both capacitors the next wave will occur later, which confirms the total time Δt at all loads.

2.3 Serial discharge of capacitors Cs, C1 and C2 without delay of the discharge of the capacitor Cs

As an experiment, let's try a circuit of three series-discharging capacitors with denominations of 2 uF.

circuit (node 2 - diode VD8 - node 8) and discharge circuit (node 8 - key S2 - diode VD9 - load R_L- node 3) is added to the circuit. Load resistance R_L= 500 Ohms. The scheme is shown in the figure 2.16 .

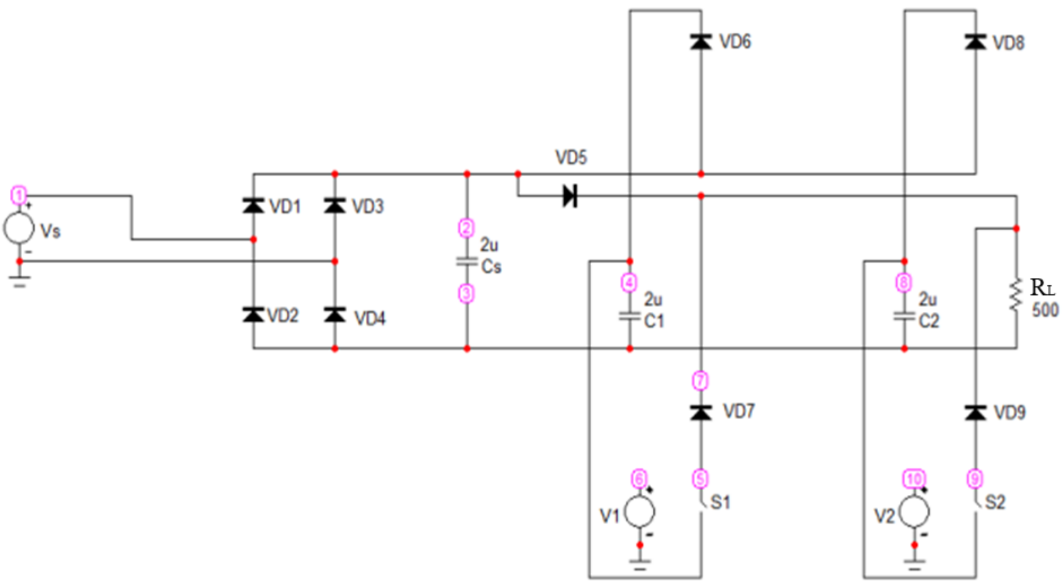

Figure 2.16 - Scheme of alternating discharge of capacitors Cs, C1 and C2 without delay of the discharge of the capacitor Cs

Figure 2.17 shows the voltage waveform on the resistor R_L(Figure 41).

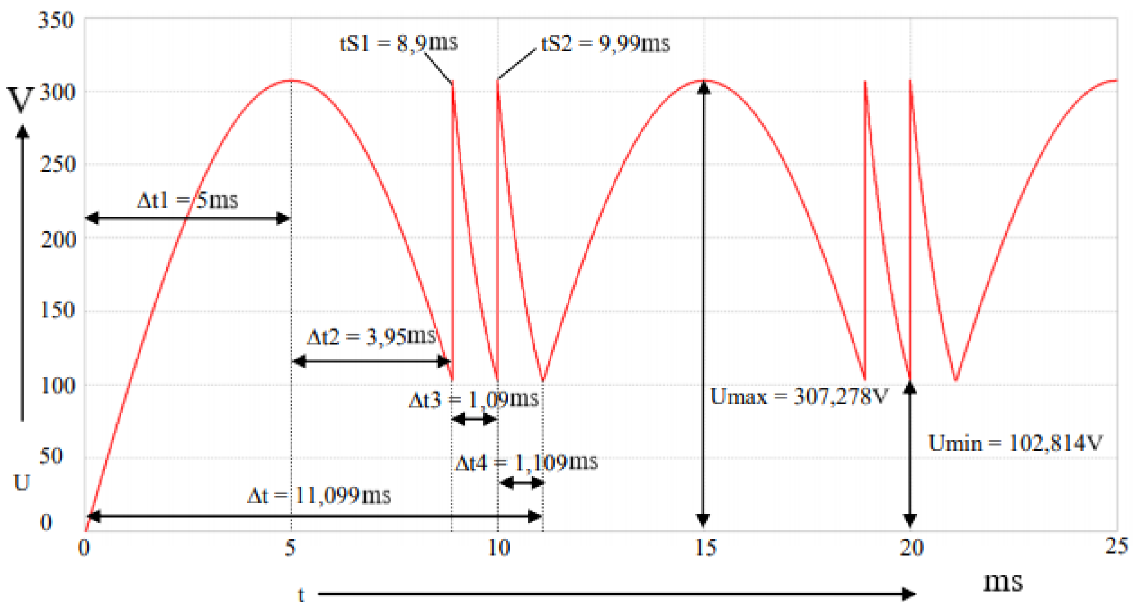

Figure 2.17 - Oscillogram of the output voltage of the filter with alternating discharge of capacitors Cs, C1 and C2 without delay of the discharge of the capacitor Cs at R_L= 500 Ohm

The control system of switches S1 and S2 was set so that the minimum voltage level was the same after the discharge of each capacitor. U_{min} in this method is equal to 102,524 V.

Figure 2.18 shows the voltages on the capacitors Cs, C1 and C2.

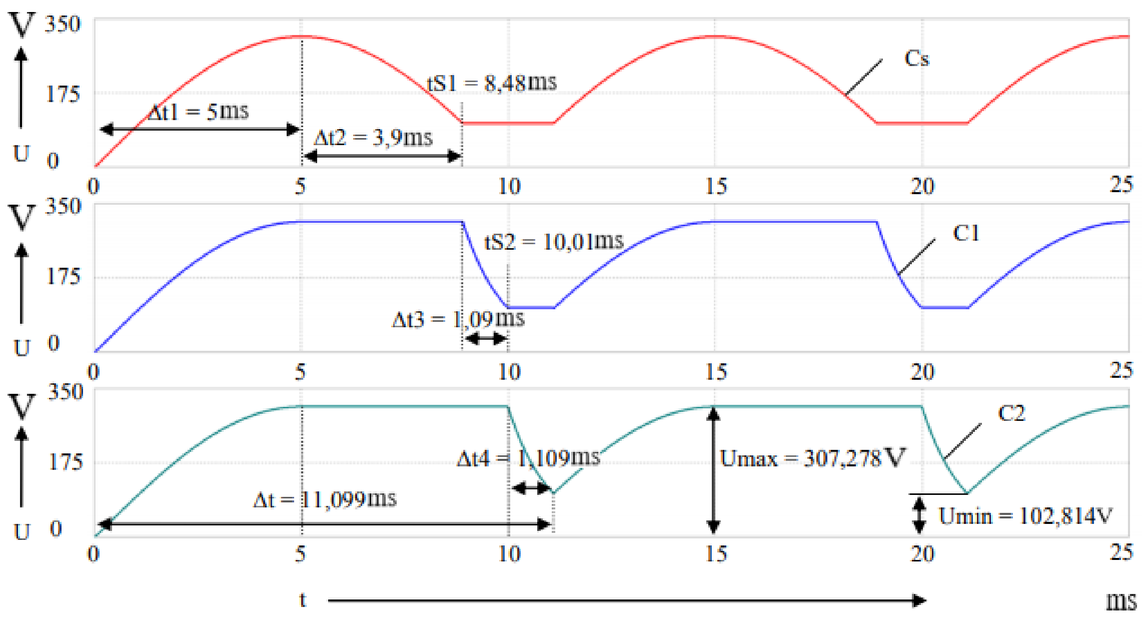

Figure 2.18 - Voltage on capacitors Cs, C1, C2 in alternating discharge without delay of the discharge of capacitor Cs at R_L= 500 Ohm

It is seen that all three capacitors are charged for a time Δt1 = 5 ms, until the voltage after the diode bridge reaches its amplitude value. During the time Δt2 is discharged into the load only Cs. Capacitors C1 and C2 remain charged, as switches S1 and S2 are open, and diodes VD6 and VD8 do not allow capacitors C1 and C2 to discharge back into the circuit.

After Δt2 = 3.9 ms, at time tS1 = 8.9 ms, the key S1 is closed and the capacitor C1 begins to discharge to a load RL. Diode VD5 does not allow C1 to discharge on Cs. Capacitor C1 is discharged at time Δt3 = 1.09 ms. Capacitor Cs, at this time, can not be discharged through its discharge circuit, as the voltage at the cathode of the diode VD5 will be greater than that remaining in Cs, therefore, VD5 will be closed. At the end of the time period Δt3, the key S2 is turned on. This occurs at time tS2 = 9.99 ms. Capacitor C2 begins to discharge under load. It is discharged in a period of time equal to Δt4 = 1,109 ms. Capacitor C1 ceases to discharge through its discharge circuit, as the voltage at the cathode of the diode VD7 will be greater than the voltage at C1, therefore, VD7 will be closed. After time Δt4 the charge of all three capacitors starts again. The total operating time of one cycle is equal to Δt = 11,099 ms.

In this method of operation, as in the previous one, it is important that the switches S1 and S2 were turned on at a time when the minimum voltage levels of all capacitors were the same. This will allow you to get the maximum level of minimum voltage, which will have a positive effect on the amplitude of the ripple of the smoothing voltage ΔU, as this parameter will be smaller.

Next, change the load resistance R_L= 100 Ohms and R_L= 1000 Ohms, and see how this factor affects the output voltage in this mode of operation of the filter. The waveforms are shown in Figures 2.19 and 2.20 , respectively.

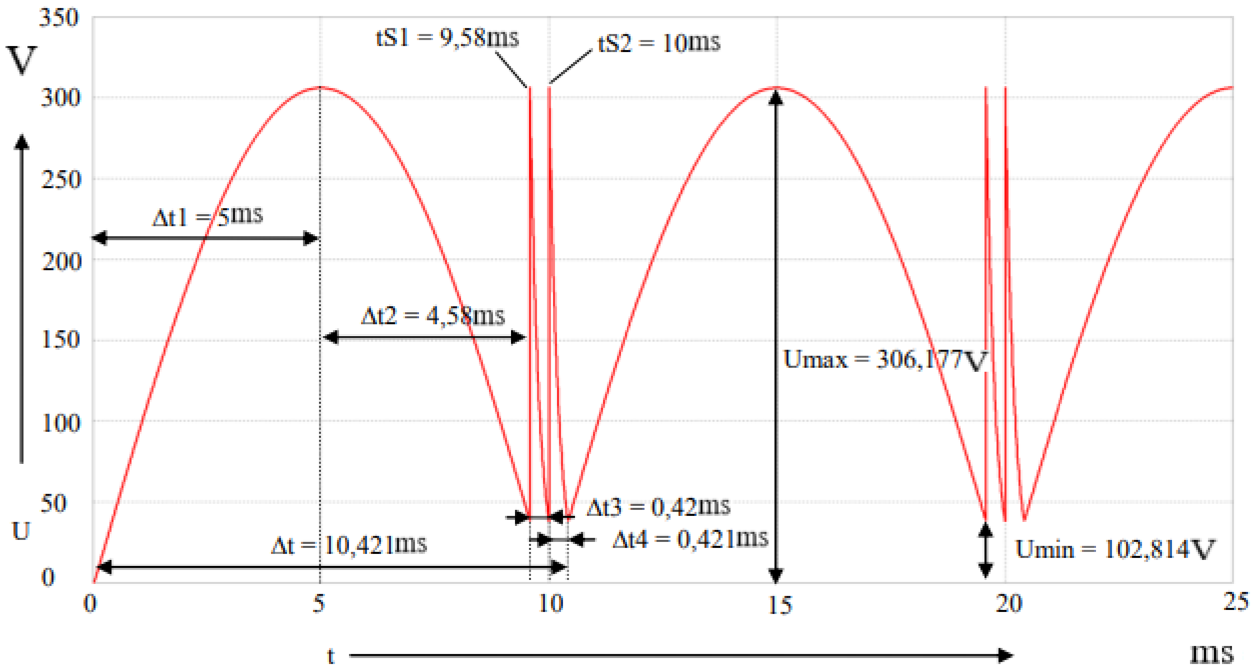

Figure 2.19 - Oscillogram of the output voltage of the filter with alternating discharge of capacitors Cs, C1 and C2 without delay of the discharge of the capacitor Cs at R_L= 100 Ohms

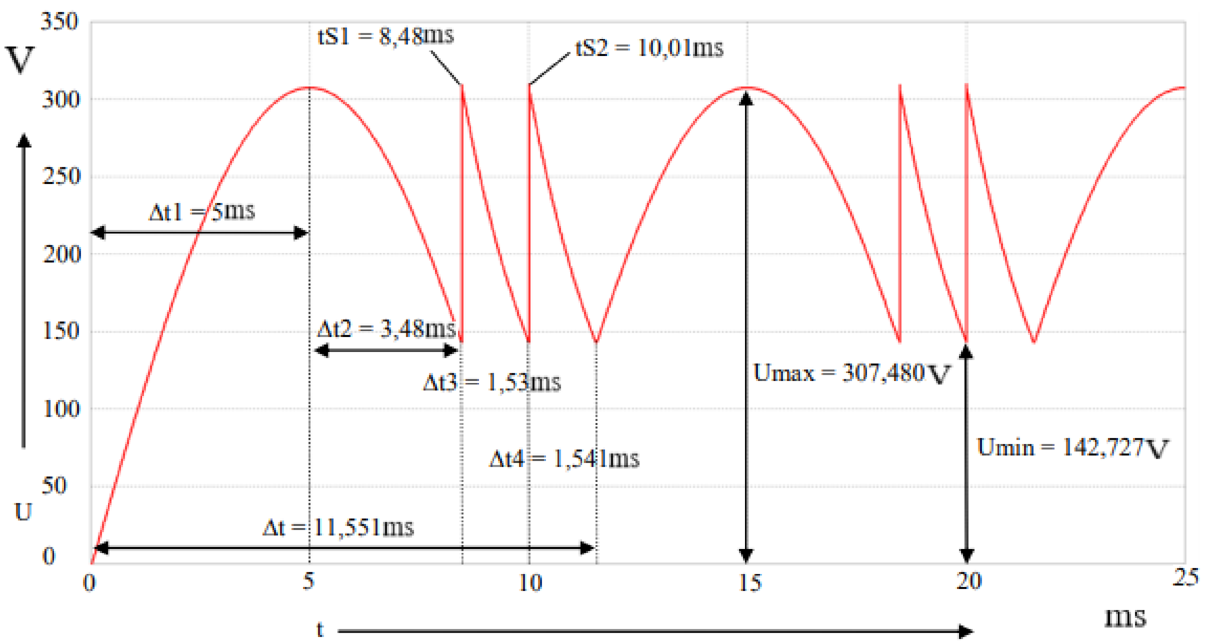

Figure - 2.20 Oscillogram of the output voltage of the filter with alternating discharge of capacitors Cs, C1 and C2 without delay of the discharge Cs at R_L= 1000 Ohm

The results of the study of successive discharges of the capacitors Cs, C1 and C2 during standard operation of the first capacitor Cs are shown in table 2.3.

