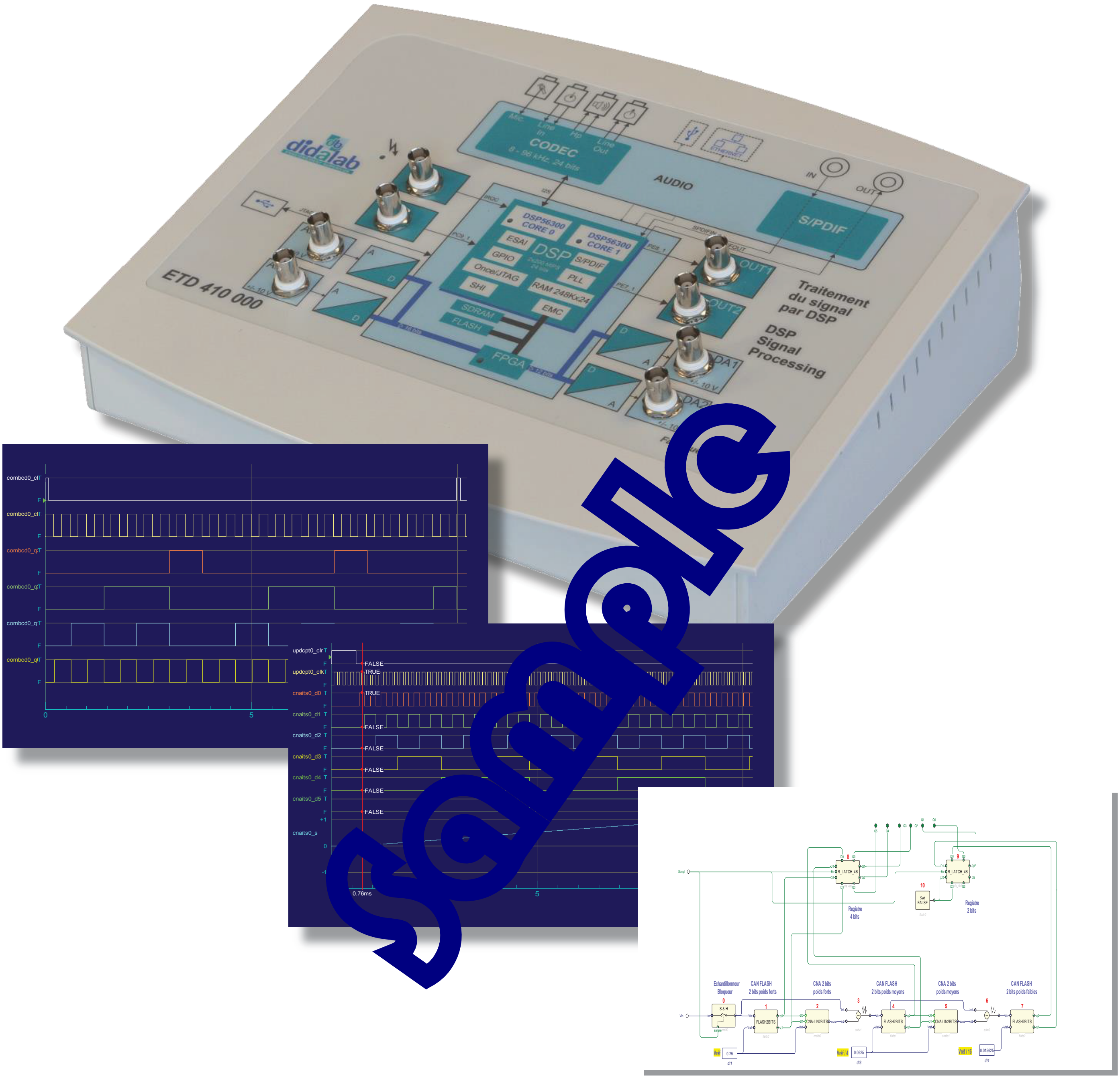
Signal Processing
Level III (BAC)



Topics and Reports

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Ref : ETD 410 021

SUMMARY

Ex.11 : ANALOG FILTERS

11.1 LOWPASS FILTER OF 1st Order

11.1.1 Background on the analog integrator

The relationship linking the output s (t) to the input e (t) of figure 1 is:

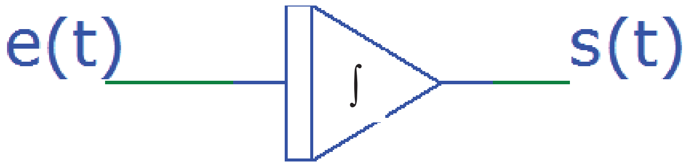


fig.1

$$\boldsymbol{s(t) = \frac{1}{\tau}\int e(t)dt \ = G\int e(t)dt \ \text{with } G = \frac{1}{\tau}}$$

