CIRCUITS AND SYSTEMS LABORATORY

EXERCISE 9

CIRCUITS WITH CONTROLLED RECTIFIERS

1. DEVICES AND PANELS USED IN EXERCISE

The following devices are to be used in this exercise:
- three-phase power supply panel, signed “Zasilacz trójfazowy”,
- *RLC* and thyristors panel, signed “Obwód RLC z tyrystorami”,
- three-phase resistance panel, signed “Odbiornik trójfazowy – R”,
- three-phase inductance panel, signed “Odbiornik trójfazowy – L”,
- 3-phase capacitors panel, signed “Odbiornik trójfazowy – C”,
- oscilloscope HP 54603B,
- ammeter.

2. PROGRAM OF EXPERIMENTS

2.1. SINGLE-PHASE, HALF-WAVE RECTIFIER WITH *RL* LOAD

The metering circuit configuration for examination of a single-phase, half-wave controlled rectifier with *RL* load is shown in figure 1. For taking the measurements one should:
1) set up the proper time range by adjusting the [Time/Div] knob of the oscilloscope, allowing to read the switch on and off angles of the thyristor,
2) adjust the amplification for both X and Y channels of the oscilloscope with use of the [Volts/Div] knobs,
3) set up the proper ammeter range depending on the switch on angle of the thyristor – the smaller the switch on angle the larger the ammeter range,
4) turn on the supply,
5) print the current, thyristor and inductance voltages time functions plots from the oscilloscope for a different values of $tg\varphi$,
6) read the switch on and off angles using the oscilloscope cursors for two different $tg\varphi$ values and for:
   - two resistance values of 15 and 30 Ω with a single inductance value *L*,
   - two inductance values of the equivalent impedance of $\underline{Z}_1 = (2 + j15)\Omega$ and $\underline{Z}_2 = (4 + j60)\Omega$ with a single resistance value *R*,
7) print the current and supply voltage time functions graphs for a single $tg\varphi$ value and different angles Θ_{on} storing them on a single plot with use of the oscilloscope auto-store function,
8) measure the current values for particular switch angle values and write the results in table 1.

The oscilloscope display parameters should be set up in a way to assure that an angle of 180° is represented by equal number of time divisions, e.g. if the straight angle is represented by 5 divisions, a single division represents 36°.