Table 2.3 - The result of the study of successive discharges of the capacitors Cs, C 1 and C2 during standard operation of the first capacitor Cs

	C_S=C1=C2=2μF at R_L=100Ω	C_S=C1=C2=2μF at R_L=500Ω	C_S=C1=C2=2μF at R_L=100Ω
U_{max} (V)	306.177	307.278	307.480
U_{min} (V)	38.023	102.524	142.727
ΔU (V)	268.54	204.754	164.753
tS1 (ms)	9.58	8.9	8.48
tS2 (ms)	10	9.99	10.01
Δt1 (ms)	5	5	5
Δt2 (ms)	4.58	3.9	3.48
Δt3(ms)	0.42	1.09	1.53
Δt4 (ms)	0.421	1.109	1.541
Δt (ms)	10.421	11.099	11.551

Analyzing table 2.3, it is seen that at R_L= 100 Ohms, capacitors Cs, C1 and C2 discharge faster on the load and therefore begin to show their smoothing properties much later than at R_L= 500 Ohms. The minimum voltage is 38.023 V, which is much lower than at higher load resistance.

The maximum level remained almost unchanged. The switch-on time of the tS1 key was 9.58 ms, so it can be concluded that the filter exhibits its smoothing properties later. At R_L= 1000 Ohms, the situation is mirror image. The minimum smoothed voltage is 142.727 V, which is the best of all loads.

The key activation time tS1 is 8.48 ms. Filter smoothing is more efficient. According to the study, the turn-on time of the capacitor C2 is practically unchanged, the difference is 0.01 ms. The charge time of capacitors Δt1 is the same for any load, the time Δt2 is different. The higher the load resistance, the smaller the range Δt2 due to the fact that the switch S1 is turned on earlier, due to better filter performance.

It should be noted that the discharge time periods (Δt3 and Δt4) of capacitors C1 and C2 increase with increasing load resistance. This is due to the fact that, as in the case of capacitor Cs, C1 and C2 discharge more slowly at R_L= 1000 Ohms, and before charging all capacitors the next wave will occur later, which confirms the total time Δt at all loads.

2.4 Finding the limit of the minimum voltage level in the alternating discharge of capacitors without delaying the discharge of the capacitor Cs

Based on paragraphs 2.1.2 and 2.1.3, it is seen that the minimum voltage level U_{min} changes. To find the limit of this value, circuits with alternating discharge of capacitors in the standard operation of the capacitor Cs with a larger number of capacitors were studied. Figure 2.21 shows a circuit with eight capacitors whose capacitance is 0.75 μF.

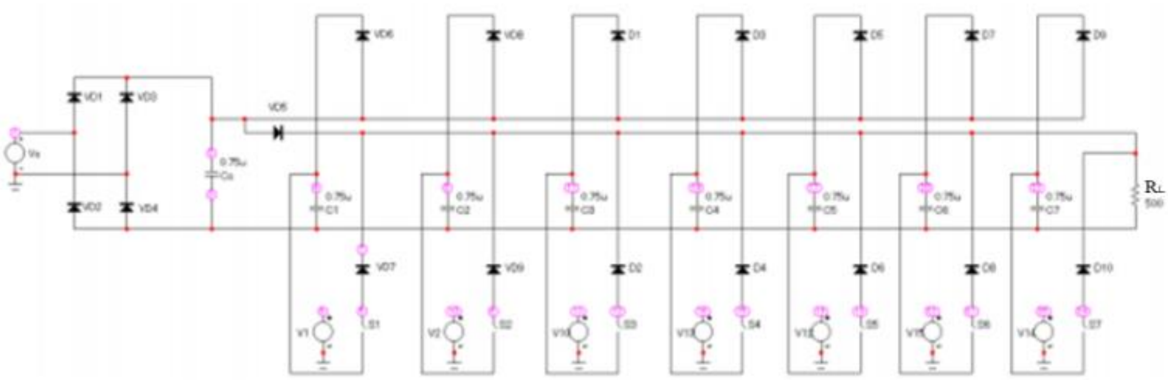

Figure 2.21 - Scheme of alternating discharge of eight capacitors with standard operation of the capacitor Cs

The oscillogram of the output voltage is shown in Figure 2.22.

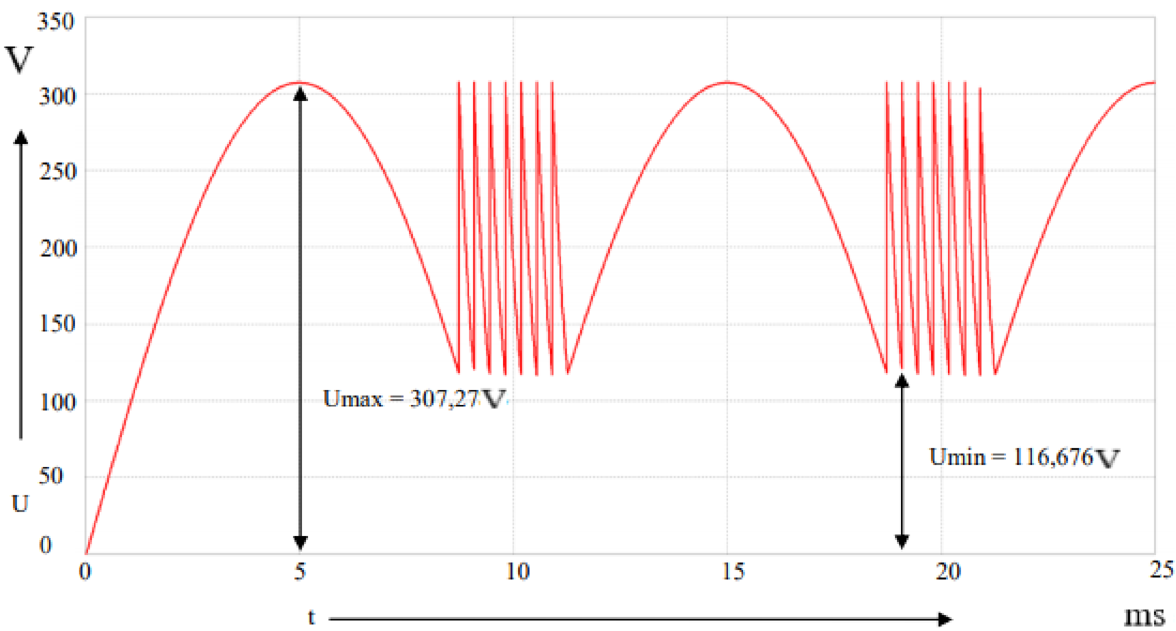

Figure 2.22 - Oscillogram of the output voltage of the filter with alternating discharge of eight capacitors with standard operation of the capacitor Cs

The study was conducted only at a load resistance R_L= 500 Ohms , therefore, and the final conclusion of the parameters of this scheme will be compared only with those schemes where the resistance was R_L= 500 Ohms.

In this method, the minimum voltage U_{min} = 116,676 V, the maximum voltage U_{max} = 307,278 V. The amplitude of the voltage ripple ΔU = 190,602 V. Other parameters were not removed, as at this point they are not required.

The principle of operation of the scheme is similar to the previous paragraphs 2.1.2 and 2.1.3.

Next, a circuit was assembled that already contains twelve capacitors. The capacity of each is 0.5 μF.

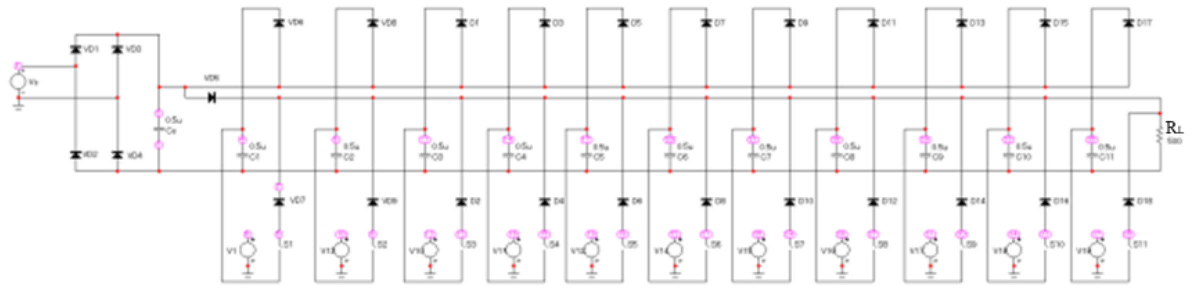

Figure 2.23 - Scheme of alternating discharge of twelve capacitors with standard operation of the capacitor Cs

The oscillogram of the output voltage is shown in Figure 2.24.

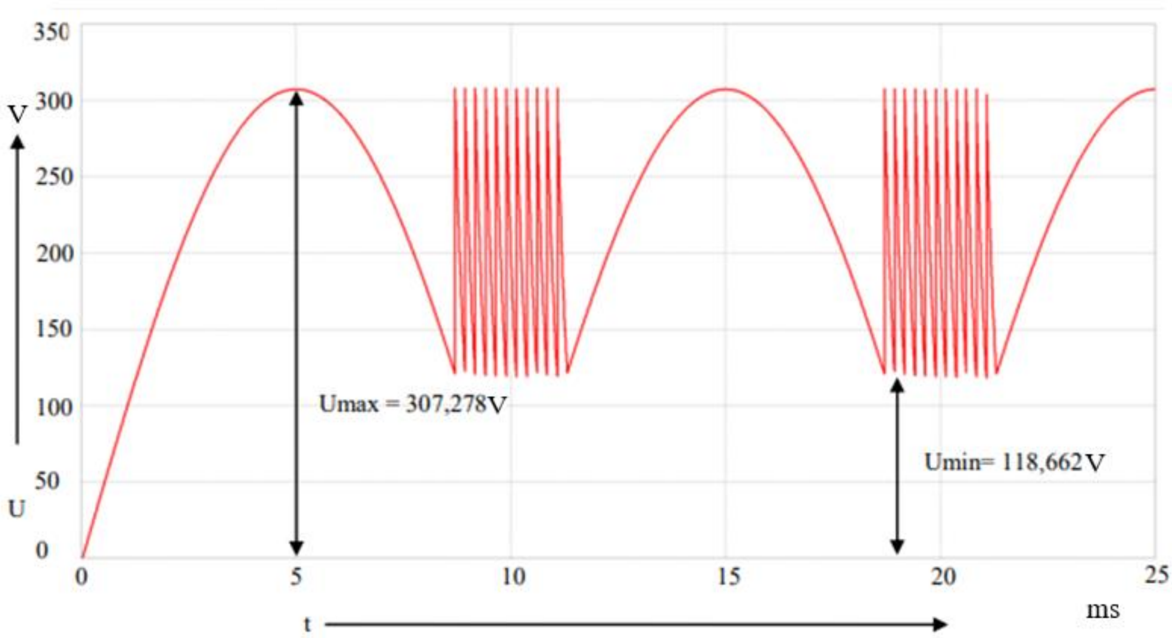

Figure 2.24 - Oscillogram of the output voltage of the filter with alternating discharge of twelve capacitors with standard operation of the capacitor Cs

In this method, the minimum voltage U_{min} = 118,662 V. In this method, the minimum voltage U_{min} = 116,676 V, the maximum voltage U_{max} = 307,278 V. The amplitude of voltage ripples ΔU = 188,616 V. The minimum voltage U_{min} slowly increases with increasing number of capacitors, therefore, ΔU decreases at the same U_{max} . The total capacity is the same and equal to 6 uF. Circuits with a large number of capacitors have not been studied, because the larger the number of capacitors, the more charge and discharge circuits are added to the circuit for each capacitor, so the filter control system becomes more complicated.

2.5 Discharge of capacitor C1 with a delay of the discharge of the first capacitor

An experiment was performed (Figure 50), where there was no capacitor Cs, and only the capacitor C1 remained, with the same value of 6 μf, as in paragraph 2.1.1.

Capacitor C1 was discharged to the load with a delay. The oscillogram of the voltage at the output of the filter at R_L= 500 Ohm was taken (Figure 2.25).

