DOI 10.34185/1562-9945-1-144-2023-03
UDC 004.42:621.317.351
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SOFTWARE FOR MEASURING THE NONLINEARITY COEFFICIENT OF VOLT-AMPERE CHARACTERISTIC FROM RASTER IMAGE OF OSCILLOGRAM

Abstract. The web application that allows by scanning a raster image of the pulsed signals analog oscillogram registered in the region of high electric currents to measure the nonlinearity coefficient of volt-ampere characteristic and its dependence on voltage and current is described.
Keywords: web application, raster image, scanning, volt-ampere characteristic, non-linearity coefficient.

Statement of the problem and purpose of research. When studying semiconductor materials and electronic devices based on them, it becomes necessary to measure the volt-ampere characteristic (VAC) in the region of high electric currents. Such measurements are necessary in the study of the VAC nonlinearity of oxide ceramic materials for varistors [1]. To exclude the thermal breakdown of samples, measurements are performed on short single voltage pulses. One can use single exponential voltage pulses, which allow to measure the volt-ampere characteristic in a certain voltage range [2]. By varying the amplitude of such pulses, measurements can be made over a wide range of voltage. The work [3] describes a program for measuring the volt-ampere characteristic with high accuracy by scanning data of a raster image of analog oscillogram of voltage and current pulses.

The purpose of this work is the creation of software that allows by scanning the oscillogram raster image of voltage and current pulses to measure the nonlinearity coefficient of volt-ampere characteristic and its dependence on voltage and current.

Major part. As is known [1], the volt-ampere characteristic of nonlinear materials and electronic devices based on them can be approximated by the dependence:

$$I = BU^{\alpha}, \qquad (1)$$

where I – current; U - voltage; B - constant; α is the nonlinearity coefficient of volt-ampere characteristic.

From relation (1) it follows that the coefficient of nonlinearity α at any point of the VAC can be determined by the formula

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

$$\alpha = R_S/R_D, \tag{2}$$

where $R_S = U/I$ – the static resistance; $R_D = dU/dI$ – the differential resistance.

Fig. 1 shows schematically the oscillogram raster image of voltage and current when an exponential voltage pulse is applied to element with a nonlinear volt-ampere characteristic.

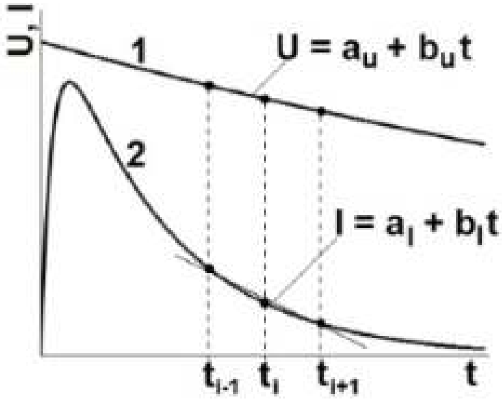

Figure 1 - Schematic representation of oscillograms of voltage (1) and current (2) pulses

The work [3] describes software for measuring the instantaneous voltage $U(t_i)$ and current $I(t_i)$ at time t_i by scanning the signal lines coordinates of voltage and current in the analog oscillogram raster image (Fig. 1). Based on these data, the static resistance R_S can be determined as $R_S = U(t_i)/I(t_i)$. This value of R_S corresponds to the point of volt-ampere characteristic with voltage $U(t_i)$ and current $I(t_i)$. The differential resistance R_D required to calculate the nonlinearity coefficient α by formula (2) can be found from the scaning data of coordinates in three points of the oscillogram raster image (Fig. 1) for the voltage line (curve 1) and the corresponding points for the line of current (curve 2). Using the scales of raster image found from the oscillograms scanning data of calibration signals and coordinates of zero lines for voltage and current, the program calculates by least squares method the coefficients b_U and b_I for straight lines drawn through three points (Fig. 1). Differential resistance R_D is calculated as $R_D = b_U/b_I$. Based on the obtained values of R_S and R_D, the program using formula (2) finds the nonlinearity coefficient α at the point of volt-ampere characteristic with voltage $U(t_i)$ and current $I(t_i)$.

Volt-ampere characteristic and dependence of nonlinearity coefficient on voltage and current can be obtained by scanning with a certain step of the coordinates of voltage and current pulses along the time axis in the oscillogram raster mage (Fig. 1).

