

SOFTWARE FOR MEASURING OF DIFFERENTIAL RESISTANCE BY SCANNING OF DIGITAL IMAGES OF ANALOG OSCILLOGRAMS

Abstract. A program for measuring the differential resistance of varistor materials by scanning digital images of analog oscillograms is described. The program was created using the languages HTML, CSS, JavaScript and Canvas technology. The software environment for its execution are Internet browsers. The program can be used to measure linear resistance, which limits the nonlinearity of current-voltage characteristics of varistor materials at high electric currents.

Keywords: digital image, determination of parameters by scan data, differential resistance, varistor materials.

Statement of the problem and purpose of research. Currently, for overvoltage protection of electronic devices and electrical equipment, varistors on the base of zinc oxide are widely used, since they have a highly nonlinear current-voltage characteristic (CVC) [1]. The efficiency of overvoltage protection is significantly influenced by the linear volume resistance of zinc oxide grains in varistor material. This resistance reduces the nonlinearity of CVC at the high electric currents [2]. Therefore, the measurement of such resistance is an important task.

In [3] a method for measuring the specific linear resistance ρ_{lin} which limits the nonlinearity of current-voltage characteristic of varistor materials at high electric currents was proposed. This method is based on the concept of differential resistance. The method allows determining the value of ρ_{lin} by data obtained at measurement of the differential resistance of varistor material at high electric currents. In this case it is necessary to register the CVC of varistor material with high accuracy. This can be done using the digital images of oscillograms of voltage and current pulses recorded with a two-beam analog storage oscilloscope [4]. Such images are easily obtained using a digital photo camera. The instantaneous values of voltage and current can be measured using the data obtained at scanning of digital images of oscillograms [4]. The high resolution of a digital photo camera makes it possible to

provide a relative error of measurement no more than $\pm 1\%$, since the absolute error in scanning digital images does not exceed ± 1 pixel.

Software is required to scan digital images and processing the scan results. To create it, it is convenient to use the languages and technologies using in the Internet. These are the languages HTML, CSS, JavaScript, and Canvas technology. The software environment for programs created by these means can be any internet browser.

The aim of this work is to create a program for measuring the differential resistance of varistor materials based on data of scan for digital images of analog oscillograms of voltage and current pulses obtained when the sample is exposed to a single voltage pulse of exponential shape.

Major part. As knowing, the differential resistance R_{dif} is defined as the ratio of the voltage increment ΔU to the current increment ΔI , namely $R_{dif} = \Delta U / \Delta I$. Thus, to determine R_{dif} it is necessary to measure the voltage and current values at least two points of the current-voltage characteristic. As shown earlier [4], with known voltage scale M_{cU} and current scale M_{cI} for digital image of oscillogram, the electric field strength E_i and current density J_i in varistor material for a sample with thickness L and area of electrodes S can be calculated based on the scan coordinates y_{iU} and y_{iI} . These coordinates are corresponded to the same coordinate x_i on the lines of voltage and current pulses, respectively. The expressions for calculation E_i and J_i have view:

$$E_i = \frac{1}{L} (M_{cU} (y_{0U} - y_{iU}) - M_{cI} R (y_{0I} - y_{iI})), \quad (1)$$

$$J_i = \frac{M_{cI}}{S \cdot R} (y_{0I} - y_{iI}), \quad (2)$$

where y_{0U} , y_{0I} are coordinates which were scanned on zero voltage and current lines of the oscillogram; R is the resistance of a precision resistor connected in series with the sample to register the current.

The use of sufficiently short single pulses of an exponential form makes it possible to register sections of the current-voltage characteristic in the region of high electric currents. The program below calculates the differential resistivity ρ_{dif} (ρ_{duf}) using six points selected by user on the digital image of oscillogram for voltage and current pulses. When scanning, the user selects three points on the line of voltage pulse and three points on the line of current pulse, which have same values of x_i coordinate. The program, based on scanning data calculates the values of E_i and J_i for three points of the current-voltage characteristic using formulas (1), (2). On the base of these data, program calculates ρ_{dif} using the least squares method for the linear

regression case. In addition, the program provides calculation of the average current density J_{av} within three points of the CVC and its reciprocal value $1/J_{av}$. It also calculates at current density J_{av} the average distance L_b between intergranular energy barriers operating in the reversible electric breakdown mode.

