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SOFTWARE FOR PROCESSING DIGITAL IMAGES OF ANALOG OSCILLOGRAMS

Abstract. Program for processing digital images of oscillograms was created by means for development of client web applications. On the basis of scan data obtained for digital images of analog oscillograms, a program allows to measure amplitude, duration, frequency, time constant of transient process and duration of signal fronts with a precision of the digital oscilloscope. The program can be executed in any Internet browser.

Keywords: digital image, software, oscillograms, signals parameters measurement.

Introduction. In spite of the wide use of digital oscilloscopes for measurements, the need for analog oscilloscopes remains quite large, since such oscilloscopes are much cheaper than digital oscilloscopes, and their real-time operation excludes distortions related to discretization of signals in digital oscilloscopes. The drawback of analog oscilloscopes is the relatively low accuracy of signals parameters measurement (5-10%) in comparison with digital oscilloscopes (2 - 3%). However, as shown in [1], the accuracy of the measuring of signals parameters from the oscillograms of analog oscilloscopes can be significantly increased if using raster (digital) images of oscillograms. Digital images of oscillograms can be obtained from the screen of analog oscilloscope by a digital photographic camera.

Digital images are a way of discretization the information presented in a visual form. When known scales for such images, the definition of objects parameters in image are possible on a basis of coordinates obtained by the scanning of these objects. Since the absolute scanning error is small ±1 pixel, this allows providing the high accuracy for parameters determination of electric signals. For processing digital images of oscillograms, software is required that allows to download graphic files to the computer, scan digital images and perform necessary calculations based on the scan data.

Problem definition. Creation of a program for measurement of the electrical signals parameters by scanning of digital images of oscillograms obtained by means of an analog oscilloscope is the purpose of this work.

Major part. Oscillograms contain information on such signal parameters as amplitude, instantaneous voltage, duration, frequency, duty factor. If the signal contains an exponential component, then the time constant of transient process and the duration of fronts are the additional parameters. The program should ensure the determination of all the above parameters. Since the algorithm of processing depends on the type of signal, one can select such signals: single pulse, periodic and exponential signals. The parameters of single pulse are the amplitude A and the duration timp. Parameters of periodic signal are amplitude A, frequency f and duty ratio Q = Timp/timp, (Timp – signal cycle). In the case of exponential pulses and pulses with exponential component, in addition to the indicated parameters, the time constant of the transient process τ, as well as the duration of the pulse fronts tf are of interest.

Taking into account foregoing, the processing steps for digital images of analog oscillograms can be represented in the form of a block diagram, shown in Fig. 1. At the stage of loading the image “Image upload”, the graphic file selected by user is displayed on the computer screen. The scales of the image are determined at the scaling stage “Scaling”. For this purpose, one can use a digital image of the oscillogram of a calibration signal: a pulse with a known amplitude AC and a duration timpC; a sinusoidal signal with a known frequency and amplitude. Some analog oscilloscopes have calibration blocks that generate such signals.

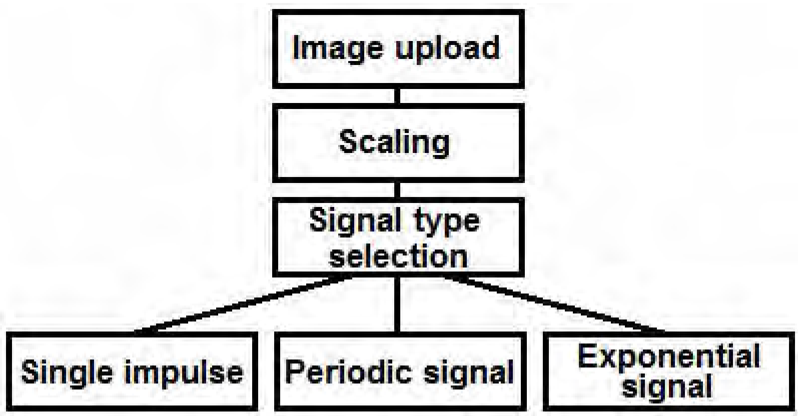

Figure 1 - Stages of processing digital image of analog oscillogram

For determining the scale factor MU of the voltage, the scanning of digital image must be performed at the amplitude level of the calibration signal (coordinates xAC, yAC) and at the zero line of the oscillogram (coordinates x0, y0). For determining the MT time scale factor, the scanning must be performed at two points in the digital image of the oscillogram that correspond to the leading and trailing edges of the calibration pulse and have the same coordinate values y (coordinates x1TC, y; x2TC, y). The values of scale factors can be calculated by the formulas:

$$M_U = A_C / |y_{AC} - y_0|; \quad M_T = t_{impC} / |x_{1TC} - x_{2TC}|. \tag{1}$$

If a sinusoidal signal with frequency fC is used for the time calibration, scanning is performed at two points of the zero line of oscillogram corresponding to the signal period. In this case the scale factor is MT = 1/(fC|x1TC − x2TC|). The oscillograms of testable signals should be obtained with the same sweep and amplification as for oscillograms of the calibration signal for correct use of the scale factors.