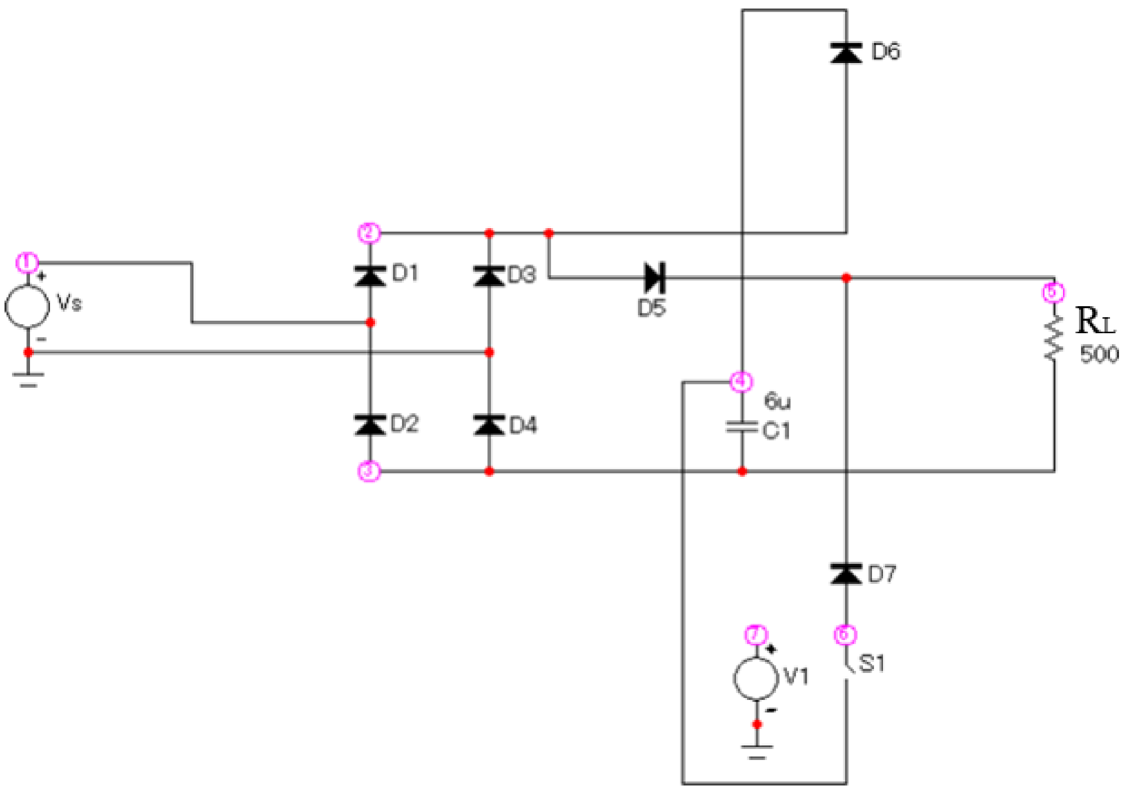

Figure 2.25 - Scheme of the filter with the discharge of the capacitor C1 in the absence of the capacitor Cs with a delay of the discharge of the capacitor C1

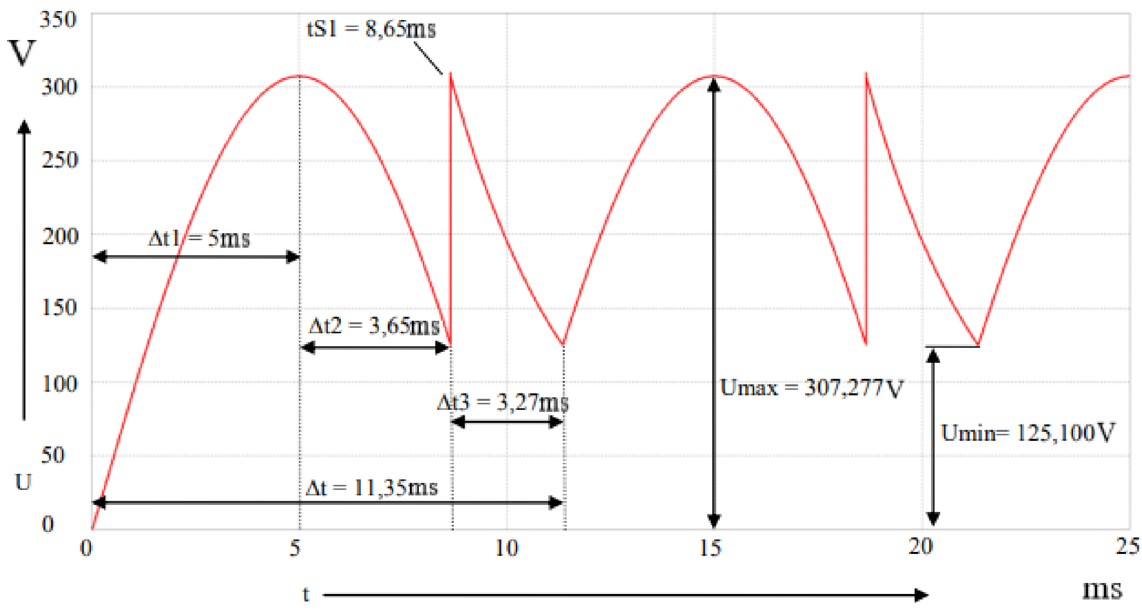

Figure 2.26 - Oscillogram of the output voltage of the filter with a discharge of the capacitor C1 with a time delay at R_L= 500 Ohms

The control system of the key S1 was set so that the minimum voltage level was the same after the discharge of the capacitor C1. The minimum voltage U_{min} in this method is 125,100 V.

Figure 2.27 shows the voltage across capacitor C1.

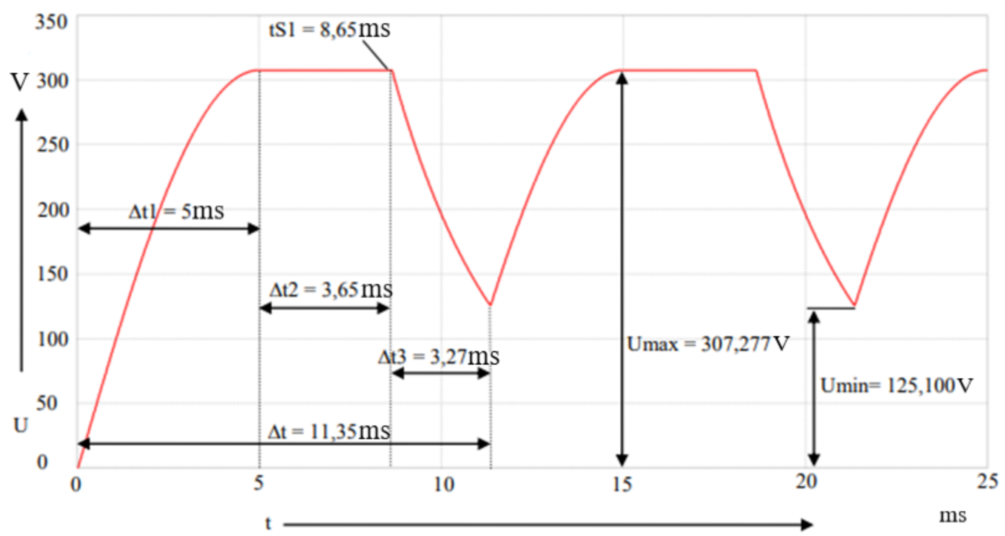

Figure 2.27 - Oscillogram of the voltage on the capacitor C1 with a time delay at R_L= 500 Ohms

It is seen that the capacitor C1 is charged for a long time Δt1 = 5 ms, until the voltage after the diode bridge reaches its amplitude value. In the time period Δt2 = 3.65 ms to the load resistance RLapplied rectified voltage after the diode bridge. Capacitor C1 during this period of time remains charged, as the key S1 is open, and the diode VD6 does not allow capacitor C1 to discharge back into the circuit. The voltage at RLis currently not smoothed. After a period Δt2, at time tS1 = 8.65 ms, the key S1 is closed and the capacitor C1 begins to discharge into the load R_L. Capacitor C1 is discharged at a time Δt3 = 2.7 ms. At the end of the time period Δt3, a new cycle begins, which charges the capacitor C1 to the maximum value. The total operating time of one cycle is equal to Δt = 11.35 ms.

In this method of operation, as in the previous ones, it is important that the switch S1 is turned on at a time when the minimum voltage values were the same. This will allow you to get the maximum level of minimum voltage, which will have a positive effect on the amplitude of the ripple of the smoothed voltage ΔU, as this parameter will be smaller.

Next, change the load resistance R_L= 100 Ohms and R_L= 1000 Ohms, and see how this factor affects the output voltage in this mode of operation of the filter. The waveforms are shown in Figures 2.28 and 2.29 , respectively.

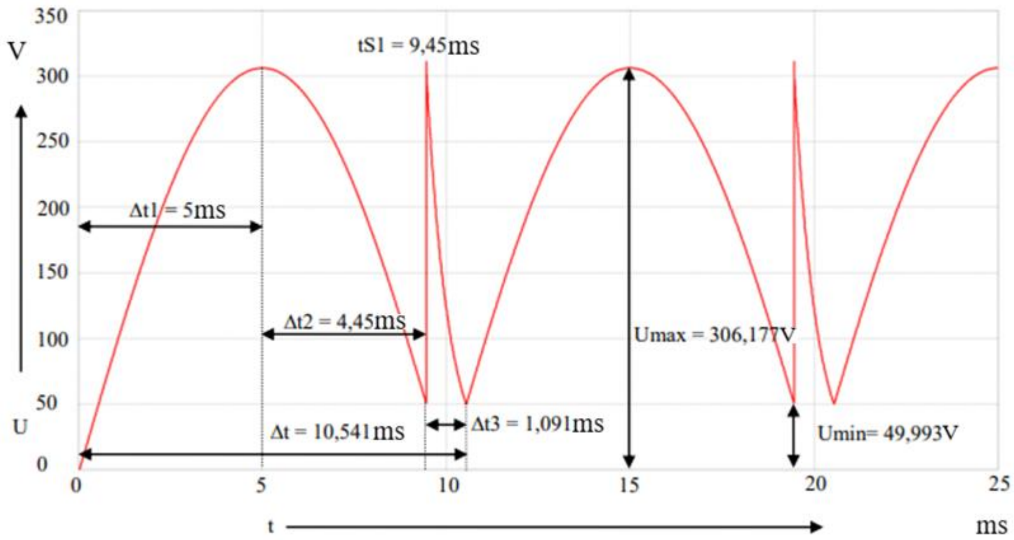

Figure 2.28 - Oscillogram of the output voltage of the filter with a discharge of the capacitor C1 with a time delay at R_L= 100 Ohms

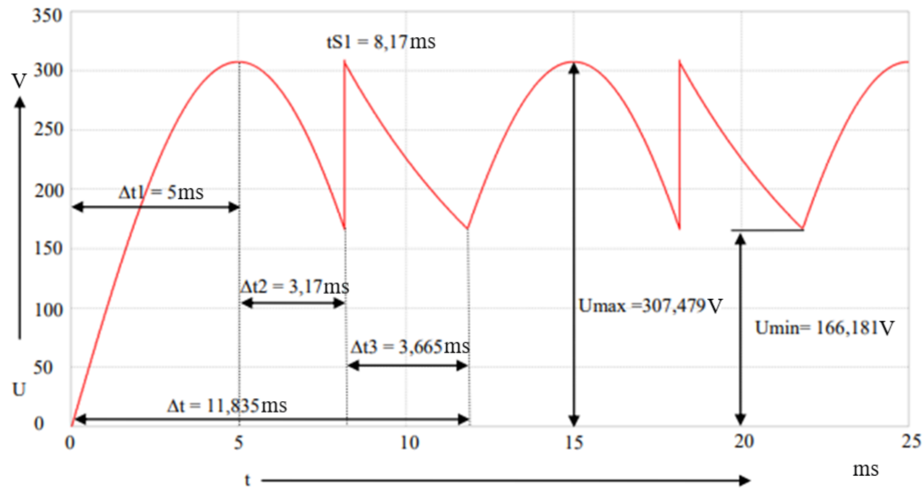

Figure 2.29 - Oscillogram of the output voltage of the filter with a discharge of the capacitor C1 with a delay in the discharge time of the first capacitor at R_L= 1000 Ohms

The results of the study of the discharge of the capacitor C1 with a delay in the discharge time of the first capacitor, without the use of the capacitor Cs are shown in table 2.4.

Table 2.4 - The results of the study of the discharge of the capacitor C1 with a time delay, without the use of the capacitor Cs.

	C1=2μF at R_L=100Ω	C1= 2μF at R_L=500Ω	C1= 2μF at R_L=100Ω
U_{max} (V)	306.177	307.277	307.479
U_{min} (V)	49.933	125.100	166.181
ΔU (V)	256.244	182.177	141.298
tS1 (ms)	9.45	8.65	8.17
Δt1 (ms)	5	5	5
Δt2 (ms)	4.45	3.65	3.17
Δt3(ms)	1.091	2.7	3.665
Δt (ms)	10.541	11.35	11.835

Analyzing table 2.4, it is seen that the charge time of the capacitor Δt1 at all loads is the same. In the period of time Δt2 to the load applied rectified voltage after the rectifier and the load resistance does not affect the smoothing properties in this area, as there is no smoothing.

However, the time period Δt2 differs when the load resistance R_L. This is due to the fact that the switching time (tS1) of the capacitor C1 changes. The change is due to the fact that the discharge time of the capacitor C1 (Δt3), at a higher load resistance, is greater, therefore, there is a more efficient smoothing. The minimum voltage after the discharge of the capacitor will be higher at R_L= 1000 Ohms, so to combine the minimum voltages during the cycle, you need to turn on the key earlier. More efficient smoothing leads to the fact that the total cycle time Δt also becomes longer.

