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| **Name:** |

**PURPOSE**

The purpose of this lab is to learn how to treat periodic signal in terms of its Fourier components, and how to use the transfer function of a four terminal linear circuit to calculate the output waveform for a given complex input waveform.

In general a periodic input signal *V*(*t*) of a fundamental frequency *0* could be represented as a Fourier series:

where *n* is the harmonic number, and **n=*n*0, *Vn* and *n* are the frequency, amplitude and phase of the corresponding harmonic. When the signal *V*(*t*) is applied to a four terminal linear circuit each harmonic could be considered as independently propagating through the circuit. Each harmonic propagates through the circuit according to the circuit transfer function **H**(*j*), and at the output of the circuit it is equal to . As the result, the output signal, which is still a sum of all harmonics, is equal to

We will work today with two waveforms, square and triangle. The Fourier series representation for both waveforms is

and

**Do it before you come to the lab**

A low pass RC filter is shown in Fig. 1.



Figure 1. Low pass RC filter.

Calculate the transfer function **H**(*j*), its single term low **H**low(*j*) and high **H**high(*j*) frequency approximations, and the corresponding corner frequency c.

**Show here your calculations of the transfer function H(*j*), its single term low Hlow(*j*) and high Hhigh(*j*) frequency approximations, and the corresponding corner frequency c.**

A high pass RC filter is shown in Fig. 2.



Figure 2. High pass RC filter.

Calculate the transfer function **H**(*j*), its single term low **H**low(*j*) and high **H**high(*j*) frequency approximations, and the corresponding corner frequency c.

**Show here your calculations of the transfer function H(*j*), its single term low Hlow(*j*) and high Hhigh(*j*) frequency approximations, and the corresponding corner frequency c.**

**Low pass RC filter.**

Build the low pass RC filter shown in Fig. 1 using a 500  resistor and a 0.1 F capacitor. Use the 'Transfer function.vi' Labview program to measure the magnitude |**H**(*j*)| and the phase shift **(*j*) of the transfer function. Estimate the 'corner' frequency *c measured*.

*c measured*=

**Insert here two figures:**

**- First, a figure that shows measured and calculated magnitude of the transfer function |H(*j*)|, including low and high frequency single term approximations. Show the corner frequency on the figure.**

**- Second, a figure that shows measured and calculated phase shift of the transfer function **(*j*) , including low and high frequency single term approximations. Show the corner frequency on the figure.**

Calculate the expected 'corner' frequency *c expected* and compare it with the measured one. Show your calculations.

*c expected*=

Apply a square wave to the input of the filter. Set a fundamental frequency *0* of the square wave to the 'corner' frequency of the filter. Save the output waveform using the capabilities of the oscilloscope. Measure the magnitude |**H**(*j*)| and phase shift **(*j*) of the transfer function for the first 10 harmonics of the square wave. Reconstruct the signal that you expect at the output of the filter using the Fourier representation of the square wave and the measured transfer function for the corresponding harmonics. Compare the measured output waveform with the reconstructed waveform.

I recommend that you try a couple of exercises when you compare the reconstructed and measured waveforms:

- Build a few reconstructed waveforms, consisting of only the fundamental frequency, first 3 harmonics, 5 harmonics and all 10 harmonics. You should see that the reconstructed signal becomes closer and closer to the measured signal as the number of used harmonics increases;

**Insert here a figure that shows the measured output waveform and reconstructed waveforms that consist of different numbers of harmonics. Include your observation and conclusion.**

- Repeat the same exercise, but this time do not take into account the phase shift **(*j*) of the transfer function. This exercise will show the importance of the phase shift.

**Insert here a figure that shows the measured output waveform and reconstructed waveforms that consist of different numbers of harmonics. But this time do not take into account the phase shift of the transfer function. Include your observation and conclusion.**

**High pass RC filter.**

Build the high pass RC filter shown in Fig. 2. using a 500  resistor and a 0.1 F capacitor. Use the 'Transfer function.vi' Labview program to measure the magnitude |**H**(*j*)| and the phase shift **(*j*) of the transfer function. Estimate the 'corner' frequency *c measured*.

*c measured*=

**Insert here two figures:**

**- First, a figure that shows measured and calculated magnitude of the transfer function |H(*j*)|, including low and high frequency single term approximations. Show the corner frequency on the figure.**

**- Second, a figure that shows measured and calculated phase shift of the transfer function **(*j*) , including low and high frequency single term approximations. Show the corner frequency on the figure.**

Calculate the expected 'corner' frequency *c expected* and compare it with the measured one. Show your calculations.

*c expected*=

Apply a triangle wave to the input of the filter. Set a fundamental frequency *0* of the square wave to the 'corner' frequency of the filter. Save the output waveform using the capabilities of the oscilloscope. Measure the magnitude |**H**(*j*)| and phase shift **(*j*) of the transfer function for the first 10 harmonics of the triangle wave. Reconstruct the signal that you expect at the output of the filter using the Fourier representation of the triangle wave and the measured transfer function for the corresponding harmonics. Compare the measured output waveform with the reconstructed waveform.

I recommend that you try a couple of exercises when you compare the reconstructed and measured waveforms:

- Build s few reconstructed waveform, consisting of only the fundamental frequency, first 3 harmonics, 5 harmonics and all 10 harmonics. You should see that the reconstructed signal becomes closer and closer to the measured signal as the number of used harmonics increases;

**Insert here a figure that shows the measured output waveform and reconstructed waveforms that consist of different numbers of harmonics. Include your observation and conclusion.**

- Repeat the same exercise, but this time do not take into account the phase shift **(*j*) of the transfer function. This exercise will show the importance of the phase shift.

**Insert here a figure that shows the measured output waveform and reconstructed waveforms that consist of different numbers of harmonics. But this time do not take into account the phase shift of the transfer function. Include your observation and conclusion.**