Lodz University of Technology
Institute of Physics

Laboratory of electronics

Exercise E13IFE

Power supply

Version 1.1 (April 2018)

Table of contents:

Before you start to perform an experiment you are obliged to have mastered the following theoretical subjects:

1. Semiconductor rectifier diodes. [1], [2].
2. Half-wave rectifier. [1].
3. Full-wave rectifier. [1].

1. Purpose of the exercise

The comprehension and measurement of the semiconductor rectifiers is the purpose of this experiment. The half-wave and full-wave silicon diode rectifiers with and without low-pass output filters are investigated.

2. Hazards

Type	Absence	Low	Medium	High
electrical radiation hazards		+		
optical radiation hazards	+			
mechanical hazards (including acoustic hazards, noise)	+			
electromagnetic radiation hazards (invisible)	+			
biological hazards	+			
ionizing radiation hazards	+			
chemical hazards	+			
thermal hazards (including explosion and fire)	+			

The cables with banana plugs are designed exclusively for use in low-voltage circuits - do not connect them to the mains supply 230 V.

3. Introduction

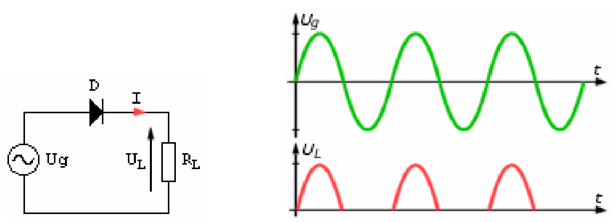

Fig.1. Schematic diagram of half-wave rectifier circuit and oscillograms of input U_g and output U_L voltage signal [4].

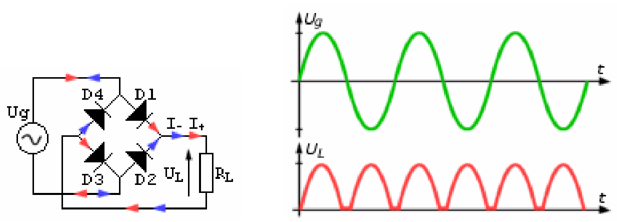

Fig.2. Schematic diagram of full-wave rectifier circuit and oscillograms of input U_g and output U_L voltage signal [4].

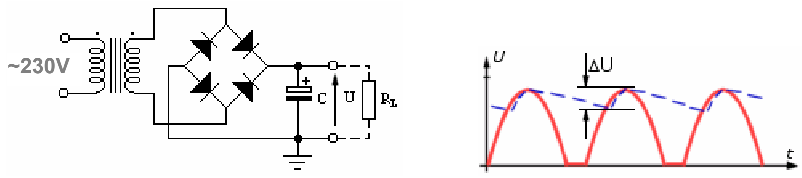

Fig.3. Schematic diagram of full-wave rectifier circuit with simple capacitor filter and oscillogram of output U voltage signal [4].

In order to ensure low AC ripple voltage at the load R_L the following condition should be satisfied

$$R_L \cdot C >> 1/f. \tag{1}$$

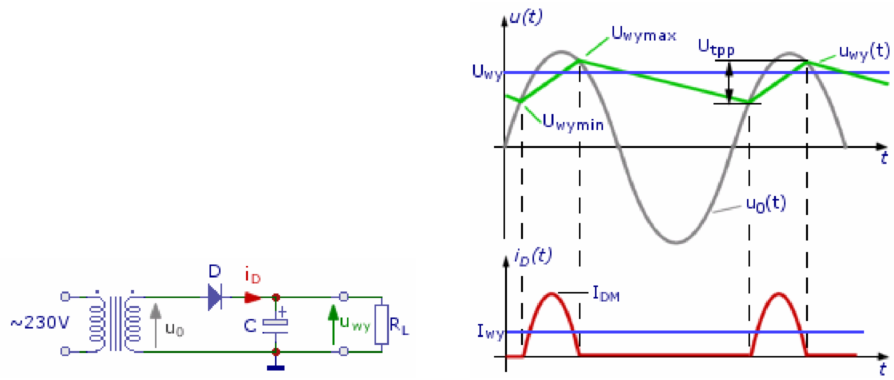

Fig.4. Schematic diagram of half-wave rectifier circuit with simple capacitor filter and oscillograms of output signals of voltage and diode current [4].

