1 Study of a step-down pulse-width DC-DC converter

1.1 Objective

The study of electromagnetic processes, external, regulatory and energy characteristics of a step-down pulse-width converter at an active-inductive load shunted by a diode.

1.2 Lab Description

In this laboratory work, we use: "Bench Power Module"/Модуль питания стенда/ (single-phase), "DC-DC Converters"/Преобразователи постоянного напряжения/, "Power Meter"/Измеритель мощности/, "Load"/Нагрузка/ (single-phase), and two-channel oscilloscope modules.

The front panel of the module "DC-DC Converters"is shown in Fig. one. The transformer circuit UZ1 is presented as a serial (voltage decreasing) key, and UZ2 as a parallel (increasing) key.

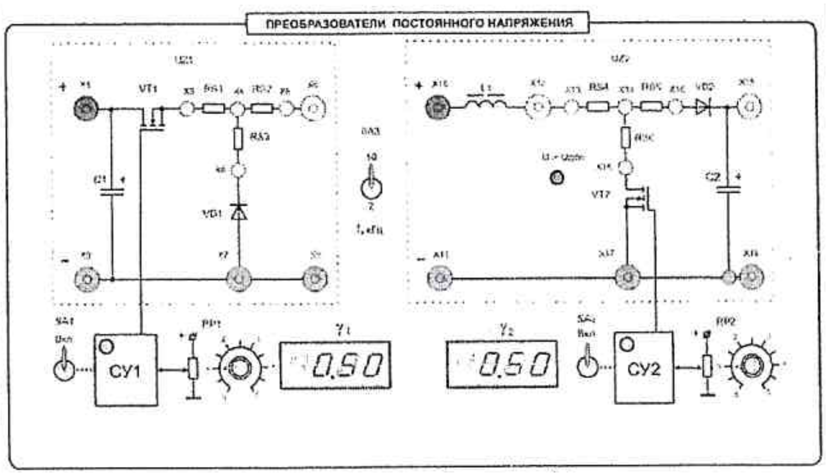


Рис. 1: The front panel of the module "DC-DC Converters".

The serial key is switched on by the toggle switch SA1, and the LED of the SU1/СУ1/ unit lights up. The fill factor (duty cycle) of the key is regulated by the RP1 potentiometer and is displayed on the adjacent 4-digit indicator. Similarly, $SA2$ and $RP2$ control the operation of the parallel key. When the permissible voltage is exceeded on the key, the led "$U > U_{\text{доп.}}$"lights up. The frequency of switching the keys is determined by the position of the toggle switch SA3. All shunts $RS1$ - $RS6$ with a resistance of 1 Ohm and are designed to take current waveforms.

1.3 The task

1. Assemble the circuit in accordance with fig. 1.1.
2. Take the waveforms of currents and voltages on the circuit elements for the given parameters.
3. Remove the adjusting $U_{Load} = F(\gamma)$ and energy $P_d = F(\gamma)$, $P_{Load} = F(\gamma)$, $\eta = F(\gamma)$, $q_i = F(\gamma)$ characteristics of the converter with a constant value of the load resistance R_{Load} and given U_d and $f_{carrier}$.
4. Observe the external $U_{Load} = F(I_{Load})$ and energy $P_d = F(I_{Load})$, $P_{Load} = F(I_{Load})$, $\eta = F(I_{Load})$, $q_i = F(I_{Load})$ characteristics at a constant duty cycle γ for given U_d and $f_{carrier}$.
5. To study the influence of the carrier frequency $f_{carrier}$ on the ripple coefficient q_i of the load current i_{Load}.

1.4 Initial data

The base point (mode) for which the waveforms are taken and through which the recorded characteristics pass:

mode – continuous;

carrier frequency $f_{carrier} = 2kHz$;

duty cycle $\gamma = 0.7$;

power supply voltage $U_d = 25V$;

load current $I_{Load} = 0.7A$.

