Maritime University of Szczecin

ORGANISATIONAL UNIT:
Department of Communication Marine Technologies

INSTRUCTION

ELECTRICAL ENGINEERING AND I ELECTRONIC
Laboratory
Exercise no 1: Some laboratory instruments

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Contents

1. SOME LABORATORY INSTRUMENTS

1.1. The purpose and range of the exercise

The purpose of the exercise is to master knowledge of the basic concepts of electronics and master the ability to measure basic electrical and electronic quantities.

Issues

1. Basic electrical quantieties and elements.
2. Electrical signals.
3. Basic theory of electrical circuts lows.
4. Principles of measurements.
5. The use of basic measuring devices – multimeters and osciloscopes.

Control questions

1. What do we call an electrical signal ?
2. Give classifications of electrical signals.
3. What signals are called analog signals ?
4. What signals are called digital signals ?
5. What signals we call binary signals ?
6. What signals are called impulse signals ?
7. Give examples of pulse, rectangular, triangular and sawtooth signals.
8. Draw and characterize the sinusoidal waveform.
9. Draw and characterize the impuls waveform.
10. Give an effective value definition of voltage (curent).
11. Give an average value definitione of voltage (curent).
12. What does mean constant (direct) signal, but what does mean alternating signal ?
13. List the basic units of the SI system?
14. List SI system prefixes and their multipliers.
15. List symbols and units of: electric charge, electrical voltage, electric current, capacieties, resistance, inductance, power, energy, frequency, time
16. Give a formula on volatage gain (amplification) (power gain, amplification) expressed w dB.
17. Give a formula between the length of the electromagnetic wave and its frequency.
18. Give the speed of propagation of the electromagnetic wave (light)
19. Draw graphic symbols of basic electronic elements.
20. Give the content of Ohm's law.
21. Give the content and patterns describing Kirchhoff's laws.
22. Give a formula for the equivalent resistors of the resistors connected in series.
23. Give a formula for the equivalent resistors of the resistors connected in parallel.
24. Give a formula for the equivalent capacitance of the capacitors connected in series.
25. Give a formula for the equivalent capacitance of the capacitors connected in parallel.
26. Specify how to connect a voltmeter and ammeter to measure low resistance and how to measure high resistance.
27. Which internal resistance should have the ideal ammeter and ideal voltmeter and how to connect them to the circuit ?

1.2. Description of the laboratory stand

The set of devices used in the exercise includes:

- stabilized power supply
- digital multimeter,
- analog oscilloscope,
- digital oscilloscope,
- function generator.

1.3. The course of the exercise

The exercise has demonstrative character. Make notes about laboratory instruments and how to use them yourself.

1.4. The conditions of completion

The condition for passing is:

- to write a short test at the beginning of the exercises with a positive result;
- doing the exercise;
- preparing a report according to the instructions below;
- defense report on the next class;
- confirmation of mastering the scope of the exercise during the last completion classes;

The report should describe the course of the exercise, describe the instruments presented by the trainers. In particular, it should be:

- explain why the power supplies are used;
- explain the importance of voltage stabilization and current stabilization;
- describe how to take measurements using a digital meter;
- list electrical quantities measured using a digital meter;
- describe the purpose of laboratory generators;
- specify which quantities can be set on the generator;
- describe the purpose of the oscilloscope, list the types of oscilloscopes;
- describe how to take measurements using an oscilloscope;
- describe the method of taking measurements of the constant (direct) signal and alternative signal;
- describe the basic control elements of the oscilloscope.

1.5.1. The concept of electrical signals

An electrical signal is a time course of voltage or current used to transfer information, e.g. sound, image, data, control stimuli, etc..

The basic classification distinguishes analog (continuous) and digital (discrete) signals (fig. 1.1.).

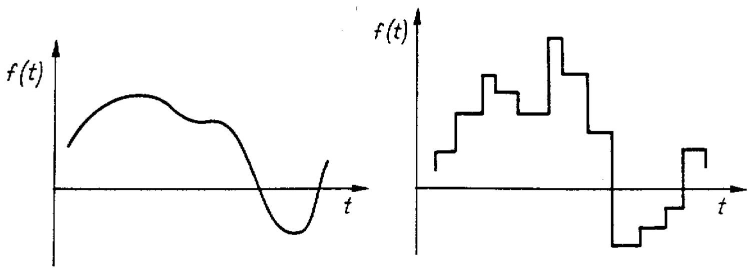


Fig. 1.1. Example of analog ang discrete signals

Analog signals they can take infinitely many values not very different from each other, in other words, the set of values of the analog signal is not countable. *Digital signals* can take infinitely many values, and so their values is cauntable. Analog signals can change to any moment but digital signals only in certain time piont. A special types of these signals are harmonic signals called sinusoidal signals and two values called binary signals.

The signals commonly known as impulse are also important in the technique. *Impulse* signal is signal with a big amplitudę lasting very shortly. In practice most often, the term impulse refers to the courses whose duration is much shorter than the repetition period (fig. 1.2).