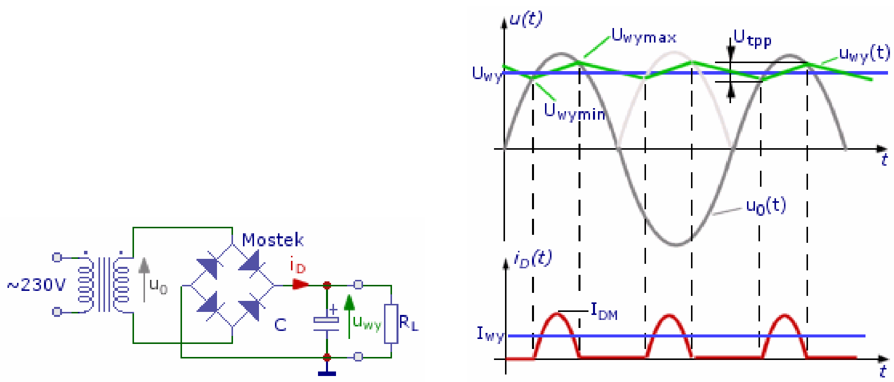

Fig.5. Schematic diagram of full-wave rectifier circuit with simple capacitor filter and oscillograms of output signals of voltage and diode current [4].

The ripple peak-to-peek voltage at the output of simple capacitor filter is given by

- for half-wave rectifier: $$U_{tpp} \approx \frac{I_{wy}}{C \cdot f} \quad , \tag{2}$$

- for full-wave rectifier: $$U_{tpp} \approx \frac{I_{wy}}{2 \cdot C \cdot f} \quad , \tag{3}$$

where $f = 50\text{Hz}$ is the frequency of power line and I_{wy} is the DC component of the output current.

Assuming that the ripple signal at the output of full-wave rectifier with a smoothing capacitor has a triangular shape (see Fig. 5, the green curve) the root mean square (rms) value of the ripple voltage can be found as

$$U_{sk} = \frac{U_{tpp}}{2\sqrt{3}} . \tag{4}$$

Experimental values of ripple factors may be defined employing rms value U_{sk} as well as peak-to-peak value U_{tpp} of ripple voltage:

$$k_t = \frac{U_{sk}}{U_{wy}} \quad , \tag{5}$$

$$M_t = \frac{U_{tpp}}{U_{wy}} \quad , \tag{6}$$

For the circuit shown in Fig. 5 theoretical values of ripple factors are:

$$k_t = \frac{1}{4\sqrt{3} \cdot f \cdot C \cdot R_L} \quad , \tag{7}$$

$$M_t = \frac{1}{2 \cdot f \cdot C \cdot R_L} \quad . \tag{8}$$

4. Available equipment

4.1. Multimeters

The voltages and currents in the experimental module will be measured using digital multimeters. The following models may be used: Metex, model M-3800 or M-4650, Protek 506, UNI-T UT804, or KEMOT KT890 [3].

4.2. Oscilloscope

The waveforms on input and output of the experimental modules are observed on a dual channel oscilloscope SDS1052DL [3].