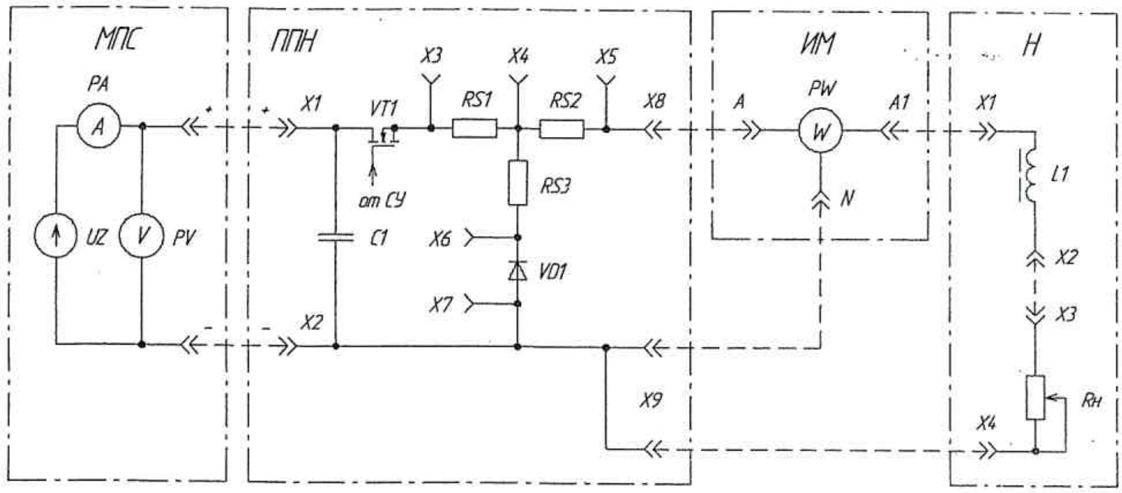
The base point can be changed as instructed by the teacher.

1.5 Guidelines

1. Assemble the circuit for the study of the DC-DC converter in accordance with Fig. 1.1. Additional external connections are indicated by dashed lines.

   Set the preset carrier frequency $f_{carrier}$ with the $SA3$ toggle switch. Set potentiometer knobs $RP1$, $RP2$ to position "0".

   Fig. 1.1. Schematic diagram for the study of a step-down DC-DC converter.



Set the handle of the load current regulator RP in the "Load"module (H) to the "0"position corresponding to the minimum load current (maximum load resistance R_{Load}).

Turn on the automatic machine $QF1$ "Stand Power Module" (SPM).

Switch on the "Grid"/"Сеть"/ toggle switch of the "Power Meter" module. To transfer the "Power Meter" module to the mode of measuring constant currents and voltages, simultaneously press the "$P/Q/S$"and "$f/\cos\varphi/\varphi$"buttons Keep the buttons pressed until "DC"/"Постоянный ток"/ appears on the display. Set measurement limits: toggle switch "U"30 V, toggle switch "I"2A.

Toggle switch SA1 to turn on the power of the control system of the "DC/DC Converter"module. Turn on the power source switch $SA1$ in the SPM module. Use potentiometer $RP1$ to set the target voltage of the power supply.

2. Take the waveforms of currents and voltages on the circuit elements for the given parameters.

   a) take the waveforms of the voltage on the transistor switch u_{VT} and the current through the transistor i_{VT}. To do this, check the desired value of the supply voltage U_d and set the desired value of the duty cycle γ with the handle of potentiometer $RP1$ (basic mode). Using the current regulator knob RP using the Power meter, set the desired value of the load current I_{Load}. Connect the channel $CH1$ of the oscilloscope to the shunt $RS1$ ("input socket , the case of the oscilloscope $\perp$ – socket $X4$), and the input of the channel $CH2$ – to socket $X1$ (voltage on the transistor key).

   Attention: hereinafter, before taking the oscillograms, check

the position of the zero line by moving the switch mode of the input inputs of the amplifiers "AC-GND-DC" to the position "GND". This line is first plotted on the waveform.

Draw from the oscilloscope screen the waveform. Define scales by voltage, current and time;

6) take the waveforms of the voltage on the diode u_D and the current through the diode i_D at the same given values U_d, γ and I_{Load}. To do this, connect the oscilloscope channel $CH1$ to the $RS3$ shunt ("input"is socket $X6$, the oscilloscope case $\perp$ is socket $X4$), and the channel input $CH2$ is connected to socket $X7$. Draw the oscillogram from the oscilloscope screen, preserving the scale;

c) take the waveforms of the voltage at the load u_{Load} and the load current i_{Load} at the same given values U_d, γ and I_{Load}. To do this, connect the oscilloscope channel $CH1$ to the $RS2$ shunt ("input socket $X4$, the oscilloscope case $\perp$ – socket $X5$), and the channel input $CH2$ – to socket $X7$ (load voltage). To obtain a positive voltage deviation u_{Load}, press the $CH2$ INV button on the oscilloscope. Draw waveforms from the oscilloscope screen, keeping the scale. Using the i_{Load} waveform, determine in what mode the circuit operates (continuous or intermittent current in the load).