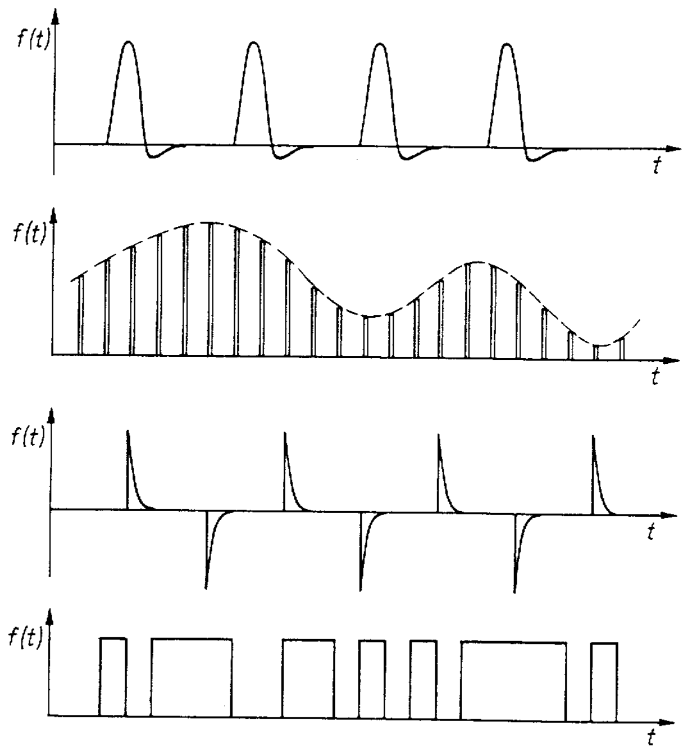


fig. 1.2. Examples of impuls signals

The pulses can be positive or negative, single or group, periodically or non-periodically repeated etc. Many common features with pulse signals has rectangular periodic signals (fig.1.3) and triangle signals (fig.1.4).

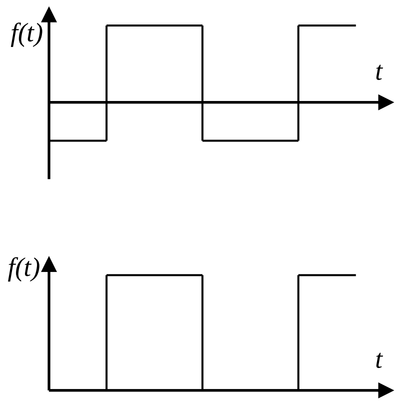


fig. 1.3. Examples of rectangular signals

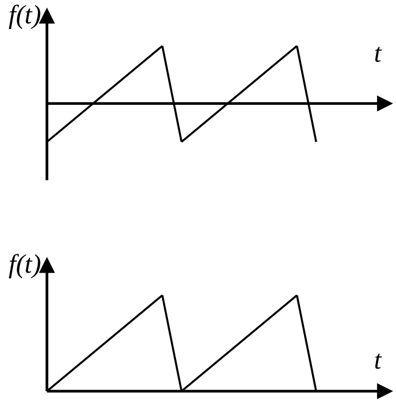


fig. 1.4. Examples of triangular signals

1.5.2. Parameters used in the description of electrical signals

On fig. 1.5. shows the sinusoidal waveform of the electric current. *Actual value* of this signal (sinusoidal current) *i(t)* determines the following relationship:

$$i(t) = I_m \sin(\omega t + \psi)$$

in where:

- I_m – maximal value (*amplitude*) of current;
- ψ – initial phase of current in moment $t = 0$;
- $\omega t + \psi$ – phase of current in moment t;
- $\omega = 2\pi f$ – pulsation (angular frequency);
- $f = 1/T$ – frequency, which is the inverse of the period T.

In one period T the phase of current changed about 2π, i.e. $\omega = 2\pi$.

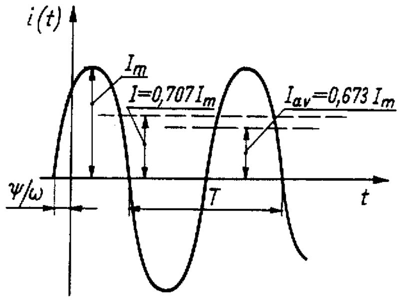


Fig. 1.5. Graphical interpretation of sinusoidal signal parameters

Average value of periodic signal (current) of T period express relantionship:

$$I_{ef} = \sqrt{\frac{1}{T}\int_0^T i^2(t)dt}$$

It corresponds to the value of direct current which, flowing through a given cross-section of the conductor, would transfer the same charge as the alternating current at the same time. In sinusoidal current cases effective value of current is equal their amplitudę divided by $\sqrt{2}$, and

$$I_{\text{ef}} = I_m/\sqrt{2} \approx 0{,}707\ I_m$$

Effective value *of periodic signal (current) of T period* express relantionship:

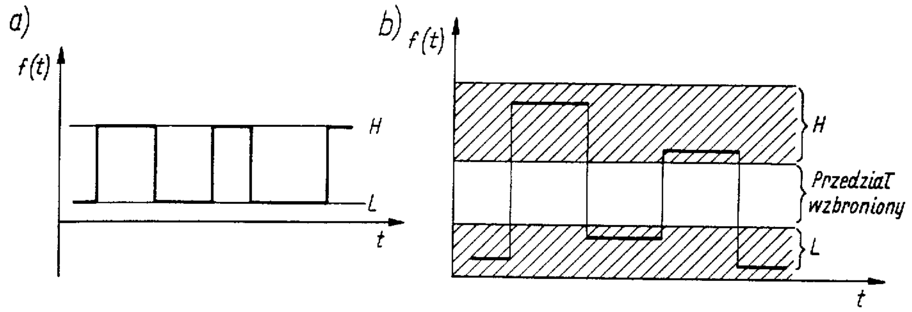
$$I_{av} = \frac{1}{T}\int_0^T i(t)dt$$

It corresponds to the value of direct current which, flowing through a resistor with constant (immutable) resistance value, will cause it to release the same amount of energy (in the form of heat), which is a sinusoidal current flowing at the same time. Because in the case of a sinusoidal current, the average value for the entire period, i.e. the full-term value is equal to zero, therefore usually the time equal to half of the period is taken to determine the mean value of the sinusoidal current $T/2$, then

$$I_{av} = \frac{2}{T}\int_0^{T/2} i(t)dt = \frac{2}{\pi} I_m \approx 0{,}637\ I_m$$

The quotient of the effective and average value (current) determines the so-called shape factor of the curve $k = I_{ef}/I_{\text{av}}$, which is equal for sinusoidal waveforms $k = \pi/2\sqrt{2} \approx 1{,}11$.

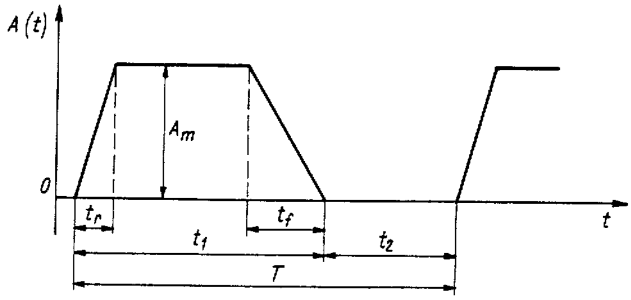
Binary signals (fig. 1.6.a) is characterized by the fact that it accepts only two different values usually marked with symbols L, H **(**Low, High) or 0,1. Digits 0, 1 are called *bits (Binary digit*). Voltage and current values corresponding to these two binary values (0, 1) they do not have to be determined with absolute accuracy. It is enough that they are contained in certain fairly wide ranges of levels L, H, separated by a range of forbidden values (fig. 1.6.b).



Rys. 1.6. Graphical interpretation of binary signal parameters

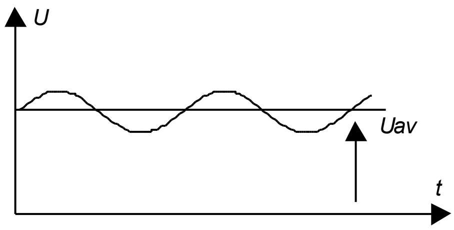
he binary signal presented as a function of time is in the form of a pulse train (binary). It represents specific information expressed in the appropriate code, e.g. binary natural, decimal binary cods (BCD) etc. The ordered collection of the following bits follows each other are named codeworld. A characteristic feature of each code is the length of the codeword, expressed in a number of bits in them. A unit called byte is used to determine the length of a word *(byte),* consisting of a conventional number of bits; usually 1 byte corresponds to 8 bits. Depending on whether the individual bits of the codeword are transmitted sequentially (in series) or simultaneously (in parallel), the binary signals are serial and parallel.

The basic parameters of the pulse signal are the maximum value (amplitude) A_{m} and *rise times* t_r, *fall* t_f, *duration* t_1**,** *interval* t_2**,** and also *repeted period* $T = t_1 + t_2$. Graphical interpretation this signal parameters are showed on fig. 1.7. Quotient duration (pulse width) t_1 i and repeted period T defines so called . *impulse filling factor* (eg. $k_w = t_1/T$).



Rys. 1.7. Graphical interpretation of impulse signal parameters

In electronics often appear, the determination of the signal constant component and the signal variable component. In many cases it is difficult to talk about a constant voltage, if the voltage varies in some insignificant ranges in relation to the whole voltage. he component of the constant electrical wave (electric voltage, electric current) is the average value of this waveform (fig 1.8). The variable component of the waveform is the difference between the waveform and its constant component (fig 1.9). In other words, the constant component is the part of the waveform that does not change, and the variable component is only the part that changes.



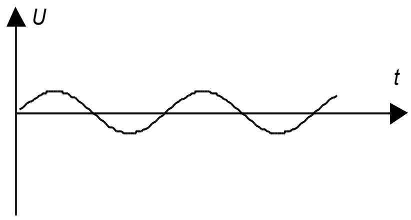


fig. 1.8 Illustration of a waveform with a constant and variable component fig. 1.9 The course with variable component only

1.5.3. Physical quantities and their units of measurement used most often in electronics

A unit of measure is a conventionally accepted value of a given physical quantity, which is used to compare other values of the same size with each other. The set of measurable size units is called the ***unit of measurement system***. The International System of Units now applies (Système International d'Unitès), in short called the **SI** layout. This system includes 7 basic units and 2 supplementary units (tab. 1.1), derived units consistent with the basic and supplementary units and prefixes for creating multiple and submultiples (tab. 1.2).