2.6 Conclusion to the section

The main task of this part of the thesis is to compare the amplitude of voltage ripples ΔU standard C0-filter (P.2.1.1) with the amplitudes of voltage ripples in the circuits of alternating capacitors (p.2.1.2 - p.2.1.5). The total capacity of all filters is 6 μF. Also part of the work of this part is to determine the effect of changes in load on the amplitude of the pulsation in all filters. The amplitude of the voltage ripple ΔU of all circuits at three load resistances is shown in tables 2.5, 2.6, 2.7

Table 2.5 - The results of studies at Rn = 500 Ohms

Filter Type	Ripple Amplitude Voltage
P.2.1.1.C0-Filter (C0 = 6μF)	234.83
P.2.1.2.Cs ,C1-Filter (Cs = C1 = 3μF)	216.568
P.2.1.3.Cs ,C1,C2-Filter (Cs = C1= C2 = 2μF)	204.754
P.2.1.4.Cs , …. ,C7-Filter (Cs = …= C7= 0.75μF)	190.602
P.2.1.4.Cs , . ,C11-Filter (Cs = …= C11= 0.75μF)	188.616
P.2.1.5.C1-Filter (C1 = 6μF)	182.177

Table 2.6 - The results of studies at R_L= 100 Ohms

Filter Type	Ripple Amplitude Voltage ΔU (V)
P.2.1.1.C0-Filter (C0 = 6μF)	291.695
P.2.1.2.Cs ,C1-Filter (Cs = C1 = 3μF)	275.071
P.2.1.3.Cs ,C1,C2-Filter (Cs = C1= C2 = 2μF)	268.154
P.2.1.5.C1-Filter (C1 = 6μF)	256.244

Table 2.7 - The results of studies at R_L= 1000 Ohms

Filter Type	Ripple Amplitude Voltage ΔU (V)
P.2.1.1.C0-Filter (C0 = 6μF)	185.041
P.2.1.2.Cs ,C1-Filter (Cs = C1 = 3μF)	173.561
P.2.1.3.Cs ,C1,C2-Filter (Cs = C1= C2 = 2μF)	164.753
P.2.1.5.C1-Filter (C1 = 6μF)	141.298

If we consider each table separately, it is seen that the amplitude of the voltage ripple ΔU in all circuits p.2.1.2-p.2.1.5 is less than the amplitude of the standard C0-filter. Therefore, it can be concluded that the circuits of the alternating discharge of capacitors, regardless of the number and delay in switching on the capacitors, are better than the standard C0-filter, regardless of the load resistance. The main thing is that the load resistance was the same.

It is seen that in the circuits with alternating discharge of capacitors (p.2.1.2 - p.2.1.4) with standard operation of the capacitor Cs with increasing number of capacitors, the amplitude of the voltage ripple decreases. In the circuits of alternating discharge of capacitors with a time delay of capacitor C1, without the use of capacitor Cs (p.2.1.5) with increasing capacitors does not lead to a decrease in the amplitude of voltage ripples ΔU. Minor voltage changes (within one volt) can be considered a limb when removing the parameters.

Therefore, we can conclude that when increasing the capacitors in circuits with alternating discharge with a time delay of the discharge C1, without the use of the capacitor Cs does not lead to improved parameters.

However, even so, the parameters ΔU in § 2.1.5 are better than the parameters ΔU in § 2.1.4. Therefore, it can be concluded that the filters of the alternating discharge of capacitors with a time delay of the discharge C1, without the use of the capacitor Cs give the best parameter ΔU from the studied circuits.

However, this conclusion can be made only on the basis of this thesis, as it is likely that the most optimal parameter ΔU, can be obtained if the circuit with alternating discharge capacitors in standard operation of the capacitor Cs will be more than 12 capacities, as with increasing capacitors in this circuit leads to a decrease in ΔU, however, this leads to an increase in the elements in the circuit and create a more complex control system, so the best circuit can be considered the circuit according to 2.1.5 - discharge capacitor C1 with discharge delay of the first capacitor, as this the circuit contains only one capacitor, so it has only one charge and discharge circuit, as well as the best parameter ΔU. Other circuits that have this parameter contain more elements.

3 CALCULATION SECTION

3.1 Comparison of semiconductor switches of the old and new model during operation of the switching power supply circuit

In switching power supplies, a field-effect transistor is more often used as a key element. The field-effect transistor was invented a long time ago and its parameters are improving every year. An important parameter for a switching power supply is its opening time and closing time. Theoretically, the longer the opening time and closing time, the greater the energy loss for the key element. The task of this paragraph is to prove that the field-effect transistor of the old model, in which the opening and closing times are worse than the transistor of the new model.

Figure 3.1 shows a diagram of a boost switching power supply of the 2nd kind, which will be used to test transistors. PBVC

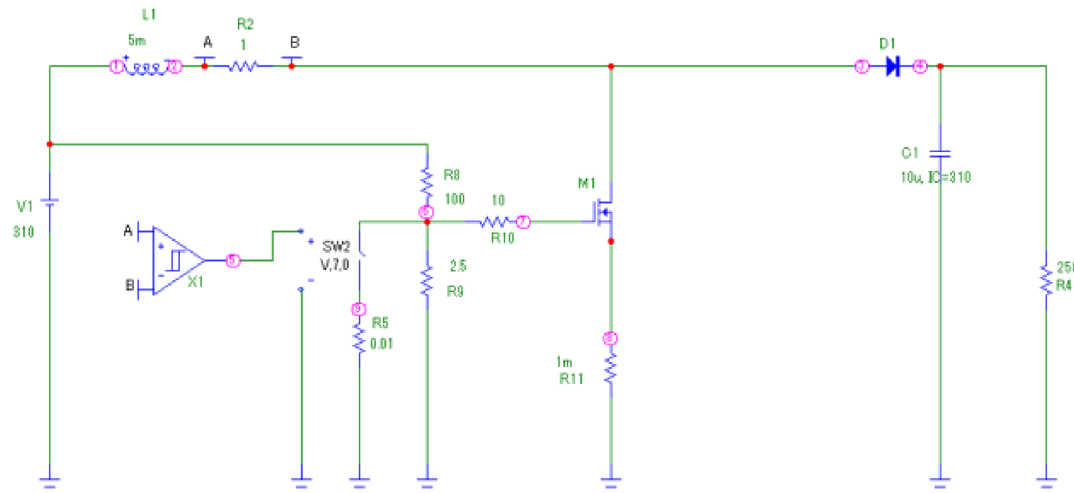

Figure 3.1 - Scheme of boost switching power supply, simulated in the program Micro-cap

Next, field-effect transistors of the old and new models were found. Common parameters of these transistors were drain-source voltage $U_{c\,i}$ = 600 V and drain current I_c = 4 A.

The field-effect transistor KP709 was chosen from the old model. This transistor was found in the 1994 directory, so it can be argued that it was invented no later than this year. The AOD4S60 transistor taken from the documentation of 2012 was chosen as a new model.3 Considering the transistor AOD4S60, it was determined that the turn-on time of this transistor is 8 ns, and the decay time is 12 ns. When considering the transistor KP709, it was determined that the turn-on time of this transistor is 400 ns, and the decay time is 800 ns. The Micro-cap program created a circuit for testing transistors for on and off times (Figure 3.2).

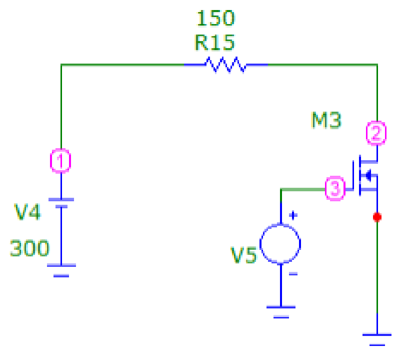

Figure 3.2 - Scheme of checking the transistors at the time of inclusion and time of decline

The V4 generator emitted pulses with a period of 0.2 μs, the duty cycle was 0.1 μs. Based on the method of MICRO-cap, Spice-parameter RG (volume resistance of the shutter) is responsible for the switching time. The spice parameter CBD (capacitance of this part of the stack-substrate transition at zero offset) is one of the parameters of the output capacitance of the transistor. The spice parameter CGDO (specific capacity of the gate-leak overlap) is one of the parameters of the bulk charge in the "on" state.

Figure 3.3 shows a diagram from which you can correctly determine the leading edge tr and the trailing edge tf of the field-effect transistor. It is seen that the removal of time does not occur with the beginning of the rise or fall of the pulse, but when the voltage parameter should be 10% of the maximum, and ends the removal when the voltage reaches 90% of the maximum value. In our case it is 30 V and 270 V.

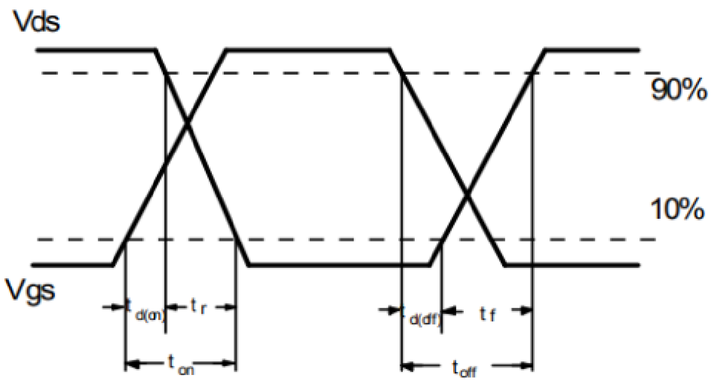

Figure 3.3 - Diagram for the correct determination of the leading edge tr and the trailing edge tf of the field-effect transistor

Next, changing only the parameters RG, CBD and CGDO regulated the time of the leading edge tr and the trailing edge tf of both field-effect transistors. The remaining Spice parameters were taken as standard. The results of the AOD4S60 transistor are shown in Figure 3.4.

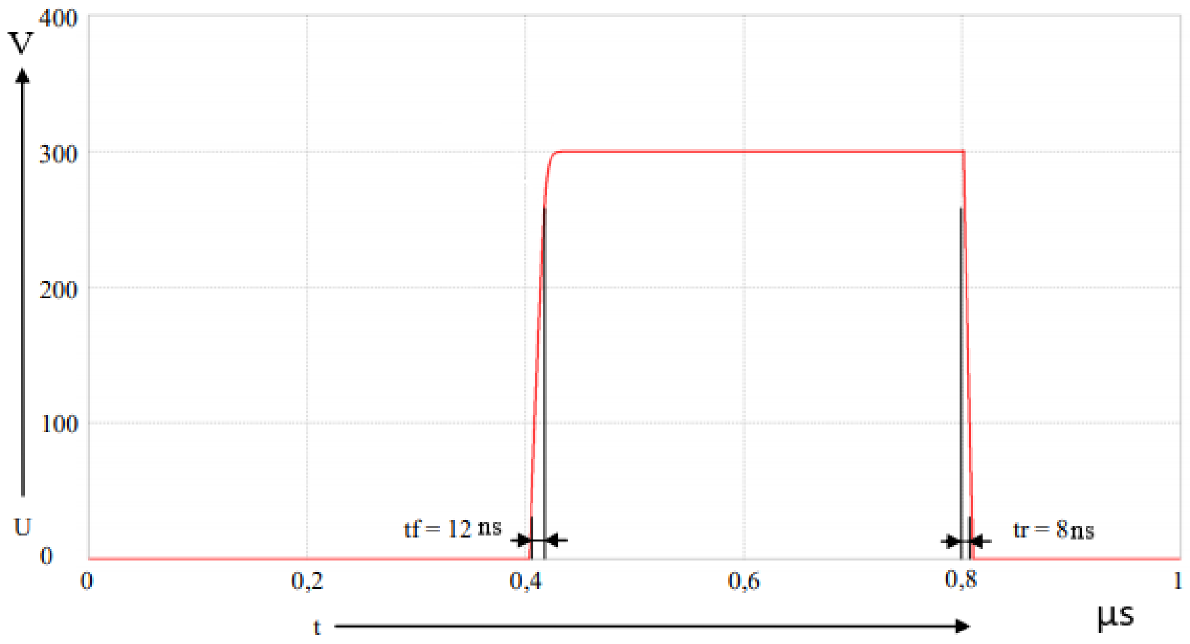

Figure 3.4 - Locating the front and rear fronts of the transistor AOD4S60

For the transistor AOD4S60 the following parameters were obtained: RG = 45 Ohms, CBD = $0.3 \cdot 10^{-9}$ F and CGDO = $0.8 \cdot 10^{-11}$ F / m.

The results of the transistor KP709 are shown in Figure 3.5.

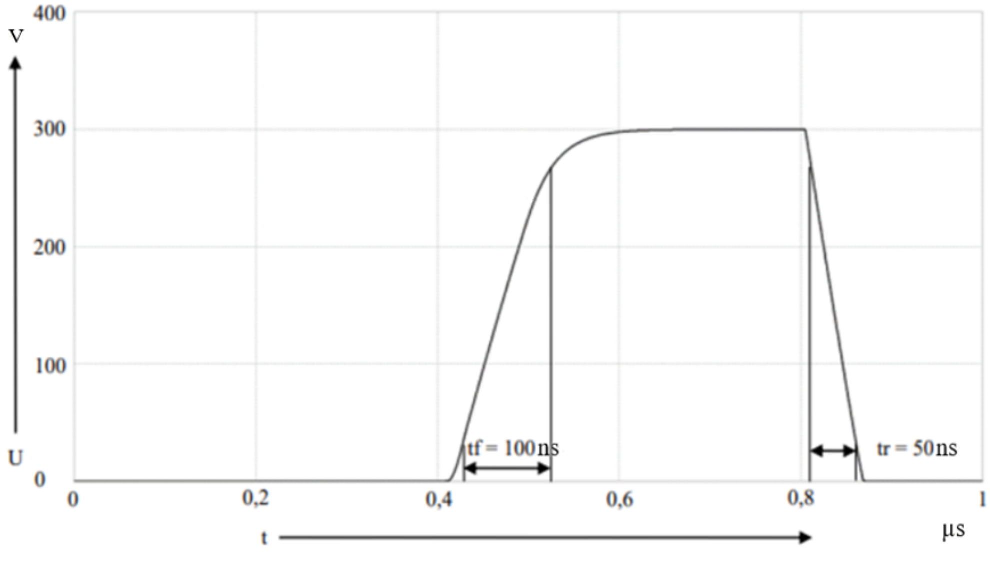

Figure 3.5 - Locating the front and rear fronts of the transistor KP709

For the transistor KP709 the following parameters were obtained: RG = 250 Ohm, CBD = $3.5 \cdot 10^{-9}$ F and CGDO = $1 \cdot 10^{-11}$ F / m. When removing the parameters, errors in the X-axis and Y-axis took place, however, these errors are negligible.

3.1.1 Operation of the circuit at a current amplitude of 0.5 A

The generated parameters RG, MJ and CGDO were inscribed in the Spice parameters of the transistor M1 in the diagram Figure 3.1. Other parameters were standard. The circuit is designed so that the frequency of the semiconductor switch directly depends on the amplitude of the choke current ΔIL.