4.3. Experimental modules of the power supply

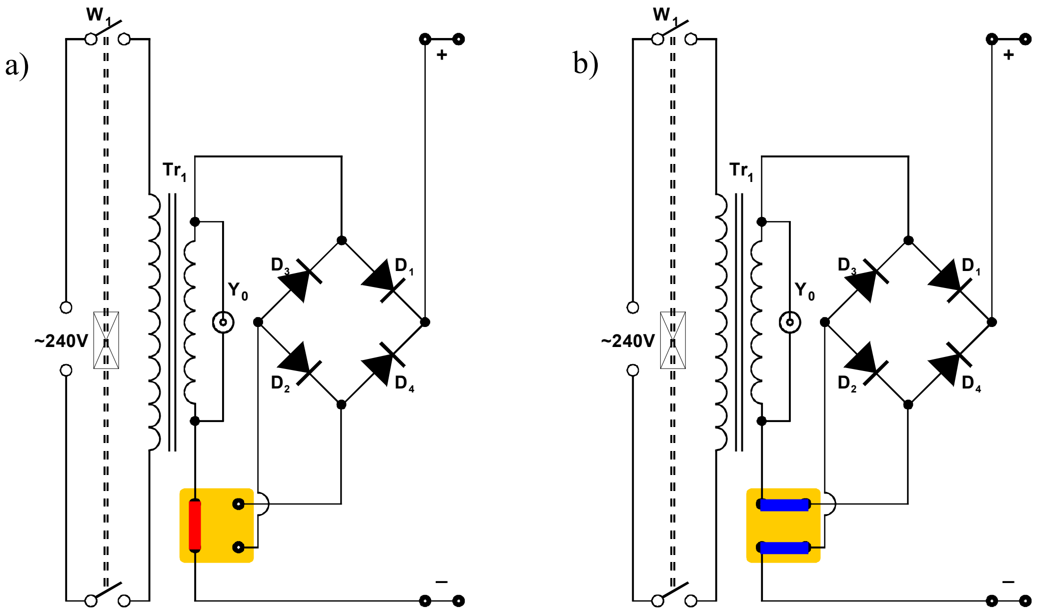

Fig. 6. Configuration mode of rectifier to work as (a) half-wave (red color jumper) or (b) full-wave (blue color jumpers).

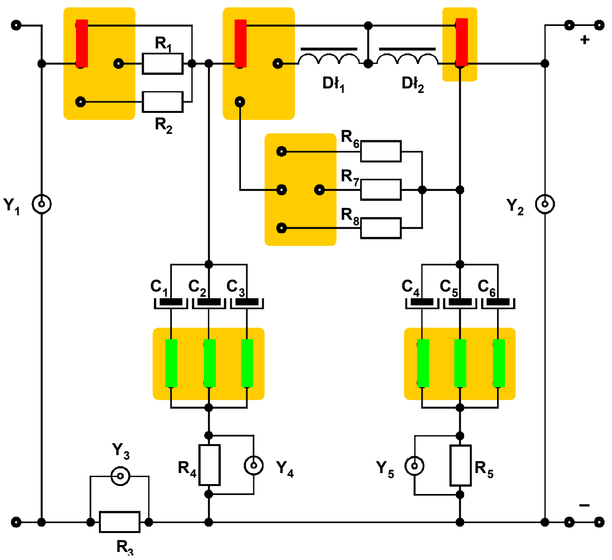

Fig. 7a. Simple capacitor filter. Red color jumpers are fixed. Green color jumpers are used to change the capacitance of filter.

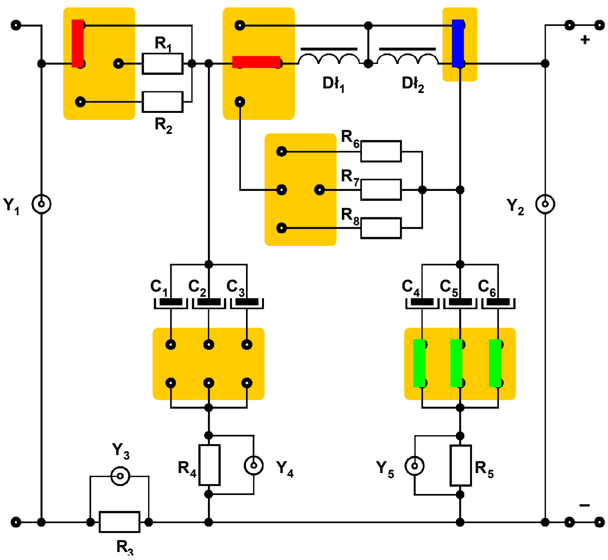

Fig. 7b. LC filter of Γ type. Red color jumpers are fixed. Green color jumpers are used to change the capacitance of filter. Blue color jumper is used to short/unshort the $Dł_2$ choking coil (to decrease/increase inductance).