Table 1.1. Basic and supplementary measures units of the SI system

Quantity	Unit		
	Name	mark	
Length Mass Time Current Temperature Light Quantity (quantity) of matter	meter kilogram second amper kelwin kandela mol	m kg s A K cd mol	basic
Flat angle Solid angle	radian steradian	rad sr	Supplementary

Tabela 1.2. Prefixes and designations for creating multiple units and submultiples of the SI system

Prefix	Mark	Multiplier
Eksa	E	1 000 000 000 000 000 000 = 10^{18}
Peta	P	1 000 000 000 000 000 = 10^{15}
Tera	T	1 000 000 000 000 = 10^{12}
Giga	G	1 000 000 000 = 10^{9}
Mega	M	1 000 000 = 10^{6}
Kilo	k	1 000 = 10^{3}
Hekto	h	100 = 10^{2}
Deka	da	10 = 10^{1}
Decy	d	10^{-1} = 0,1
Centy	c	10^{-2} = 0,01
Mili	m	10^{-3} = 0,001
Mikro	µ	10^{-6} = 0,000 001
Nano	n	10^{-9} = 0,000 000 001
Piko	p	10^{-12} = 0,000 000 000 001
Femto	f	10^{-15} = 0,000 000 000 000 001
Atto	a	10^{-18} = 0,000 000 000 000 000 001

The main advantage of the SI system is that each of the derived units can be expressed by the product of the powers of the basic and supplementary units, with the numeric factor in this expression being equal to 1.

Examples:
0,025 [A] = 25 [mA]
0,000000007 [F] = 7 [nF]
36000000 [Hz] = 36 [MHz]

Some SI-derived units have their own names, e.g. load unit - coulomb [C], etc.. the units of electrical and magnetic quantities of the SI system most often used in electronics are listed.

Table 1.3. Units of measurement of selected electrical and magnetic quantities of the SI system

Quantity	**Unit**		**Relationships between units**
	Name	**Mark**	
Electric charge	Culomb	C	1C = 1A·s (1A·h = 3600 C)
Voltage	volt	V	1V = 1W/A
Capacity	farad	F	1F = 1C/V
Resistance	om	Ω	1Ω = 1V/A
Conductance	simens	S	1S = 1/Ω
Inductance	henr	H	1H = 1V·s/A
Magnetic induction	tesla	T	1T = 1Wb/m^2
Magnetic stream	weber	Wb	(1Gs = 10^{-4} T)
Electric permittivity	farad on metr	F/m	
Magnetic permittivity	henr on metr	H/m	
Power	wat	W	1W = 1V·A
Energy, work, heat	joul	J	1J = W·s
Frequency	herc	Hz	1Hz = 1/s

Often, the voltage gain or amplification of the power of a certain electronic circuit is expressed by means of a unit called a decibel. Voltage amplification and power amplification counts according to the formula:

$$k_p = 10\log_{10}\left[\frac{P_{wy}}{P_{we}}\right] \quad [dB]$$

$$k_u = 20\log_{10}\left[\frac{U_{wy}}{U_{we}}\right] \quad [dB]$$

where P_{we} *i* U_{we} are input power and voltage, P_{wy} *i* U_{wy} are output power and voltage, k_p *i* k_u power amplification, amplification of the expressed voltage in dB.

The unit set is supplemented with tab. 1.4., Which lists the most important physical constants.

Table 1.4. Selected physical constants

Quantity	Mark	value	unit
Elementary charge	e	$-1{,}6022\cdot10^{-19}$	C
The resting mass of the electron	m_e	$9{,}1091\cdot10^{-31}$	kg
The resting mass of the proton	m_p	$1{,}6725\cdot10^{-27}$	kg
The resting mass of the neutron	m_n	$1{,}6748\cdot10^{-27}$	kg
Planck's constant	h	$6{,}6262\cdot10^{-34}$	J·s
Boltzmann constant	k	$1{,}3807\cdot10^{-23}$	J/K
Light speed in the vacuum	c_0	$2{,}9979\cdot10^{+8}$	m/s
Magnetic permeability of the vacuum	μ_0	$4\pi\cdot10^{-7}$	H/m
Electrical vacuum permeability	ε_0	$8{,}8541\cdot10^{-12}$	F/m

In radiocommunications, the concept of an electromagnetic wave is often used. The most commonly used electromagnetic wave parameters are the frequency f expressed in Hertz and the wavelength λ expressed in meters. The relationship between them is expressed by the formula

$$\lambda = c \cdot T = \frac{c}{f} \quad [m]$$

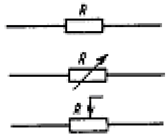
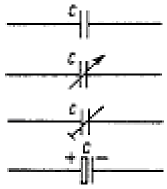
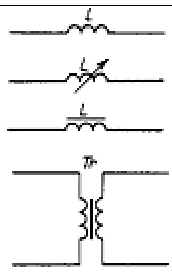
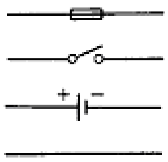
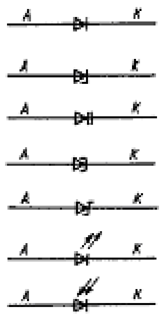
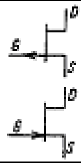
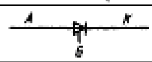
where c is the speed of propagation of an electromagnetic wave approximately $c \approx 3\cdot10^{+8}$ m/s, but T equal wave period:

$$T = \frac{1}{f} \quad [s]$$

It can be assumed that the speed of propagation of the electromagnetic wave in the air is the same as in vacuum and is the same as the speed of light.