The algorithm for processing digital images of analog oscillograms executed by the program consists of the following stages: 1). Loading a digital image of oscillogram into browser window; 2). Introduction of the initial data for the studied sample: L, S, R and of the band gap E_g for the basic material component (ZnO or SnO₂). Scaling of digital image of oscillogram using calibration signals or calibration intervals of oscilloscope grid. 4). Determination of the coordinates of zero line y_{0U} , y_{0I} for voltage and current pulses. 4). Scanning of the coordinates y_{iU} , y_{iI} , x_i ($0 \leq i \leq 2$) on the lines of voltage and current pulses of oscillogram. 5). Calculation based on the initial data, scales and scanning data of the above parameters and the error in determining of current density J. 6). Results output.

For the software implementation of the described algorithm, the languages HTML 5, CSS 3, JavaScript were used. For visually display of scan points and draw straight lines necessary for digital image processing Canvas technology was used. For this a canvas with dimensions of 2300×1750 pixels was created on a web page by <canvas> tag. Fig. 1 shows the program window at the initial stage of its execution.

To control the processing digital images, the program interface contains a toolbox with visible and hidden blocks. Visible blocks can be seen in Fig. 1. In the upper right corner of the window there is a block for displaying the current coordinates of the mouse cursor. In the upper left corner of the browser window, there is a block containing a set of buttons designed to launch scripts serving various stages of processing digital images of oscillograms. For each processing stage, the program displays a user instruction explaining his actions at this stage. Such instruction is in the center of screen in Fig. 1.

