MARITIME UNIVERSITY OF SZCZECIN

ORGANIZATIONAL UNIT:
DEPARTMENT OF MARINE COMMUNICATION TECHNOLOGIES

INSTRUCTION

ELECTRICAL ENGEENERING AND ELECTRONICS
Laboratory
Exercise No 5: Power supplies

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Is valid from: 25. IX 2017	

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5. POWER SUPPLIES

5.1. The purpose and scope of the exercise

The aim of the exercise is to have knowledge of the construction, parameters, characteristics and use of power supplies.

Issues

1. Definition of the power supply.
2. Block structure of the power supply.
3. Rectifier circuits.
4. Filtration in the power supply.
5. Stabilization in the power supply.
6. Pulse stabilizers

Control questions

1. Discuss the basic types of rectifiers
2. Discuss the block structure of the power supply.
3. Discuss the purpose of the individual parts of the power supply.
4. What is the principle of straightening?
5. What do we call a rectifier?
6. What do we call a half-wave rectifier?
7. What we call a full-wave rectifier?
8. What is a bridge rectifier (Graetz)?
9. What do we call the ripple factor?
10. What are the advantages and disadvantages of the basic rectifier circuits?
11. What are the roles of filters placed on the output of the rectifier?
12. What types of filters are used at the output of the rectifier?
13. What are stabilizing systems?
14. How does the simplest voltage stabilizer with the Zener diode work?
15. How does the serial stabilizer with the transistor work?
16. What is a serial stabilizer with an additional amplifier?

5.2. Description of the laboratory stand

A set of instruments:

1. The autotransformer.
2. Transformer
3. One-channel oscilloscope,
4. Voltmeter,
5. Circuit board for testing of power supply

5.3. The course of the exercise

The first part of the exercise uses an oscilloscope. The test systems are the basic rectifier circuits built on semiconductor diodes. In the second part of the exercise, the influence of the filter on the output voltage waveform and the influence of the load on the output voltage of the rectifiers is examined. The third part of the exercise examines the dependence of the stabilizers output voltage on the input voltage. An autotransformer, transformer and voltmeter are used. The tested objects are: power supply with Zener diode, power supply with transistor stabilizer and monolithic power supply.

WARNING! AUTOTRANSFORMER CAN ONLY BE USED ON THE PERMISSION OF A LEADER EXERCISE.

5.3.1. Study of rectifier circuits

Assemble the measuring system from Fig.5.3.1.

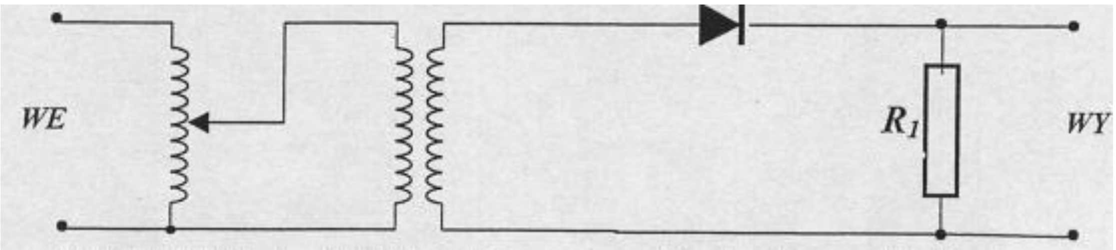

Fig. 5.3.1. The measuring system for testing a half-wave rectifier

Redraw the voltage waveforms observed on the oscilloscope at the input and output of the system. Measure and note the amplitude and period of voltage at the input and output.

Assemble the measuring system from Fig. 5.3.2.

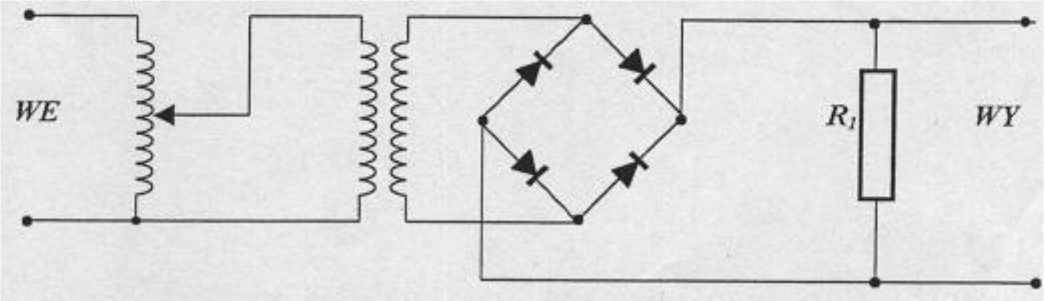

Fig. 5.3.2. The measuring system for testing a full-wave rectifier

Redraw the voltage waveforms observed on the oscilloscope at the input and output of the system. Measure and note the amplitude and period of voltage at the input and output.