Next, the frequency of the choke current varied from 3.5 A to 4 A (Figure 3.6). Amplitude of pulsations of choke current ΔIL = 0,5 A.

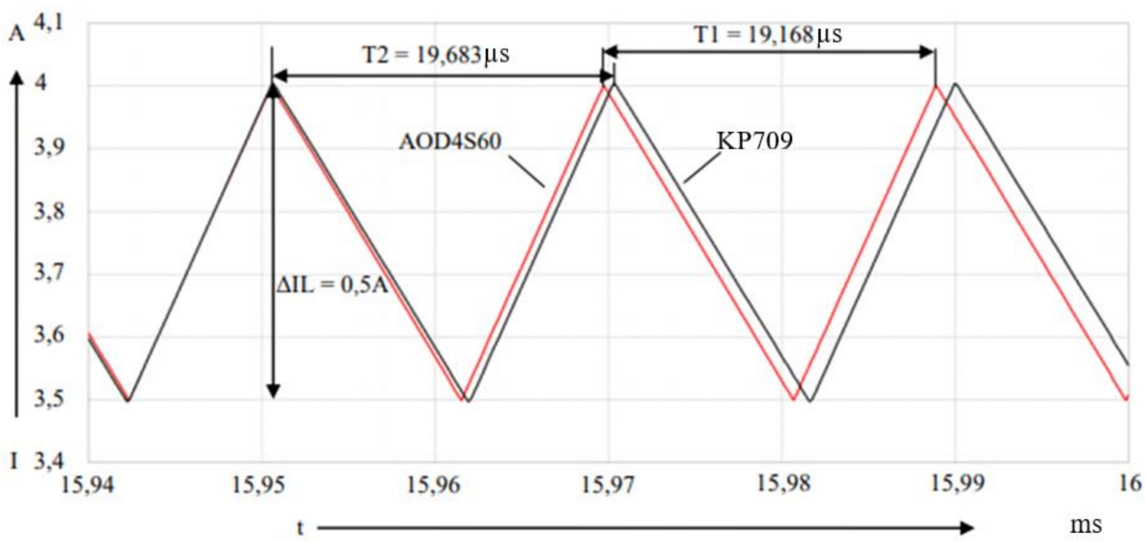

Figure 3.6 - Choke currents at ΔIL = 0.5 A with transistors AOD4S60 and KP709

The PBVC control system changes the choke current from 3.5 A to 4 A. In this case, it turns out that the frequency of the transistor AOD4S60 is ≈ 52170 Hz, and the transistor KP709 ≈ 50805 Hz. Therefore, the frequency of the key will differ by 1365 Hz. The change in frequency occurs because in the old transistor, to increase the on and off time increased the capacitance in the Spice parameters. This affects the fact that when switching the switch, the choke current continues to flow in the previous direction for some time so the amplitude of the pulsations of the choke current will not be 0.5 A, but slightly more, so there is an increase in the period. This factor is not strongly manifested at ΔIL = 3 A, as at low frequencies the capacitive resistance of the capacitor increases, the choke current when changing the position of the key changes faster.

The following shows the oscillograms of the output voltage of the PBVC using two transistors with pulsations of the choke current of 0.5 A.

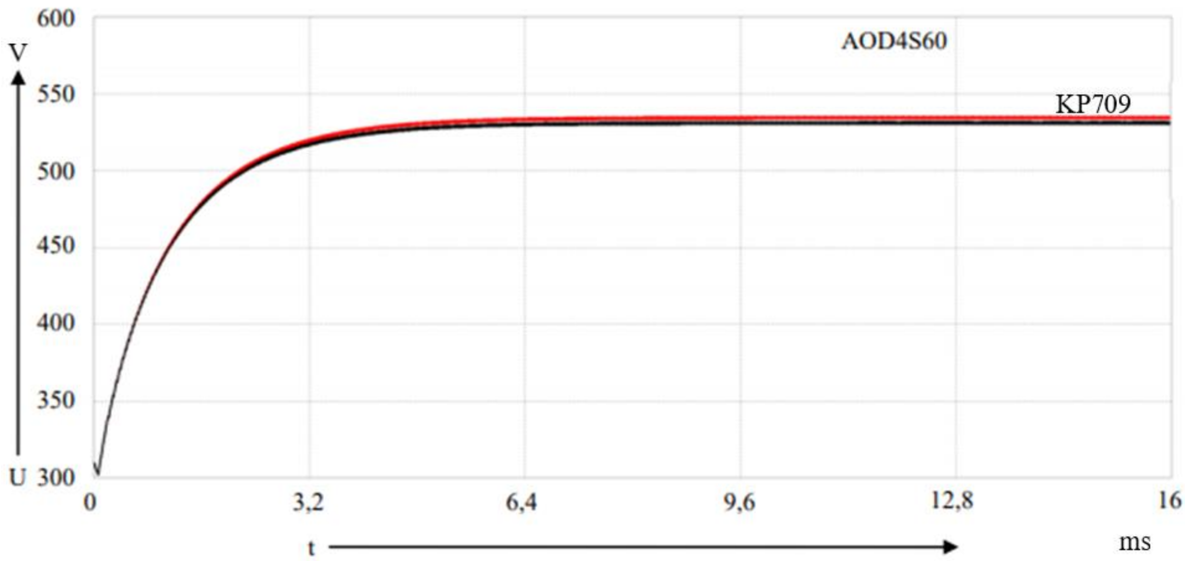

Figure 3.7 - Comparison of PBVC output voltages using old and new transistor at ΔIL = 0.5 A

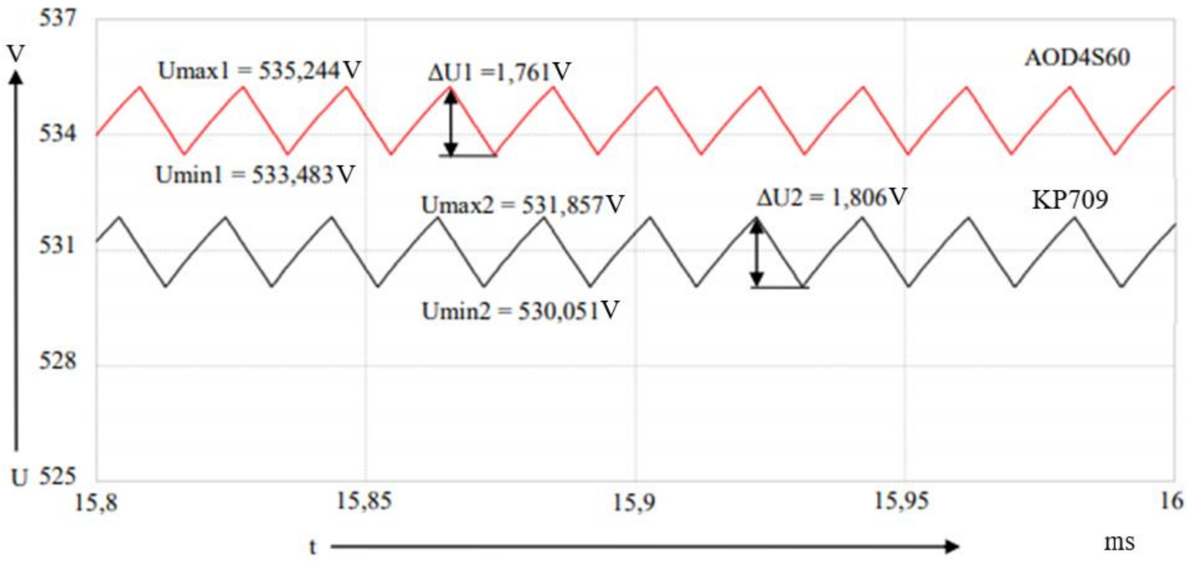

Figure 3.8 - Comparison of PBVC output voltages on an enlarged scale

Since these frequencies are higher than in paragraph 2.3.1, the amplitudes of the ripple of the output voltages will be smaller. The output voltages will also be higher, as the average choke current is 3.75 A, so more energy goes into the load. In the previous paragraph, the average current was 2.5 A. If the circuit is a new transistor AOD4S60, the output voltage is higher. This is due to the fact that the on and off time of the transistor KP709 is longer, so the old one dissipates more energy into heat. Compared with paragraph 2.3.1, at higher frequencies, this factor is more pronounced, as the period of operation of the key is significantly reduced, and the on and off time of the transients remained the same. Next was a comparison of energy dissipation on transistors shown in Figure 3.9.

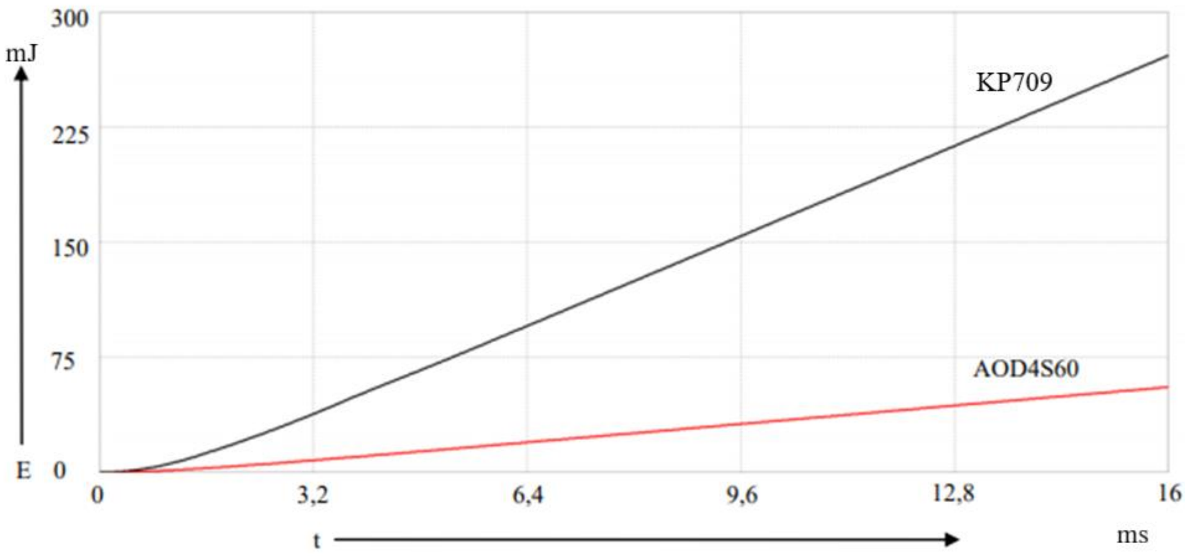

Figure 3.9 - Energy dissipation on transistors at ΔIL = 0.5 A

Theoretically, the higher the key frequency, the greater the loss on the key element, as the active operation of the transistor is due to the shorter period of operation of the key. However, the new transistor has a fairly fast on and off time, which even at higher frequencies has less loss compared to the old one, which operates at a lower frequency.

3.1.2 Operation of the circuit at a choke current amplitude of 0.2 A

Next, the choke current frequency varied from 3.8 A to 4 A (Figure 3.10).

Amplitude of pulsation of choke current ΔIL = 0,2 A.

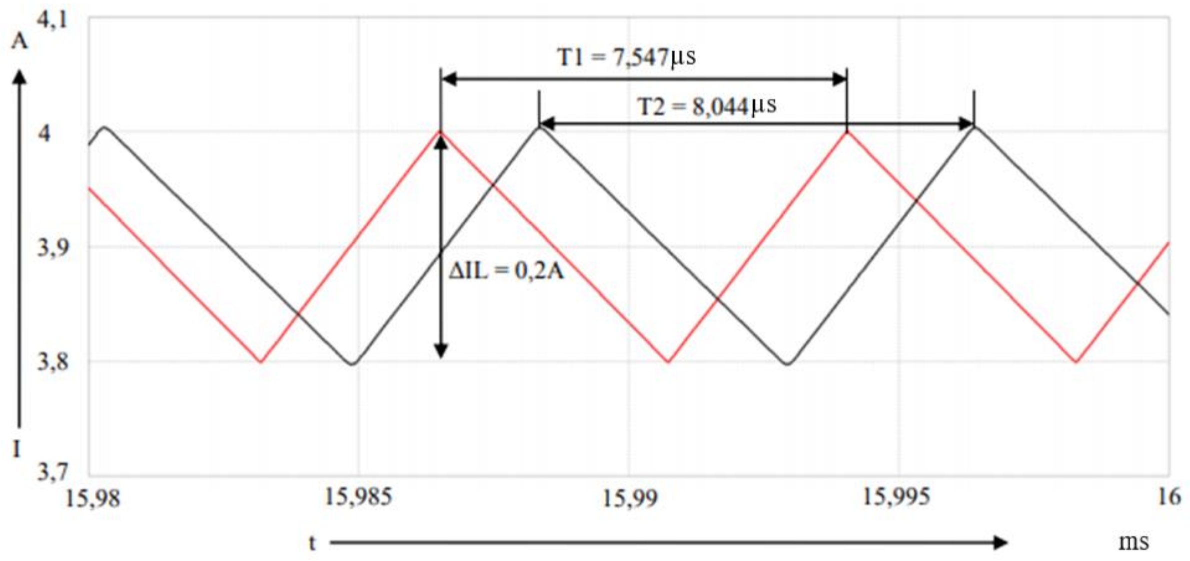

Figure 3.10 - Choke current with ΔIL = 0.2 A with transistors AOD4S60 and KP709

The PBVC control system changes the choke current from 3.8 A to 4 A. In this case, it turns out that the frequency of the transistor AOD4S60 is ≈ 132.503 Hz, and the transistor KP709 ≈ 124.316 Hz. Therefore, the frequency of the key will differ by 8.187 Hz. The change in frequency occurs because in the old transistor, to increase the on and off time increased the capacitance in the Spice parameters. This affects the fact that when switching the switch, the choke current continues to flow in the previous direction for some time, so the amplitude of the pulsation of the choke current will not be 0.2 A, but slightly more, so there is an increase in period. Reducing the amplitude of current ripples leads to greater changes in frequencies relative to each other in different transistors.

The following shows the oscillograms of the output voltage of the PBVC using two transistors at ΔIL = 0.2 A.