Table 1.5 presents graphic symbols of some more frequently used electronic components.

Tabela 1.5 Symbole graficzne niektórych częściej stosowanych elementów elektronicznych

Name	Symbol
Resistor (permanent, constant) Variable resistor Potentiometer	
Capacitor (permanent, constant) Variable capacitor Trimmer Electrolytic capacitor	
Inductance (constant) Inductance variable Inductor with magnetic core Transformer	
Fuse Connector Electrical (electrochemical) link Line	
Diode Stabilization diode (Zener diode) Capacitive diode Tunnel diode Schottky diode Light emitting diode Photodiode	
Transistor (bipolar) PNP Transistor (bipolar) NPN	
Field-effect transistor with channel N Field-effect transistor with channel P	
Thyristor (triode)	

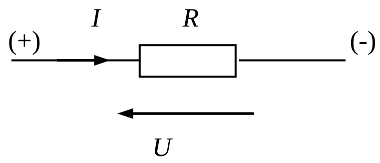
1.5.4. Issues included in the theory of circuits

Circuit theory is a scientific discipline dealing with research (analysis and synthesis) of electrical circuits. **Electrical circuits** this is, in a general sense, a closed structure formed by properly connected electrical elements in which the flow of electric current is possible. **Element** in such a circumference it is considered as a kind of "brick" (indivisible part), being a model of a certain phenomenon or physical features related to the electric circuit. An important issue for the analysis of circuits is also the modeling of elements included in the electric circuits.

In the theory of circuits, mathematics is used - especially from mathematical analysis, matrix algebra, complex number algebras, Fourier series, differential and integral equations, integral transformations (Laplace, Fourier), numerical methods, etc.. The condition for proper understanding of the functioning of electrical circuits is also knowledge of issues from various branches of physics, such as electrostatics and magnetostatics, electric current, electromagnetism, and matter construction. Continuous development of microelectronics, digital and analogue technology and many related fields of science and technology constantly raises new needs, which causes that the problem of circuit theory is constantly evolving

1.4.5. Basic laws governing phenomena occurring in electrical circuits

Ohm's law was formulated in 1826 by G.S. Ohms for DC circuit.



Rys. 1.10. Illustration of the equation of resistance

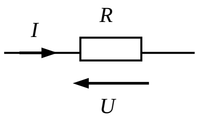
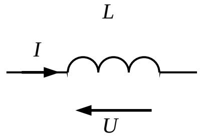
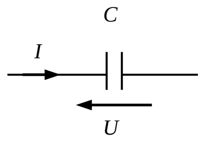
Ohm's law states that: the electrical voltage U at the ends of the conductor section is proportional to the intensity of the electric current I flowing through this section (rys. 1.10.), thats mean:

$U = RI$ [V]

where R is a proportionality factor, called resistance (or active electrical resistance).

Ohm's law refers to branches of an electrical circuit that does not contain energy sources (Kirchhoff's law applies to the branch of an electrical circuit containing energy sources). In AC circuits, the voltage and current in a given element are related by means of differential-integral relations, which are a generalized form of Ohm's law (Table 1.6.)

Tabela 1.6. Uogólnione prawo Ohma

Kinds of Elements	**Resistance** 	**Inductance** 	**Capacity** 
Ohm's Law form for instantaneous values	$u(t) = R \cdot i(t)$ $i(t) = \frac{u(t)}{R}$	$u(t) = L\frac{di(t)}{dt}$ $i(t) = \frac{1}{L}\int u(t)dt$	$u(t) = \frac{1}{C}\int i(t)dt$ $i(t) = C\frac{du(t)}{dt}$

Kirchhoff's Law (formulated in 1847 by G. R. Kirchhoff) expresses the principles of current distribution and voltage distribution in electric circuits. **Kirchhoff's first law**, on the balance of currents in the electrical circuit node, determines the relationship

$$\sum_k I_k = 0$$

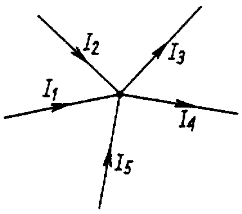
meaning that the algebraic sum of the currents in the node of the electric circuit is equal to zero. For the node shown in Figure 1.11, assuming that the currents flowing into the node are positive and the currents flowing from the node are negative (or vice versa, which is a matter of contract), the first Kirchhoff's law can be written in the form of an equation

$$I_1 + I_2 - I_3 - I_4 + I_5 = 0$$

which in turn can be rewritten in the form

$$I_1 + I_2 + I_5 = I_3 + I_4$$

expressing the following content: the sum of currents flowing into the electrical circuit node is equal to the sum of the currents flowing out of this node.



