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Modeling of Processes in Mechanical Engineering Using the Simulink Package

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ABSTRACT: In many areas of mechanical engineering, models of various devices are quite complex and contain a large number of various nonlinear characteristics in the form of one-dimensional, two-dimensional and three-dimensional dependencies. In the process of developing a model of any device or during its modification, many parameters and characteristics (nonlinear dependencies) can be specified, changed, supplemented.

Simulink is widely used in automatic control and digital signal processing for multi-domain modeling and model-based design. Block diagrams (models) are constructed by dragging blocks from the component library into the user-created model editing window and connecting the blocks with lines.

KEYWORDS: modeling, mechanical engineering, Simulink, block diagram.

I. INTRODUCTION

In the process of developing a model of a device or when modifying it, many parameters and characteristics (nonlinear dependencies) can be specified, changed, supplemented, etc.

When working with fairly complex models of technical devices in MATLAB/Simulink, it is very convenient to store all the necessary numerical data parametrically, that is, in the form of variable names and arrays that are contained in the MATLAB Workspace [1].

For long-term work, all this data (one-dimensional and multidimensional arrays of characteristics, as well as model parameters in the form of numbers or vectors) is conveniently contained in one file, which can be stored on disk and transferred from one computer to another, as well as edited. For modeling in Simulink, data from a file of this type can be loaded into the MATLAB Workspace [2].

Most Simulink models fit into the following general scheme (Fig. 1).

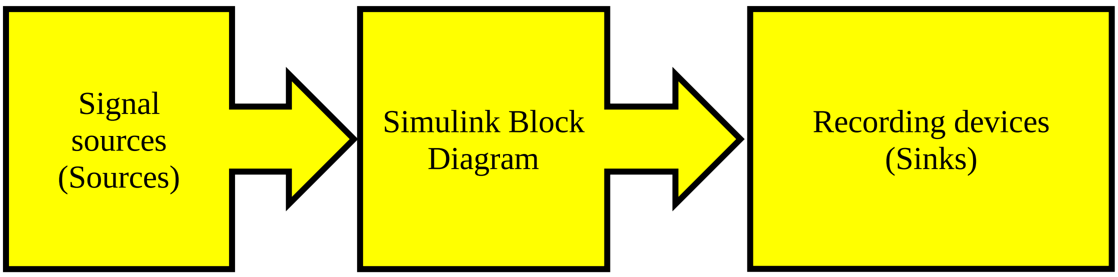

Fig. 1. General scheme of Simulink models.

The output signal of the source is a variable that affects the system described in the form of a structural diagram. The transformed signal of the source, after passing through the structural diagram, is recorded using special devices. Simulink models can include one or more blocks of sources and recorders. But the above diagram is not universal, since the models may not contain blocks from any of the groups highlighted in the diagram, such as simple models consisting only of signal sources and recording devices, or more complex models of self-oscillating systems. In the structural diagram, such systems do not have an input effect.

ISSN: 2350-0328
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Vol. 11, Issue 10, October 2024

II. CONSTRUCTION OF AN AMPLITUDE-MODULATED SIGNAL

As an example, let us consider the construction of an amplitude-modulated signal (Fig. 2).