After choice of the signal type on the stage "Signal type selection" (Fig. 1), following loading and scanning of the oscillogram raster image, the program calculates signal parameters on a basis of scan data.

If signal is the single pulse, the scanning of the coordinates for its amplitude A (x1, y1; x2, y2) and duration timp (x3, y3; x4, y4) must be performed. The values of these parameters are calculated by the formulas:

$$A = M_U \cdot |y_1 - y_2|; \quad t_{imp} = M_T \cdot |x_3 - x_4|. \tag{2}$$

If we select the point on the zero line of oscillogram as the time zero (x0), then formulas (2) can be used for calculation of the instantaneous voltage of signal with respect to the selected moment of time (x0 = x4).

For periodic signals, the amplitude A (x1, y1; x2, y2), the duration timp (x3, y3; x4, y4) and the signal period Timp (x3, y3; x5, y5) must be scanned. The amplitude A is calculated by the formula (2), the frequency f and the duty ratio Q by the formulas:

$$f = \frac{1}{M_T(x_5 - x_3)}; \quad Q = \frac{x_5 - x_3}{x_4 - x_3}. \tag{3}$$

Since the quantization step for digital image is 1 pixel, the absolute scan error is Δx = ± 1 pixel. Then as it follows from the equations

(2), (3), the absolute errors in measuring of amplitude ΔA, duration Δtimp and frequency, without taking into account the degree of blurring of the oscillogram line, can be determined by the formulas:

$$\Delta A = 2M_U; \quad \Delta t_{imp} = 2M_T; \quad \Delta f = \frac{2}{M_T(x_5 - x_3)^2}. \qquad (4)$$

In the case of signals of exponential form, the method proposed in [2] can be used to determine the time constant of the transient process τ and the duration of the pulse fronts tf. The method is based on the linearity of the dependence ln (U (t)) ~ t, which is characteristic for signal with exponential shape. In this case the array of coordinates obtained by scanning of the oscillogram line for a signal with exponential component can be used. The scanning performs in the time interval t1 ≤ t ≤ tN. Such scanning gives the array of coordinates xi, yi (1 ≤ i ≤ N). Since the value of the instantaneous voltage is measured from the zero line of oscillogram, it is necessary to scan this line for get the coordinate y0. The program defines y0 using two points of zero line with the coordinates x01, y01 and x02, y02 as y0=(y01+y02)/2. It allows taking into account possible distortion of zero line of analog oscilloscope in the scan interval.

The scan data allow calculating the time ti = MT|xi − x1| and the logarithm of voltage ln(U(ti)) = ln(MU·|yi–y0|) in this moment of time. This gives are the arrays ti and ln(U(ti)) (1 ≤ i ≤ N), whose elements specify the coordinates of the points of line dependence ln(U(t)) ~ t with a certain degree of accurancy. Program uses these points for construction of a straight line lnU = b + at by the method of least squares. It calculates coefficients a, b by the known formulas for linear regression [3]. The value of τ for the transient process is defined as τ = |1/a|. According to [2], the values of absolute Δτ and relative δ errors in the determination of τ can be calculated as

$$\Delta\tau = \pm\frac{2\tau^2\Delta}{(t_N - t_1)}, \qquad (5)$$

$$\delta = \pm\frac{2\tau\Delta}{(t_N - t_1)}100\%, \qquad (6)$$

where the value Δ is equal

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$$\Delta = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\ln(U(t_i)) - b - at_i)^2} \ . \qquad (7)$$

The above mentioned method for determining of the signals parameters by means of the digital images of analog oscillograms was used to create the program. The program was created by means of the languages HTML, CSS, JavaScript and the jQuery library. This allows opening and performing program in any Internet browser.