Rys. 1.11. A separate electrical circuit node illustrating Kirchhoff's first law

Kirchhoff's second law regarding voltage balance in the loop of the electrical circuit determines the relationship:

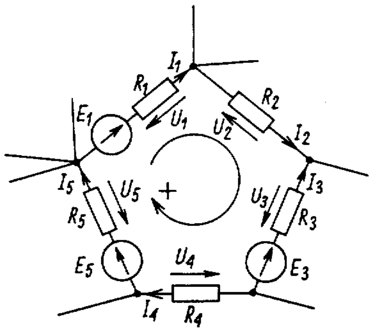
$$\sum_k E_k - \sum_k U_k = 0$$

meaning that the algebraic sum of all voltages (the source Ek and the receiver Uk) in the eye of the electric circuit is equal to zero.

For the eye shown in Fig. 1.12 with the positive return of the current flowing in the pond (positive for the return of the tensions in the direction of the circumference, i.e. the clockwise direction),:

$(E_1\text{-}E_3+E_5) - (U_1+U_2\text{-}U_3+U_4+U_5) = 0$

in which U_1,, U_2-, U_3 ... these are voltage drops respectively R_1 R_2, R_3, ... induced by branch currents with steady-state positive positive currents.



Rys. 1.12. An isolated loop of the electrical circuit illustrating Kirchhoff's second law

With any variation in voltages and currents, Kirchhoff's laws refer to the instantaneous values of these quantities. These laws are valid regardless of the type of elements being combined, provided, however, that they are clustered elements, i.e. they are characterized by the fact that all quantities describing them are only functions of time and do not depend on spatial variables.. Kirchhoff's law is used to determine the voltages and currents in branched circuits with known values of their elements (ex. *E*, *R*).

By using the basic laws of electrical circuits, you can transform branch circuits. For example, a circuit containing resistors connected in series $R_1...R_n$ can be simplified by replacing them with one resistor *R*, whose resistance is equal to the sum of resistances of individual resistors, i.e.

$$R = R_1 + R_2 + R_3 + ...R_n = \sum_{k=1}^{n} R_k$$

Similarly, a circuit consisting of resistors connected in parallel $R_1...R_n$ can be replaced with a circuit containing one resistor R, whose resistance is determined by the relationship:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ... + \frac{1}{R_n} = \sum_{k=1}^{n} \frac{1}{R_k}$$

The resultant capacity of capacitors is slightly different. A circuit containing capacitors connected in series $C_1...C_n$ can be simplified by replacing them with one C capacitor, whose capacity is determined by the formula:

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ... + \frac{1}{C_n} = \sum_{k=1}^{n} \frac{1}{C_k}$$

A circuit composed of capacitors connected in parallel $C_1...C_n$ can be replaced by a circuit containing one capacitor *C*, whose capacity is equal to the sum of capacities of individual capacitors:

$$C = C_1 + C_2 + C_3 + ...C_n = \sum_{k=1}^{n} C_k$$

Electronics often need to measure electrical quantities. The basic measuring instruments are a voltmeter - measuring the electrical voltage and an ammeter - measuring the intensity of the electric current. The voltmeter should always be connected in parallel to the tested circuit, and the ammeter should always be connected in series to the circuit being tested.

The ideal voltmeter should have infinitely large resistances in order to not interfere with the work of the tested part of the circuit $R_V \to \infty$. But the ideal ammeter should have a resistance close to 0, $R_A \to 0$. In practice, each voltmeter has a certain resistance generally quite large, however, when testing some circuits should be taken into account the correction of the measured voltage. Similarly, the ammeter connected in series to the circuit with a relatively small but non-zero resistance, which can falsify the result of the measured current.

The non-ideal properties of the voltmeter and ammeter must be taken into account when measuring the resistance. According to Ohm's law, when U is the voltage measured by the voltmeter and I the current measured by the ammeter, the measured resistance is:

$$R = \frac{U}{I} \qquad [\Omega]$$

The connection method of the voltmeter and ammeter is not indifferent to the size of the measured resistance. If the measured resistance is quite large (eg comparable to the internal resistance of the voltmeter, the resistance test should be connected as shown in Figure 1.13, while if the measured resistance is quite small (comparable to the internal resistance of the ammeter), the circuit should be connected as in Figure 1.14

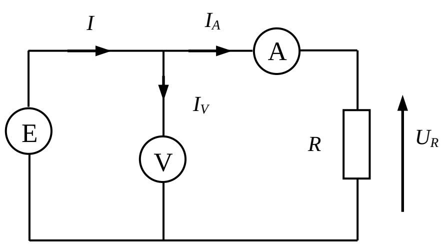


Fig. 1.13 A system for measuring a large resistance

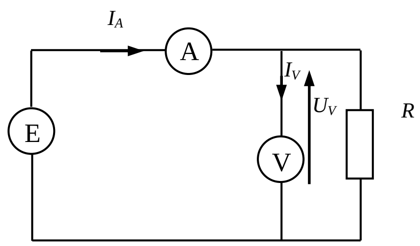


Fig. 1.14 A system for measuring a small resistance

For a system for measuring a large resistance assuming that I_A is a current measured by an ammeter and flowing through an ammeter, R_A an internal resistance of ammeter, U_V voltage measured by a voltmeter, U_R voltage drop on a tested resistor R, we can write based on Ohm's law:

$$R = \frac{U_R}{I_A}$$

From the second Kirchhoff law we get:

