

Developing a Frequency Response Analyzer for Electric Circuits Using MATLAB[®] Simulink

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Abstract: This work is about developing a procedure which obtains frequency response for any linear time invariant circuit in MATLAB[®] Simulink environment. A flowchart has been proposed to obtain frequency response by mathematical linear blocks which are available in Simulink and finally an example has been used to demonstrate the merits of the developed frequency response analyzer.

Keywords: Frequency Response Analysis (FRA), linear time invariant, MATLAB[®] Simulink.

1. INTRODUCTION

Frequency Response Analysis (FRA) is both theoretical and experimental method to determine the behavior of the systems. Through its non-destructive characteristic, this technique has been applied in recent years for most of the circuits and systems in service [1-5]. Frequency response of the system presented by block diagram can be obtained by BODE-diagram technique in Simulink environment [6,7], but it cannot be used for circuits created in Simulink. The method suggested in [8] has been considered in this work which can achieve a frequency response based on theoretical definition.

The layout of the paper is as follows:

In section 2 we give a brief review of the frequency response. Section 3 discusses about the proposed algorithm based on theoretical definition of frequency response in related references such as [8] and presents a full flowchart describing the procedure.

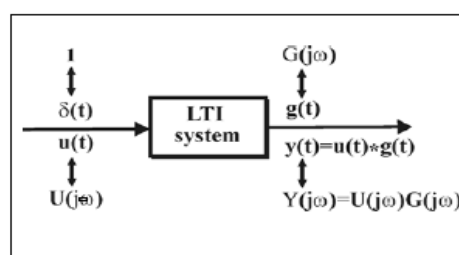
MATLAB and Simulink implementation are fully explained in section 4 and finally, a second order circuit is studied and the results of FRA are presented by waveforms.

2. THEORETICAL

Consider a continuous-time, linear time-invariant system between the input $x(t)$ and the output $y(t)$ as shown in figure(1).

The function $G(j\omega)$ is called the frequency response of the system, where $x(j\omega)$, $y(j\omega)$ and $G(j\omega)$ are the fourier transforms of input $x(t)$, output $y(t)$, and impulse response $g(t)$, respectively.

The Frequency Response Analysis (FRA) is a simple method for obtaining detailed information about the considered linear system.



Figure(1): Relationships between inputs and outputs in a LTI system

Recall that in the case of mono-frequency sinusoidal input signal $x(t)$ as below:

$$X(t) = a \cos(\omega t) \quad (1)$$

The steady-state response of a linear, stable system with transfer function $G(s)$ is :

$$Y(t) = b \cos(\omega t + \Phi) \quad (2)$$

The amplitude and phase of the system frequency response can be computed giving:

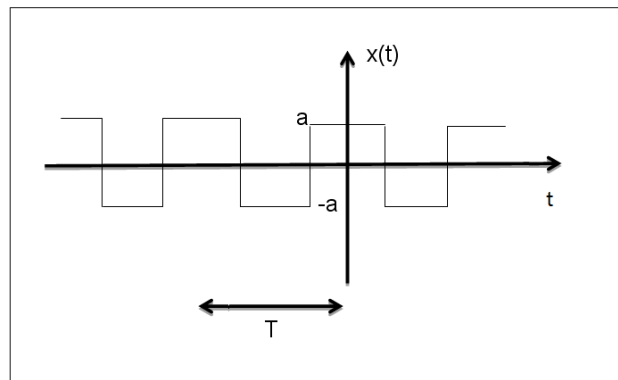
$$G(\omega) = 20 * \log \left| \frac{b}{a} \right|, \Phi(\omega) = \Phi \quad (3)$$

That will be presented by two waveforms.

3. PROPOSED ALGORITHM

As we know linear time variant systems will make output with same frequency to the fed input and also any combination of inputs will have similar behavior in output oscillations.

Therefore a periodic-square waveform which is shown in figure(2) has been considered as input signal which can be simply provided in FRA devices and also simulation softwares.