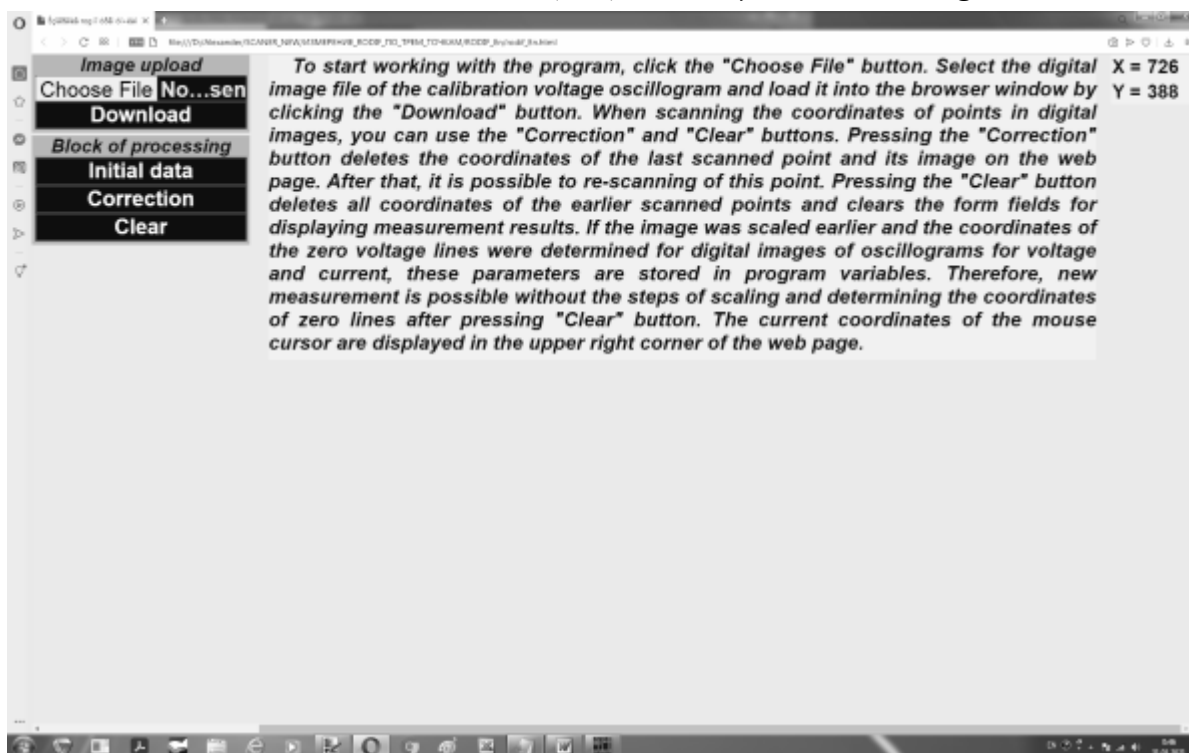


Figure 1 - Program window at the initial stage of execution

The "Choose File" and "Download buttons" are used to select a file of digital image and download it to the browser window. The group of buttons located below the "Block of processing" heading is used to processing of the loaded digital image. When one press the "Initial data" button, a hidden block with form fields for entering the initial data L , S , R and E_g opens. The "Correction" button is needed to correct the scanned data. When it pressed, the coordinates of last scanned point are deleted from the arrays of scanned data, and the circle centered in this point and the lines associated with it are erased on the canvas. The "Clear" button is used to completely delete of the scanned data and erasure the visual results of scan on the canvas. It should be noted that after pressing "Clear" the scales M_{cu} , M_{ci} of digital image and the coordinates of zero lines y_{0U} , y_{0I} are saved in the program variables. This makes it possible to re-process of digital image, bypassing the steps of scaling and determining the coordinates of zero lines of voltage and current.

After loading the digital image of oscillogram into the browser window, user instruction with message "Press the "Initial data" button" is opened. User clicks this button and opens the block for loading of the initial data. Then he enters initial data to the form fields of the block and clicks the "Download" button. The initial data is transferred to the program variables, and a hidden block for voltage scaling is opened. This block contains a form field for entering the value of calibration voltage

and the button "Calculate scale". User enters a calibration voltage into the form field and scans the ends of the interval corresponding to this voltage in the digital image of oscillogram.

Scanning is performed by clicking the left mouse button at the selected point of digital image. On the "mouseup" event, a script is executed that reads the coordinates of the point into the scanned data arrays. This script uses Canvas technology to draw a circle, the center of which has the coordinates of the scanned point. Script draws also a vertical straight line with thickness of 1 pixel from the center of this circle. Such lines are needed to select scan points on the oscillogram of current pulse with the same value of x_i coordinate as for points scanned on the oscillogram of a voltage pulse. The circles representing the scanned points are connecting by straight lines.

After pressing the "Calculate scale" button of the voltage scaling block, the M_{cU} scale is calculated and its value transmits to the corresponding program variable. This hides the current block and opens a hidden block for scaling of current. This block has the same organization and formatting as the voltage scaling block. After pressing "Calculate scale" button, the M_{cI} scale is calculated, the current block is hidden, and a hidden block opens to determine the coordinate of zero voltage line y_{0V} in digital image of oscillogram.

This block contains the "Determine" button. The user scans two points on zero voltage line of the digital image of oscillogram and presses the "Determine" button. A program script start takes place, which calculates y_{0V} as the average value of y coordinates for two scanned points and opens a hidden block to determine the coordinate of electric current zero line in oscillogram y_{0I} . This block and script that supports it are organized like the block and script for determining of y_{0V} coordinate.

When the user clicks the "Determine" button of the block for determining of the y_{0I} , this block is hidden and the block opens, which is designed to perform the final stages of processing the digital image of oscillogram. In Fig. 2 shows a view of window with such block after performance of the program. The block contains a button "Calculate" and two tables with hidden form fields for output of results. The first table consists of three columns for output the electric field strength E , current density J , and the relative error of current density determining "Error". These data are presented for three points of the current-voltage characteristic at which measurements were made. The second table is used to output in hidden fields of form the values: J_{av} , ρ_{dif} (ro_{dif}), $1/J_{av}$ and L_b .

