Technical University of Lodz

Department of Semiconductor and Optoelectronics Devices

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ELECTRONIC MEASUREMENT LAB.

Experiment No 4

Frequency characteristics of two-port networks (filters)

Goal:

The goal of this experiment is to familiarise students with measurement methods of four terminal networks.

The main task in experiment is to identify and plot amplitude vs. frequency and phase-frequency characteristics of two-port network, so called the Bode plot

SPECIFICATION OF USED INSTRUMENTS:

The following instruments and software are used:

Instruments

1. Digital generator DDS type DF1410
2. 2-channet Digital Oscilloscope type RIGOL 1052E with FFT module
3. Advantech USB-4711A multifunction ADC/DAC module
4. RIGOL DM3051Sampling Multimeter
5. Student's ,,PSoC-GRAM-ADDA" kit

Software:

1. Software Program Data4711 used for ,,PSoC-GRAM-ADDA"
2. DataDSP – data acquisition software to of ,,PSoC-GRAM-ADDA" kit
3. Microsoft EXCEL for measurement data handling

THEORY

Theoretical basis

Dynamic properties of the two-port network can be determined analytically using differential equations from which the, analytic form geometrical interpretation can be led out. Transfer functions are commonly used in the analysis of such systems in which the complex variable are used: $s = a + jb$ ($j = \sqrt{-1}$):

$$G(s) = \frac{Y(s)}{X(s)}$$

where Y(s) is the Laplace transform of the output y(t) ,

X(s) is the Laplace transform of the input x(t) .

Experimentally we determine the transfer function by entering the input of a suitably chosen, a time varying input signal (excitation) *x (t)* and recording the output signal *y (t).* Apply some standard input signals. The most important of these standard excitation signals are: pulse signals: step, Dirac pulse and sine wave from the group of continuous signals.

The response of the system (element) to excitation represents its the dynamic behaviour under standard excitation. In other words, it is the dynamic characteristics represents the variation of the output signal *y (t)* vs. *x (t)* of the input excitation of a time-varying signal. In a dynamic system the value of the output depends not only on the current input value, but also on the state of the system at the time of the input signal prior to application.

A transfer function

If ***G(s)*** is represented by ***s = j(ω),*** the resulting complex number is called spectral transmittance ***G(jω).*** Spectral transmittance can be presented in various graphical forms. In practice, the most common are: amplitude-phase vs, frequency in logarithmic scale and phase vs. frequency in semi logarithmic scale and amplitude vs. phase plots.

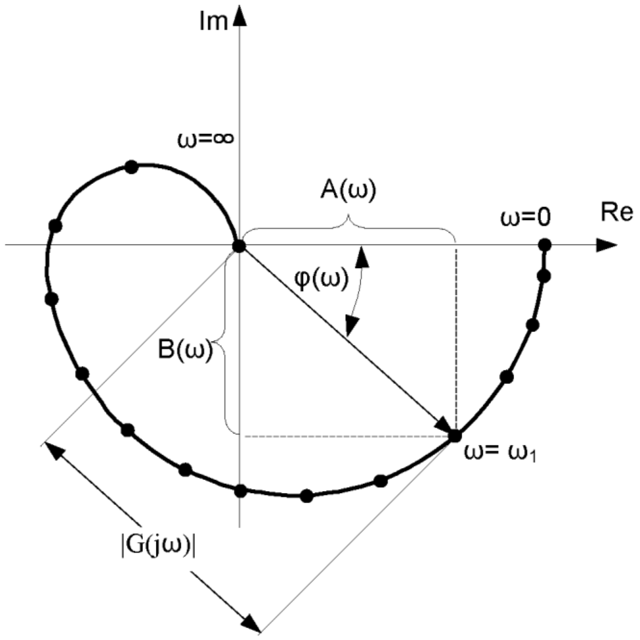


Fig. 1. Nyquist plot: (a parametric plot of a transfer function)