In the study of semiconductor materials to represent the volt-ampere characteristic are used the current density *J*= *I*/*S* and the electric field strength *E*=*U*/*L* (*L* is the sample thickness; *S* is the electrodes area). Oscillogram of the current pulse is registered as voltage drop across the precision resistor *R* connected in series with the sample. Therefore the program provides the input of values L, S, R as initial data.

Taking into account the above, program implements the following algorithm for processing of the oscillogram raster image: 1). Loading of image into browser window. 2). Embedding image in a canvas to implement vector graphics. 3). Introduction of initial data: L, S, R. 4). Determination of voltage M_{cU} and current M_{cI} scales. 5). Determination of the zero lines coordinates y_{0U} and y_{0I} for voltage and current. 6). Scanning of the coordinates arrays (y_{iU}, x_{iU}), (y_{iI}, x_{iI}) along the lines of voltage and current pulses. 7). Calculation of instantaneous values of electric field strength $E(t_i)$, current density $J(t_i)$ and nonlinearity coefficient $\alpha(t_i)$. 8). Output of results.

The described algorithm is implemented using the languages HTML 5, CSS 3, JavaScript and the Canvas technology. The program uses Internet browsers as a software environment.

The user performs scanning by click with the left mouse button at the selected points in raster image. Point coordinates are read in pixels by the *mouseup* event, using the *pageX* and *pageY* properties of the *event* object of JavaScript. Program stores the coordinates of the points in arrays of scanned data. Using Canvas technology around the scanned point program draws circle with a radius of 10 pixels centered in the scan point. Neighboring points are connected by a straight line. Scanning begins from a voltage pulse. To facilitate the selection of a point on the current pulse oscillogram corresponding to a given voltage a vertical line is drawn from the scanned point, crossing the line of the current pulse. Based on the arrays of scanning data program calculates the values $E(t_i)$, $J(t_i)$, the nonlinearity coefficient $\alpha(t_i)$ and the relative error of measurement $J(t_i)$. These data are displayed on the program web page in hidden form fields. Since the selection of scanning points is carried out visually, to improve the accuracy of such selection program provides the ability to invert the color of raster image.

Fig. 2 shows the view of program window after execution with inverted color of the oscilogram raster image.

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

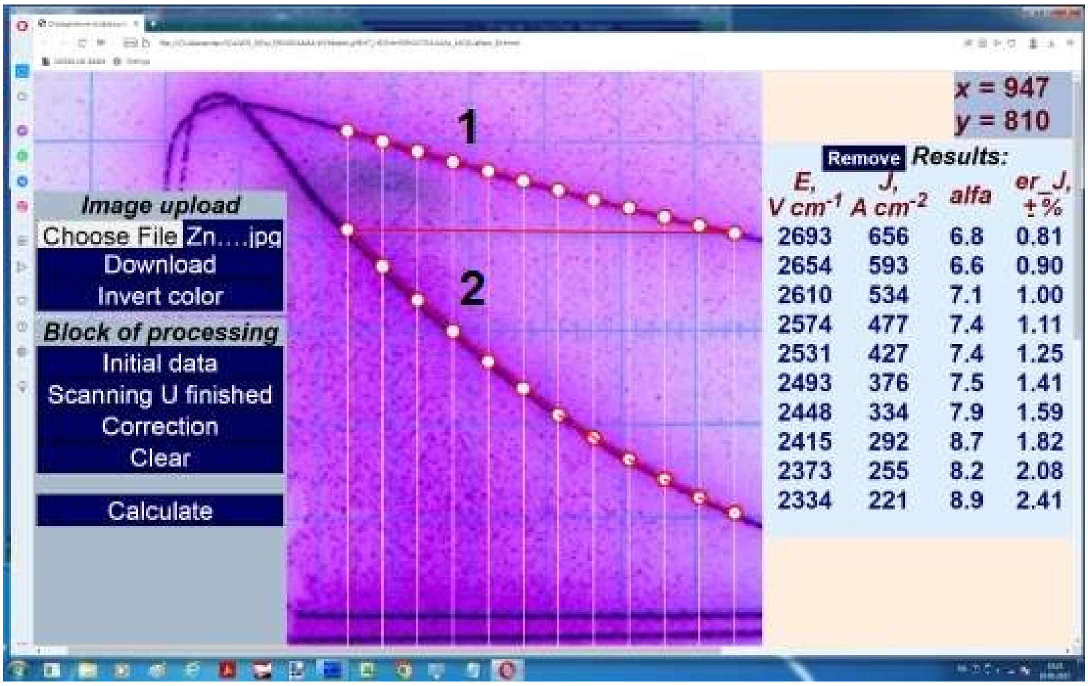

Figure 2 - Program window after execution. Oscillograms of impulses: 1 – voltage; 2 – electric current. Measurements was executed for a sample of zinc oxide based varistor ceramics