At the final stages of program execution, processing begins with scanning the voltage pulse of oscillogram. This process is controlled by a script that, after scanning the third point, generates the message "Scanning of the voltage pulse is complete. Perform the scan of current pulse." The user scans oscillogram of current pulse in the same sequence and at the same values of coordinate's x_i as for the voltage pulse. The vertical lines drawn when scanning the voltage pulse use for this, as can be seen in Fig. 2. During the scanning of current pulse, the message "Scanning is complete, press the "Calculate" button" appears. After click "Calculate" button, the results appear in the hidden form fields of the tables (Fig. 2).

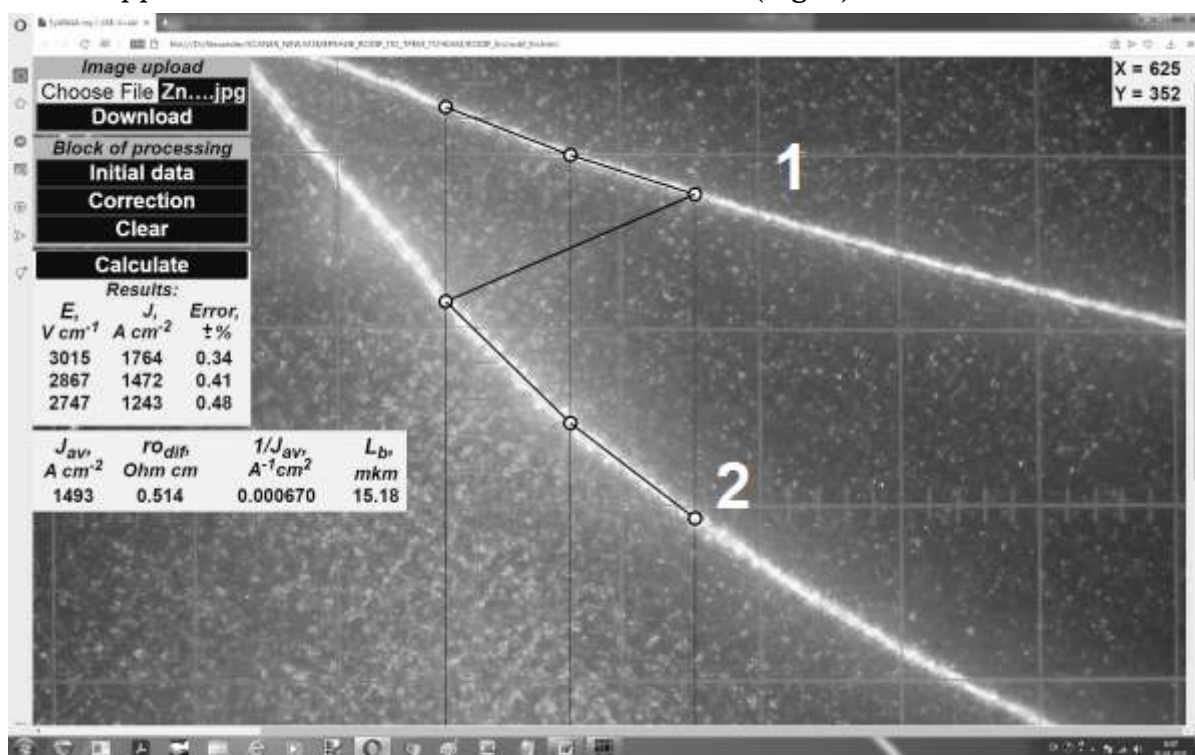


Figure 2 - Program window after execution. Oscillograms of impulses: 1 - voltage; 2 - electric current. Oscillogram for a sample of CH2-1 varistor

Conclusions. Use the languages HTML, CSS, JavaScript and means of the Canvas technology, the program for measurement of differential resistance of varistor materials by scanning the digital images of analog oscillograms has been created. The software environment for program executing is Internet browsers. The program can be used to measure the linear resistance limiting the nonlinearity of current voltage characteristic of varistor materials at high electric currents.