$$U_V = I_A \cdot R_A + I_A \cdot R = I_A \cdot R_A + U_R$$

After simple transformations, we get a formula for the measured resistance:

$$R = \frac{U_V - I_A \cdot R_A}{I_A} = \frac{U_V}{I_A} - R_A$$

Assuming that the resistance of the ammeter R_A is much smaller than the measured resistance R, i.e. that $R_A \to 0$ we get $R_A \to 0$ we get:

$$R \approx \frac{U_V}{I_A}$$

Because in the large resistance measurement circuit the ammeter measures only the current flowing through the measured resistance and the voltmeter measures the voltage being the sum of the voltage drop across the resistor R and the voltage drop on the non-zero resistance of the ammeter R_A, this system is called the correct current measurement system. For the system for measuring the small resistance assuming that I_A is the current measured by the ammeter and flowing through an ammeter,

U_V measured by a voltmeter, R_V, internal resistance of the voltmeter, I_R current flowing through the tested resistor R, we can write based on Ohm's law:

$$R = \frac{U_V}{I_R}$$

The current measured by the ammeter I_A is equal to the sum of the current flowing through the I_V voltmeter and the current flowing through the measured I_R resistance. We get the first Kirchoff law:

$$I_A = I_R + I_V$$

the current I_V flowing through the voltmeter is equal:

$$I_V = \frac{U_V}{R_V}$$

After simple transformations, we obtain a formula for the measured resistance:

$$R = \frac{U_V}{I_A - \frac{U_V}{R_V}}$$

Assuming that the internal resistance of an R_V voltmeter is much greater than the measured resistance R, i.e. that $R_A \to \infty$ we get:

$$R \approx \frac{U_V}{I_A}$$

Because in the resistance measurement system a small resistance, voltmeter measures the voltage drop only on the measured resistance R and the ammeter measures the current that is the sum of the current flowing through the measured resistance and the finished internal resistance of the R_V voltmeter, this system is called the correct voltage measurement system.

1.7 Efekty kształcenia

Metody i kryteria oceny				
EK1	Ma podstawową wiedzę w zakresie pojęć, praw z zakresu elektrotechniki i elektroniki.			
Metody oceny	egzamin pisemny, egzamin ustny, sprawdziany i prace kontrolne w semestrze.			
Kryteria/ Ocena	2	3	3,5 - 4	4,5 - 5
Kryterium 1 Wiedza w zakresie pojęć elektrotechniki i elektroniki.	Brak lub niewystarczająca podstawowa wiedza w zakresie pojęć i definicji związanych z tematem.	Opanowana podstawowa wiedza w zakresie pojęć i definicji związanych z tematem.	Zna i potrafi scharakteryzować/omówić podstawowe pojęcia i definicje Zna i potrafi scharakteryzować/omówić podstawowe i rozszerzone pojęcia, definicje.	Zna i potrafi przeanalizować pojęcia i definicje oraz wskazać możliwości ich wykorzystania w technice morskiej Biegle zna i potrafi przeanalizować oraz wskazać możliwości wykorzystania w technice morskiej.
Kryterium 2 Wiedzę w zakresie praw elektrotechniki i elektroniki.	Brak lub niewystarczająca podstawowa wiedza w zakresie praw związanych z tematem.	Opanowana podstawowa wiedza w zakresie praw związanych z tematem.	Zna i potrafi scharakteryzować/omówić podstawowe prawa Zna i potrafi scharakteryzować/omówić podstawowe i rozszerzone prawa.	Zna i potrafi przeanalizować prawa oraz wskazać możliwości ich wykorzystania w technice morskiej Biegle zna i potrafi przeanalizować oraz wskazać możliwości wykorzystania w technice morskiej.
EK2	Posiada umiejętność wykorzystania podstawowych praw elektrotechniki i elektroniki do analizy rachunkowej podstawowych elementów i obwodów elektronicznych.			
Metody oceny	zaliczenie ćwiczeń, laboratoriów/ symulatorów, sprawozdanie/ raport.			
Kryteria/ Ocena	2	3	3,5 - 4	4,5 - 5
Kryterium 1 Umiejętność wykorzystania podstawowych praw elektrotechniki i elektroniki do analizy rachunkowej podstawowych elementów i obwodów elektronicznych.	Brak lub niewystarczająca podstawowa wiedza w zakresie wykorzystania pojęć, definicji i praw związanych z tematem.	Opanowana podstawowa wiedza w zakresie wykorzystania pojęć, definicji i praw związanych z tematem.	Zna i potrafi wykorzystać podstawowe pojęcia, definicje i prawa do analizy podstawowych obwodów Zna i potrafi wykorzystać podstawowe i pochodne pojęcia, definicje i prawa do analizy podstawowych obwodów w technice morskiej.	Zna i potrafi wykorzystać podstawowe i pochodne pojęcia, definicje i prawa oraz wzajemne zależności między nimi w technice morskiej Biegle zna i potrafi przeanalizować oraz wskazać możliwości wykorzystania w technice morskiej.
EK3	Ma podstawową wiedzę teoretyczną w zakresie struktury, przetwarzania, transmisji i pomiarów sygnałów elektrycznych.			
Metody oceny	egzamin pisemny, egzamin ustny, sprawdziany i prace kontrolne w semestrze.			
Kryteria/ Ocena	2	3	3,5 - 4	4,5 - 5