Figure(2): function $x(t)$

The fourier coefficients of the mentioned function are calculated as the following relations[8]:

$$x(t) = a_0 + \sum_{n=1}^{\infty} (a_n \cos(n\omega t) + b_n \sin(n\omega t)) \quad (4)$$

$$a_0 = \frac{1}{T} \int_{-0.5T}^{0.5T} f(x) \cdot dx = 0 \quad (6)$$

$$a_n = \frac{2}{T} \int_{0.5T}^{0.5T} f(x) \cdot \cos(n\omega t) \cdot dt = \begin{cases} \frac{4\pi}{\pi n} & (n \text{ odd}) \\ 0 & n(\text{even}) \end{cases} \quad (7)$$

$$b_n = \frac{2}{T} \int_{-0.5T}^{0.5T} f(x) \cdot \sin(n\omega t) dt = 0 \quad (8)$$

Consequently, $x(t)$ has only odd multiple frequencies and an addition with $xx(t)$ which is defined as below can make even multiple frequencies for our input signal.

$$xx(t) = x(t) * \cos(t) \quad (9)$$

By substituting $x(t)+xx(t)$ as the input signal to the circuit, we will have the output of the circuit which consists of the whole frequencies observed in input signal.

Then we need to obtain a method to determine the amount of amplitude and phase of the input and output signal for each frequency.

The procedure of calculating the amplitude and phase of input and output signal is determined by presented flowchart in figure (3) which is based on the relations (5) to (8) in theory.

4. MATLAB® SIMULINK

MATLAB is a powerful software that has been prepared for a wide range of researches through its accurate calculations by professional tool boxes. Also this software profits "Simulink" that is a comfortable work space for modeling most physical environments.

In this work ,a m-file has been written in MATLAB which a frequency interval has been defined in.

For each iteration, we run the Simulink model for a specified frequency and transmit the parameters of input and output to the m-file for being saved as a matrix which is schematically shown in figure (4).

Finally the frequency response of the system can be presented according to the constructed matrix by two waveforms that are the amplitude and the angle versus frequency.

The Simulink model has been prepared as discussed in section 3 for each frequency.

Figure (5) shows the block diagram of the input signal that is finally transformed to a power signal for supplying the object circuit.

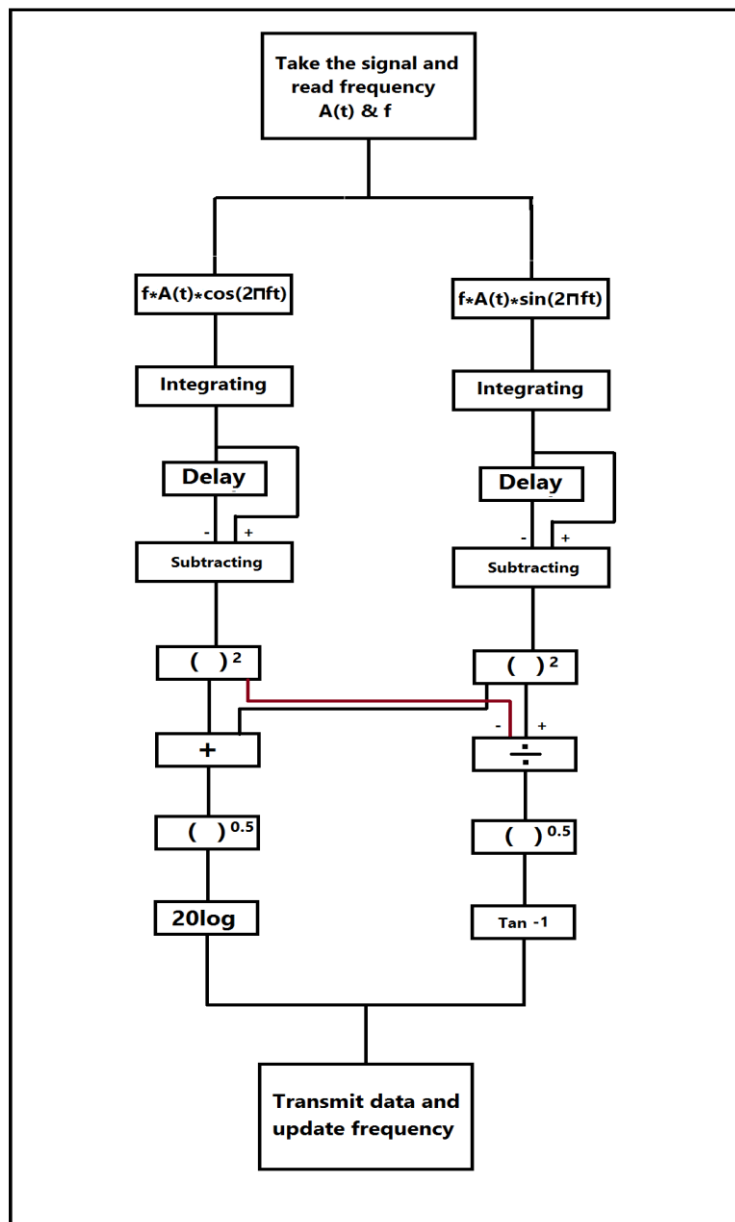


Figure (3): Flowchart of calculating the amplitude and phase for input and output signals

