Digital systems and basics of electronics

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materials: $ftp(public)://aszmigie/SYC/ENG$

Introduction, physical fundamentals of electronics - lecture 1

Semestral Schedule

1. Introduction, physical fundamentals of electronics,
2. Passive elements,
3. Passive Signal Processing,
4. Semiconductors - diodes and transistors,
5. Operational amplifiers,
6. Introduction to digital systems,
7. Minimization of Boolean functions,
8. Combinational functional blocks,
9. Sequential Circuits - introduction,
10. Designing of Sequential Circuits,
11. Computer systems, microprocessors and microcontrollers,
12. Microcontrollers and embedded systems,
13. Microcontroller peripherals,
14. Communication interfaces,
15. Microcontrollers in control systems,

Semestral laboratory schedule

Laboratory is one week sifted accordingly to lecture. First laboratory is not evaluated.

1. Introduction to laboratory,
2. Voltage and current measurement,
3. Passive elements study,
4. Resistor divider, RC and RL passive filters,
5. Diodes and transistors characteristic study,
6. Operational amplifiers,
7. Logical gates and signals - physical and simulation,
8. Minimization of Boolean functions,
9. Commutational circuits, arithmetic and logic, ALU,
10. Realization of simple sequential circuits - registers, counters etc.,
11. Designing and realization of Sequential Circuits,
12. Introduction to μC Arduino,
13. Peripherals - AD converters, LCD display etc.,
14. Serial communication interfaces I2C, SPI, UART,
15. Events handling, buttons etc. Introduction to Raspberry Pi.

How to pass SYC

- There are 70p to get - 14 exercises, 5 points each,
- The final grade is based on the table

grade	points
2	0 - 35
3	35,5 - 42
3,5	42,5 - 49
4	49,5 - 56
4,5	56,5 - 63
5	63,5 - 70

SYC Laboratory organization notes

- *Laboratories* take place in computer rooms s02,
- *Laboratories 1 - 6* will realize with electronic laboratory equipments (oscilloscopes, generators, multimeters, etc.)
- *Laboratories 7 - 15* will realize with system based on circuit AVR ATmega328 (Arduino) and with simulator *logisim-win-2.1.6.exe*,
- *Laboratory 1* will not be evaluated.
- Grade consists of following component
  - *the level of preparation* - short entering test is suggested if supervisor will not decide different,
  - *accomplishing lab*,
  - *Final result* - supervisor can decide to make raport or other documentation.

Electric potential and voltage

The electric potential φ_A at a point A is equal to the work W (energy measured in joules) done to replace electrical charge q to the infinity divided by the charge q (measured in coulombs)

$$\varphi_A = \frac{W_{A \to \infty}}{q}$$

Voltage U_{AB} is the electric potential difference between two points A i B. Voltage is an ratio of work (energy) done to transport electrical charge between two points to the value of charge q.

$$U_{AB} = \varphi_B - \varphi_A = \frac{W_{A \longrightarrow B}}{q}$$

Reference potential - ground

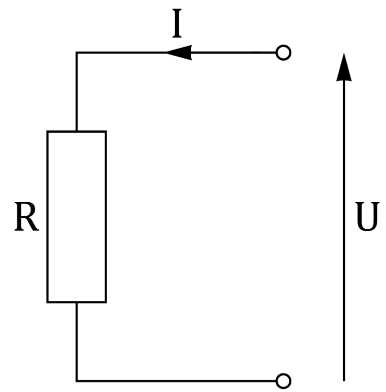
- Definition of electric potential is not too much practical from technical point of view,
- Ground or earth (symbol $\perp$) can refer to the reference point OV in an electrical circuit from which voltages are measured, a common return path for electric current,
- Consequently ground is related with negative pole of power supply,
- Often ground is direct physical connection to the Earth (but it is not necessary).

Electric current

- *An electric current* is a flow of electric charge,
- In electric circuits this charge is often carried by moving electrons in a wire. It can also be carried by ions in an electrolyte,
- Electric charge flows when there is voltage present across a conductor.