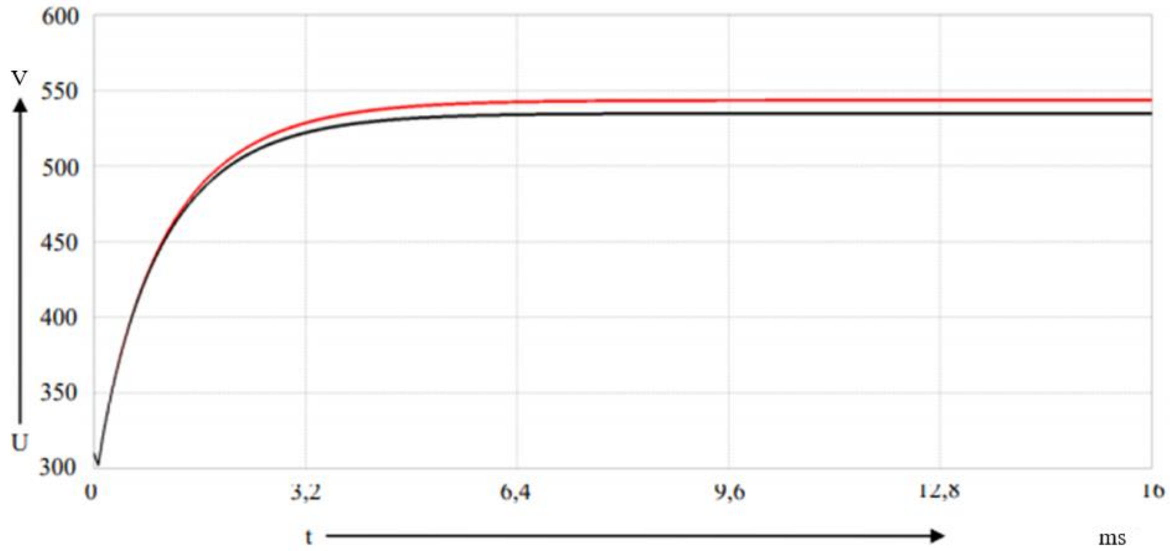

Figure 3.11 - Comparison of PBVC output voltages using old and new transistors at ΔIL = 0.2 A

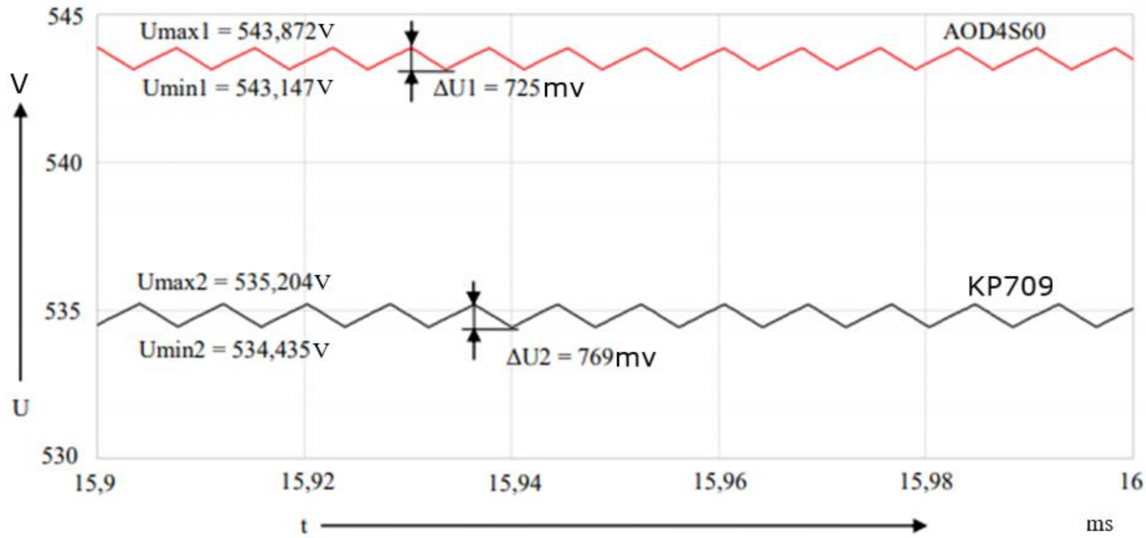

Figure 3.12 - Comparison of PBVC output voltages on an enlarged scale

Since these frequencies are higher than in paragraph 2.3.1 and in paragraph 2.3.2, the amplitude of the ripple of the output voltage will be smaller. The output voltages will also be higher, as the average choke current is 3.9 A, so more energy goes into the load. If there is a new transistor AOD4S60 in the circuit, the output voltage is higher. This is due to the fact that the on and off time of the transistor KP709 is longer, so the old one dissipates more energy into heat.

Next was a comparison of the dissipated energy on the transistors shown in Figure 3.13.

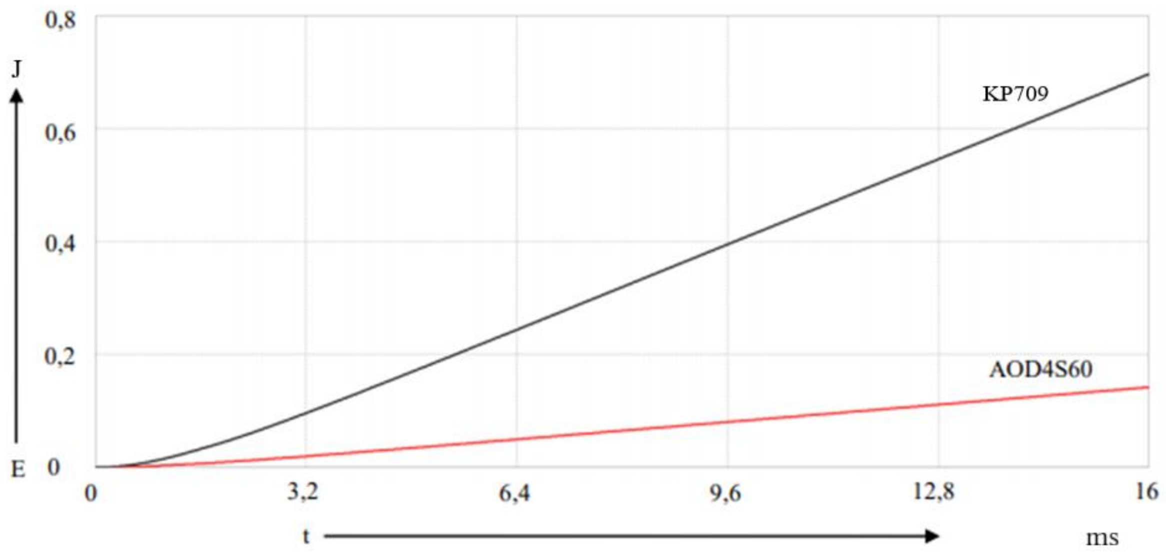

Figure 3.13 - Energy dissipation on transistors at ΔIL = 0.2 A

As in the previous paragraph, the new transistor has a fairly fast on and off time, which even at higher frequencies has less loss compared to the old one, which operates at a lower frequency.

3.2 Comparison of diodes of the old and new model in the circuit of a switching power supply

In switching power supplies, one of the important elements in addition to the semiconductor switch is the diode. Their number in the circuit may vary depending on the source circuit. Important parameters of the diode are the time of scattering of the bulk charge Trr and the dynamic resistance R_d . The task of this point of the diploma project is to prove that the diode of the old sample, in which the time of scattering of bulk charge is worse than that of the transistor of the new sample in PBVC.

Diodes of old and new model were found. The common parameters of these diodes were the reverse voltage U_{sv} = 600 V and direct I_{pr} = 10 A. From the old sample was selected pulse diode KD412B . This diode was found in the 1994 directory [30], so it can be argued that it was invented no later than this year. The diode FR1007 taken from the documentation of 2013 was chosen as a new sample .

The Schottky diode STPSC1006D was also found, which also belongs to the new sample, but has an even better scattering time of the bulk charge Trr [32]. Considering the diode KD412B, it was determined that its Trr = 1500 ns and R_d = 0.05 Ohm. Diode FR1007 has Trr = 500 ns and R_d = 0.03 Ohm, and Schottky diode STPSC1006D has Trr = 0, as it has a negligible time and is considered zero and R_d = 0.045 Ohm. In the Micro-cap program, a circuit for testing transistors for on and off times was created (Figure 3.14).

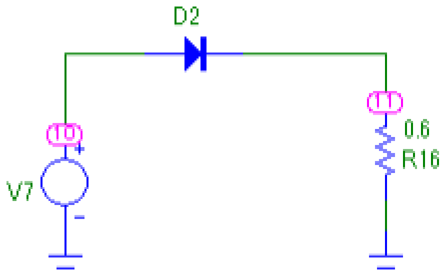

Figure 3.14 - Scheme of diode testing at time Trr

The V7 generator emitted pulses with a period of 6 μs, the duty cycle was 3 μs. Based on the method of MICRO-cap. The spice parameter TT (Charge Transfer Time) is responsible for the time of scattering of the bulk charge Trr. Next, the TT parameter was changed for the first two diodes to find the Trr parameter. For a Schottky diode, the TT parameter is zero. The results are shown in oscillograms 85-86.

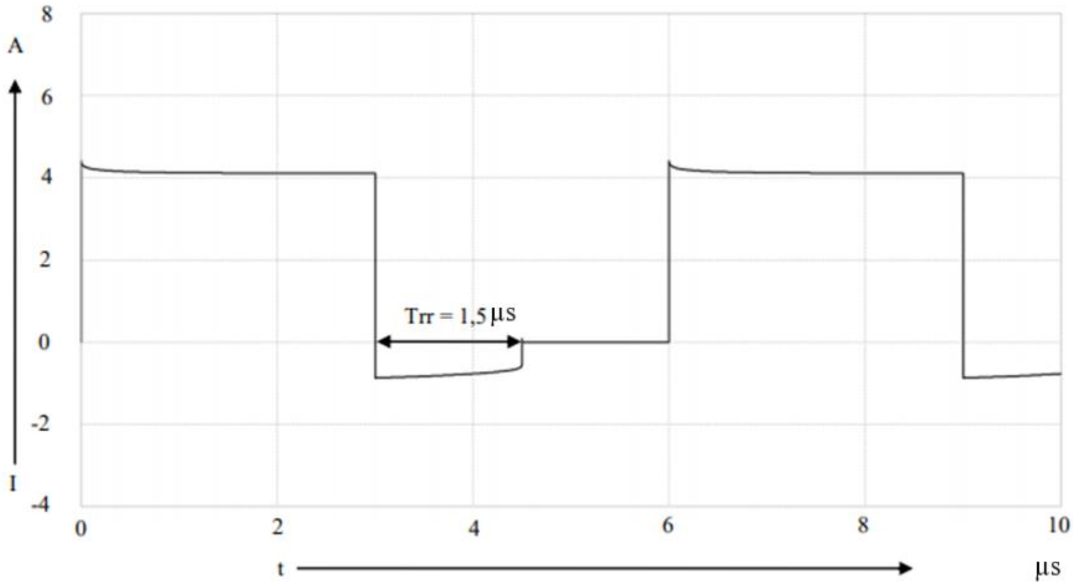

Figure 3.15 - Oscillogram of the diode current KD412B

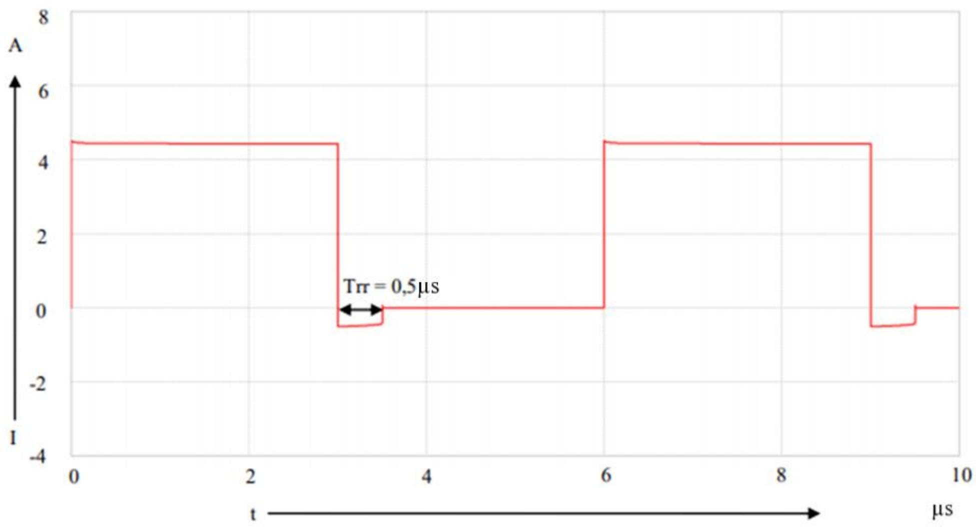

Figure 3.16 - Oscillogram of the current diode FR1007

For the diode KD412B the following parameter was obtained: TT = $0{,}815 \cdot 10^{-6}$ s, and for the diode FR1007 the parameter TT = $0{,}214 \cdot 10^{-6}$ s was obtained. Also with the help of the Model Editor program, the parameters IS, RS, N, IKF were found, thanks to which it is possible to correctly find R_d.

3.2.1 Operation of the circuit at a choke current amplitude equal to 0.5 A

The formed parameters were inscribed in the Spice-parameters of the diode D1 in the diagram Figure 3.1 . Other parameters were standard. As in paragraphs 2.3.1 - 2.3.3, the circuit will be studied at different amplitude currents of the choke ΔIL. At this point, the choke current varied from 3.5 A to 4 A. In the figure 3.17 shows the choke currents when using different diodes.