5.3.2. Testing the effect of the filter on the output voltage waveform

Assemble the measuring system from Fig. 5.3.3.

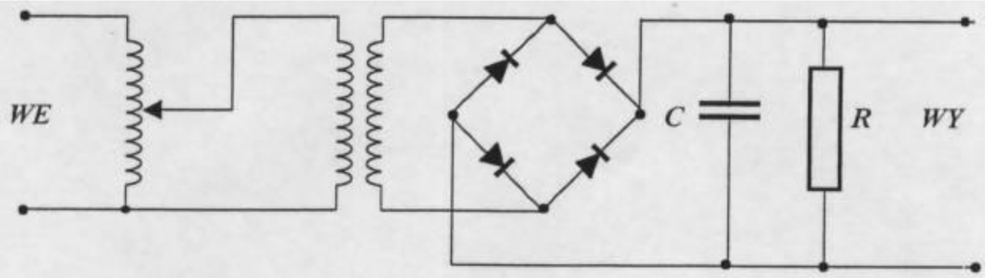

Fig. 5.3.3. A measuring system for testing rectifying filters

Connect the load resistances R_1. Changing the capacitors in the filter, redraw the C_1, C_2 and C_3. waveforms.

Measure the ripple factor on the output for all nine combinations of load resistor and capacitor in the filter.

C_1 = 47 μF	C_2 = 470 μF	C_3 = 1000 μF
R_1 = 1 kΩ	R_2 = 0,5 kΩ	R_3 = 0,3 kΩ

Measuring of the ripple factor:

The ripple factor is defined as follows:

$$k_f = \frac{U_{\approx}}{U_{=}} \cdot 100\%$$

where:

k_f - ripple factor,
$U_{\approx}$ - the value of the AC component of the output voltage,
$U_{=}$ - the value of the DC component of the output voltage,

τ is a time constant calculated from the equation: $\tau = RC$

To measure the DC and AC components of the output voltage, connect two voltmeters to the power supply output. First voltmeter set on DC voltage measurement, 20V range. Set the second voltmeter to the AC voltage measurement for the 2V range. Measure the ripple factor on the output for all nine combinations of load resistor and capacitor in the filter.

5.3.3. Study of transient stabilizer characteristics $U_O = f(U_I)$

Assemble the measuring system from Fig. 5.3.4.

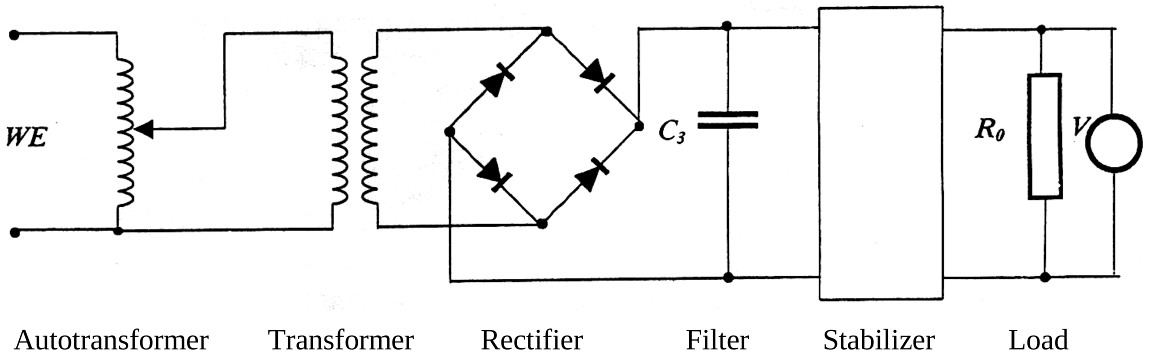

Fig 5.3.4. A measuring system for testing stabilizers

For all three stabilizers at first load $R_0 = \infty$ (disconnect), and next $R = R_1, R_2, R_3$ measure the output voltages by changing the voltage on the autotransformer from 110 V to 220 V. Use the autotransformer scale to measure. In the report, draw the characteristics $U_O = f(U_I)$ for all stabilizers. In each stabilizer for all three load resistances. Connect the capacitor C_3 as a filter.

5.4. Assessment conditions

The condition for assessment of the exercise is:

- to write a short test at the beginning of the class with a positive result,
- to do the exercise,
- preparing a report according to the instructions below,

- positive assessment of the report on the next class.

