1 Study of a step-up (boost) pulse-width DC-DC converter

1.1 Objective

The study of electromagnetic processes, external, regulatory and energy characteristics of a boost pulse-width converter constant voltage.

1.2 Lab Description

In this laboratory work are used: “Stand power module”/«Модуль питания стенда»/ (single-phase), modules “DC-DC Converters”/ «Преобразователи постоянного напряжения»/, “Meter power”/ «Измеритель мощности», “Load”/ «Нагрузка»/ (single-phase) and two-channel oscilloscope.

Front panel of the “DC/DC Converter” module shown in fig. 1. As a series (step-down voltage) the key is a diagram of the converter 071, and as a parallel (up) key

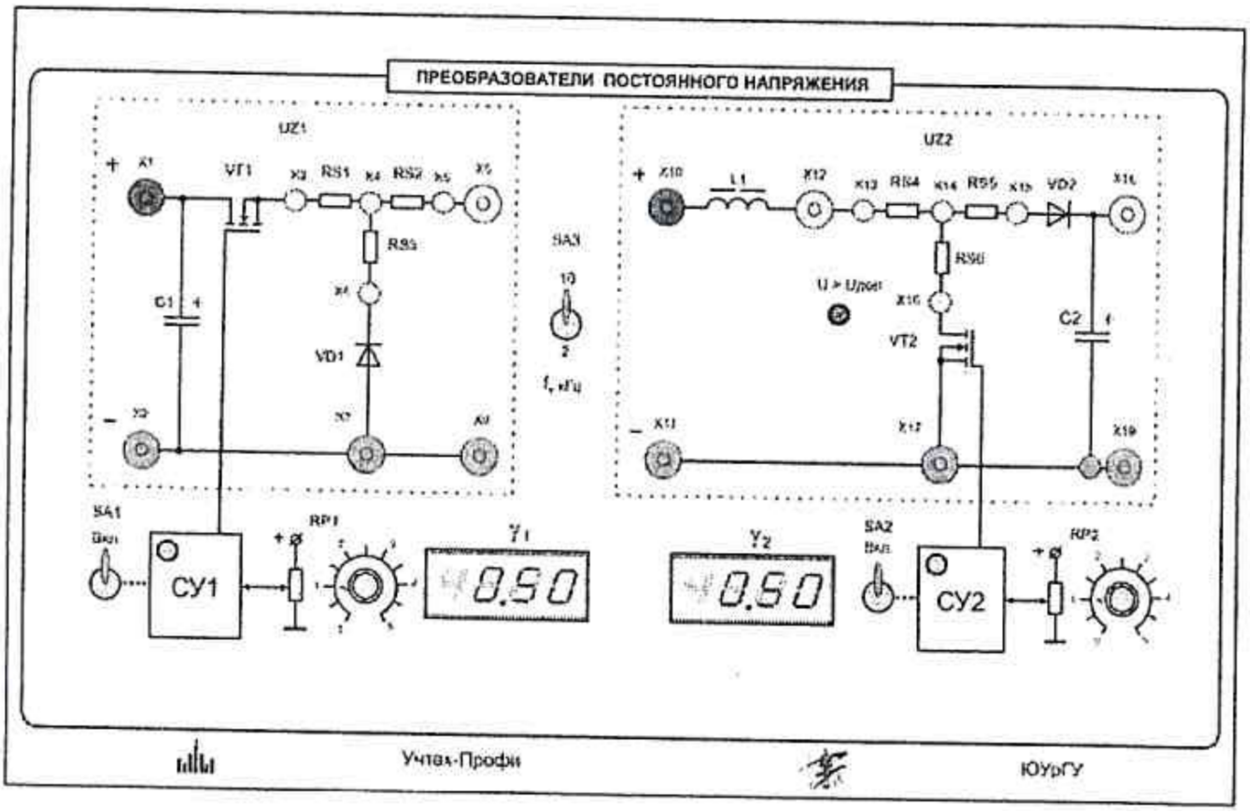

Рис. 1: The front panel of the module "DC-DC Converters".