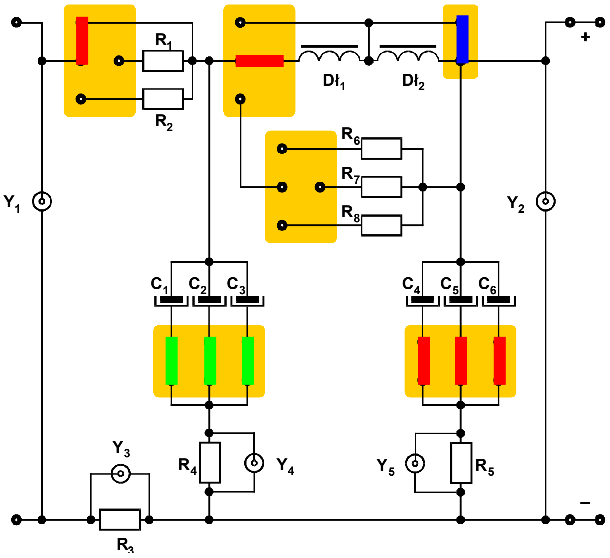

Fig. 7c. LC filter of Π type. Red color jumpers are fixed. Green color jumpers are used to change the capacitance of filter. Blue color jumper is used to short/unshort the $Dł_2$ choking coil (to decrease/increase inductance).

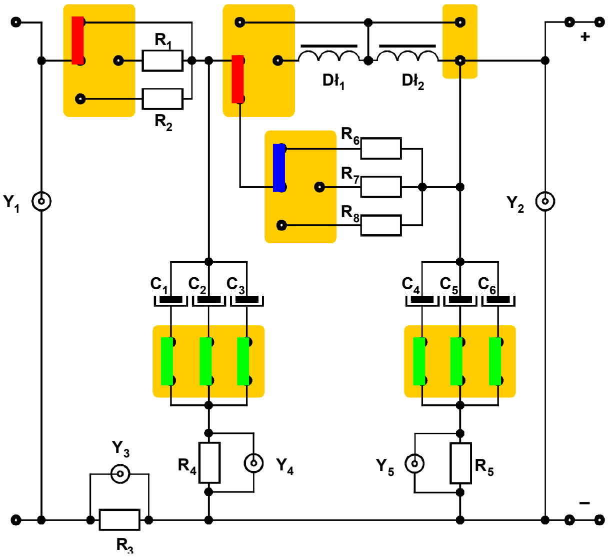

Fig. 7d. RC filter of Π type. Red color jumpers are fixed. Green color jumpers are used to change the capacitance of filter. Blue color jumper is used to select one of three different resistances.

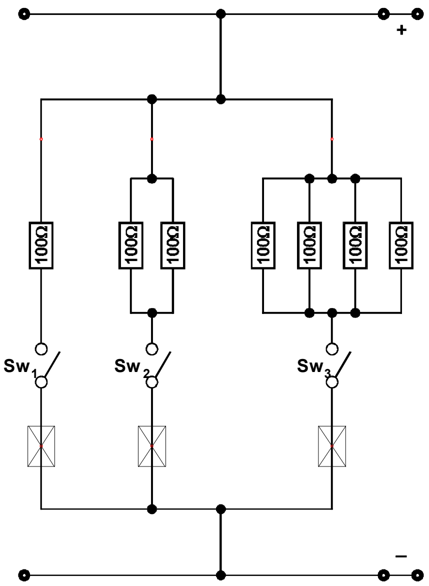

Fig. 8. Configuration of resistance load. Three switches (Sw_1, Sw_2, Sw_3) allow to select 8 different values of resistance load. Notice the status of control LEDs of switched on load sections.