REFERENCES

1. Levinson L.M. Electronic ceramics: properties, devices and applications / L.M. Levinson—New York: Marcel Dekker, 1988.—170 p.
2. Clarke D.R. Varistor ceramics. / D.R. Clarke // Journal of the American Ceramic Society.—1999.—V.82.—p. 485-502.
3. Ivon A.I. High-current measurement of the grain resistivity in zinc oxide varistor ceramics / A.I. Ivon, R.I.Lavrov, A.B. Glot // Ceramics International.— 2013.—V.39.—p. 6441-6447.
4. Ivon A.I. Processing of the digital images of analogous occillograms at pulsed measurements / Ivon A.I., Istushkin V.F., RybkaYu.M., Savran S.V. // System technologies.—2020.— issue 1 (126).— p. 54-65.

Received 03.02.2021.

Accepted 06.02.2021.

Програма для вимірювання диференційного опору шляхом сканування цифрових зображень аналогових осцилограм

Описано програму для вимірювання диференційного опору варисторних матеріалів за даними сканування цифрових зображень аналогових осцилограм. Цифрові зображення отримують шляхом фотографування осцилограм імпульсів напруги і струму з екрану двопроменевого аналогового запам'ятовуючого осцилографа при подаючи на зразок варисторного матеріалу поодинокого експоненціального імпульсу напруги. Завдяки високій роздільній здатності цифрової фотокамери і абсолютній похибці сканування ± 1 піксель, забезпечується відносна похибка вимірювання миттєвих значень напруги і струму не більше ± 1 %. Сканування відбувається шляхом клацання лівою клав'яшею миші в обраній точці цифрового зображення. Диференційний опір програма розраховує з використанням методу найменших квадратів на підставі даних сканування, отриманих в трьох точках цифрових зображень осцилограм імпульсів напруги і струму. При обробці цифрових зображень забезпечується візуалізація точок, де було виконано сканування, а також можливість корегування даних сканування.

Програма реалізована засобами мов HTML, CSS, JavaScript і технології Canvas. Програмним середовищем для її виконання є браузері мережі Інтернет. Програма може бути застосована при вимірюванні лінійного опору, що обмежує нелінійність вольтамперної характеристики варисторних матеріалів в області сильних електричних струмів.

Программа для измерения дифференциального сопротивления путем сканирования цифровых изображений аналоговых осциллограмм

Описана программа для измерения дифференциального сопротивления варисторных материалов по данным сканирования цифровых изображений аналоговых осциллограмм. Программа реализована средствами HTML, CSS, JavaScript и технологии Canvas. Программной средой для ее выполнения являются браузеры сети Интернет. Программа может применяться при измерении линейного сопротивления, которое ограничивает нелиней-

ность вольтамперной характеристики варисторных материалов в области сильных электрических токов.

Ивон Александр Иванович - профессор, д.ф.-м.н, профессор кафедры электронных вычислительных машин Днепропетровского национального университета имени Олеса Гончара.

Истушкин Валерий Федорович - доцент, к.т.н., доцент кафедры электронных вычислительных машин Днепропетровского национального университета имени Олеса Гончара.

Ивон Олександр Іванович – професор, д.ф.-м.н, професор кафедри електронних обчислювальних машин Дніпровського національного університету імені Олеса Гончара.

Істушкін Валерій Федорович – доцент, к.т.н., доцент кафедри електронних обчислювальних машин Дніпровського національного університету імені Олеса Гончара.

Ivon Alexander - doctor of sciences (physics and mathematics), professor of the department of electronic computers of the faculty of physics electronics and computer systems of the Oles Honchar Dnipro National University.

Istushkin Valery - candidate of technical sciences, associate professor of the department of electronic computers of the faculty of physics electronics and computer systems of the Oles Honchar Dnipro National University.