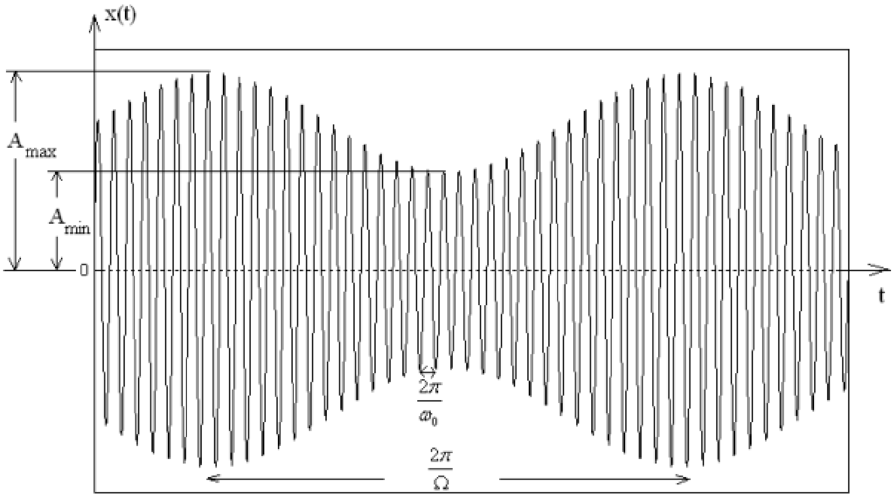

Fig. 2. Graph of the amplitude-modulated function.

The dependence of the signal on time t is determined by the expression $A(t)sin\omega_0 t$,, where the amplitude A changes according to the following law:

$A(t) = A_{max}(1 + msin\Omega t)$ with a frequency $\Omega \ll \omega_0$. To characterize the relative change in the amplitude of modulated oscillations, the parameter $m = \frac{(A_{max}-A_{min})}{(A_{max}+A_{min})}$ is used – the modulation coefficient.

Let's write the signal as follows:

$$x(t) = A_{max}(1 + \ msin\Omega t)sin\omega_0 t = (A_{max} + A_{max}msin\Omega t)sin\omega_0 t \qquad (1)$$

We will "assemble" this expression from blocks in Simulink. For certainty, let's set the following signal parameters:

$A_{max} = 10;$
$\omega_0 = 2\pi\ 0.5\ rad/s;$
$\Omega = 2\pi\ 0.1\ rad/s;$
$m = 5/15.$

To build a model from the "Sources of signals and effects" section of the "Simulink" library, drag the sinusoidal signal block into the model's working window. Its icon is shown in Fig. 3.

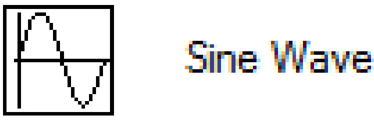

Fig. 3. Icon of the sine wave block.

We will need two sources of sinusoidal signals to set the fill frequency and the amplitude change frequency. You can drag this block twice into the working window or copy and paste the sinusoidal signal block from the buffer that is already there (Fig. 4). To paste an object from the buffer, you must first specify the insertion location by left-clicking on the intended insertion location, and then execute the Edit/Paste command.

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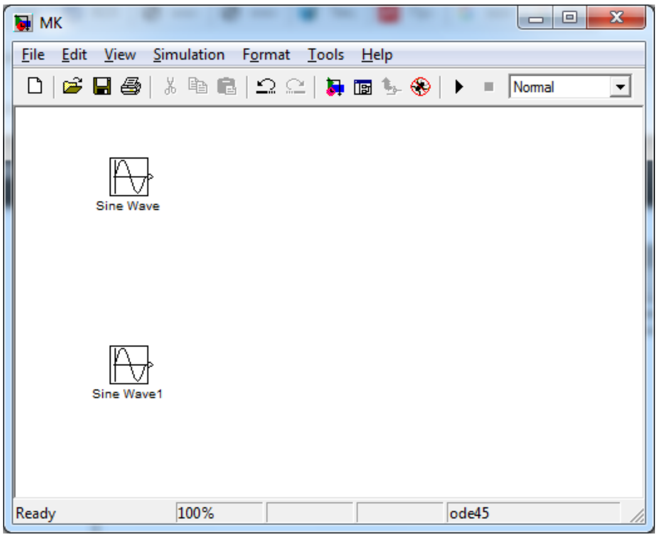

Fig. 4. Beginning of construction of the amplitude-modulated signal model.

Double-clicking on the block icon opens a window containing the description and parameters of the block. For the harmonic signal source, this window is shown in Fig. 5.