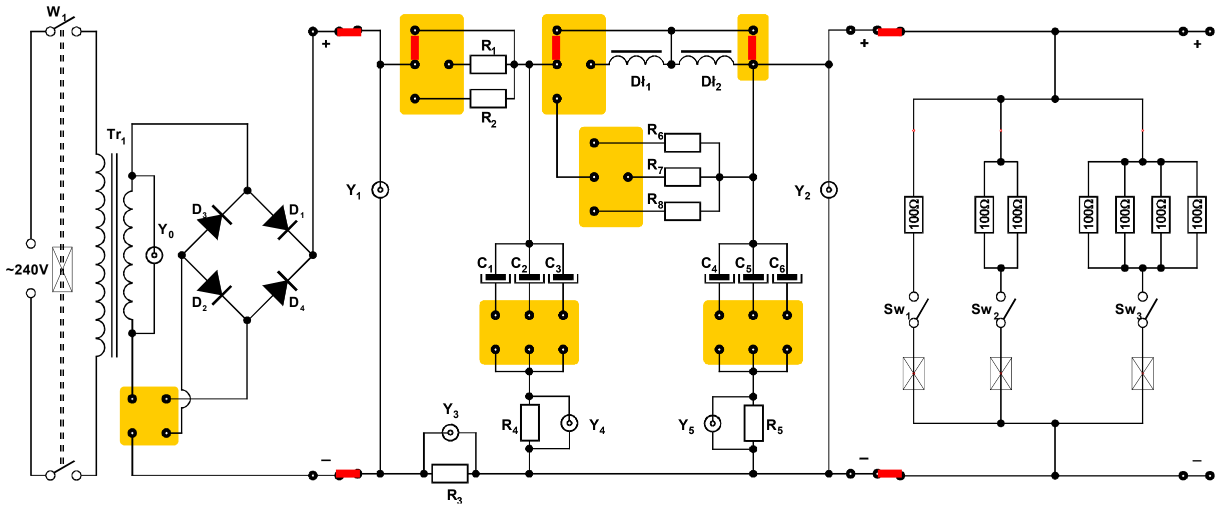

Fig. 9. Total schematic diagram of investigated setup to observe rectified voltage for the half or full-wave rectifier circuits.