The serial key is turned on by the toggle switch $SA1$, with this lights up the LED control panel СУ1. Duty cycle is adjustable by potentiometer

$RP1$ and displayed on a nearby 4-bit indicator. Similarly, $SA2$ and $RP2$ control the parallel key. If the key voltage exceeds the permissible voltage, the LED lights up $U > U_{\text{доп}}$ ($> U_{perm}$). The frequency of the switching keys is determined by the position of the toggle switch $SA3$. All shunts $RS1$ – $RS6$ with a resistance of 1 Ohm are designed to take waveforms of currents.

1.3 The task

1. Assemble the circuit in accordance with fig. 2.1.
2. Take the waveforms of currents and voltages on the circuit elements for the given parameters.
3. Take the control $U_L = F(\gamma)$ and energy $P_d = F(\gamma)$, $P_L = F(\gamma)$, $\eta = F(\gamma)$, $q_{ripple} = F(\gamma)$ characteristics of the converter at a constant value of the load resistance R_L and the given U_d and carrier frequency $f_{carrier}$.
4. Take the external $U_L = F(I_L)$ and energy $P_d = F(I_L)$, $P_L = F(I_L)$, $\eta = F(I_L)$, $q_{ripple} = F(I_L)$ characteristics with the duty cycle γ for given U_d and $f_{carrier}$.
5. Investigate the influence of the carrier frequency f on the ripple coefficient q_{ripple} of the voltage at the load u_L.

1.4 Initial data

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

carrier frequency	$f = 2$ kHz;
ducy cycle	$\gamma = 0.6$;
power supply voltage	$U_d = 15$ V;
load current	$I_L = 80$ mA.

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. 2 Additional external connections are indicated by dashed lines.

   Set the given carrier frequency $f_{carrier}$ with the $SA3$ toggle switch. Set potentiometer knobs $RP1$, $RP2$ to position «0». Set the handle of the load current regulator RP in the "Load"(«Нагрузка») module (H) to the «0» position corresponding to the minimum load current (maximum load resistance).

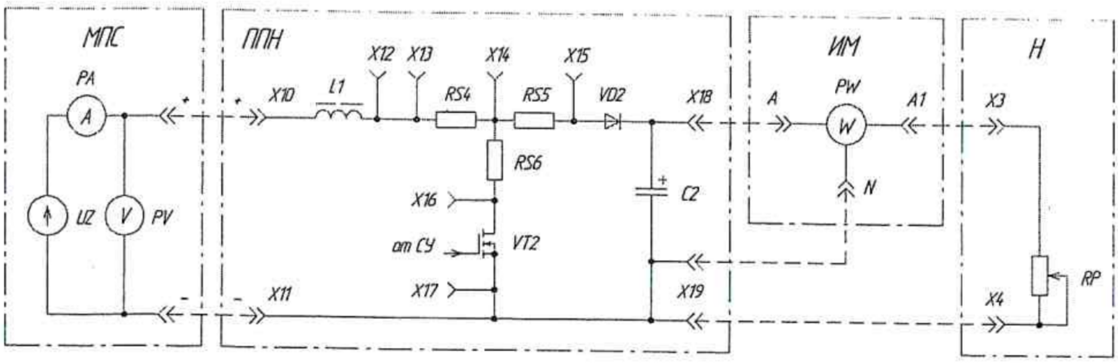

Рис. 2: Schematic diagram for the study of a step-up DC-DC converter

Turn on the automatic switch $F1$ "Stand power module"/«Модуль питания стенда» (МПС).

Switch on the "Grid"/«Сеть» toggle switch of the "Power Meter"/«Измеритель мощности» module. To transfer the "Power Meter"/«Измеритель мощности» 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» 300 V, toggle switch «I» 0.2 A.

Toggle switch $SA1$ to turn on the power of the control system of the "DC/DC Converter"/«Преобразователь постоянного напряжения» module.

Switch on the power supply toggle switch $SA2$ in the "Stand power module"/МПС module, and using the potentiometer $RP1$ set the set 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 set value of the supply voltage U_d and set the set value of the ducy cycle γ with the handle of the potentiometer $RP2$ (basic mode). Using the knob of the current regulator RP, set the set value of the load current I_L. Connect the channel $CH1$ of the oscilloscope to the $RS6$ shunt ("input" – socket $X14$, the oscilloscope case "$\perp$" – socket $X16$), and the input of channel $CH2$ – to socket $X17$ (voltage on the transistor key). To obtain a positive voltage deviation u_{VT}, press the $CH2\,INV$ button on the oscilloscope.