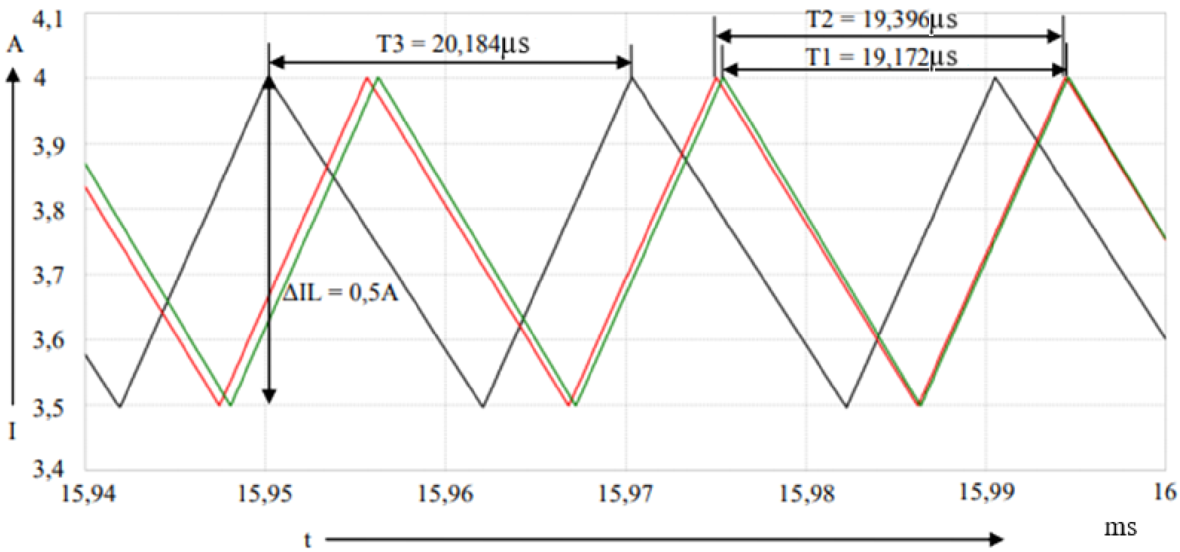

Figure 3.17 - Choke current with ΔIL = 0.5 A with diode KD412B in the circuit

Based on the graphs, it can be seen that the choke current frequency is as follows: with the old diode ≈ 49544 Hz, with the new diode ≈ 51557 Hz, and with the Schottky diode ≈ 52159 Hz. The following shows the oscillograms of the output voltage of the PBVC using three diodes at ΔIL = 0.5 A.

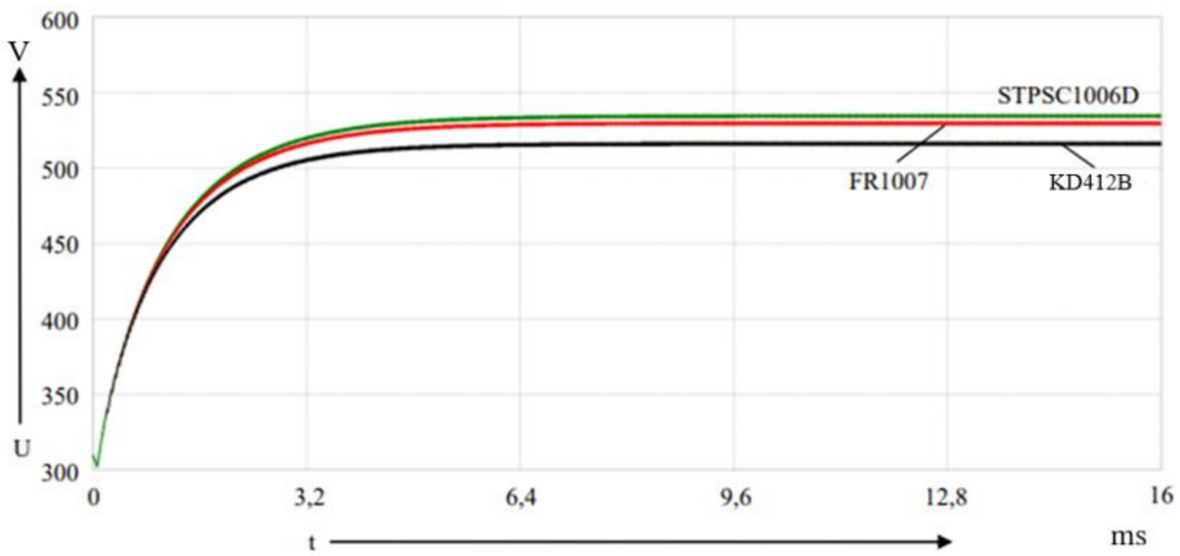

Figure 3.18 - Comparison of PBVC output voltages using all three diodes at ΔIL = 0.5 A

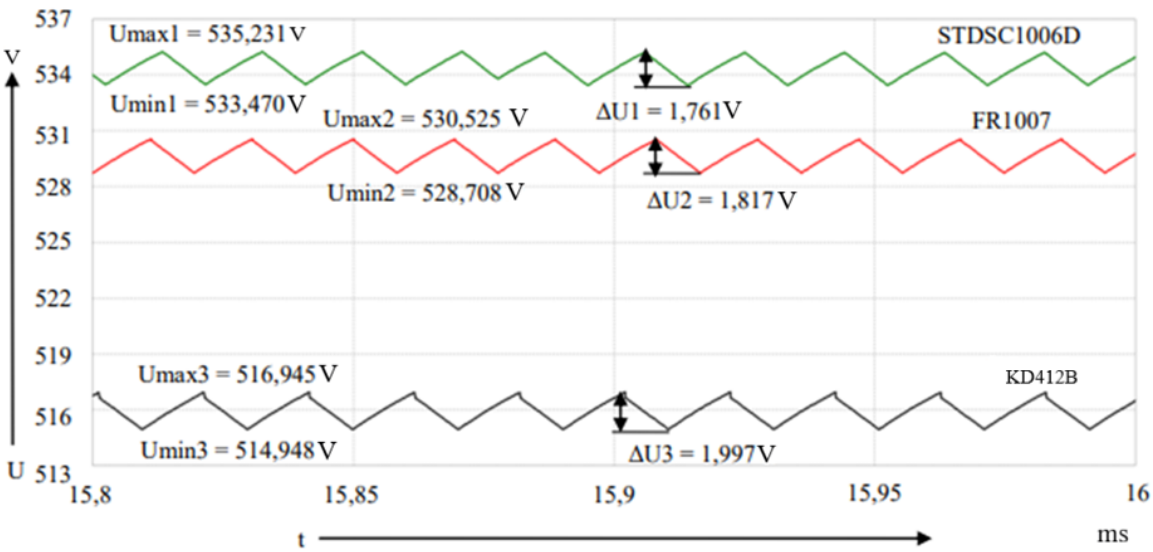

Figure 3.19 - Comparison of PBVC output voltages using all three diodes on an enlarged scale

At higher frequencies of the semiconductor switch, the output voltage is lower if you use the old diode. the cycle time has decreased, therefore, the recovery time of the closing properties of the diode remains the same for each diode, so the losses also increase, which will directly affect the output voltage. The following is the characteristic of energy dissipation on diodes at the amplitude of pulsations of the choke current equal to 0.5 A, which confirms that the losses have increased on the diodes, but much more losses in KD412V.

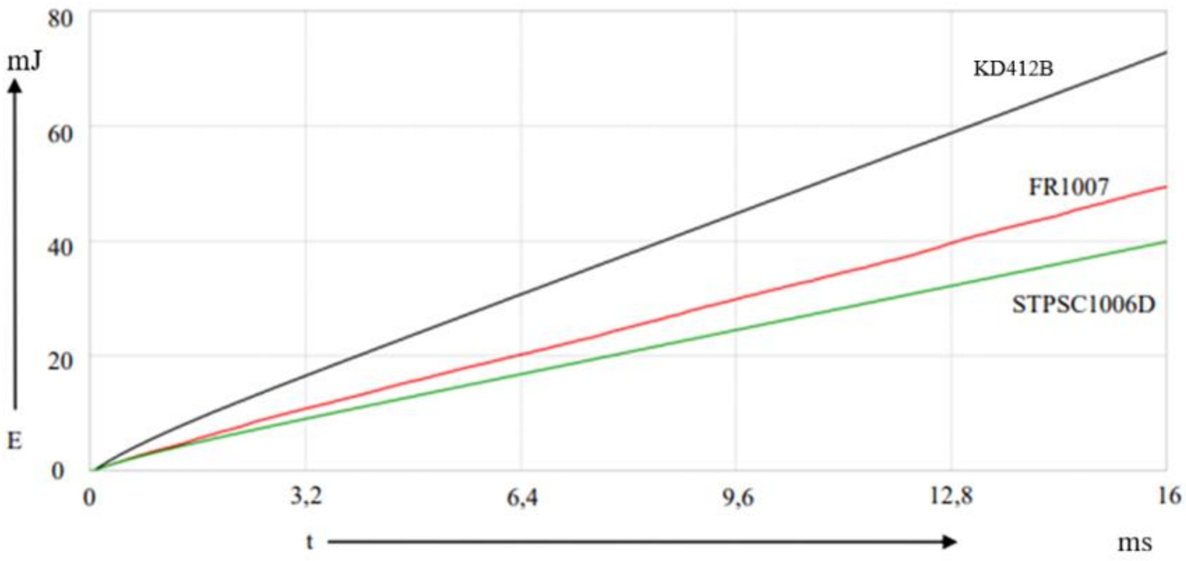

Figure 3.20 - Scattered energy on diodes with ΔIL = 0.5 A

3.2.2 Operation of the circuit at a choke current amplitude of 0.2 A

The following shows the choke currents at ΔIL = 0.2 A.

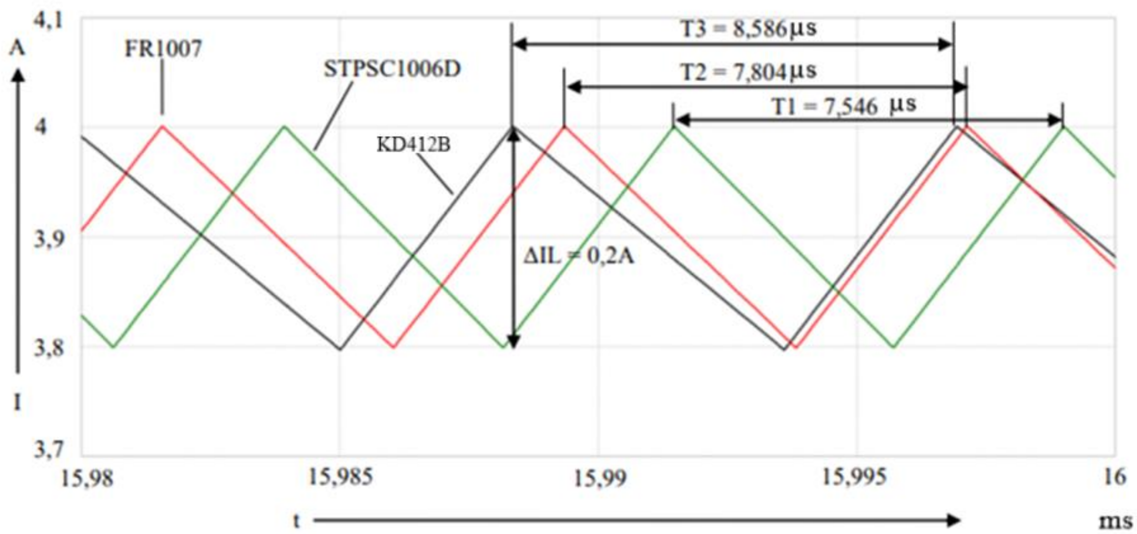

Figure 3.21 - Choke current at ΔIL = 0.2 A with different diodes

Based on the graphs, it can be seen that the choke current frequency is as follows: with the old diode ≈ 116469 Hz, with the new diode ≈ 128 139 Hz, and with the Schottky diode ≈ 132521 Hz. The following shows the oscillograms of the output voltage of the PBVC using three diodes at ΔIL = 0.2 A.

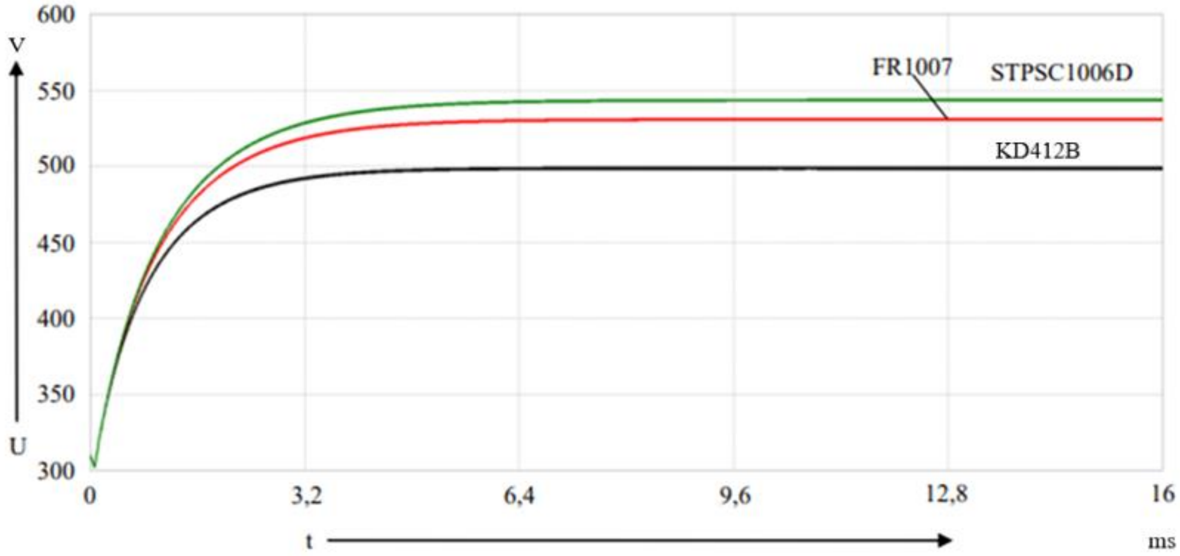

Figure 3.22 - Comparison of PBVC output voltages using all three diodes at ΔIL = 0.2 A