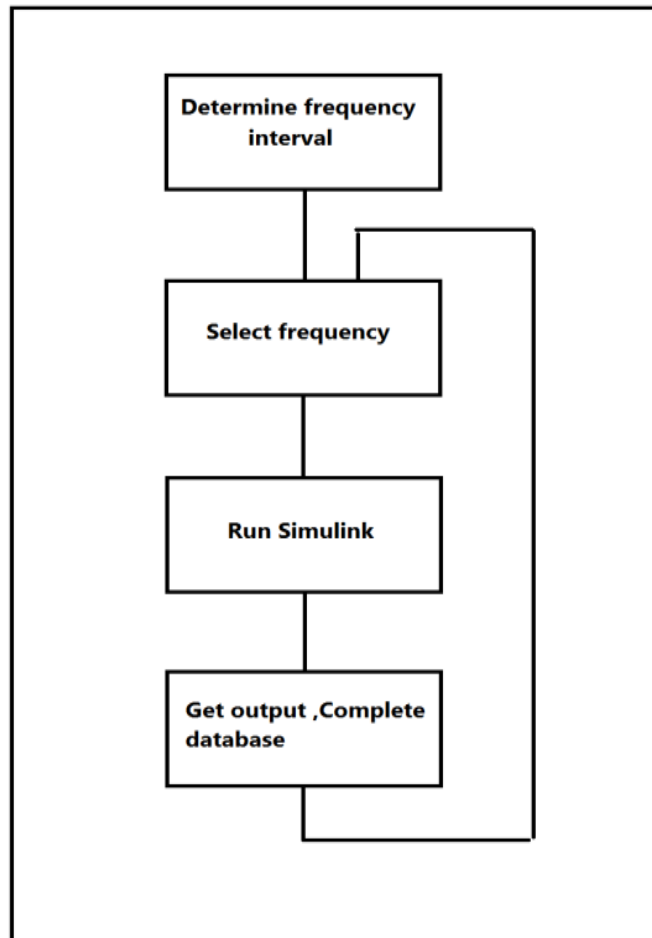
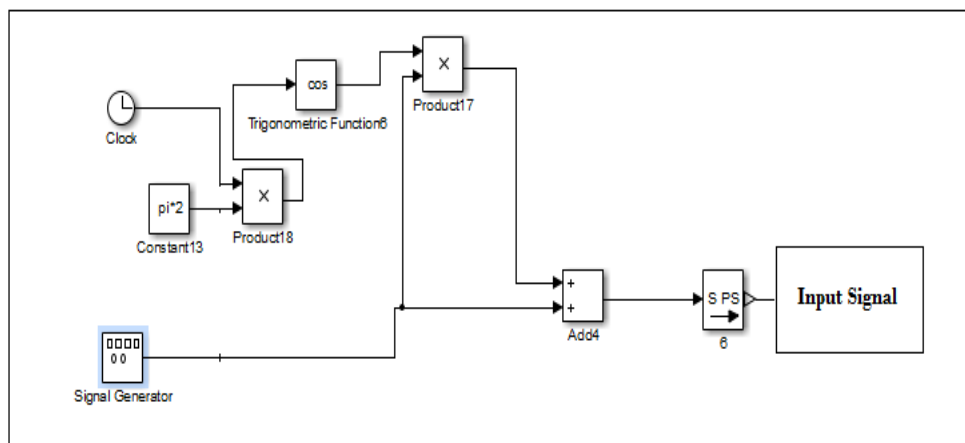


Figure (4): Structure of m-file written in MATLAB



Figure(5): Block diagram of input signal

Fourier coefficients which are the essential items for calculating frequency response values have been evaluated according to the proposed flowchart as shown in figure (6).

And finally as it can be seen in figure(7) calculations of amplitude and phase for frequency response has been executed and the output of this block diagram are transmitted to the source m-file.