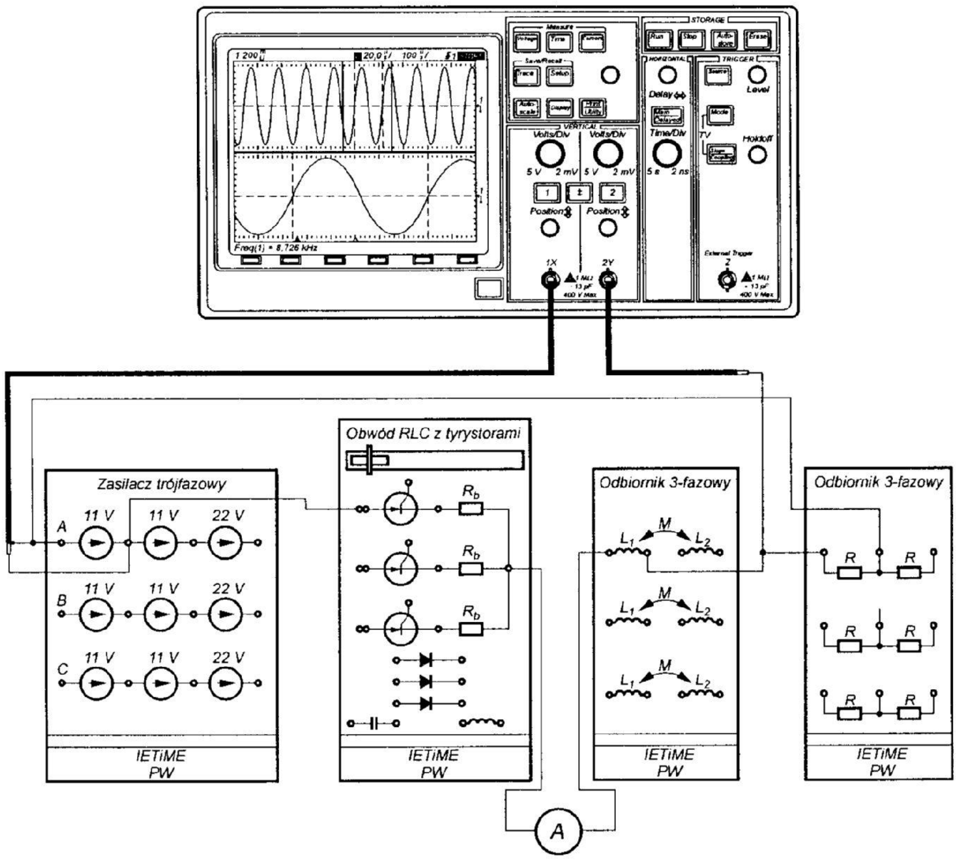


Fig. 1 Metering circuit configuration for examination of a single-phase, half-wave controlled rectifier with *RL* load

Table 1

Results table

U_i = V, R = Ω, L = H		
Θ_{on} [°]	Θ_{off} [°]	I [A]

2.2. SINGLE-PHASE, HALF-WAVE RECTIFIER WITH *RC* LOAD

The metering circuit configuration for examination of a single-phase, half-wave controlled rectifier with *RC* load is shown in figure 2. For taking the measurements one should:

1) set up the proper time range on the oscilloscope, allowing to read the switch on and off angles of the thyristor,

2) adjust the amplification for both X and Y channels of the oscilloscope,
3) turn on the supply,
4) read the switch on and off angles using the oscilloscope cursors for two different time constants obtained for the following *RC* values:
   - R = 30 Ω, C = 50 μF,
   - R = 30 Ω, C = 100 μF,
5) print the current and voltages time functions plots from the oscilloscope for the above cases.