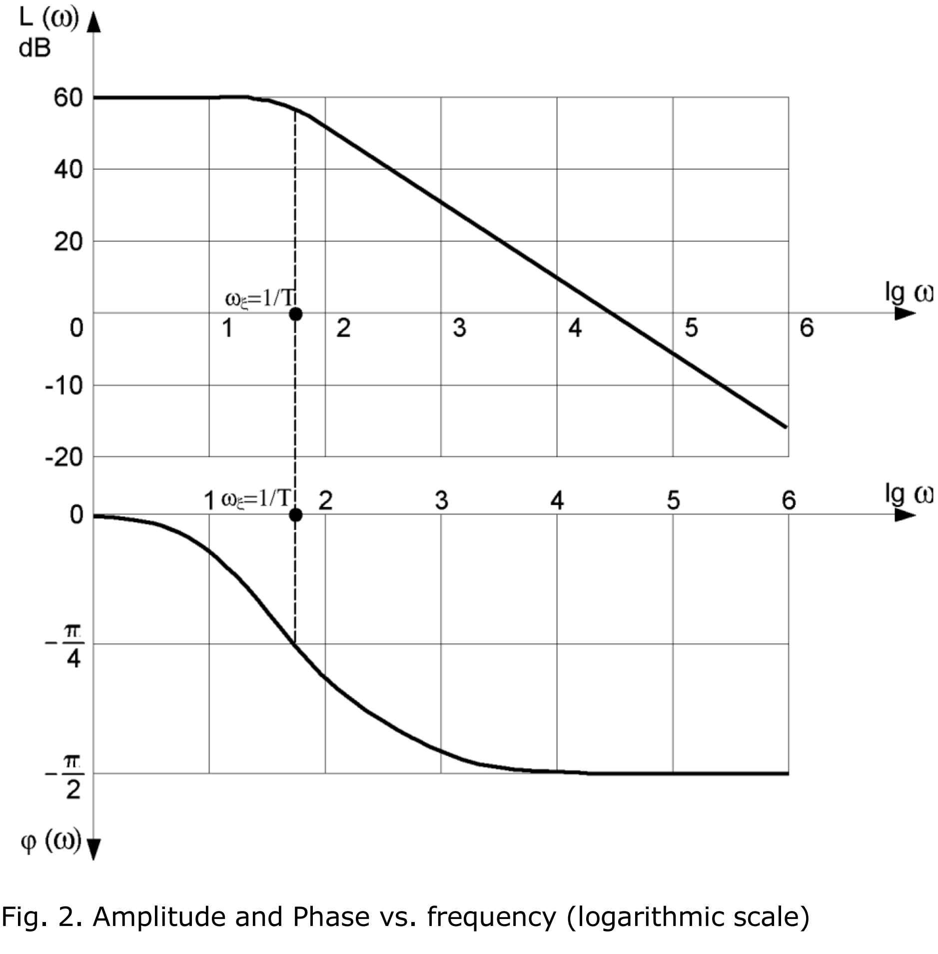


Fig. 2. Amplitude and Phase vs. frequency (logarithmic scale)

In measuring practice, mostly we are dealing with the following type of systems (elements): proportional - zero order, inertial of first -order, inertial of second-order, oscillatory of Second-order with inertia.

$G(j\varpi) = G(s)\big|_{s=j\varpi}$ - Spectral transmittance

$G(j\varpi) = P(\varpi) + jQ(\varpi)$ - Transmittance as a function of a complex variable

$P(\varpi) = \mathrm{Re}[G(j\varpi)]$ - the real part of the transmittance

$Q(\varpi) = \mathrm{Im}[G(j\varpi)]$ - The imaginary part transmittance

$G(j\varpi) = G(\varpi)e^{j\Phi(\varpi)}$ - Spectral transmittance in the form of an exponential

$G(\varpi) = |G(j\varpi)| = \sqrt{P^2(\varpi) + Q^2(\varpi)}$ - Module of the transmittance

$\Phi(\varpi) = arctg\,\frac{Q(\varpi)}{P(\varpi)}$ - Argument of the transmittance

The basic elements of the two-port (four-terminal) networks investigated in the experiment are as follows:

1. I order inertial system

Spectral transmittance and its real and imaginary component:

$$G(j\omega) = \frac{k}{(Tj\omega + 1)} \qquad P(\omega) = \frac{k}{(\omega^2 T^2 + 1)}$$

$$Q(\omega) = -\frac{kT\omega}{(\omega^2 T^2 + 1)}$$

Spectral transmittance module and phase angle:

$$G(\omega) = \frac{k}{\sqrt{\omega^2 T^2 + 1}}$$

$$\Phi(\omega) = -arctg\,\omega T$$

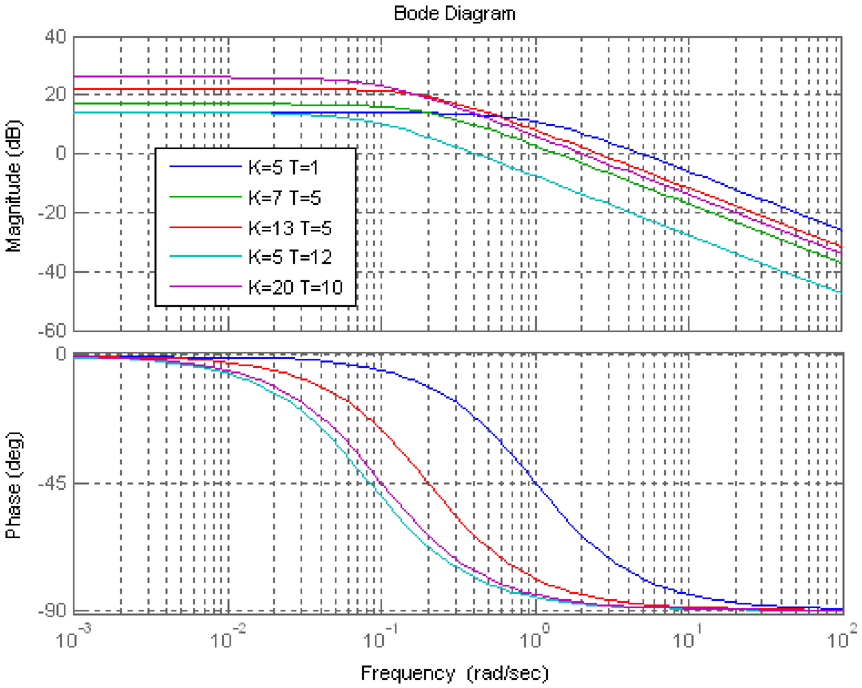


Fig. 3 The amplitude vs. frequency and phase vs. frequency of the I-order inertial system (logarithmic scale)

The dependence of time constant T is easily noticeable; the point at ω= 1/T is a cut-off point. The phase varies in the range(0 -Π/2).

2. The II order inertial system

Spectral transmittance and its real and imaginary component:

$$G(j\omega)=\frac{k}{T_0^2(j\omega)^2+2T_0\xi j\omega+1}$$

$$P(\omega)=\frac{k(1-T_0^2\omega^2)}{(1-T_0^2\omega^2)^2+4T_0^{\ 2}\xi^2\omega^2}$$

$$Q(\omega)=-\frac{2kT_0\ \xi\omega\ \ )}{(1-T_0^2\omega^2)^2+4T_0^{\ 2}\xi^2\omega^2}$$

Spectral transmittance module and phase angle:

$$G(\omega)=\frac{k}{\sqrt{(1-T_0^2\omega^2)^2+4T_0^{\ 2}\xi^2\omega^2}} \qquad \Phi(\omega)=-arctg\,\frac{2\xi T_0\omega}{1-T_0^2\omega^2}$$

The phase varies in the range(0 -∏/2)

The damping factor ξ varies in the range (0 1).