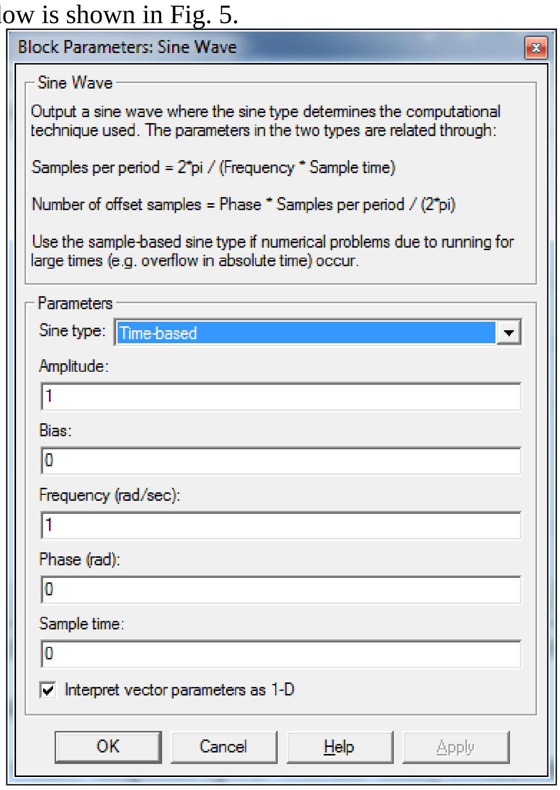

Fig. 5. Harmonic signal source dialog box.

The upper part of the window shows the general expression for calculating the output signal O(t) of this block

$$O(t) = Amp * \sin(Freq * t + Phase) + Bias \quad (2)$$

and explanations regarding the use of this block as a source of discrete signals. From expression (2) it is clear that the output signal is a sine wave with amplitude «Amp», cyclic frequency «Freq», phase «Phase» and shift along the ordinate axis «Bias».

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Let us consider in detail the window of parameters of the sine wave signal block (Fig. 5). In the main part of the window you can set the block parameters. This block can be used as a source of continuous in time and discrete signals.

You can select the block type in the Sine type drop-down list (Fig. 6):

• continuous signal source – time based,
• discrete signal source – sample based.

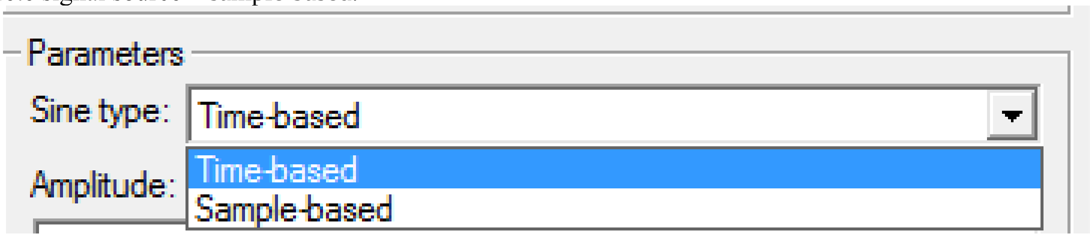

Fig. 6. Selecting a continuous or discrete signal source.

We will select a continuous signal source with a variable t corresponding to the simulation time. In the following cells of the window, you can set the parameters of the signal itself: amplitude, ordinate shift (bias), frequency in rad/s (frequency), phase in rad. (phase). Let the maximum amplitude of our modulated signal be equal to 10, the fill frequency - 0.5 Hz and the envelope frequency - 0.1 Hz. Then the block parameters will look like shown in Fig. 7.

When setting numerical parameters, keep in mind that a period, not a comma, should be used as a decimal separator.

In the last cell of the block parameters dialog box, you can set the quantization period Sample time if the block is used as a discrete signal source, or leave the value 0 for a continuous signal source.