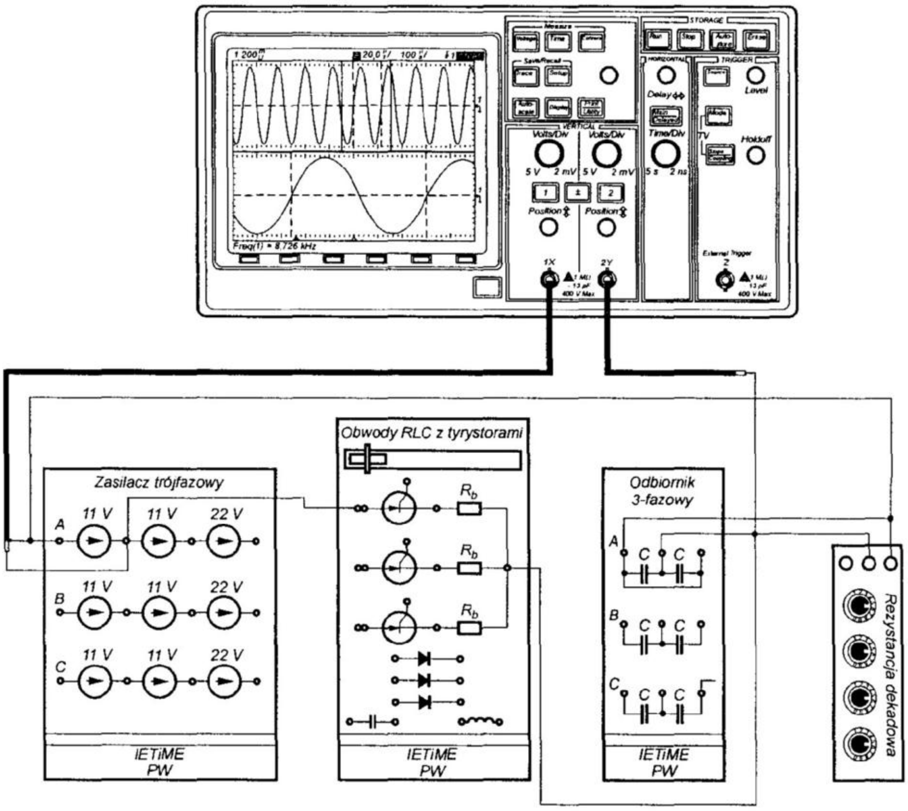


Fig. 2 Metering circuit configuration for examination of a single-phase, half-wave controlled rectifier with *RC* load

2.3. THREE-PHASE, HALF-WAVE RECTIFIER

The metering circuit configuration for examination of a three-phase, half-wave controlled rectifier with resistance load is shown in figure 3. During the assemble of the circuit one should pay attention to assure the accordance of the particular thyristor with phase. For taking the measurements one should:

1) set up the time range of 1 ms/div on the oscilloscope,
2) adjust the amplification for both X and Y channels of the oscilloscope, and make sure to take the constant component into account,
3) turn on the supply,
4) print the current and three-phase supply voltages time functions graphs for the two different angles Θ_{on} (e.g. 0° and around of 90°) storing them on a single plot with use of the oscilloscope auto-store function.

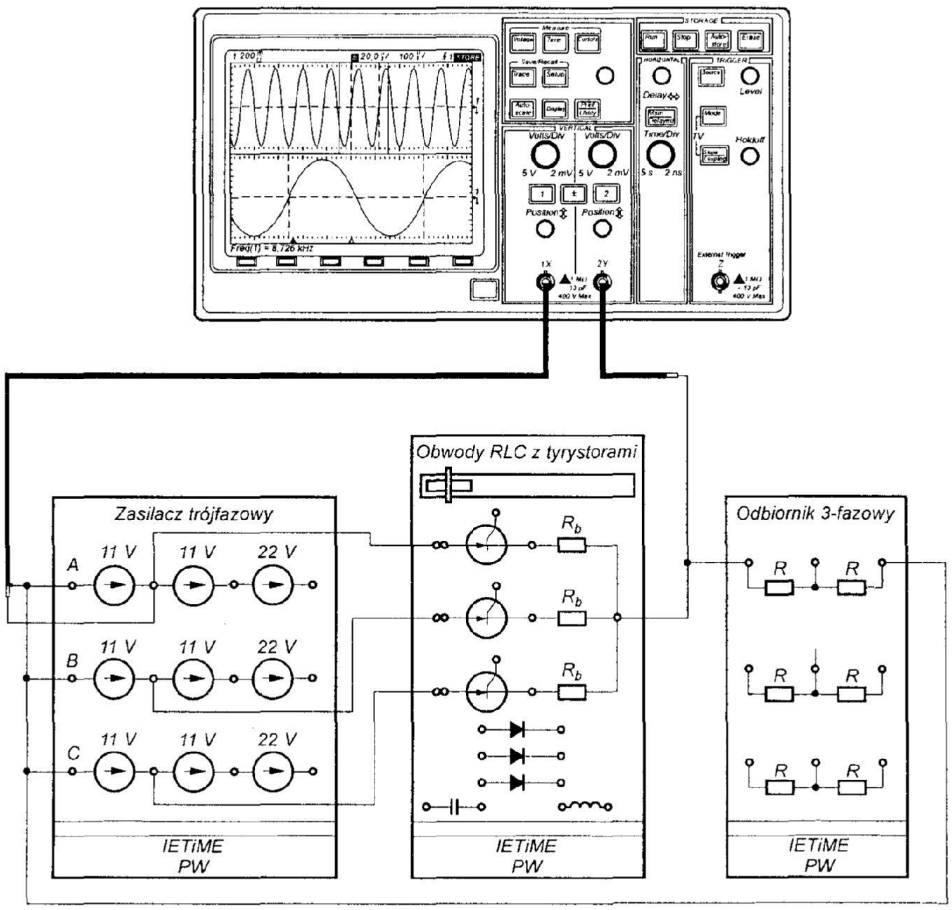


Fig. 3 Metering circuit configuration for examination of a three-phase, half-wave controlled rectifier with resistance load