Program executes the processing of digital images of analog oscillograms according to the stages in Fig. 1. It has an interface consisting of four blocks: a block of tools, a block for displaying the current coordinates of the cursor, an instruction block, a block for selecting a graphic file, and displaying the scanned coordinates. The "Tools" block contains the "Start processing" button that initiates the image processing, the "Continue" button allows to go to the next stage of processing, the "Came back" button providing a return to the previous stage of processing and the "Reset" button that returns the program to its initial state. Blok for display of the current coordinates of the cursor moves synchronously with the cursor. The hidden fields of the forms "X =" and "Y =" in this block are using for display of the current coordinates of the cursor x and y. The instruction block is opened at each stage of processing. It contains the user instruction that determines his action for given stage of the processing. This block contains the «Remove» button that allows hiding the block. Block for selecting a graphic file and displaying the scan coordinates contains a file type field and the “Обзор” button (“Выберите файл” for Opera and Google Chrome browsers). This block also contains the table with header «N X Y» for display of the scan coordinates. For display and hiding of blocks, the program uses the show () and hide () functions of the jQuery library. For the positioning of blocks, program uses the appropriate CSS properties and properties of “style” object in JavaScript.

The "Tools" block has different interface options for different stages of processing digital image of the oscillogram. These options include the necessary set of form fields and buttons to control the processing and display of its results. For get information about the current coordinates of the cursor and for display their in the block of current coordinates, the program uses a script that is activated by the "mousemove" event. The program starts performance after clicking the "Start processing" button. The program window for implementing the stages of image loading and scaling is opened. The window view after these stages is shown in Fig. 2.