Ohm's law

The resistance of a resistor can be defined in terms of the voltage drop across the resistor and current through the resistor related by Ohm's law

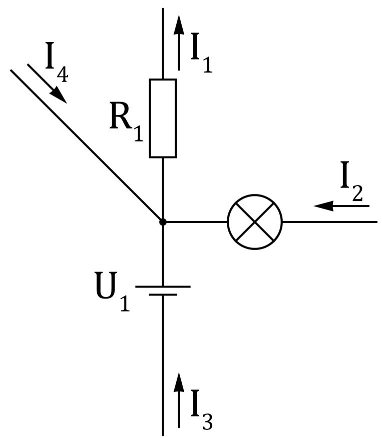


$$R = \frac{U}{I}$$

where R is the resistance $[\Omega]$, U is the voltage across the resistor $[V]$, and I is the current through the resistor $[A]$. Whenever a current is passed through a resistor, a voltage is dropped across the ends of the resistor.

Kirchhoff's Current Law KCL *(Kirchhoff's first law)*

At any point in an electrical circuit the sum of currents flowing towards that point is equal to the sum of currents flowing away from that point.



$$i_1(t) + i_4(t) = i_2(t) + i_3(t)$$

Kirchhoff's Current Law can be stated alternatively as:

"the algebraic sum of the branch currents entering (or leaving) any node of a circuit at any instant of time must be zero."

In this form, the label of any current whose orientation is away from the node is preceded by a minus sign. The currents entering node must satisfy

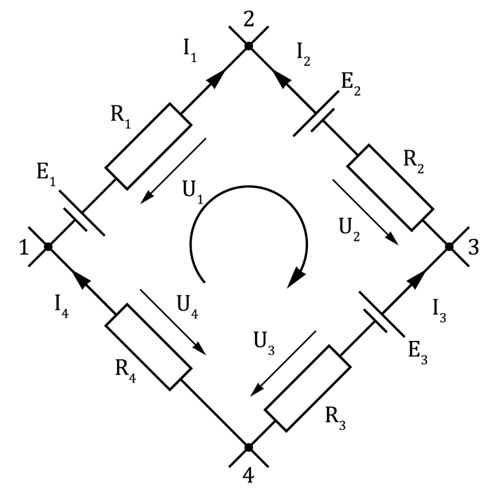
$$i_2(t) + i_3(t) - i_1(t) - i_4(t) = 0$$

In general, the currents entering or leaving each node of a circuit must satisfy. Sign "+" says that current flows into the node and "-" flows out.

$$\sum_k i_k(t) = 0$$

Kirchhoff's Voltage Law KVL *(Kirchhoff's second law)*

The directed sum of the electrical potential differences around a closed circuit must be zero.



$$e_1(t) - v_1(t) - e_2(t) + v_2(t) - e_3(t) + v_3(t) - v_4(t) = 0$$

Kirchhoff's Voltage Law

KVL can be expressed mathematically as "the algebraic sum of the voltages drops around any closed path of a circuit at any instant of time is zero." This statement can also be cast as an equation:

$$\sum_k V_k(t) = 0$$

Measurement of physical quantity

Physical measurement can be classified:

- *Direct measurement* - the value of physical quantity is determined directly in measuring process, eg. voltage measurement with voltmeter, mass with weight etc.,
- *Indirect measurement* - the desired value of physical quantity is not determined directly in measuring process, but measurement enables estimate desire value eg. current measurement by measuring voltage drop on resistor, distance measure by time of flight measurement etc.

Measurement and its uncertainty

- To make the measurement reliable uncertainty analysis must be done,
- Uncertainty measurement describe the quality of measurement,
- Usually uncertainty measurement is estimated by the measurement error,
- Uncertainty of measurement can by also related to specificity of measurement or equipment characteristic eg. distance measurement with ultrasonic sonar - the problem of directionality of ultrasound etc.