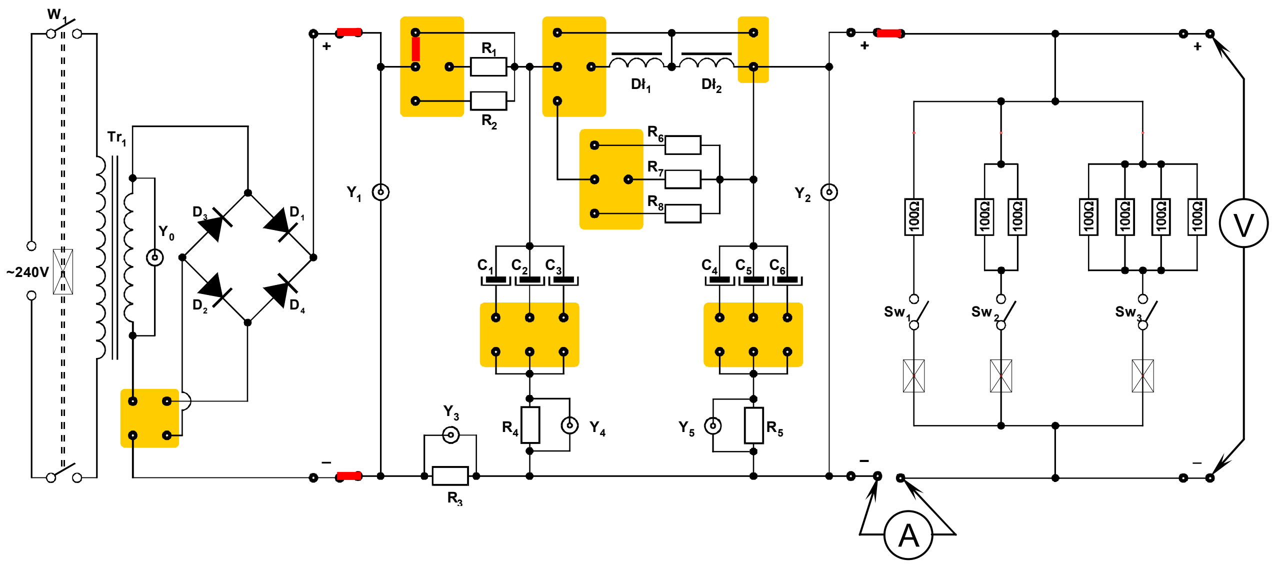

Fig. 10. Total schematic diagram of investigated setup to observe ripple voltage for different filters and various resistances of load.

5. Experimental procedure

5.1. Basic version

1. Connect the circuit according to the diagram presented in Fig. 9. Use the jumper to select the half-wave mode of rectifier (see Fig. 6a). Check if all of Sw_1, Sw_2, Sw_3 switches are set to 0 ($R_L \rightarrow \infty$, minimum load). Connect the two channels of oscilloscope to Y_0 and Y_1 BNC connectors on the front panel of experimental module. Set the input amplification of the both oscilloscope channels to 5V/DIV. NOTICE: the real gain of input channel connected to Y_0 is 10V/DIV because of safety lab regulations (the voltage on Y_0 is two times lower then the real output voltage of secondary winding of a transformer). **Ask the supervisor to approve the circuit configuration before you switch on the power.** Use the W_1 switch to power on the circuit. Draw oscillograms of input signal of supply voltage (before rectifier) and related output signal of rectified voltage – see Fig. 1.
2. Use the jumpers to select the full-wave mode of rectifier (see Fig. 6b). Draw the related oscillograms – see Fig. 2.
3. Repeat the measurements (described above in steps 1 and 2) for 3 different R_L loads. Use the Sw_1, Sw_2, Sw_3 switches to select R_L values of load – minimum, maximum and third other. Draw related oscillograms.
4. Use the W_1 switch to power off the circuit.
5. Connect the circuit according to the diagram presented in Fig. 10 to observe and measure the ripple voltage. Use the jumper to select the half-wave mode of rectifier (see the Fig. 6a). Check if all of Sw_1, Sw_2, Sw_3 switches are set to 0 ($R_L \rightarrow \infty$, minimum load). Use the jumpers to select the simple capacitor filter at the middle front panel of module (see Fig. 7a). Set the capacitance to $C = C_1$. Select 200 or 400 V DC and 20A DC ranges of DMMs. WARNING: you have to connect the red wire of DMM ammeter to terminal marked as 20A. Connect the two channels of oscilloscope to Y_2 and Y_3 BNC connectors on the front panel of experimental module. Signal from Y_2 allow to measure the ripple voltage of rectifier. **Ask the supervisor to approve the circuit configuration before you switch on the power.** Use the W_1 switch to power on the circuit. Read the peak-to-peak ripple voltage U_{tpp} (see the Fig. 4) directly from the oscilloscope display. Notice the indications of DMMs (U_{wy}, I_{wy}). Write down the obtained results in the Table 1.
6. Make the measurements for minimum 3 different values of R_L load. Take into account the case of the minimum and maximum load ($R_L \approx 14.3\Omega$). Write down the obtained results (I_{wy} , U_{wy} and U_{tpp}) in the Table 1.
7. Repeat the measurements (described above in steps 5 and 6) for step-by-step increased three different values C of capacitance filter and next for full-wave mode of rectifier. Write down the obtained results in the Table 1. (in the column "Rectifier mode" note down if the half or full-wave rectifier was investigated). Derive the C values of parallelly connected capacitances using data from "Table of passive electronic components" (see Appendix A1). Evaluate R_L loads using data from the front panel of experimental module.

Table 1. Simple capacitor filter.