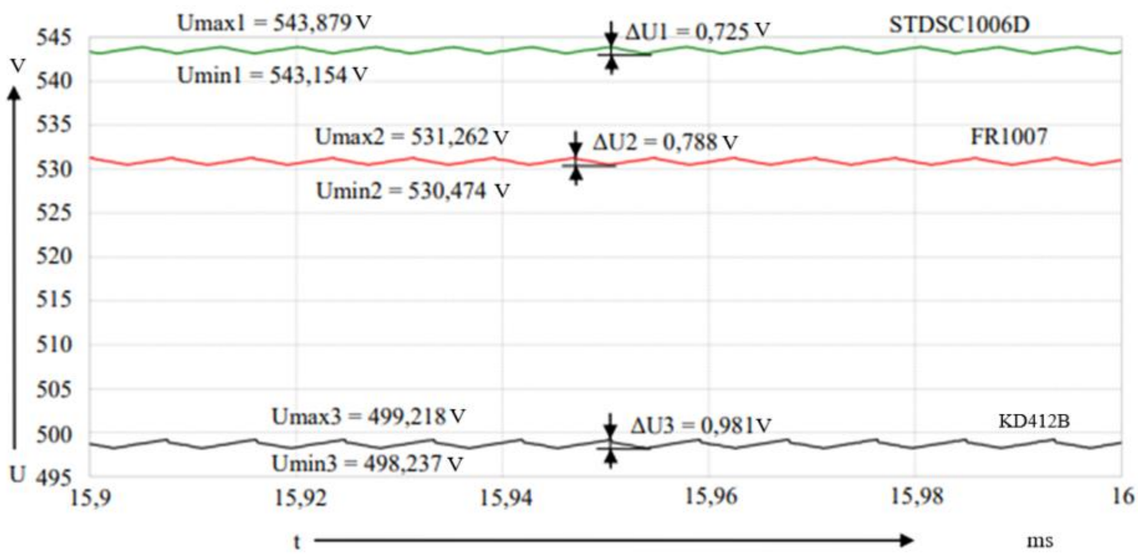

Figure 3.23 - Comparison of PBVC output voltages using all three diodes (enlarged scale)

At even higher frequencies of the semiconductor switch, the output voltage is lower, as in the previous paragraph, if you use the old diode. The cycle time has become even shorter, and the recovery time of the closing properties of the diode remained the same for each diode, so the losses also increase, which will directly affect the output voltage. The following is the characteristic of energy dissipation on diodes at the amplitude of pulsations of the choke current equal to 0.2 A.

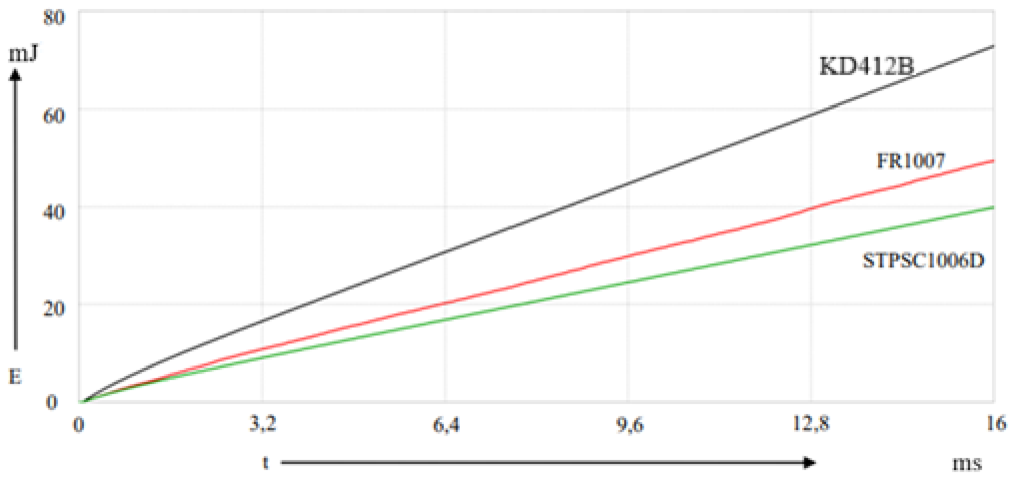

Figure 3.24 - Scattered energy on diodes with ΔIL = 0.2 A

As in previous cases, at higher frequencies, the dissipated energy is higher in the old diode, and the Schottky diode has the best value.

3.3 Conclusion to the section

Based on the results obtained, we can conclude that with a large amplitude of the choke current will be quite low frequency of the key. At this frequency, it does not matter what the transistor will be - old or new. The frequency will be almost the same and different opening and closing times of transistors will have little effect on the output voltage and energy dissipation on the transistors.

With amplitude pulsations of the choke current equal to 0.5 A and 0.2 A, the frequency of the key will increase significantly. The larger it is, the more energy will be dissipated on the cell, as the period decreases and the on and off time of the transistors remains the same. The old transistor has a higher value of time, therefore, and its losses will also be greater, which will affect the output voltage, which will be lower.

Based on the results obtained, we can conclude that with a large amplitude of the choke current will be quite low frequency of the key. At this frequency, it does not matter whether the diode will stand - old, new or Schottky diode. The frequency will be almost the same and different recovery times of the diode will have little effect on the output voltage of the PBVC and the energy dissipated on the diodes. With the amplitudes of the pulsations of the choke current equal to 0.5 A and 0.2 A, the frequency of the key will increase significantly. The larger it is, the more energy will be dissipated on the diodes, as the period decreases and the recovery time of the diode remains unchanged. The old diode is now larger, and therefore the losses in it also will be larger , which will affect the weekend voltage that will be less .

4 . LIFE SAFETY AND FUNDAMENTALS OF LABOR PROTECTION

Electrical safety - is a system of organizational and technical measures to protect people from the dangerous and harmful effects of electric current, electric arc, electromagnetic field, static electricity.

The main measures of protection against electric shock are:

· Ensuring the unavailability of live parts for accidental contact;

· Use of electricity with safe voltage values;

· Elimination of the danger of electric shock in the event of voltage on parts of electrical structures;

· Use of personal protective equipment against electric shock.

Inaccessibility of live parts for accidental contact is achieved by insulating them with non-conductive materials. Conductors must have working insulation. In some cases, *additional, reinforced* or *linear insulation is used.*

Inaccessibility of the location of conductive parts is achieved by placing them at a height, under the floor or hidden in the walls. Unprotected live parts that can be touched by people are securely protected in all cases if the voltage exceeds:

- 65 V - in rooms without increased danger;
- 42 V - in rooms with increased danger;
- 12 V - in particularly dangerous areas.

In the case of voltages above 250 V, not only unprotected but also insulated conductive parts are protected.

Application of low voltages - very effective protection against electric shock. For power supply of control circuits of the technological equipment established in especially dangerous rooms and rooms with the increased danger; control circuits for mobile equipment and for powering hand tools use a voltage not exceeding 42 V. On the cabinets and control panels of the equipment are placed sockets with a voltage not exceeding 12 V to include portable luminaires used during periodic inspections of hard-to-reach places.

Protective earthing, grounding and disconnection - the main measures to protect people from electric shock in the event of voltage on parts of electrical structures.

4.1 Improving the stability of operation organizations in emergencies

Sustainability of the organization in emergencies - is its ability to produce established types of products in the specified volumes and range, or accurately perform their functional duties.

Improving the sustainability of work begins with the organization and the study of the sustainability of the organization. The main purpose of the study is to identify weaknesses in the work and develop a set of measures to eliminate them.

The study includes three stages:

• organizational stage;

• assessment of the sustainability of the organization;

• development of measures to increase the sustainability of the organization.

Assessment of the sustainability of the organization includes the assessment of:

• the probability of external and internal emergencies of natural, man-made, military nature and their impact on the life of the organization;

• reliability of the system of protection of employees of the organization from the striking factors of emergencies of military, man-made and natural nature;

• physical stability of buildings, structures that provide systems;

• stability of material and technical supply and production links;

• stability of the control, communication and notification system;

• readiness of the organization to restore the violated function.

Measures to increase the sustainability of work are divided into: organizational, engineering and special.

Organizational activities include:

• forecasting the consequences of possible emergencies and developing action plans for peacetime and wartime;

• training of management staff to work in emergency situations;

• training of employees of the organization to comply with safety measures and methods of action in case of emergency;

• development of instructions to reduce the risk of accidents in the organization, as well as accident-free shutdown, localization of accidents, elimination of their consequences and the organization of the restoration of the broken production;

• creation and organization of the work of the commission to increase the stability of the organization and the dispatch service of the organization;

• preparation of the organization's forces and means for carrying out measures to eliminate the consequences of emergencies and resume production activities;

• establishing the size of dangerous areas around potentially dangerous objects of the organization;

• preparation for the evacuation of employees of the organization, the population, farm animals from dangerous areas;

• creation and maintenance of emergency alert and management systems in constant readiness, etc.

Engineering measures are aimed at improving the physical stability of buildings, structures, technological equipment, utilities, as well as to create conditions for rapid restoration work, increase the protection of workers, farm animals, plants and agricultural products.

Special measures are aimed at creating conditions for the organization's work in an emergency mode and to ensure the protection of workers in emergencies and to quickly eliminate the consequences of these situations.

4.2 Electrical safety measures

Technical means and measures for protection against electric shock include:

- use of low voltages;
- insulation of live parts (working, additional, reinforced, double);
- ensuring the inaccessibility of uninsulated live parts;
- protective earthing;
- zeroing, protective shutdown;
- equalization of potentials;
- electrical separation of networks;
- compensation of earth fault currents;
- fencing devices;
- warning alarm;
- locking; safety signs;

- means of protection and safety devices, etc.

Low voltage is a rated voltage not exceeding 42 V and is used to reduce the risk of electric shock. Regulatory documents provide for the use of two values of low voltages in production conditions - 12 V and 42 V. In rooms with high risk and especially dangerous voltage for local lamps, repair lighting and hand tools should not exceed 42 V. In addition, in particularly dangerous rooms, under adverse conditions (for example, work sitting or lying on a conductive floor) to power hand-held portable lamps requires an even lower voltage −12 V.

4.3 Fire safety measures

Establish the following fire regime in the premises, which provides:

- the order of smoking cigarettes. Smoking in houses and premises is prohibited. There are special places for smoking on the territory of the facilities, which are marked with fire safety signs or inscriptions - "Place for smoking" and equipped with urns for cigarette butts. The use of open flames is prohibited on the territory of the facilities (heating of frozen heating pipes, incineration of industrial waste, garbage, dry leaves, etc.);

- the procedure for using electric heating appliances. Boiling , heating and cooking are carried out in specially equipped places for this purpose with the use of electric kettles with automatic devices for switching off electric heating elements;

- the procedure for working with electrical appliances. It is forbidden to leave unattended electrical appliances and office equipment connected to the mains - personal computers, office equipment, radios, electric heaters, fans, air conditioners;

- the procedure for performing flammable works. Carrying out fire and other fire-hazardous works (gas-electric welding, gas-cutting, heating bitumen and resin) is allowed after carrying out preparation of the place of these works, coordination with the fire safety engineer and implementation of all planned fire safety measures; inspection of workplaces and premises at the end of the working day. Before finishing work and closing the premises, the person responsible for the fire condition of the premises (employee) must check the fire condition of the premises, disconnect voltage from all electrical installations and appliances (measuring, electronic, soldering irons, air conditioners, fans, computers, radios etc.), as well as from their power supply networks.

Close windows, windows. Detected violations of fire safety rules must be eliminated before closing the premises.

Fire safety measures in the process of work :

Staff actions in case of threat of fire or accident. Rules for switching off installations and units, the procedure for de-energizing electrical installations, calling for emergency assistance, etc.

Fire safety measures that must be observed when starting work, during work and after its completion in order to prevent fire.

GENERAL CONCLUSIONS

An inspection was conducted famous circuit design solutions of each switching power supply unit, and compared their parameters with each other. As a result, a diode bridge with a C-filter was chosen for the study as the most common circuit solution. SDCVCand PBVCwere selected as inverters.

Schematic decision that to improve the performance of switching power supplies is consistent discharge capacitors in the input blocks . This solution allows to reduce the ripple of the output voltage of the smoothed filter, while the total capacity of the filter remains the same. We can draw the opposite conclusion that with the same amplitude of pulsations of a conventional C-filter and a filter with alternating discharge of the capacitor, the latter will have a smaller total capacity. Another circuit solution is the lack of a filter capacitor at the input. This solution is only suitable for high-power low-frequency power supplies.

The analysis of the element base was given to the autogenerator unit . Diodes and field-effect transistors of the old and new models were analyzed. Since PIPs operate at high frequencies, the important parameters of the transistors are the time of opening and closing the transistor in the circuits of switching power supplies , and the diode its recovery time and dynamic resistance. In older samples, these parameters are larger and at high frequencies the loss will be much greater.

Modeling of the proposed circuit techniques was performed to confirm the above solutions and analysis. Using the program Micro-cap it was found that the discharge of the capacitor C1 with a delay delay

has the first capacitor the best indicators, in comparison with other circuit solutions of the next category of capacitors. It has also been proven that it is possible to do without a filter capacitor in the input unit.

It is important that the choke current is zero at the time when the voltage after the diode bridge is also zero, otherwise the drop in output voltage will be significantly significant. The program also collected the scheme of PBVC, which allows the analysis of the element base. The frequency of the semiconductor switch depends on the amplitude of the choke current, due to this it will be possible to conduct a more accurate analysis of the element base. Using the Model Editor program, we found Spice parameters that depend on the time of opening and closing the transistor, and the diode for its recovery time and dynamic resistance. With a large amplitude of the choke current, the frequency of the key will be quite small and the same when using any of the selected elements, so it does not matter which transistor or diode will be in the circuit.

As the amplitude of the choke current decreases, the frequency of the switch increases, but when using new elements in the circuit, the frequency increases significantly, which has a positive effect on the parameters of the choke and capacitor. Also, with increasing frequency, the losses of the old elements increase significantly, as the time of the key cycle decreases. So a lot better use more new diodes and transistors in switching power supply circuits .

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