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;

(b) to take an oscillogram of the current consumed from the i_d power source at the same given values U_d, γ and I_L. To do this, connect the oscilloscope channel $CH1$ to the $RS4$ shunt ("input" – socket $X13$, oscilloscope housing "$\perp$" – socket $X14$). Draw the waveform, save the scale;

(c) 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_L. To do this, connect the oscilloscope channel $CH1$ to the $RS4$ shunt ("input" – socket $X14$, the oscilloscope housing "$\perp$" – socket $X15$), and the channel input $CH2$ – to socket $X18$. To obtain a positive voltage deviation u_D, press the $CH2\,INV$ button on the oscilloscope. Draw the oscillogram from the oscilloscope screen, save the scale;

(d) to take a waveform of the voltage at the load u_L at the same given values U_d, γ and I_L. To do this, connect the oscilloscope housing "$\perp$" to socket $X19$, and the input of channel $CH2$ to socket $X18$. Draw the oscillogram from the oscilloscope screen, save the scale.

3. Take the control $U_L = F(\gamma)$ and energy $P_d = F(\gamma)$, $P_L = F(\gamma)$, $\eta = F(\gamma)$, $q_{ripple} = F(\gamma)$ characteristics of the converter with a constant value of the load resistance R_L and given U_d and $f_{carrier}$. Set basic mode. Determine R_L by the formula

$$R_L = \frac{U_L}{I_L}$$

By changing the γ with the handle of the potentiometer $RP2$ in the range from 0.1 to 0.8, observe the current I_d and voltage U_L. They should not exceed respectively 1 A and 100 V. Record the readings of the U_d, I_d, U_L, I_L, P_L devices, and also using an oscilloscope to measure the amplitude of the voltage ripple on the U_L 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 voltage on the U_L

load. Populate the measurements into table 2.1. Mark the transition point from continuous to intermittent (boundary current).

Table 2.1

$gamma$							notes
U_d, V							
I_d, A							
U_L, V							
I_L, A							$\gamma =$, $f_{carrier} =$
$\Delta U_L, V$							
q_{ripple}							
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

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

ripple ratio at load

$$q_{ripple} \approx \frac{\Delta U_L}{2U_L} \tag{3}$$

Repeat measurements with another, for example, twice as high load resistance R_L.

The characteristics for different R_L values are built in the same axes. Graphs for P_d and P_L capacities, build on the same axis;

4. Take the external $U_L = F(I_L)$ and energy $P_d = F(I_L)$, $P_L = F(I_L)$, $\eta = F(I_L)$, $q_{ripple} = F(I_L)$ characteristics with duty cycle γ for given U_d and $f_{carrier}$. To do this, set the set duty cycle γ with potentiometer $RP1$. Changing the load resistance with a rheostat RP, record the readings U_d, I_d, U_L, I_L, P_L, U_L, ΔU_L. in table 2.2.

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

   The characteristics for different γ values are built in the same axes. Graphs for P_d and P_L capacities, build on the same axis.

5. To study the influence of the carrier frequency $f_{carrier}$ on the ripple coefficient q_{ripple} of the voltage at the load for the basic mode.

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

   Turn off the toggle switch $SA2$ of the power supply of the "DC/DC Converter" module, and then the automatic machine $QF1$ of the "Power module of the stand".

   Table 2.2

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

1.6 Report content

The report should contain the following items:

- the name and purpose of the work;
- initial data, circuit diagram of the installation;
- processed waveforms;
- the results of experimental studies and the calculations performed on them, placed in the corresponding tables;
- constructed characteristics (regulatory, external and energy);
- conclusions on the work:

– explain the effect of the gamma duty cycle on the load voltage of the boost DC-DC converter;

– explain the influence of the fill factor y on the efficiency of the step-up DC-DC converter;

– explain the effect of the carrier frequency f on the ripple factor of the voltage q.

1.7 Control questions

- What are the components of power loss in key mode?
- What is the control characteristic of a step-up DC-DC converter? What kind does she have?
- What is the external characteristic of a step-up DC-DC converter? What kind does she have?
- How to determine the coefficient of ripple voltage on the load?
- What is affected by a change in carrier frequency?
- How to determine the efficiency of a DC / DC converter?
- How to take the waveforms of currents and voltages in the circuit?
- How to connect the inputs of two-channel oscillography of currents and voltages?