Measurement errors classification

Measurement errors can be classified :

- *Systematic errors* - regular errors (eg. equipment construction defects, unappropriate measurement conditions etc.),
- *Random errors* - caused by many different reasons. It is not possible to eliminate completely,
- *Thick error* - mistake measurements or observations. Must be rejected or measurement must be repeated.

Errors calculus

- *The Absolute error* - error in some data is the discrepancy between an exact value and some approximation to it. x_0

$$\Delta x = x - x_0$$

- *The Relative error* - is an ratio of module of absolute error to to module of the real value x_0

$$\delta_x = \frac{|\Delta x|}{|x_0|} = \frac{|x - x_0|}{|x_0|}$$

where x – measured value, Δx – absolute error. Relative error is dimensionless, usually expressed as a percentage

$$\delta_x = \frac{|\Delta x|}{|x_0|} \cdot 100\%$$

Errors analog measuring instruments

- The value of measuring error can be calculated according to the *class analog meter*. The error can be calculated as follow:

$$\Delta x = \frac{kl \cdot Z}{100}$$

  where kl – class, Z – range. Measured value x is in interval $\langle x - \Delta x, x + \Delta x \rangle$

- Uncertainty measurement is usually bigger then measuring error, in effect unperfect analog reading - must be consider in total error calculation.

Errors digital measuring instruments

For digital measuring instruments the total absolute error Δc consists of two components:

$$\Delta c = \Delta p + \Delta d$$

- $\Delta p = \pm a\%X$, where X an measuring result,
- $\Delta d = \pm n \cdot \Delta r$ where: n - digit(dgt), Δr - resolution - the smallest change of measuring physical quantity caused the change 1 (one) of least significant digit on reading display.

eg.: The notation: $\pm(0.1\% + 4dgt)$ the total absolute error is a sum of $0,1\%$ of result and 4 times of resolution for given measuring range.

The proper choice of measuring range

- **If the measured value is closer to the end of the range the result is more accurate,**
- The digital measure is more accurate if more digits are on the display.

Error of indirect measure - max - min method

In indirect measurement maximal and minimal values of measurement must be calculated. eg. for current I from Ohm's law $I = \frac{U}{R}$

$$I_{min} = \frac{U - \Delta U}{R + \Delta R} \qquad I_{max} = \frac{U + \Delta U}{R - \Delta R}$$

Next the current I and measuring error ΔI can be estimated as follow:

- $\hat{I} = \frac{1}{2} \cdot (I_{max} + Imin)$ - as mean value,
- $\Delta I = \frac{1}{2} \cdot (I_{max} - Imin)$ - the absolute error of current I.

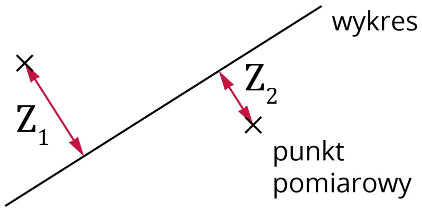
Rounding

The final value of measurement usually should be rounded. The rounding rules:

- The absolute error Δx of physical quantity X should be rounded keeping maximum two significant digits (eg. $\Delta x = 0,0084356 \approx 0,0084$),
- Absolute error can not be smaller then measuring instrument resolution,
- The measuring result should be rounded to the same decimal place as a absolute error Δx. (eg. result $X = 0,12645635523 \approx 0,1264$).
- The final result with error: $X = 0,1264 \pm 0,0084$.

Graphical representation of measurements

- The scale of chart should occur all measured values
- Measured points should be marked with points or crosses,
- Estimated curve is usually śmooth line- on the both sides of curve the number of measured points should be the same,



- Do not link measuring points with line segments - broken line is not good description of measurement!

Literature

1. Horowitz Paul, Hill Winfield.: *The art of electronics part 1-2*, 1989, ISBN-10: 0521370957 ISBN-13: 9780521370950

2. Wilkinson B.: *Digital System Design*, 1986, ISBN-10: 0132142899 ISBN-13: 978-0132142892