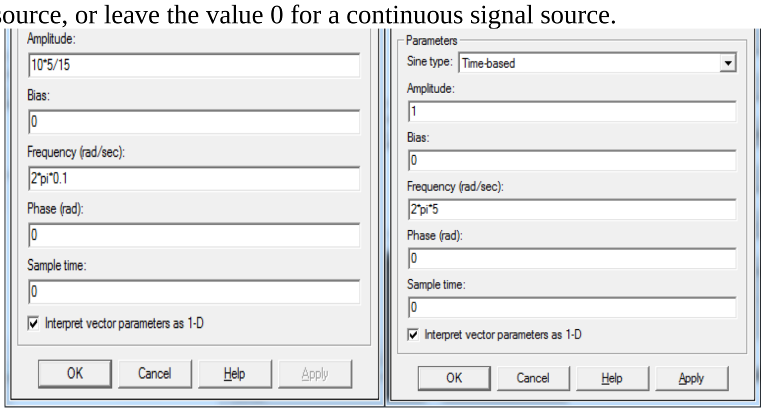

Fig 7. Selecting parameters for harmonic signal blocks.

We will also need another signal source – this is a constant shift A_max=10 for the signal amplitude. The icon of this block is shown in Fig. 8.

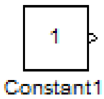

Fig. 8. Constant signal block icon.

In the parameters window of this block (Fig. 9) the value of the constant 10 is set.

ISSN: 2350-0328
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Vol. 11, Issue 10, October 2024

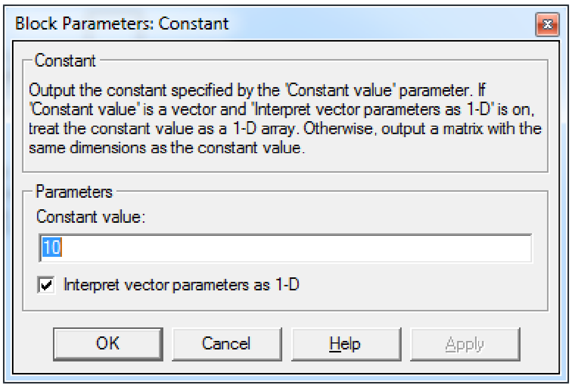

Fig. 9. Constant signal block parameters window.

To sum the signals, drag the summation block from the "Math Blocks" section to the working window. The icon for this block is shown in Fig. 10.

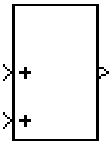

Fig. 10. Summation block icon.

Its parameter window is shown in Fig. 10. This block calculates the sum of the current signal values. In the Icon shape drop-down list, you can select:

- round–circle,
- rectangular–rectangle.

The second parameter – List of sign (list of signs) defines the number of inputs and the operation (addition or subtraction). The following signs can be used in the list: + (plus), - (minus) and | (sign separator).

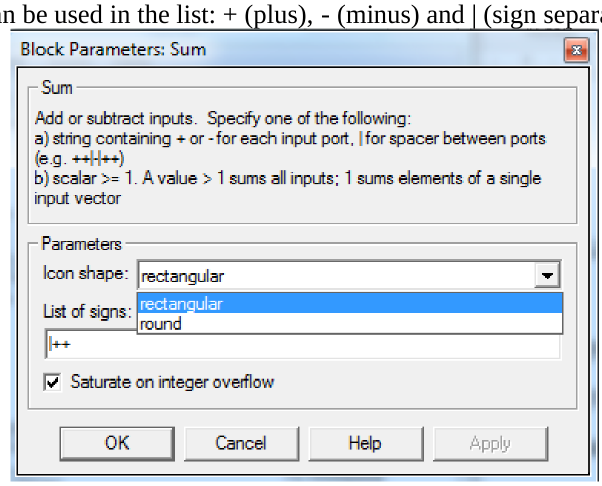

Fig. 11. Summation block parameter window.

In the List of sign parameter, you can also specify the number of block inputs. In this case, all inputs will be summing. If the number of block inputs exceeds 3, it is more convenient to use the rectangular Sum block.