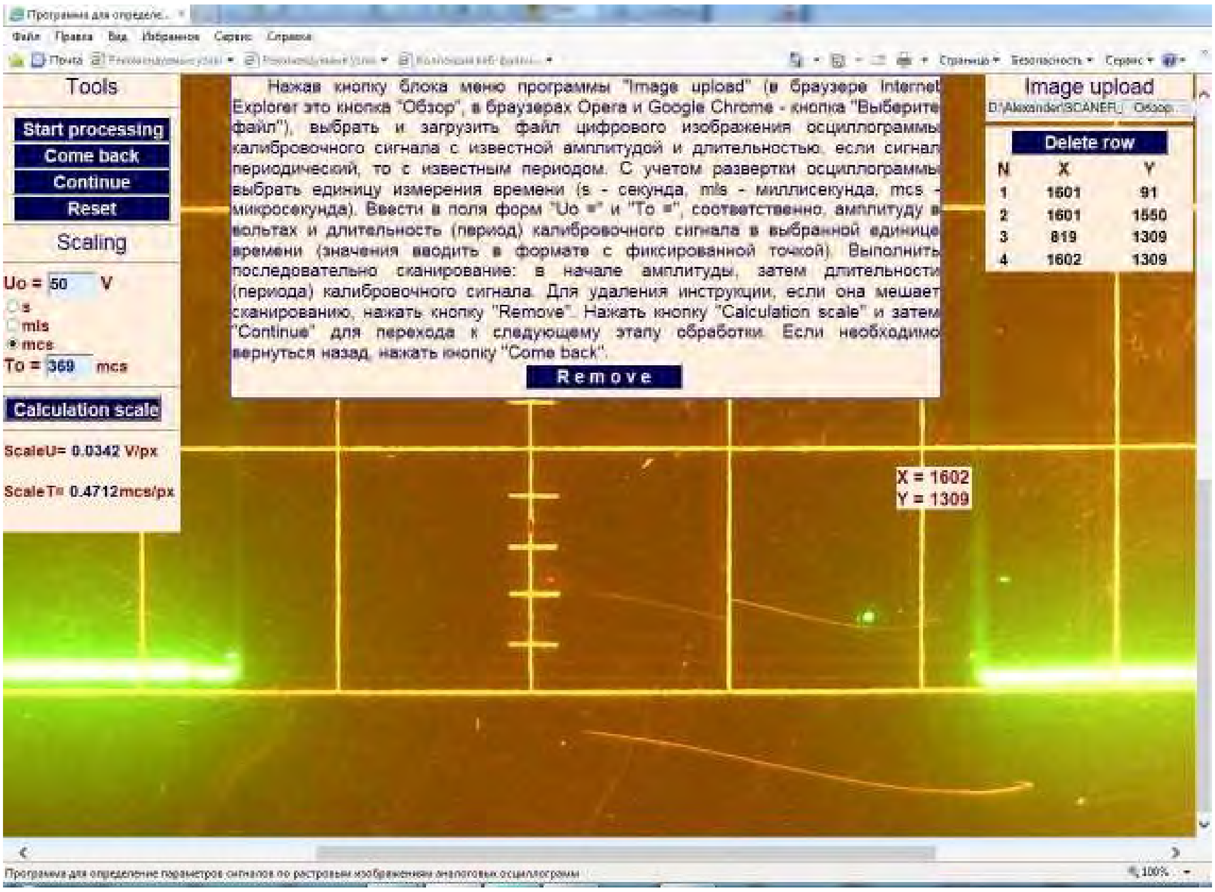

Figure 2 - The program window after completion of the scaling stage

The image of oscillogram of the calibration pulse with a known amplitude Uo and duration To is loaded at this stage. The “Обзор” button is used for this aim. The time unit is selected by means of the radio buttons (mls – the millisecond, mcs – the microsecond). The values of Uo, To must be entered to the form fields “Uo”, “To”. The scanning of amplitude and duration of the calibration pulse is performed. Scanning is performed by the clicking of left mouse key (event “click”) at the selected point of the image. A script is activated that reads the coordinates of the point, passes them to the variables of program, and writes them to the table. After pressing the button "Calculation scale" the program calculates the scales and displays them in the fields "Scale U =" and "Scale T =" (Fig. 2).

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The "Continue" button causes transition to the stage of selecting the type of the measured signal (Fig. 1). After the choice of signal type, user loads the digital image of signal to the browser window. Then after execution of the appropriate scan and clicking on the "Calculation" button, he can see results of measurement in the "Tools" block (Fig. 3).

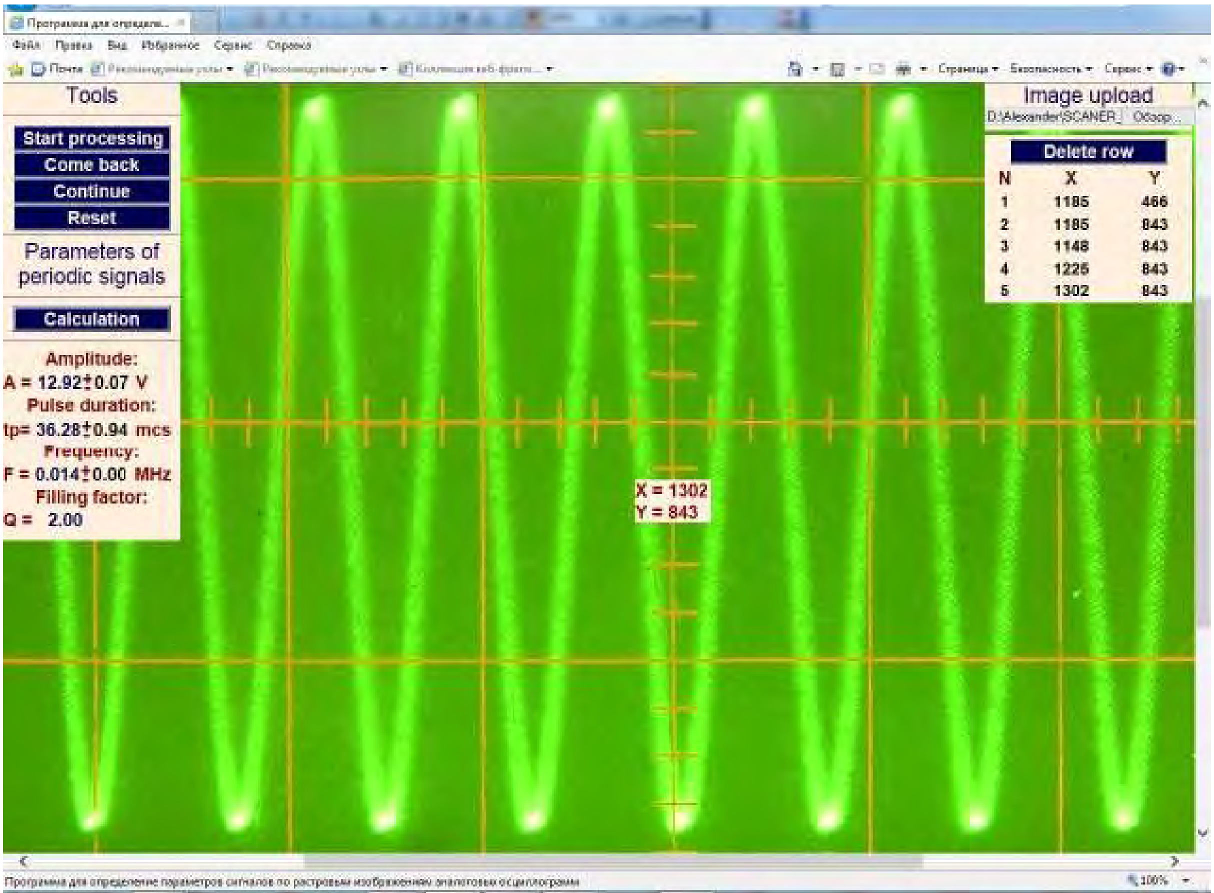

Figure 3 - The program window at final stage of determining the parameters of the periodic signal

In Fig. 3 the instruction block was deleted by the "Remove" button.