The Laplace transform of the temporal equation gives:

$$S(p) = \frac{1}{\tau}\frac{E(p)}{p} = \frac{E(p)}{\tau p}$$

This gives the transfer function:

$$H(p) = \frac{1}{\tau p}$$

11.1.2 Transfer function of a lowpass filter

They are given by the relationship:

$$T(j\omega) = T_0\frac{1}{1+\tau p}$$

11.1.3 Principle diagram

The H(p) function is realized by the integrator, **INTEGRATE Block,** whose time constant determines the filter cut-off frequency with :

$$\boldsymbol{H(p) = \frac{1}{\tau p}}$$

- From the figure 2 diagram, it demonstrates the relationship giving T(jω).

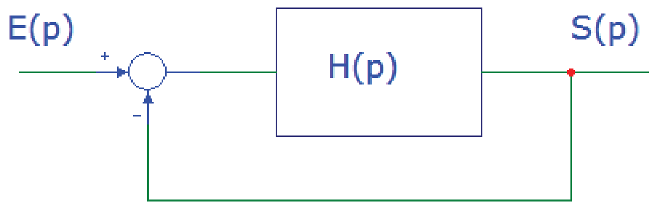


fig.2

11.2 PRACTICAL WORKS

11.2.1 Test diagram

Wire the test diagram below figure 4.
The calculation part of the Bode diagrams (Gain and Phase) comes from the demonstration diagram by M. Jean-Marie ORY, author of ETD410 module Primitives.

Note the Bode diagram and check the low-pass filter characteristics of the first order.

11.2.2 Bode Diagrams

They are given by figure 3.
Check the gain value in cut-off frequency and the slope when the frequency tends to infinity.