3. Observe the adjusting $U_{Load} = F(\gamma)$ and energy $P_d = F(\gamma)$, $P_{Load} = F(\gamma)$, $\eta = F(\gamma)$, $q_i = F(gamma)$ characteristics of the converter at a constant value of load resistance R_{Load} and given U_d and $f_{carrier}$. Set basic mode. Determine the resistance R_{Load} by the formula

$$R_{Load} = U_{Load}/I_{Load}$$

When taking off the characteristics, do not touch the RP knob in the "Load"module. By changing the γ with the handle of the potentiometer $RP1$ in the range from zero to the maximum possible value, record the readings of the instruments U_d, I_d, U_{Load}, I_{Load}, P_{Load} and also use an oscilloscope to measure the amplitude of the ripple of the load current ΔI_{Load}. To do this, switch the oscilloscope channel $CH1$ to the open input "AC"(variable component of the input signal). Measure the double amplitude of the ripple of the load current ΔI_{Load}. Measure ΔI_{Load} only in the area of continuous current. The reading put in table 1.1. Mark the transition point from continuous to intermittent (boundary current).

γ							notes
U_d, V							
I_d, A							
U_L, V							$R_L =$,
I_L, A							$f_{carrier} =$
ΔI_L, A							
q_i							
P_d,W							
P_L,W							
η							

Energy indicators calculated by the following formulas:

input power

$$P_d = U_d \cdot I_d \tag{1}$$

efficiency

$$\eta = P_L/P_d \tag{2}$$

ripple current load

$$q_i \approx \Delta I_L/(2I_L) \tag{3}$$

Repeat the measurements for another, for example, twice as large as the active resistance of the load Rн.

Characteristics for different values R_n build in the same axis. Graphs for the capacities R_d and P_L, build in the same axis;

4. Observe the external characteristic $U_L = F(I_L)$ and energy characteristics $P_d = F(I_L)$, $P_L = F(I_L)$, $\eta = F(I_L)$, $q_i = F(I_L)$ at a constant duty cycle γ for given U_d and $f_carrier$. To do this, set the set duty factor γ with potentiometer $RP1$. Changing the load resistance with rheostat RP, record the readings U_d, I_d, U_L, I_L, P_L, ΔI_L.. Indications are listed in table 1.2.

R_L, Ohm							notes
U_d, V							
I_d, A							
U_L, V							
I_L, A							$\gamma =$, $f_{carrier} =$
$\Delta I_L, A$							
q_i							
P_d,W							
P_L,W							
η							

Repeat measurements with a different γ value, for example, $\gamma = 0.5$.

Characteristics for different values γ build in the same axes. Plots for the capacities P_d and P_L ,build in the same axis.

5. To study the influence of the carrier frequency $f_{carrier}$ on the ripple coefficient q_i of the load current i_L for the basic mode.

   Set the basic mode and determine the ripple coefficient q_i of the load current i_L. Switch the $SA3$ toggle switch to another position and again determine the ripple coefficient q_i at a different carrier frequency $f_{carrier}$.

   Switch off the toggle switch $SA1$ of the power supply of the control system of the "DC/DC Converter"module. Switch off the "Grid"toggle switch in the "Power meter" module. Switch off the power supply toggle switch $SA1$ in the MPS module. Turn off the automatic machine $QF1$ "Stand power module".

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Switch off the toggle switch $SA1$ of the power supply of the control system of the "DC/DC Converter"module. Switch off the "Grid"toggle switch in the "Power meter" module. Switch off the power supply toggle switch $SA1$ in the MPS module. Turn off the automatic machine $QF1$ "Stand power module".

1.6 Report content

The report should contain the following items:

1. the name and purpose of the work;
2. initial data, circuit diagram of power circuits;
3. processed waveforms;
4. the results of experimental studies and the calculations performed on them, placed in the corresponding tables;
5. constructed characteristics (regulatory, external and energy);
6. conclusions on the work:
   (a) explain the effect of the fill factor gamma on the voltage across the load of a step-down DC-DC converter;
   (b) explain the effect of the fill factor γ on the efficiency of the step-down DC-DC converter;
   (c) explain the effect of the carrier frequency $f_{carrier}$ on the ripple coefficient of the load current q_i.