The block can be used to sum scalar, vector, or matrix signals. The types of signals to be summed must match. For example, you cannot feed integer and real type signals to the same summing block. If the number of block inputs is greater than one, the block performs element-by-element operations on vector and matrix signals. In this case, the number of elements in the matrix or vector must be the same. If you specify the number 1 (one input) as the list of signs, the block can be used to determine the sum of the vector elements.

To multiply signals, drag the product block from the "Math Blocks" section to the working window. Its icon is shown in Fig. 12.

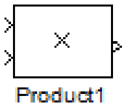

Fig. 12. Product block icon.

The parameters window for this block is shown in Fig. 13. In this window, you can set the number of input ports of the block (the number of signals to be multiplied) and the method for performing the mathematical operation (element-wise multiplication (corresponds to the .* MATLAB command) or matrix multiplication).

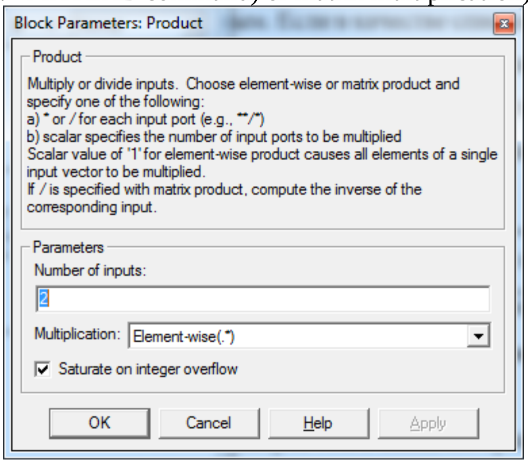

Fig. 13. Multiplication block parameters window.

Note that the "Number of inputs" parameter can be specified either as a number or as a list of characters. The characters * (multiply) and / (divide) can be used in the list of characters. If the "Number of inputs" parameter is specified as a list that includes division characters in addition to multiplication characters, the input labels will be designated by the symbols of the corresponding operations [3].

The block can be used for multiplication or division operations on scalar, vector, or matrix signals. The types of input signals in the block must match. If the number of inputs is set to 1 (one input), the block can be used to determine the product of vector elements.

To visualize the signal, we will use the "Scope" block from the "Sinks" section. This block can be used to plot graphs of the signals under study as functions of time and to observe changes in the signals during the simulation process. The icon for this block is shown in Fig. 14.

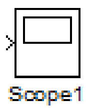

Fig. 14. Oscilloscope block icon.

When you double-click on this block, unlike the previously considered blocks, a window for viewing graphs will appear instead of a window with the block parameters. This window can be opened at any stage of the calculation (both before and after the calculation, as well as during the calculation). If a vector signal is received at the block input, the curve for each element of the vector is plotted in a separate color.

As we have seen, using the oscilloscope block, you can save data in the MATLAB workspace. Let's consider another block that performs this operation. The icon for this block is shown in Fig. 15.

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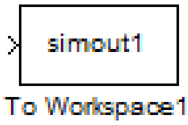

Figure 15. The data storage block icon in the MATLAB workspace.

This block is located in the library "Sinks" - signal receivers and has only one input. The parameter window of this block is shown in Fig. 16.

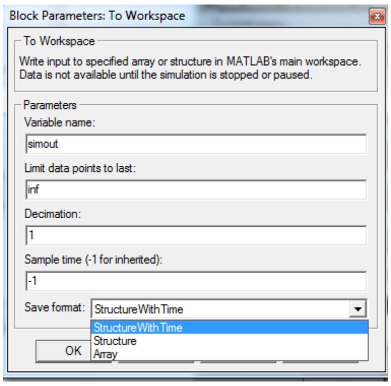

Fig. 16. The MATLAB workspace data storage block parameters window.

Let's select the data saving format - Structure with Time.