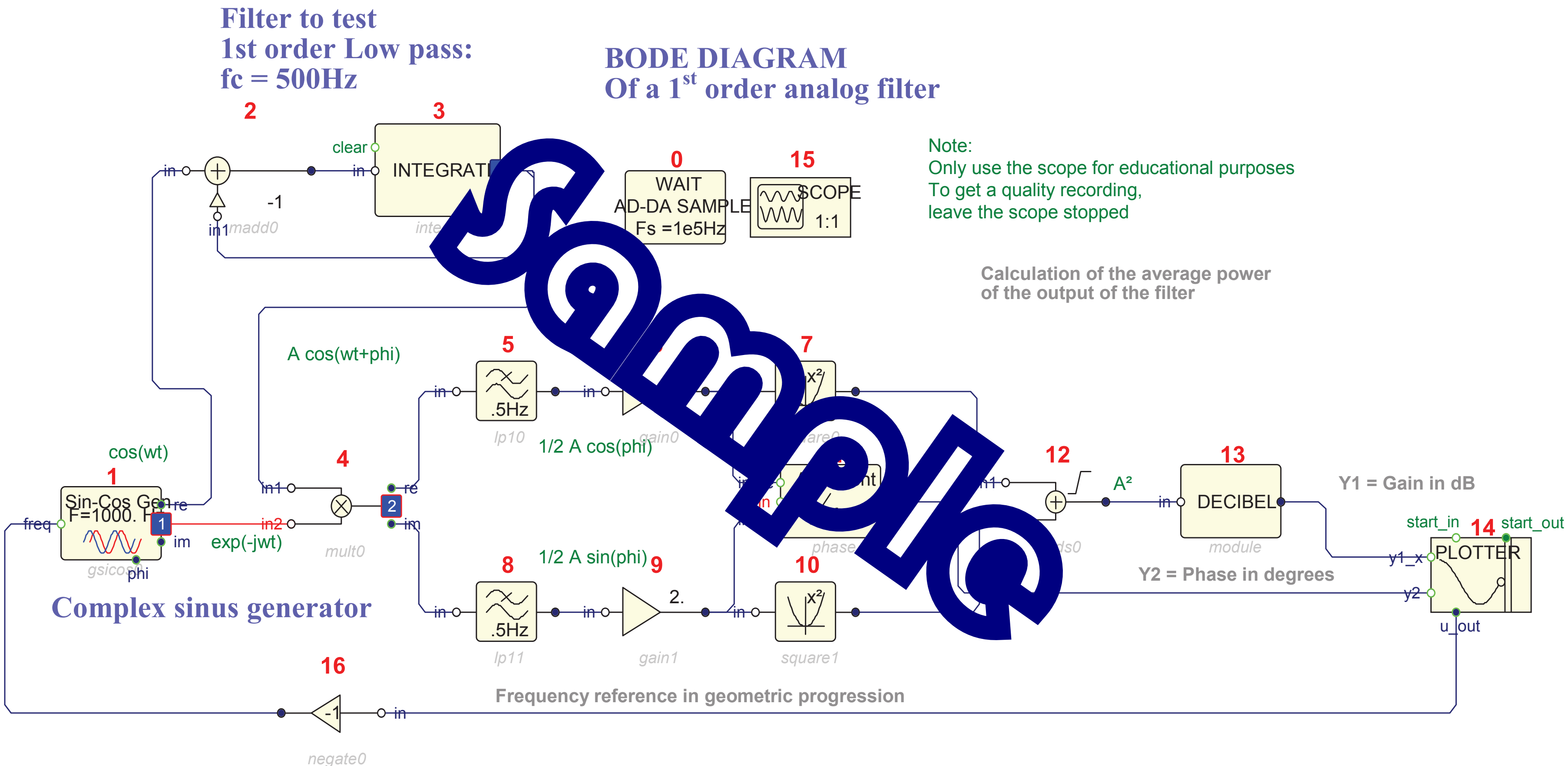

Filter to test
1st order Low pass:
fc = 500Hz
BODE DIAGRAM
Of a 1st order analog filter
Note:
Only use the scope for educational purposes
To get a quality recording,
leave the scope stopped
Calculation of the average power
of the output of the filter
WAIT
AD-DA SAMPLE
Fs =1e5Hz
SCOPE
1:1
INTEGRAT
clear
A cos(wt+phi)
cos(wt)
Sin-Cos Gen
F=1000. Hz
exp(-jwt)
Complex sinus generator
1/2 A cos(phi)
1/2 A sin(phi)
DECIBEL
PLOTTER
Y1 = Gain in dB
Y2 = Phase in degrees
A²
Frequency reference in geometric progression
start_in
start_out
u_out
.5Hz
2.
-1