Rectifier mode	#	C	R_L	I_{wy}	U_{wy}	U_{tpp}	M_t
		[μF]	[Ω]	[A]	[V]	[V]	

8. Repeat the measurements (described above in steps 5, 6, and 7) for LC filter of Γ type (see Fig. 7b). Write down the obtained results in the Table 2. (in the column "Rectifier mode" note down if the half or full-wave rectifier was investigated). Derive the values of C and L using data from "Table of passive electronic components" (see Appendix A1). Evaluate R_L loads using data from the front panel of experimental module.

Table 2. LC filter of Γ type.

Rectifier mode	#	C [μF]	L [mH]	R_L [Ω]	I_{wy} [A]	U_{wy} [V]	U_{tpp} [V]	M_t

9. Repeat the measurements (described above in steps 5, 6, and 7) for LC filter of Π type (see Fig. 7c). Write down the obtained results in the Table 3. (in the column "Rectifier mode" note down if the half or full-wave rectifier was investigated). Derive the values of C and L using data from "Table of passive electronic components" (see Appendix A1). Evaluate R_L loads using data from the front panel of experimental module.

Table 3. LC filter of Π type.

Rectifier mode	#	C [μF]	L [mH]	R_L [Ω]	I_{wy} [A]	U_{wy} [V]	U_{tpp} [V]	M_t

10. Use the W_1 switch to power off the measuring setup.

5.2. Extended version

11. Repeat the measurements (described above in steps 5, 6, and 7) for RC filter of Π type (see Fig. 7d). Write down the obtained results in the Table 4. (in the column "Rectifier mode" note down if the half or full-wave rectifier was investigated). Derive the values of C and R using data from "Table of passive electronic components" (see Appendix A1). Evaluate R_L loads using data from the front panel of experimental module.

Table 4. RC filter of Π type.

Rectifier mode	#	C [μF]	R [Ω]	R_L [Ω]	I_{wy} [A]	U_{wy} [V]	U_{tpp} [V]	M_t

12. Use the W_1 switch to power off the measuring setup.

6. Report elaboration

Report has to be composed of:

1. Front page (by using a pattern).
2. Description of experiment purposes.
3. Short introduction (basic definitions, formulas, description of used marks and symbols).
4. Schematic diagrams of tested circuits.
5. List of used instruments and devices (id number, type, setting and range values).
6. Measuring results (including oscillograms and tables).
7. Plots, calculations, analysis, interpretation and sub-conclusions related to all required points of "Experimental procedure".
8. Remarks and final conclusions.

Use obtained results to evaluate the ripple factors M_t for all cases of measured filters (see Eq. 6). The values of M_t should be written down in the related data tables.

Moreover, calculate the theoretical values of the ripple factor M_t according to Eq. 8 for a full-wave rectifier with a simple capacitor filter (the case shown in Figs. 6b and 7a, and part of the results from Table 1). Compare these theoretical values with experimental ones.

Based on the obtained values of ripple factor choose the best two filters: the first one for maximum load of rectifier ($R_L \approx 14.3\Omega$) and the second one for no load (minimum load) of rectifier ($R_L \rightarrow \infty$). Notice "the best filter" means the voltage ripple is reduced so extremely as possible by the filter.

7. References

7.1. Basic reference materials

[1] A. Rusek, *Podstawy elektroniki*, część pierwsza, WSiP, Warszawa, 1979.
[2] K. Bracławski, A. Siennicki, *Elementy półprzewodnikowe*, WSiP, Warszawa, 1986.

7.2. Other reference materials

[3] User manuals of the oscilloscope and DMMs:
http://fizyka.p.lodz.pl/pl/dla-studentow/fundamentals-of-electronics/
[4] http://www.edw.com.pl/ea/

8. Appendixes

A1. Table of passive electronic components

C_1=100µF	C_4=100µF	$Dł_1$=40mH	R_1=1Ω	R_3=0,27Ω	R_6=1Ω
C_2=470µF	C_5=470µF	$Dł_2$=40mH	R_2=10Ω	R_4=0,27Ω	R_7=10Ω
C_3=1000µF	C_6=1000µF			R_5=0,27Ω	R_8=22Ω