2.4. EXAMINING THE EFFICACY OF THE RECTIFIER FILTERS

The ripples and the efficacy of the *L*, *LC* and *RC* filters for the single-phase, half-wave rectifier will be examined in this point. The filter efficacy is evaluated as the amplitudes ratio of the variable voltage component measured on the input and output terminals of the filter: $b = \frac{U_{mi}}{U_{mo}}$. The measurements should be made with use of the oscilloscope with constant resistance load value R_0. The results for the *L*, *LC* and *RC* filters are to be written to table 2. The formulas for efficacy coefficients *b* for particular filters are given in table 3 together with their schematic diagrams.

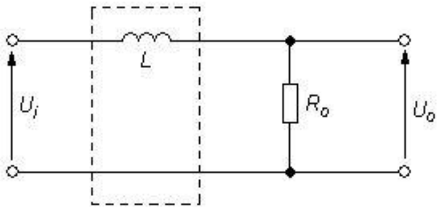
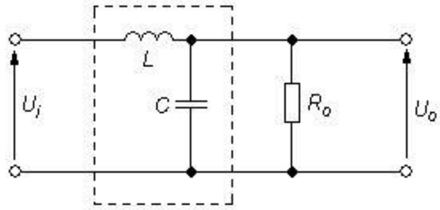
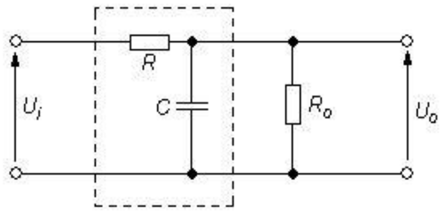
Table 2

Results table for examination of the ripple filters.

$L =$ H, $C =$ μF, $R_1 =$ Ω, $R_O =$ Ω			
	L	*LC*	*RC*
U_{mi}			
U_{mo}			
b			
$b_{theoretical}$			

Table 3

Example ripple filters and their efficacy formulas

Filter type	Efficacy coefficient *b*
inductive filter 	$b_L = \sqrt{1+\left(\frac{\omega_t L}{R_O}\right)^2}$
inductive-capacitive filter 	$b_{LC} = \sqrt{\left(\frac{\omega_t L}{R_O}\right)^2 + (1-\omega_t LC)^2}$
resistive-capacitive filter 	$b_{RC} = \sqrt{\left(1+\frac{R_1}{R_O}\right)^2 + (\omega_t R_1 C)^2}$

3. RESULTS PROCESSING

After running the experiments, one should:

1. Draw the theoretical and experimental switch angles characteristics $\Theta_{off} = f(\Theta_{on})$ for $tg\varphi$ values taken during the exercise. Use the measurements results from table 1 for the experimental characteristic and the following formula for the theoretical one:

$$\sin(\Theta_{off} - \varphi) = \sin(\Theta_{off} - \varphi)e^{-\frac{R}{\omega L}(\Theta_{off}-\Theta_{on})}$$

   Compare the two characteristics.
2. Determine the theoretical characteristic of the average output voltage value for a rectifier circuit with *RC* load in dependence of the *RC* time constant: $U_{av} = f(RC)$ with constant switch on angle value and $U_{av} = f(\Theta_{on})$ with constant *RC* value. Compare these characteristics with the printouts drawing own conclusions.
3. Compare and comment the measured efficacies *b* of the particular ripple filters with the theoretical *b* values.
4. Describe the printouts properly, marking the quantity axes and significant points and/or values.