fig.3

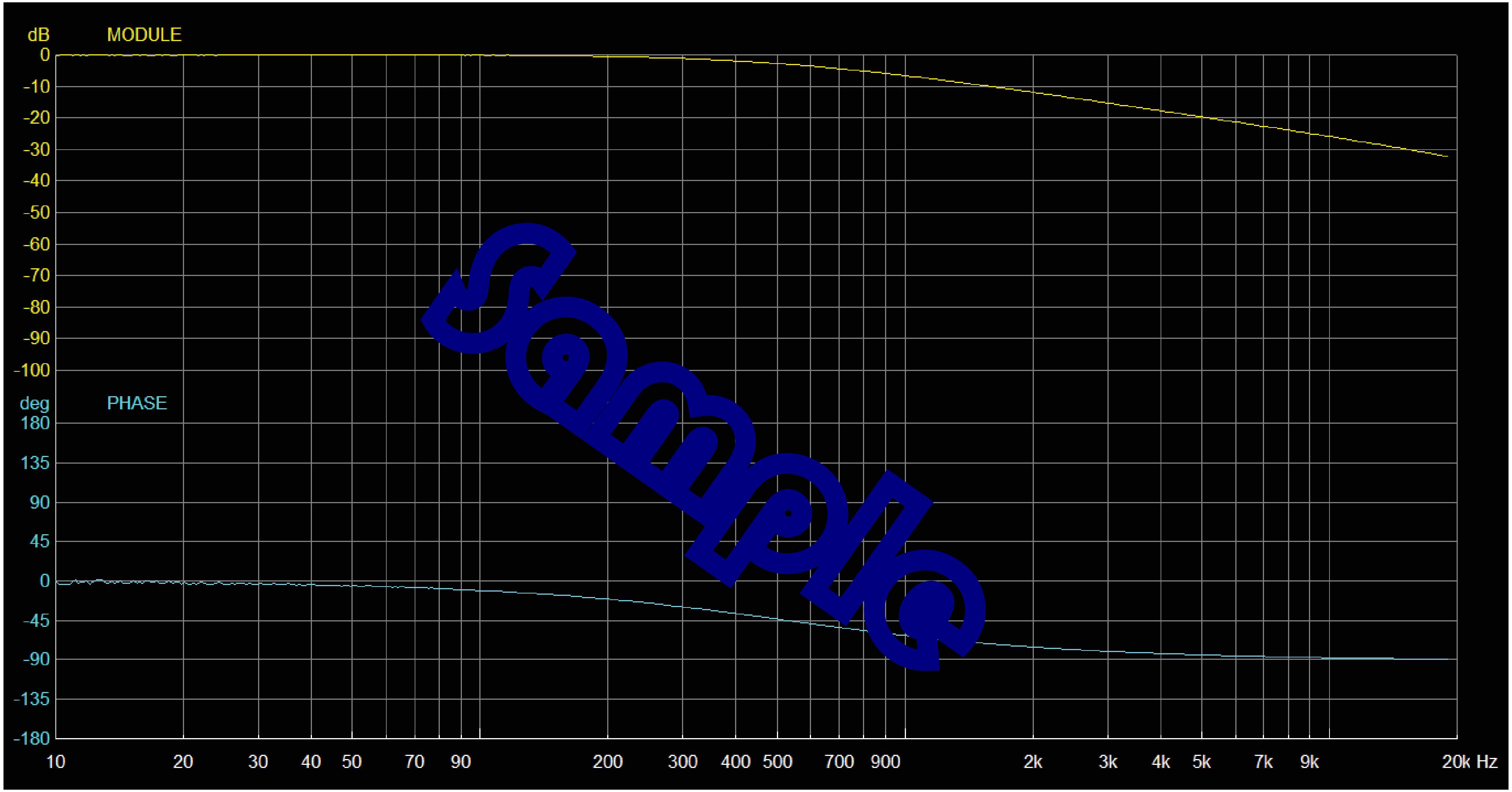

dB
MODULE
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
deg
PHASE
180
135
90
45
0
-45
-90
-135
-180
10
20
30
40
50
70
90
200
300
400
500
700
900
2k
3k
4k
5k
7k
9k
20k Hz

fig.4

11.3 UNIVERSAL FILTER

11.3.1 Principle functional diagram

It is given by the figure 4.
Before the appearance of digital computers, this function was used to simulate the differential equations, especially in Physics, in the study of systems with state variables (described by differential equations).

The S1, S2 and S3 outputs can successively and simultaneously realize the filters: **high-pass, band-pass and low-pass**; this is what gave this function, where the name is UNIVERSAL FILTER**.**

The sum of the high-pass and low-pass outputs can realize the notch or band-stop filter.

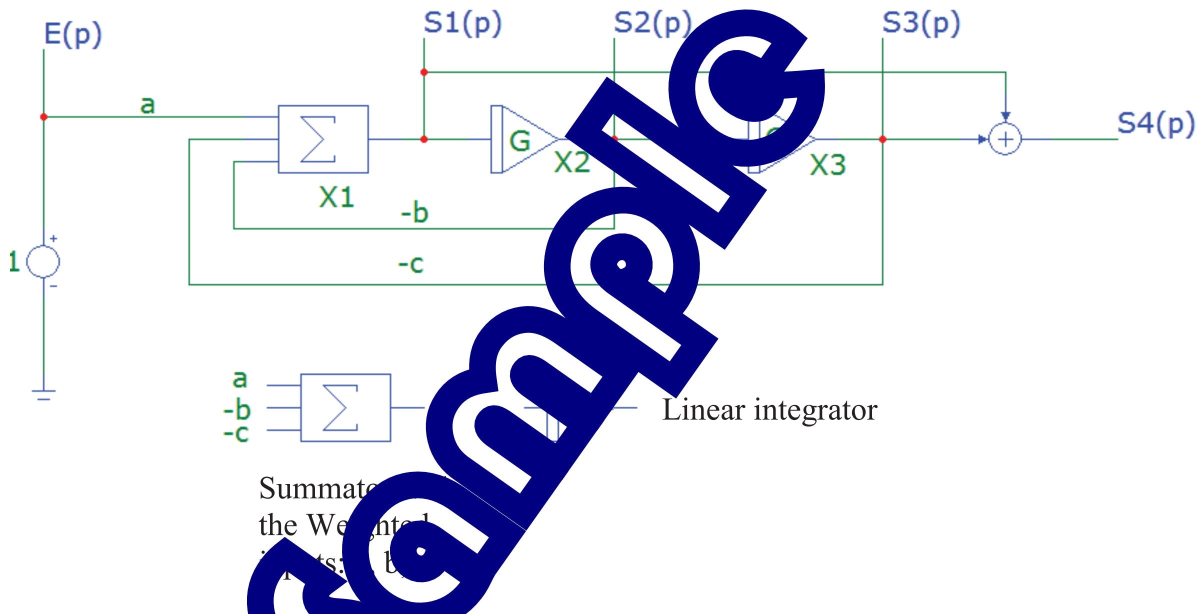


fig.4

11.3.2 4 outputs transfer functions

- From the transfer function **H(p) = 1/τp** defined in 11.1.1, determine the relationships:

$$S1(p) = f_1(S2(p), S3(p), a, b, c)$$

$$S2 = f_2\big(S1(p)\big)$$

$$S3(p) = f_3\big(S2(p)\big)$$

$$S4(p) = f_4(S1(p), S3(p))$$

- Derive the 4 following transfer functions:

$$T1(j\omega) = \frac{S1(p)}{E(p)} \qquad T2(j\omega) = \frac{S2(p)}{E(p)}$$

$$T3(j\omega) = \frac{S3(p)}{E(p)} \qquad T4(j\omega) = \frac{S4(p)}{E(p)}$$

- Set the transfer functions in their canonical form by identifying the parameters if :

$$T_{01},\ T_{02},\ T_{03,},\ T_{04,}\ m\ and\ \omega_0 :$$

$$T1(j\omega) = T_{01}\frac{\frac{p^2}{\omega_0^2}}{1 + 2m\frac{p}{\omega_0} + \frac{p^2}{\omega_0^2}} \quad ; \quad T2(j\omega) = T_{02}\frac{2m\frac{p}{\omega_0}}{1 + 2m\frac{p}{\omega_0} + \frac{p^2}{\omega_0^2}}$$

$$T3(j\omega) = T_{03}\frac{1}{1 + 2m\frac{p}{\omega_0} + \frac{p^2}{\omega_0^2}} \quad ; \quad T4(j\omega) = T_{04}\frac{1 + \frac{p^2}{\omega_0^2}}{1 + 2m\frac{p}{\omega_0} + \frac{p^2}{\omega_0^2}}$$

11.3.3 PRACTICAL WORKS

For the clarity reasons of test diagrams the function which can calculate the Gain and the Phase of the Bode diagram was encapsulated under the name **Bode fig.5 and detail in fig.6.**

- Realize the diagram of figure 7and take down the Bode diagrams of different transfer functions, compare them with the 8 to 11 figures' diagrams.
- Determine each one's important characteristics.