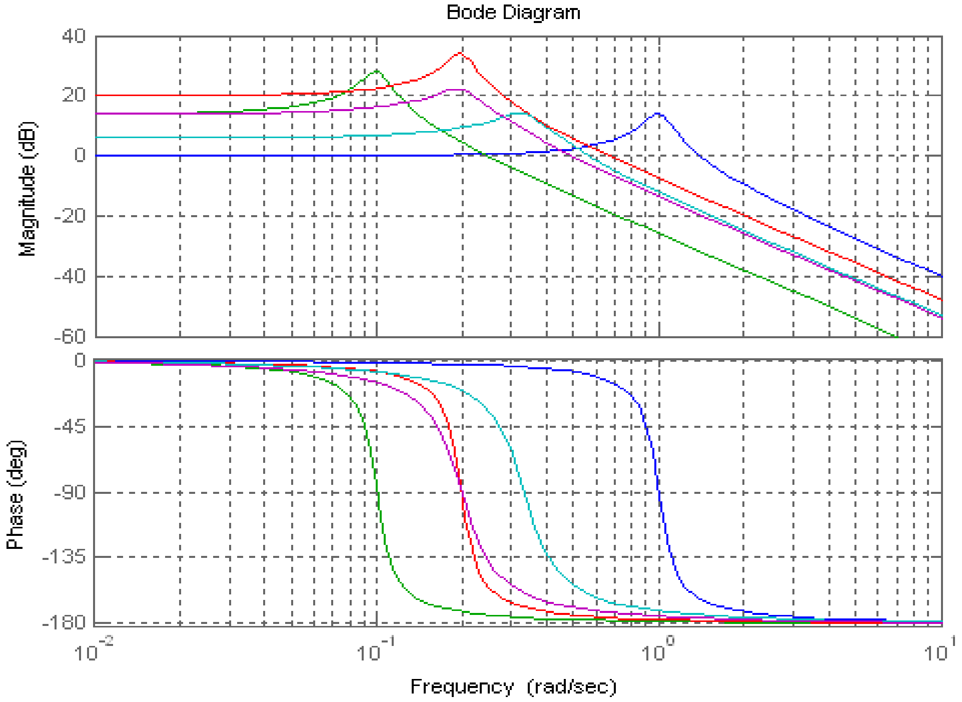


Fig. 4 The amplitude vs. frequency and phase vs. frequency of the II-order inertial system (logarithmic scale)

3. The integrating system (element) with inertia

Spectral transmittance and its real and imaginary component:

$$G(j\omega)=\frac{k}{T_1 j\omega(Tj\omega+1)} \qquad P(\omega)=\frac{kT}{T_1(\omega^2T^2+1)}$$

$$Q(\omega)=\frac{kT}{T_1\omega(\omega^2T^2+1)}$$

Spectral transmittance module and phase angle:

$$G(\omega)=\frac{k}{T_1\omega\sqrt{\omega^2T^2+1}} \qquad \Phi(\omega)=-arctg\,\omega T-\Pi/2$$

The cut-off point is : *ω=1/T*.

The phase varies in the range (--∏/2- -∏/2).

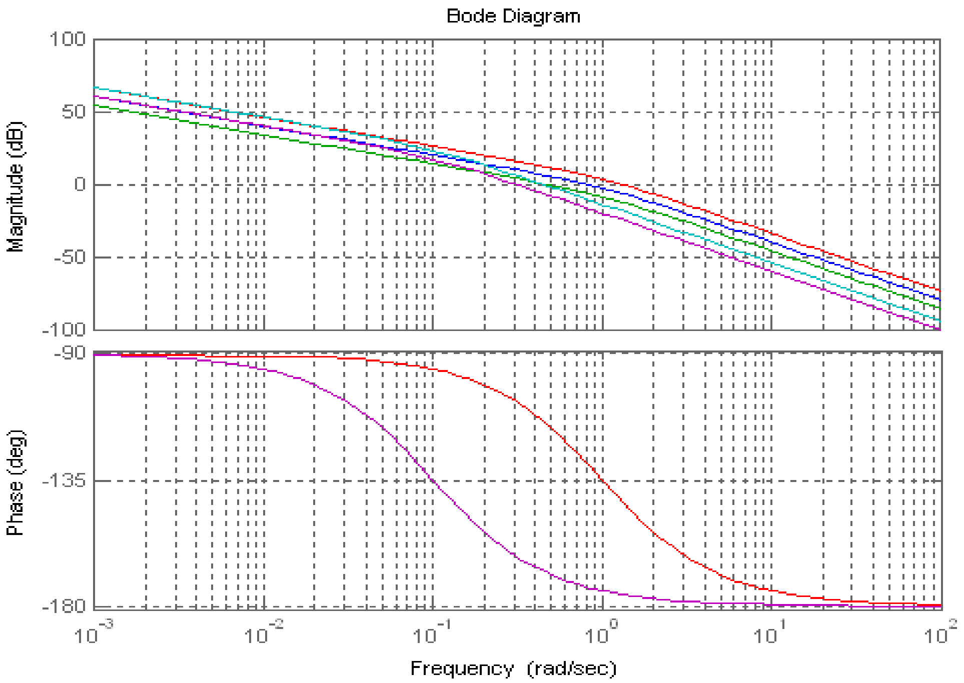


Fig. 5 The amplitude vs. frequency and phase vs. frequency of the I-order integrating system (logarithmic scale)

TASKS:

The output signal from generator should be connected to one channel of the oscilloscope and at the same time to the input of two-port system, which is a testing element.

The output signal from the two-port system should be connected to the second channel of the oscilloscope.

Please record the input signal and the output signal using an oscilloscope.

Please measure the ratio of the amplitude of the output signal to the input signal amplitude and phase shift between output and input signals.

In the second method of measuring of the characteristics of amplitude - frequency and phase-frequency apply a measuring card (with USB output).

Record the characteristics for different values of frequencies of the signal generator.