The report should include:

- diagrams of measuring systems,
- schematics of rectifying circuits, filters and stabilizers, oscillograms drawn at point 5.3.1,
- tables and chart $k_f = \mathrm{f}(\tau)$, where $\tau = RC$ is a time constant,
- explanation of the impact of the filter on the ripple factor,
- explanation of the impact of the load resistance on the ripple factor,
- explanation of the influence of the time constant on the ripple factor,
- tables and $U_O = \mathrm{f}(U_I, R_0)$ characteristics for all stabilizers. In each stabilizer for all three load resistances,
- own conclusions and observations.

5.5. Theoretical part

5.5.1. Block diagram of the power supply

The power supply is an electronic system used to convert the AC voltage commonly available in the network to the DC voltage required to supply electronic circuits. The power supply is usually built from four basic blocks as in the figure below:

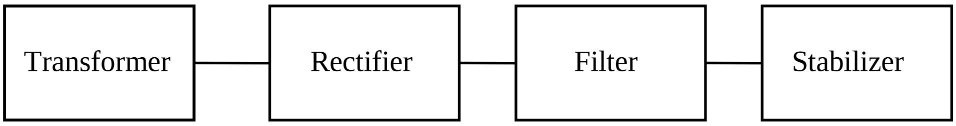

Fig. 5.5.1 Block diagram of the power supply

5.5.2. Transformer

The transformer is an inductive element consisting of at least two windings, designed to transfer energy from the primary winding to the secondary winding. In electronics, the transformer is usually used to raise or lower the voltage, and to adjust the resistance of the load placed on the secondary side to the resistance of the source located on the primary side. Often, transformers are used as coupling elements for individual stages in amplifiers. The transformer's gear (ratio of transformation) *p* is called the ratio of the number of windings of the secondary winding n_2 to the number of windings of the primary winding n_1. In an ideal transformer, i.e. lossless, we have the following relationships between turns, voltages and currents:

$$p = \frac{n_2}{n_1} = \frac{U_2}{U_1} = \frac{I_1}{I_2}$$

If we want to obtain a resistance matching, the transformer ratio must be set so that it is equal to::

$$p = \sqrt{\frac{R_2}{R_1}}$$

where: R_1 is the source resistance and R_2 is the load resistance.

5.5.3. Rectifier

The rectifier converts an alternating electrical voltage with positive and negative values into a waveform that has only one character value, either positive or negative. For this purpose, it is necessary to pass the current through a nonlinear element having the properties of unidirectional current conduction. Today, the role of such an element, especially in electronic systems, is usually a semiconductor diode. Rectifiers are used, i.a. in power supplies and demodulators. Rectifying can be performed in one-way rectifiers called half-wave rectifiers and in two-way rectifiers, otherwise known as full-wave rectifiers. In a half-wave rectifier, the alternating voltage is converted to a one-character waveform by eliminating the value of the opposite sign. The arrangement of such a rectifier and waveforms at its input and output when controlling a sinusoidal signal are shown in Figure 5.5.2.

The diode is switched on so that it only conducts for positive half-wave input. Only then the voltage is greater than the potential at the cathode (it should be at least the diode voltage barrier voltage, i.e. 0.2 V for germanium diodes or 0.65 V for silicon diodes). The average value U_{av} of voltage obtained from straightening sinusoidal voltage with effective value *U* and amplitude u_m is equal to:

$$U_{av} = \frac{\sqrt{2}}{2} U = 0.45U = 0.318U_m$$

In the negative half-period, the diode does not conduct and all voltage applied to the rectifier appears on the diode. Therefore, the diode should be chosen so that its maximum working voltage is higher than the amplitude of the rectified voltage.

U_I

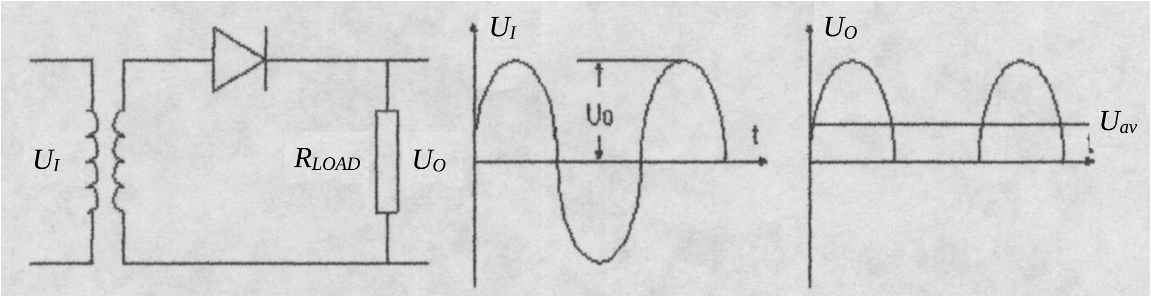

Fig. 5.5.2 Half-wave rectifier

Full wave rectifying can be done in two ways. In a system with center-tapped transformer and Graetz bridge. The rectifier system with center-tapped (split) transformer winding and waveforms with sinusoidal signal control are shown in the figure below:

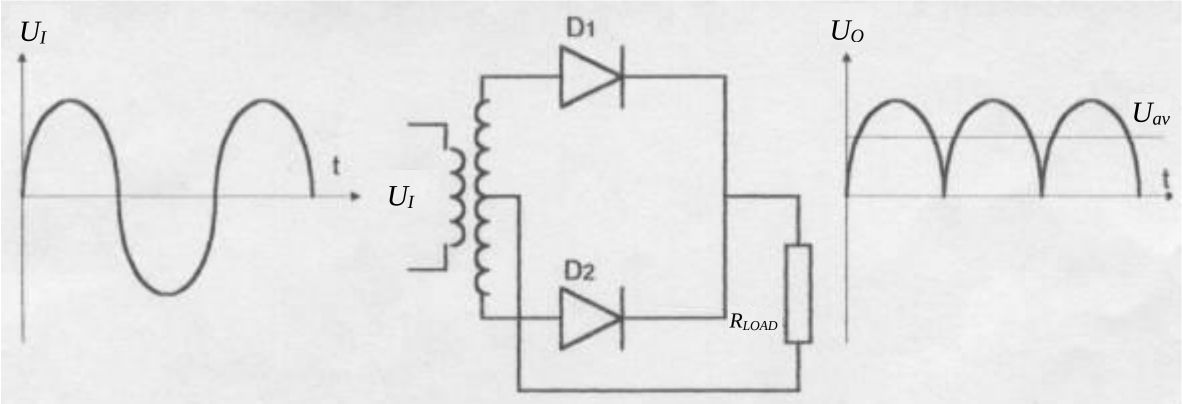

Fig. 5.5.3 Full-wave rectifier using a center-tapp transformer

The center of the transformer winding is grounded. At the zero potential, at the positive half voltage the diode D_1 conducts, and the diode D_2 does not conduct. On the other hand, at the negative voltage half the diode D_2 conducts, and the diode D_1 does not conduct. At the resistor of the load, the current at both halves flows in the same direction. The average value of the voltage at the output of the two-wire rectifier is twice as high as in the case of a one-stage rectifier.

The full-wave rectifier in bridge system, also called the Graetz system, and the waveforms when controlling the rectifier with a sinusoidal signal are shown in Figure 5.5.4.

For a positive half of voltage, diodes D_1 and D_3 conduct, and do not conduct diodes D_2 and D_4. The current flows from the upper end of the winding through diode D_1, load resistor, diode D_3 to the lower end of the winding. The diodes D_2 and D_4 conduct for negative half of the voltage. Then do not conduct diodes D_1 and D_3. The current flows from the lower end of the winding through diode D_2, load resistor and diode D_4 to the upper end of the transformer winding. The current in both cases flows in the same direction through the load resistor. In a bridge system, we get twice the output voltage than in a split winding system with the same number of windings on the secondary winding of the transformer.

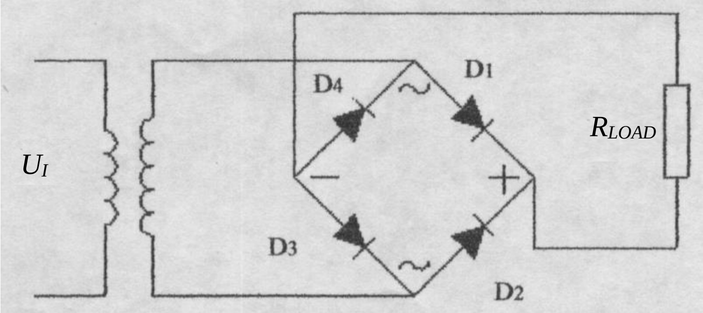

Fig. 5.5.4 Full-wave rectifier using a Graetz bridge

5.5.4. Filter

The purpose of the filter is to supply the rectifier obtained at the output to the form as close as possible to the DC voltage, i.e. the maximum "smoothing" of the voltage waveform. The simplest and the most commonly used filter in electronic systems is an electrolytic capacitor with a sufficiently large capacity connected in parallel to the load as shown in the figure below::