Program interface was created using the languages HTML 5 and CSS 3. It contains explicit and hidden toolbox blocks designed to process a raster image at different stages of algorithm. Explicit toolbox blocks are permanently displayed on a web page. These include the coordinate navigator of the current cursor position in the upper right corner of browser window (Fig. 2). To upload of raster images use the "Image upload" block. This block contains a form field of file type, "Download" button and "Invert color" button. A form field of file type is used to select a file of raster image and load it into the browser window using the FileReader and Image objects of the JavaScript language. The "Download" button is needed to embed the image in canvas. Using canvas makes it possible to display the scan results on the oscilogram raster image by means of the Canvas technology and invert its color. At click on the "Invert color" button, a script is executed that using the *getImageData()* and *putImageData()* methods of the Canvas object, inverts the color of image built-in the canvas.

The block with name "Block of processing" contains four buttons and area for displaying hidden blocks. At click on the "Initial data" button, a block with form fields for entering initial data L, S, R opens. Hidden are the scaling blocks, the blocks for determining of the oscillogram zero lines coordinates and the block for calculating the program output data. These blocks are opened at stages 4, 5 and 7 of the processing algorithm. During scaling stage, the user sequentially loads the raster images of the calibration signals oscillograms to determine the scale of voltage M_{cU} and current M_{cI}. After entering the calibration values in the form field of scaling blocks and executing the scanning, the program calculates values of M_{cU} and M_{cI}.

After scanning the voltage pulse oscullogram, the user presses the "Scanning U finished" button and begin scans the electric current pulse oscillogtam. The "Correction" button is used to correct the scan results. When this button pressed, the coordinates of the last scanned point are removed from the coordinate's arrays and the display of this point in raster image is erased. The "Clear" button launches a script for clearing arrays of scanned data, form fields with results and deleting the visual results of scanning. This script does not change the values of program variables intended for storing the initial data, scales and coordinates of the voltage and current zero lines. Therefore, one can perform further measurements with loaded raster image bypassing the first five stages of the processing algorithm.

Conclusions. Using the languages HTML, CSS, JavaScript and the Canvas technology a web application has been created for measuring in the region of high electric currents the nonlinearity coefficient of volt-ampere characteristic and its dependence on voltage and current. The measurement is done by scanning the raster images of the pulsed signals analog oscillograms.

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Received 05.01.2023.
Accepted 10.01.2023.

Програмне забезпечення для вимірювання коефіцієнту нелінійності вольт-амперних характеристик по растровому зображенню осцилограми

При дослідженні матеріалів для варисторів, що використовуються для захисту від перенапруг ланцюгів електропередач та електронних пристроїв, важливою є інформація про коефіцієнт нелінійності вольтамперної характеристики в

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

області сильних електричних струмів. Таку інформацію отримують з осцилограм імпульсів напруги і струму.

Метою даної роботи є створення програми, для вимірювання коефіцієнту нелінійності вольтамперної характеристики за даними сканування растрових зображень аналогових осцилограм імпульсних сигналів, зареєстрованих при сильних електричних струмах. Користувач виконує сканування клацанням у вибраних точках растрового зображення осцилограми. Програма позначає точки сканування та створює масиви сканованих даних на підставі яких розраховуються миттєві значення напруги, струму та коефіцієнта нелінійності вольтамперної характеристики. Відносна похибка вимірювання миттєвого струму не перевищує ±2%. У програмі передбачена можливість корекції результатів сканування. Програма створено з використанням мов HTML5, CSS3, JavaScript і технології Canvas. Інтернет браузери є програмним середовищем для її використання.

Ключові слова: веб-застосунок, растрове зображення, сканування, вольтамперна характеристика, коефіцієнт нелінійності.

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