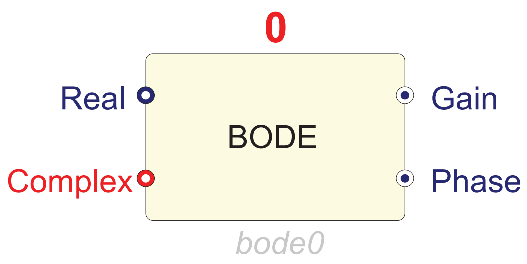
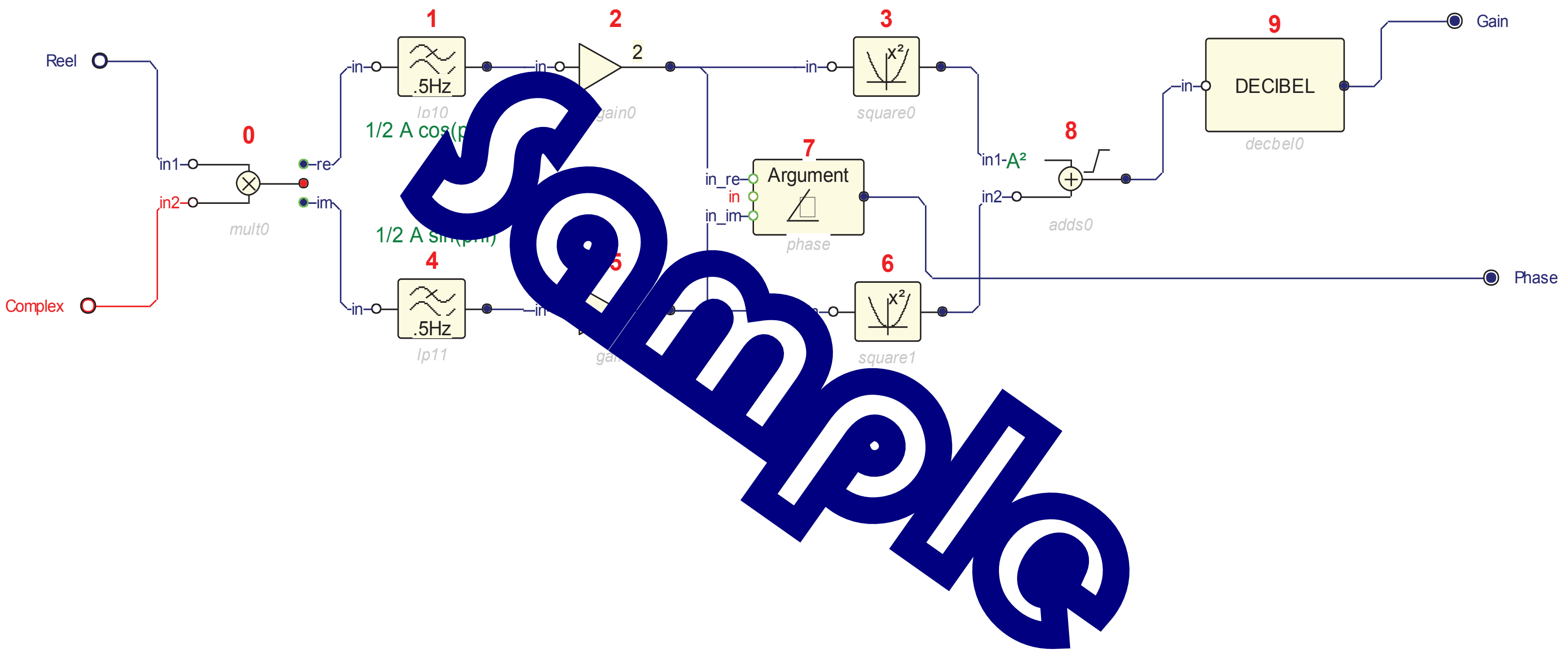
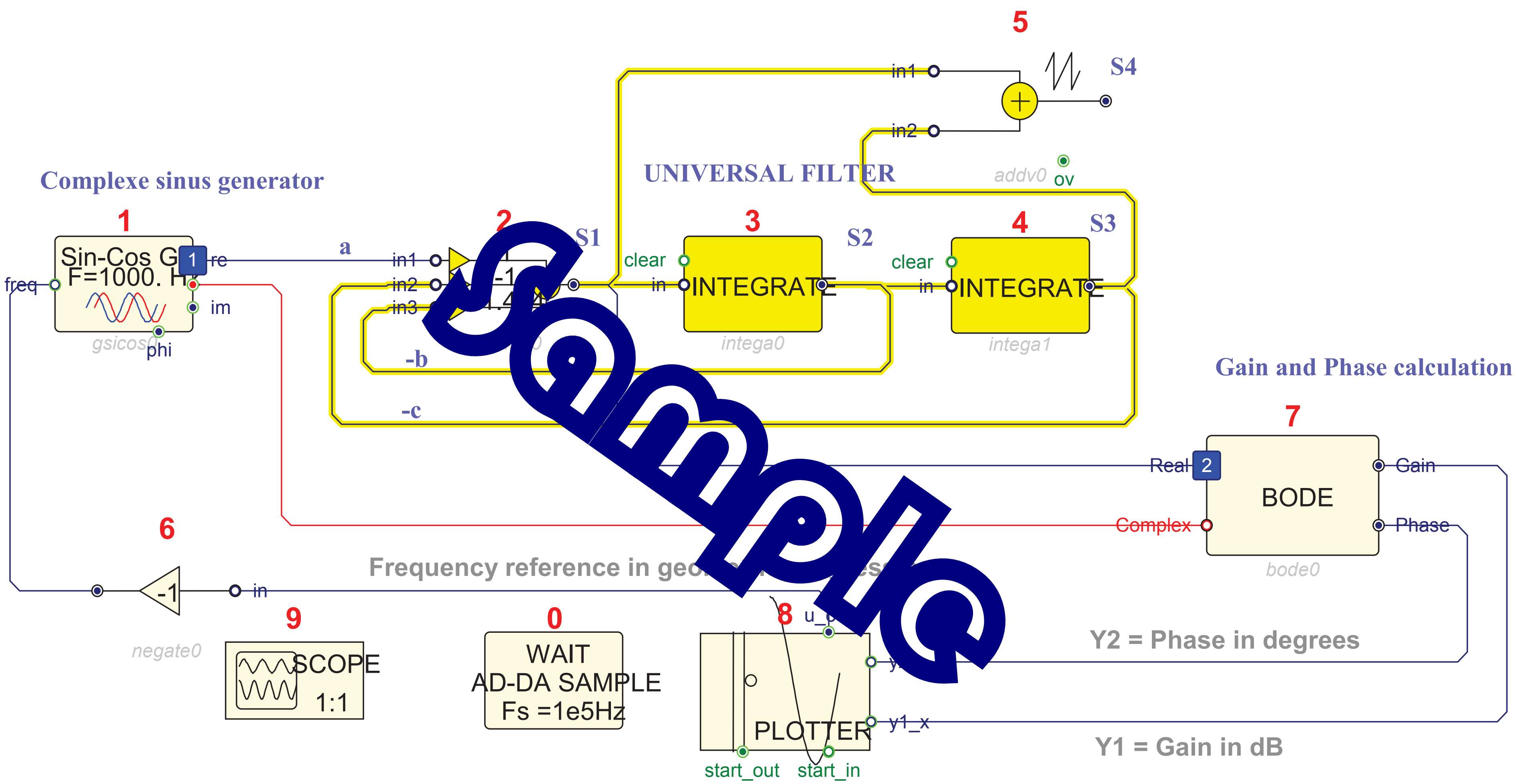