III. STAGES OF CONSTRUCTING AN AMPLITUDE-MODULATED SIGNAL

After installing all the blocks from the required libraries on the circuit, you need to connect the circuit elements. To connect the blocks, point the cursor at the "output" of the block, then press and, without releasing the left mouse button, draw a line to the input of another block. Then release the button. The connection has been created by a thick arrow at the input port of the block [4]. To create a branch point in the connecting line, move the cursor to the intended node and, pressing the right mouse button, draw a line [5]. To delete a line, select it and then press the Delete key on the keyboard. Holding down the left mouse button, you can move the connection line so that the circuit is easier to read. Let's connect all the blocks and set their parameters as described above. The finished structural diagram will look like the one shown in Fig. 5.93. We installed 3 inputs on the oscilloscope to be able to separately observe the envelope, modulated signal and fill (respectively, from top to bottom).

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Vol. 11, Issue 10, October 2024

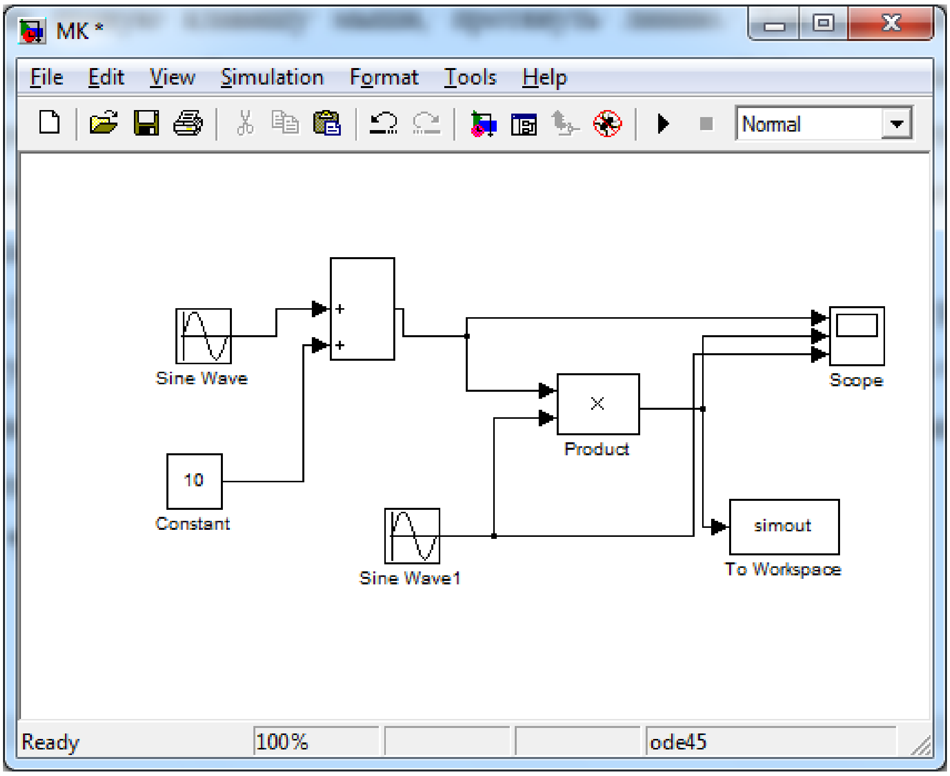

Fig. 17. Stages of constructing an amplitude-modulated signal: a finished Simulink model.

To perform the simulation, you need to click the "Start" command button on the toolbar of the model's working window or select Simulation/ Start in the menu. In this case, the program will perform the simulation with the default parameters. You can see the result in the oscilloscope window.

Now, by executing the command on the control panel of the Simulation/Configuration Parameters… menu, in the calculation parameter control window that appears, we will change the parameters "Max", "step", "size" and "Stop time", as shown in Fig. 18.