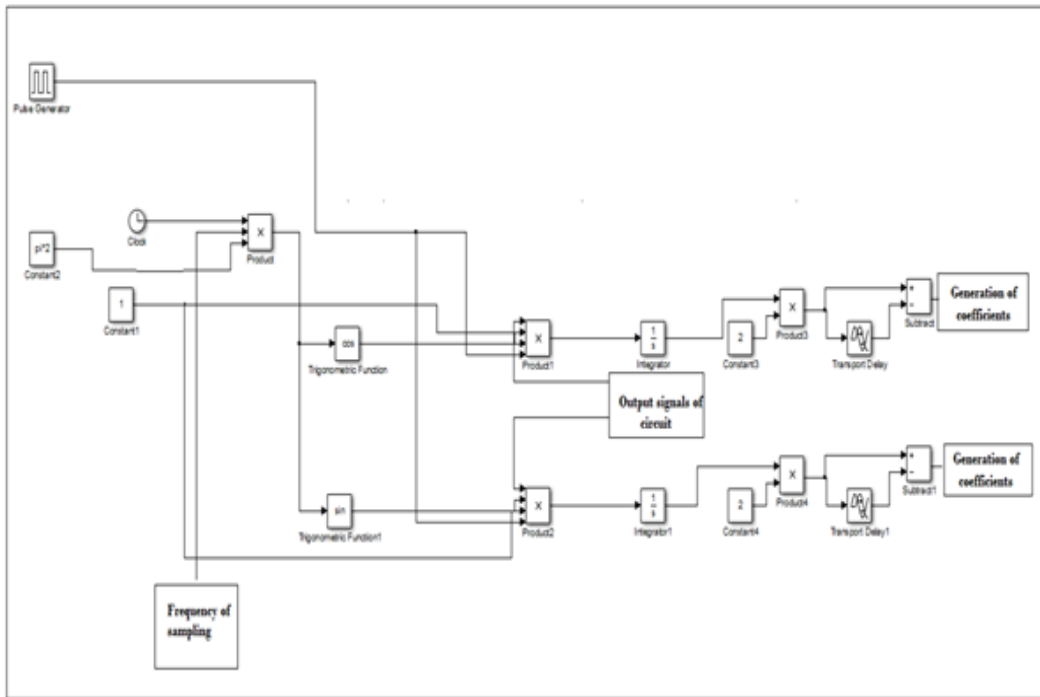


Figure (6): Calculation of fourier coefficients

6. MATLAB® SIMULINK IMPLEMENTATION AND RESULTS

The method described in previous sections has been implemented to a simple second order electric circuit which is shown in figure (8).

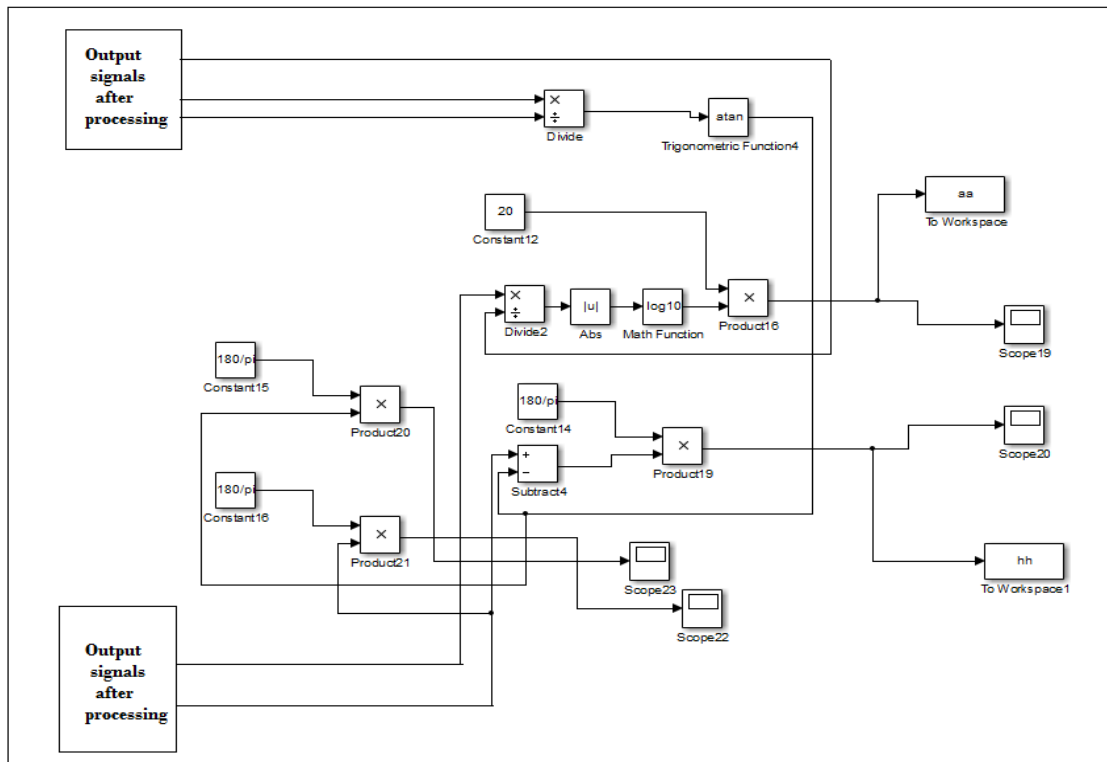
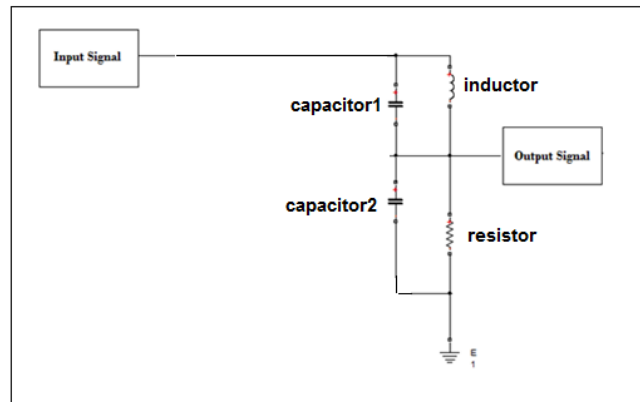