For signals with an exponential component, the number of scan data N is transmitted from field "N =" to the program by means of the "Input" button (Fig. 4). At first the scanning of zero line is performed and then the scanning of the line for pulse front. Zero line for the leading edge of rectangular pulse is the top of pulse. Zero line for the trailing edge is the zero line of oscillogram. The duration of the pulse front tf is defined as tf = 3τ (Fig. 4).

Thus, as it follows from the above examples, a program allows ensuring the accuracy of measuring the signals parameters at the level of a digital oscilloscope.

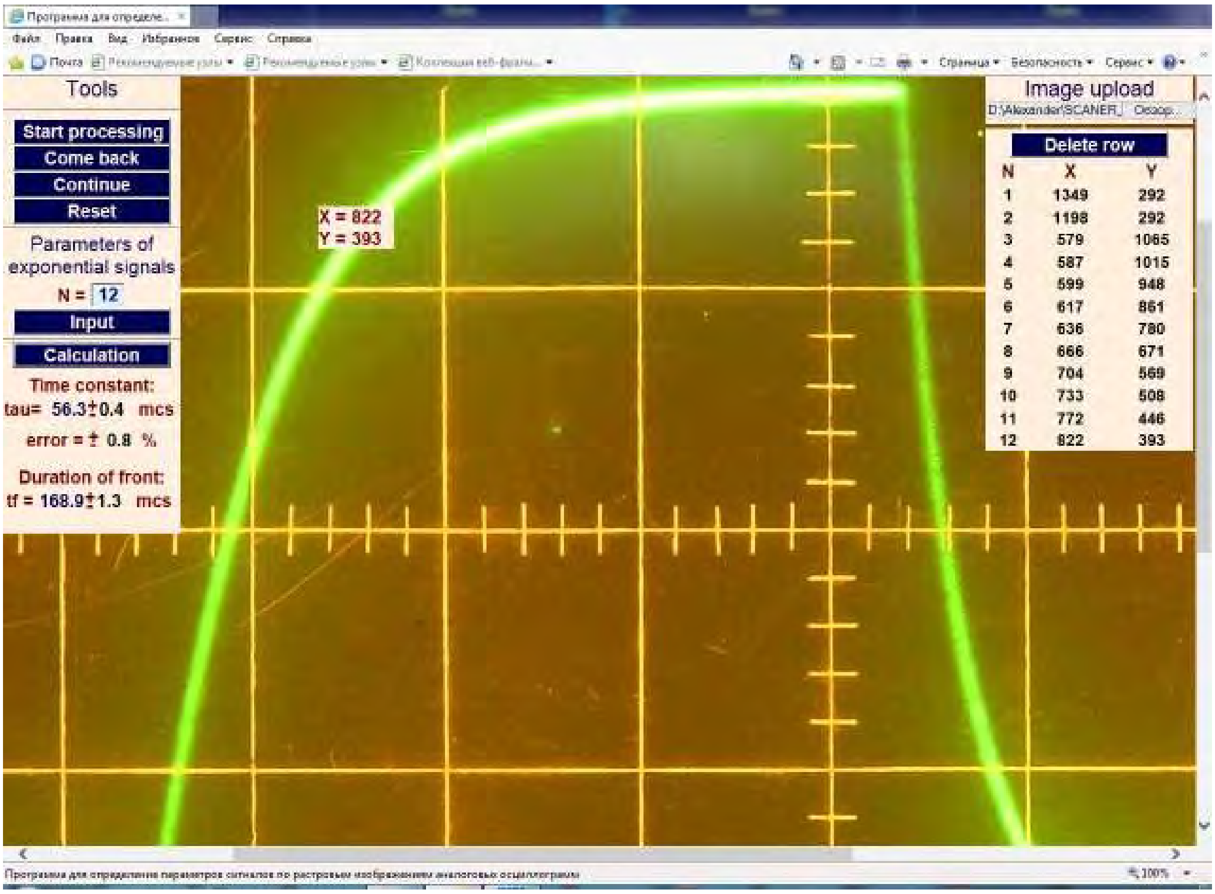

Figure 4 - The program window at final stage of determining the parameters of leading edge of a rectangular pulse distorted by the RC chain

Conclusions. A program for processing digital images of analog oscillograms was created by means for development of client web applications. The program can be opened and executed in any Internet browser. Program on the basis of scan data of digital images of analog oscillograms allows to measure amplitude, duration, frequency, the time constant of transient processes and the duration of signal fronts with a precision of the digital oscilloscope.

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