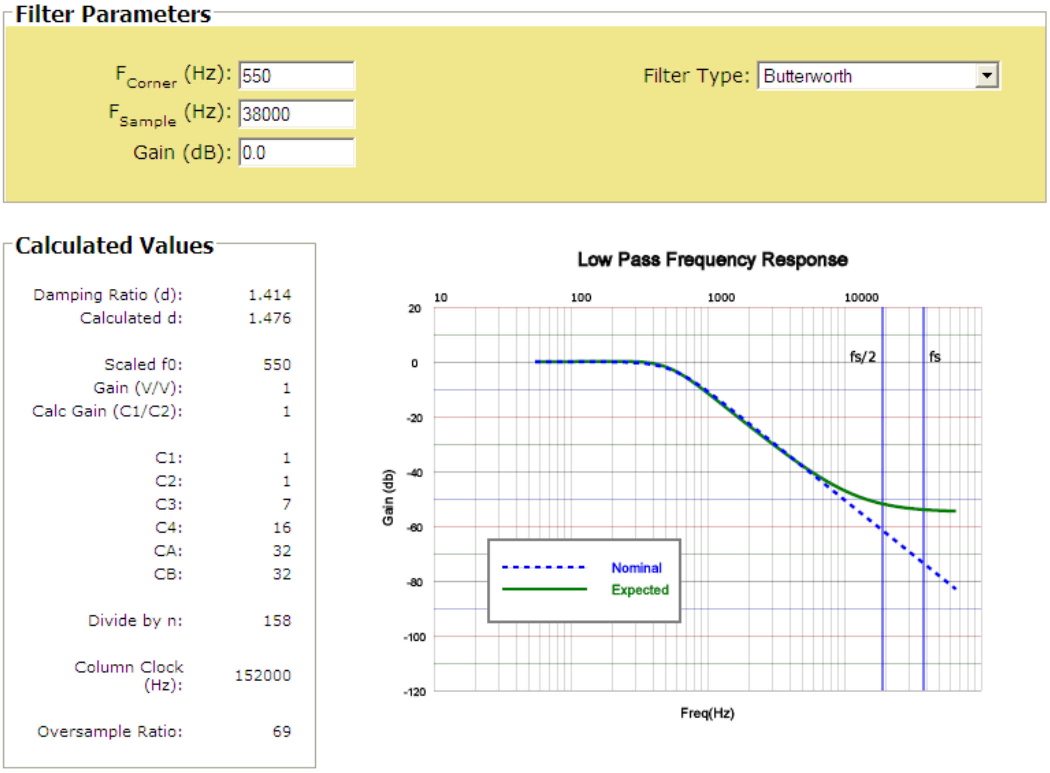
Changing the frequency of the input sine wave signal to be carried out manually on the desktop generator.

TASK 1:

Carry on investigation of amplitude-frequency characteristics and phase-frequency characteristics for a Butterworth low-pass filters, Chebyshev, and Bessel filters.

Detailed data on the parameters of signals and processing conditions will be given by the instructor.

An example of the characteristics of the filter are given in Figure 6



Filter Parameters

F_{Corner} (Hz): 550

F_{Sample} (Hz): 38000

Gain (dB): 0.0

Filter Type: Butterworth

Calculated Values

Damping Ratio (d):	1.414
Calculated d:	1.476
Scaled f0:	550
Gain (V/V):	1
Calc Gain (C1/C2):	1
C1:	1
C2:	1
C3:	7
C4:	16
CA:	32
CB:	32
Divide by n:	158
Column Clock (Hz):	152000
Oversample Ratio:	69