Figure (7): Calculations of amplitude and phase

The program has been executed for frequency interval of 1 to 200 (Hz) as we know includes the zone of resonance according to the values of capacitor, inductor and resistors.

Figures (9) and (10) show the variation of the amplitude and phase as the frequency response of the circuit.



Figure(8): A simple second order circuit with specified points for input and output

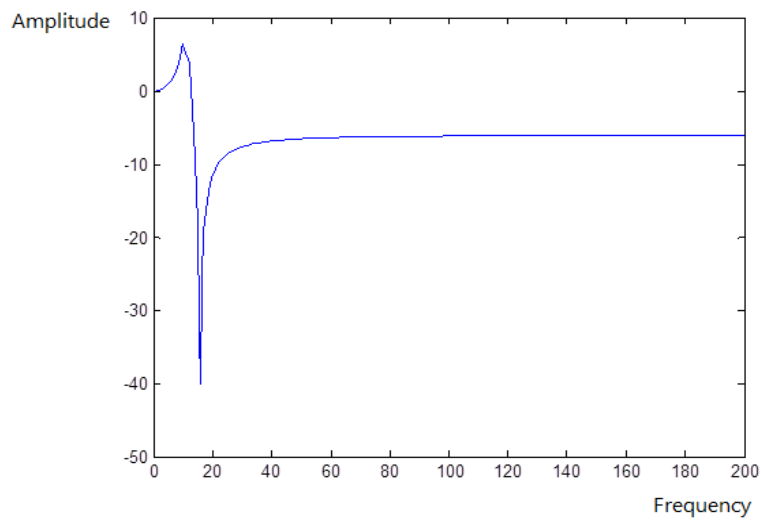


Figure (9): The amplitude versus frequency

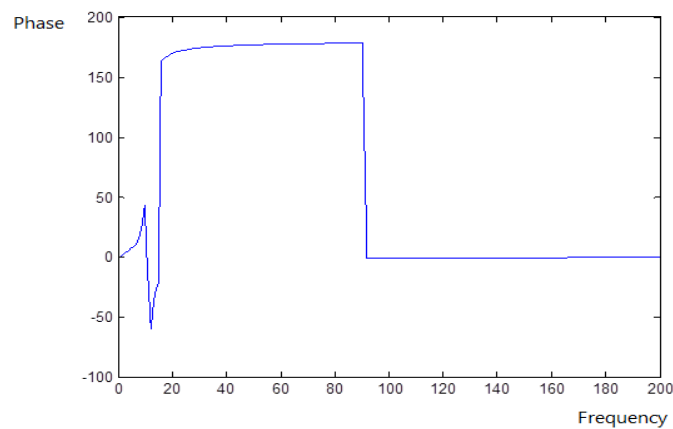


Figure (10): The phase versus frequency

7. CONCLUSIONS

The paper presents a frequency response analyzer implemented in MATLAB® Simulink environment.

The proposed method can also be applied for other physical environment such as mechanical, hydraulic model and through the facilities of Simulink.

Also it can be suggested as a powerful toolbox in Simulink for obtaining frequency response of a system directly.

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