Kryterium 1 Podstawowa wiedza teoretyczna w zakresie struktury, przetwarzania, transmisji i pomiarów sygnałów elektrycznych.	Brak lub niewystarczająca podstawowa wiedza w zakresie struktury, przetwarzania, transmisji i pomiarów sygnałów.	Opanowana podstawowa wiedza w zakresie struktury, przetwarzania, transmisji i pomiarów sygnałów.	Zna i potrafi scharakteryzować/omówić podstawowe pojęcia z zakresu struktury, przetwarzania, transmisji i pomiarów sygnałów Zna i potrafi scharakteryzować/omówić podstawowe i rozszerzone pojęcia z zakresu struktury, przetwarzania, transmisji i pomiarów sygnałów występujących w technice morskiej.	Zna i potrafi przeanalizować pojęcia z zakresu struktury, przetwarzania, transmisji i pomiarów sygnałów występujących w technice morskiej Biegle zna i potrafi przeanalizować pojęcia z zakresu struktury, przetwarzania, transmisji i pomiarów sygnałów występujących w technice morskiej.
EK4	Posiada umiejętności pomiarów, analizy i przetwarzania sygnałów elektrycznych.			
Metody oceny	zaliczenie ćwiczeń, laboratoriów/ symulatorów, sprawozdanie/ raport.			
Kryteria/ Ocena	2	3	3,5 - 4	4,5 - 5
Kryterium 1 Umiejętności pomiarów, analizy i przetwarzania sygnałów elektrycznych.	Brak lub niewystarczające podstawowe umiejętności w zakresie pomiarów, analizy i przetwarzania sygnałów.	Opanowane podstawowe umiejętności w zakresie pomiarów i analizy sygnałów.	Opanowane podstawowe umiejętności w zakresie pomiarów, analizy i przetwarzania sygnałów Opanowane w stopniu dobrym podstawowe umiejętności w zakresie pomiarów, analizy i przetwarzania sygnałów występujących w technice morskiej.	Opanowane w stopniu bardzo dobrym podstawowe umiejętności w zakresie pomiarów, analizy i przetwarzania podstawowych sygnałów występujących w technice morskiej Biegle zna i potrafi przeanalizować pojęcia z zakresu pomiarów, analizy i przetwarzania złożonych sygnałów występujących w technice morskiej.
EK5	Ma podstawową wiedzę w zakresie zasad działania, budowy, eksploatacji podstawowych obwodów i urządzeń elektronicznych.			
Metody oceny	egzamin pisemny, egzamin ustny, sprawdziany i prace kontrolne w semestrze.			
Kryteria/ Ocena	2	3	3,5 - 4	4,5 - 5

Kryterium 1 Wiedza w zakresie zasad działania, budowy, eksploatacji podstawowych obwodów i urządzeń elektronicznych.	Brak lub niewystarczająca podstawowa wiedza w zakresie zasad działania, budowy, eksploatacji podstawowych obwodów i urządzeń.	Opanowana podstawowa wiedza w zakresie zasad działania, budowy, eksploatacji podstawowych obwodów i urządzeń.	Zna i potrafi scharakteryzować/omówić podstawowe i rozszerzone pojęcia z zakresu zasad działania, budowy, eksploatacji podstawowych obwodów i urządzeń.	Zna i potrafi przeanalizować pojęcia z zakresu zasad działania, budowy, eksploatacji podstawowych obwodów i urządzeń Biegle zna i potrafi przeanalizować pojęcia z zakresu zasad działania, budowy, eksploatacji podstawowych obwodów i urządzeń występujących w technice morskiej.
EK6	Posiada umiejętność analizy działania, pomiaru parametrów oraz wyznaczania charakterystyk podstawowych obwodów i urządzeń elektronicznych.			
Metody oceny	zaliczenie ćwiczeń, laboratoriów/ symulatorów, sprawozdanie/ raport.			
Kryteria/ Ocena	2	3	3,5 - 4	4,5 - 5
Kryterium 1 Umiejętność analizy działania, pomiaru parametrów oraz wyznaczania charakterystyk podstawowych obwodów i urządzeń elektronicznych.	Brak lub niewystarczające podstawowe umiejętności w zakresie analizy działania, pomiaru parametrów oraz wyznaczania charakterystyk.	Opanowane podstawowe umiejętności w zakresie analizy działania i pomiaru parametrów podstawowych obwodów i urządzeń.	Opanowane podstawowe umiejętności w zakresie analizy działania, pomiaru parametrów oraz wyznaczania charakterystyk podstawowych obwodów i urządzeń Opanowane w stopniu dobrym podstawowe umiejętności w zakresie analizy działania, pomiaru parametrów oraz wyznaczania charakterystyk podstawowych obwodów i urządzeń.	Opanowane w stopniu bardzo dobrym analizy działania, pomiaru parametrów oraz wyznaczania charakterystyk podstawowych obwodów i urządzeń Biegle opanowane umiejętności w zakresie analizy działania, pomiaru parametrów oraz wyznaczania charakterystyk podstawowych obwodów i urządzeń występujących w technice morskiej.