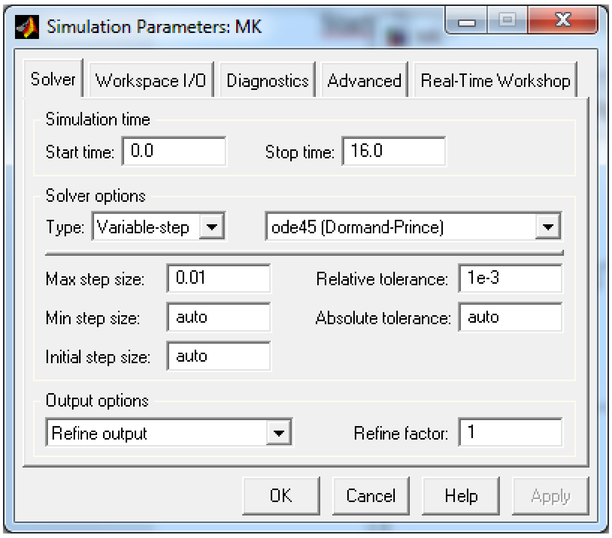

Fig. 18. Part of the calculation parameters control window.

ISSN: 2350-0328
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Vol. 11, Issue 10, October 2024

IV. RESULTS

After the calculation is completed, the resulting signals will appear on the oscilloscope screen (Fig. 19). This figure shows three graphs. The top one is the envelope, the bottom one is the fill, and the middle one is the modulated signal.

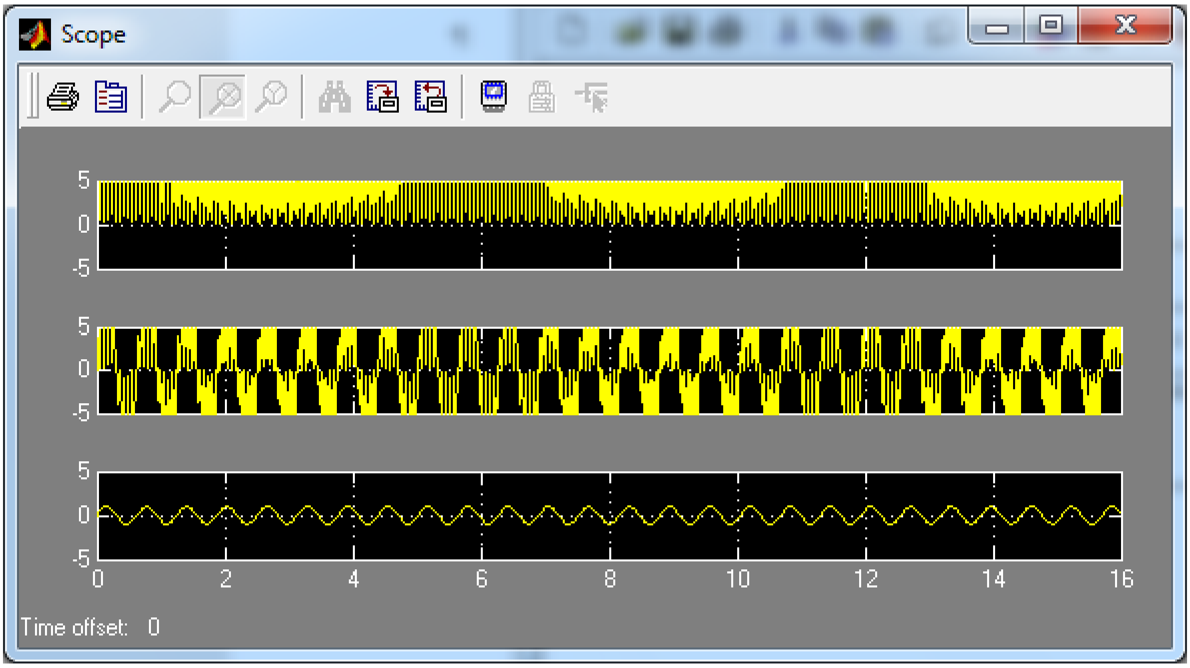

Fig. 19. Simulation result.

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