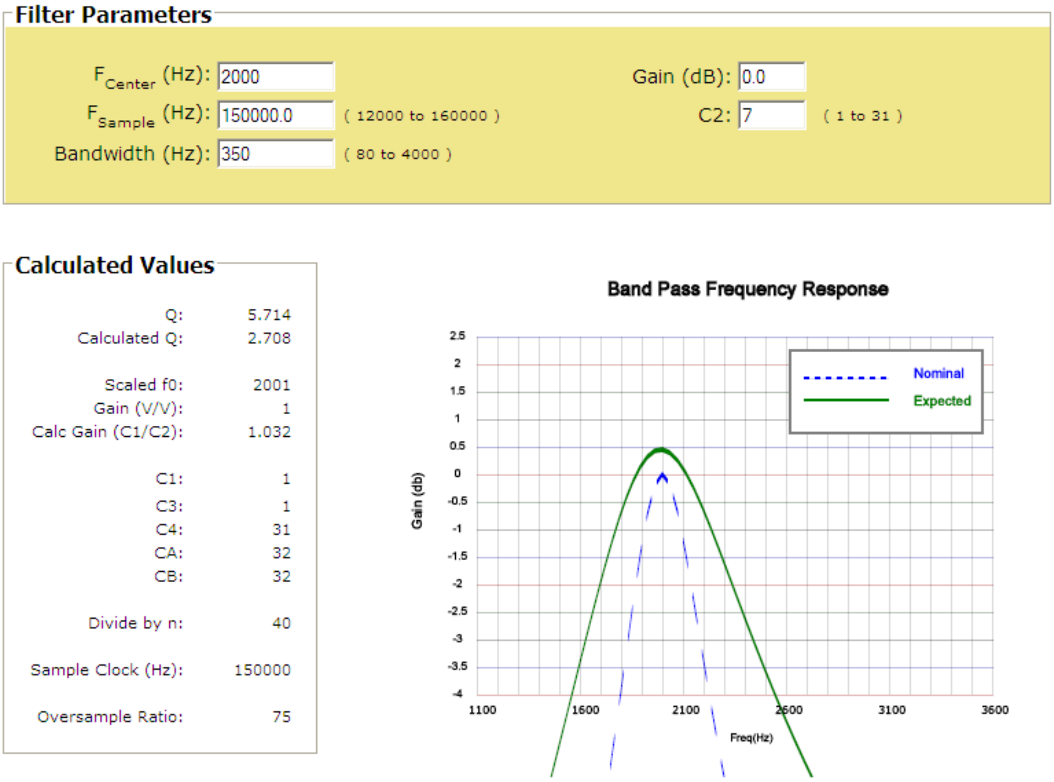
Fig. 6 Amplitude-frequency characteristics of the low-pass filter

TASK 2

Wyznaczanie charakterystyki amplitudowo-częstotliwościowej oraz charakterystyki fazowo-częstotliwościowej dla filtru pasmowego.

Szczegółowe dane odnośnie parametrów sygnałów i warunków przetwarzania będą podane przez prowadzącego zajęcia.

Przykładową charakterystykę filtru pokazano na rys. 7.



Filter Parameters

F$_{Center}$ (Hz): 2000
F$_{Sample}$ (Hz): 150000.0 (12000 to 160000)
Bandwidth (Hz): 350 (80 to 4000)
Gain (dB): 0.0
C2: 7 (1 to 31)

Calculated Values

Q: 5.714
Calculated Q: 2.708
Scaled f0: 2001
Gain (V/V): 1
Calc Gain (C1/C2): 1.032
C1: 1
C3: 1
C4: 31
CA: 32
CB: 32
Divide by n: 40
Sample Clock (Hz): 150000
Oversample Ratio: 75

Fig. 7 Characteristics of amplitude-frequency narrowband filter

FINAL REMARKS

Comments regarding of obtained results from calculations are very essential for getting a excellent grade for that experiment

LITERATURE AND OTHER RECOMMENDED MATERIAL

1. Joseph McGhee, Wlodek Kulesza, M. Jerzy Korczyński, I. A. Henederson, Measurement Data Handling Theoretical Technique, Published by Technical University of Lodz, printed by: ACGM LODART S. A. Łódź, 2001, ISBN 83-7283-007-X, pages 267 vol. 1
2. Joseph McGhee, Wlodek Kulesza, M. Jerzy Korczyński, I. A. Henederson, Measurement Data Handling Hardware Technique, Published by Technical University of Lodz, printed by: ACGM LODART S. A. Łódź, 2001, ISBN 83-7283-007-8, pages 267 vol. 2
3. S. Tumański Technika Pomiarowa, Wydawnictwa Naukowo-Techniczne WNT, Warszawa 2007

4. T.P. Zieliński Od teorii do cyfrowego przetwarzania sygnałów, Wydawnictwo ANTYKWA, Kraków 2002
5. T.P. Zieliński Zarys cyfrowego przetwarzania sygnałów. Od teorii do zastosowań Wydawnictwo WKŁ, Warszawa 2006

Additional literature:

1. *www.dspguide.com*
2. www.analog.com/processors/learning/training/dsp_book_index.html
3. *http:farnell.com/cypress-semiconductor*
4. *WWW.cypress.com*

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EXPERIMENT No:	
TITLE:	

Laboratory Group		***Telecommunication and Computer Science***	
no.	***Name and Surname***		***Student ID***
1			
2			
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Lecturer:	
Date of experiment:	
Date of report presentation:	
Mark:	
Remarks:	