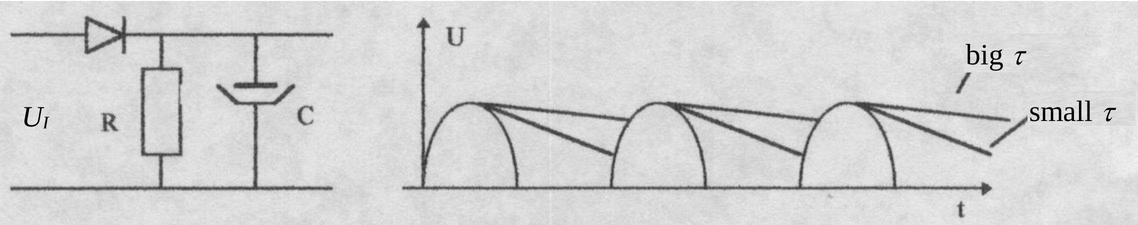

Fig. 5.5.5 The principle of filtration

The filter operation is as follows:

During the increase of the voltage at the output of the rectifier, the capacitor is charged. Because the capacitor is charged in a very low resistance circuit (diode polarized in the forward bias), the charging process is very fast. When the voltage at the output of the rectifier begins to decrease, the process of discharging the capacitor begins.

Discharge is carried out by load resistance (the diode is now polarized in the reverse direction). Depending on the capacity value and the load resistance, and strictly speaking depending on the time constant $\tau = RC$, the discharge process can be shorter or longer. A larger time constant, and therefore a larger capacity and load resistance (i.e. a higher charge in the condenser and a lower discharge current), causes a longer discharging time, the voltage becomes more constant.

The measure of the quality of filtration is the value of the ripple factor. The ripple factor k_f is called the ratio of the effective value of the AC voltage component at the filter output to the DC voltage component value at this output. The smaller the ripple factor, the better the filtration.

A better filtration can be obtained if instead of a capacitor, we connect the coil in series with the load. However, this is a much larger, heavier and more expensive element, therefore it is used only when there are particularly high requirements regarding output voltage filtration.

It should be noted that the ripple factor depends not only on the filter used, but also on the load. Increasing the load, i.e. power consumption from the power supply, causes the increase in the value of the ripple factor.

5.5.5. Stabilizer

A stabilizer is a system used to obtain a constant (more precisely, almost constant) output voltage or output current from the power supply when the supply voltage changes or load changes. The basic element currently used for the construction of stabilizers is the Zener diode.

The characteristics of the Zener diode show that when the current flows through it in the direction of the barrier (diode is reverse biased), regardless of the value of this current, the diode voltage is almost constant and equal to the so-called Zener voltage. Zener diodes are made for various voltages ranging from a few to several dozen V. The best characteristics, because the least dependent on temperature, have diodes for voltages in the range of 6 - 7 V.

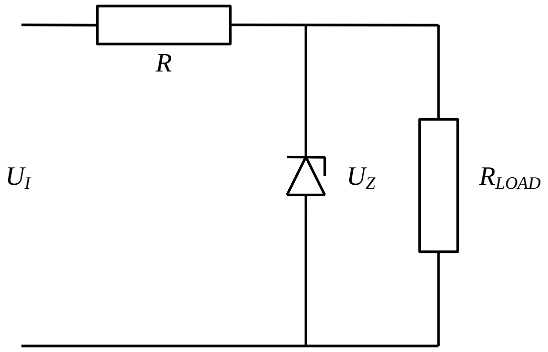

Fig. 5.5.6 Simple stabilizer witch a Zener diode

If the input voltage is lower than the Zener voltage, the current through the diode does not flow and the voltage on the load is equal to the input voltage. There is no stabilization in this case. If the input voltage exceeds the Zener voltage, a current with a value depending on the input voltage flows through the diode. On the *R* resistor, there is a voltage drop proportional to the current flowing, and the voltage on the load is constant and equal to the voltage of the Zener diode. So there is voltage stabilization.

The presented stabilizer system can be used only at low power consumption, due to limited admission power of Zener diodes. Additional transistors are often used to increase the power transmitted by the stabilizers. In this case, the Zener diode is the element determining the output voltage, while the transistor is used to adjust it.

Currently, monolithic stabilizers are becoming more and more common. The entire stabilizer system is made in the form of an integrated circuit. They are characterized by greater accuracy of stabilization.

Very often, the power supplies have additional current limiting or current stabilization systems. They allow setting the maximum output current of the power supply. The limiting system protects the power supply against overload and protects the tested system connected to the power supply before destruction.