fig.5



Reel
Complex
0
in1
in2
mult0
re
im
1
in
.5Hz
lp10
1/2 A cos(p
1/2 A sin(phi)
4
.5Hz
lp11
2
in
2
gain0
5
3
in
square0
7
in_re
in
in_im
Argument
phase
6
square1
8
in1
A²
in2
adds0
9
in
DECIBEL
decbel0
Gain
Phase

fig.6



Complexe sinus generator
UNIVERSAL FILTER
Gain and Phase calculation
1
2
3
4
5
6
7
8
9
0
Sin-Cos G
F=1000. Hz
freq
re
im
phi
gsicos0
a
in1
in2
in3
-b
-c
S1
S2
S3
S4
clear
in
INTEGRATE
intega0
intega1
in1
in2
addv0
ov
Real
Complex
BODE
Gain
Phase
bode0
-1
in
negate0
SCOPE
1:1
WAIT
AD-DA SAMPLE
Fs =1e5Hz
PLOTTER
y1_x
start_out
start_in
Y2 = Phase in degrees
Y1 = Gain in dB

fig.7

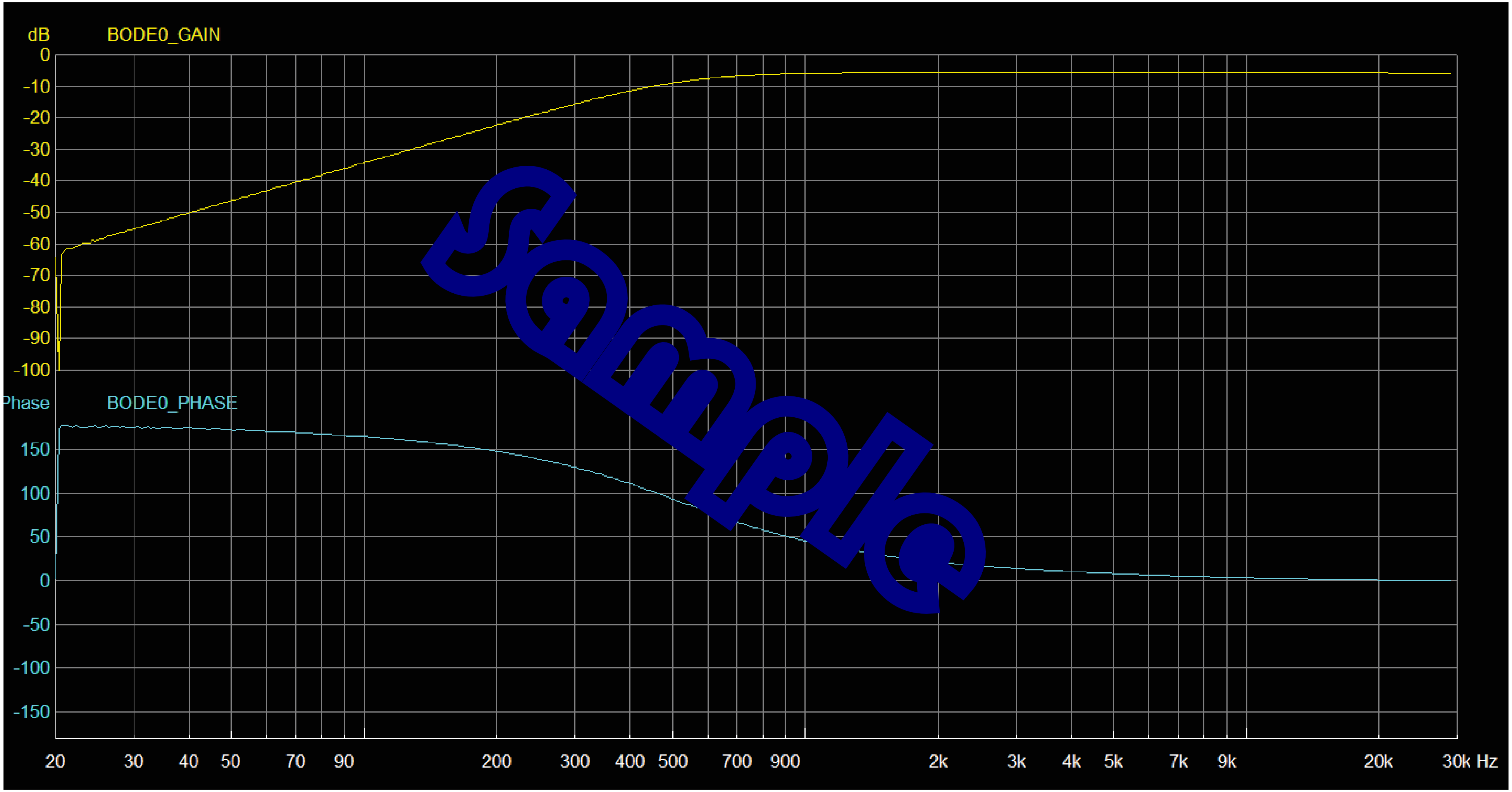
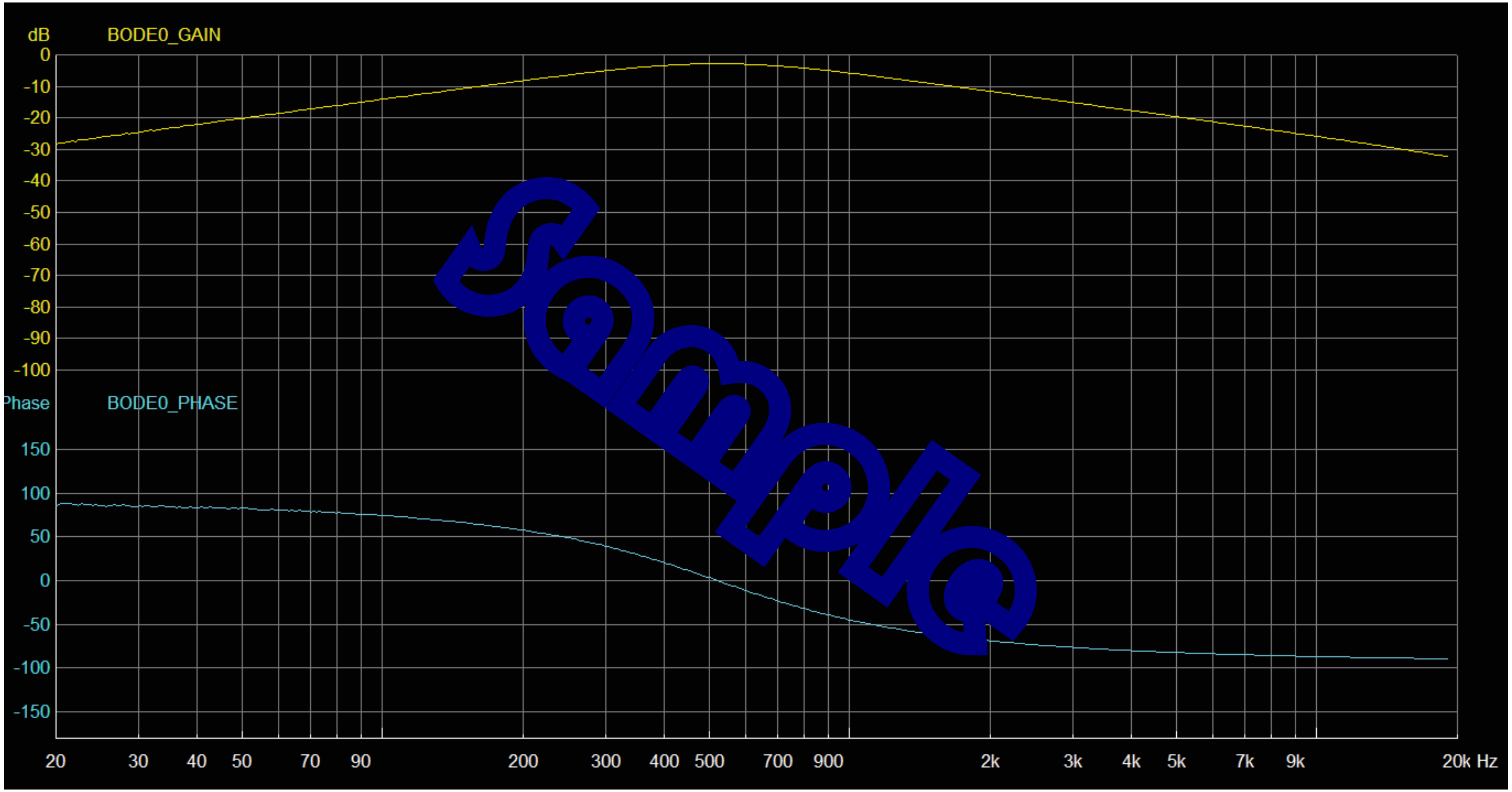

dB
BODE0_GAIN
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Phase
BODE0_PHASE
150
100
50
0
-50
-100
-150
20
30
40
50
70
90
200
300
400
500
700
900
2k
3k
4k
5k
7k
9k
20k
30k Hz
Sample

fig.8



dB
BODE0_GAIN
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Phase
BODE0_PHASE
150
100
50
0
-50
-100
-150
20
30
40
50
70
90
200
300
400
500
700
900
2k
3k
4k
5k
7k
9k
20k Hz

fig.9

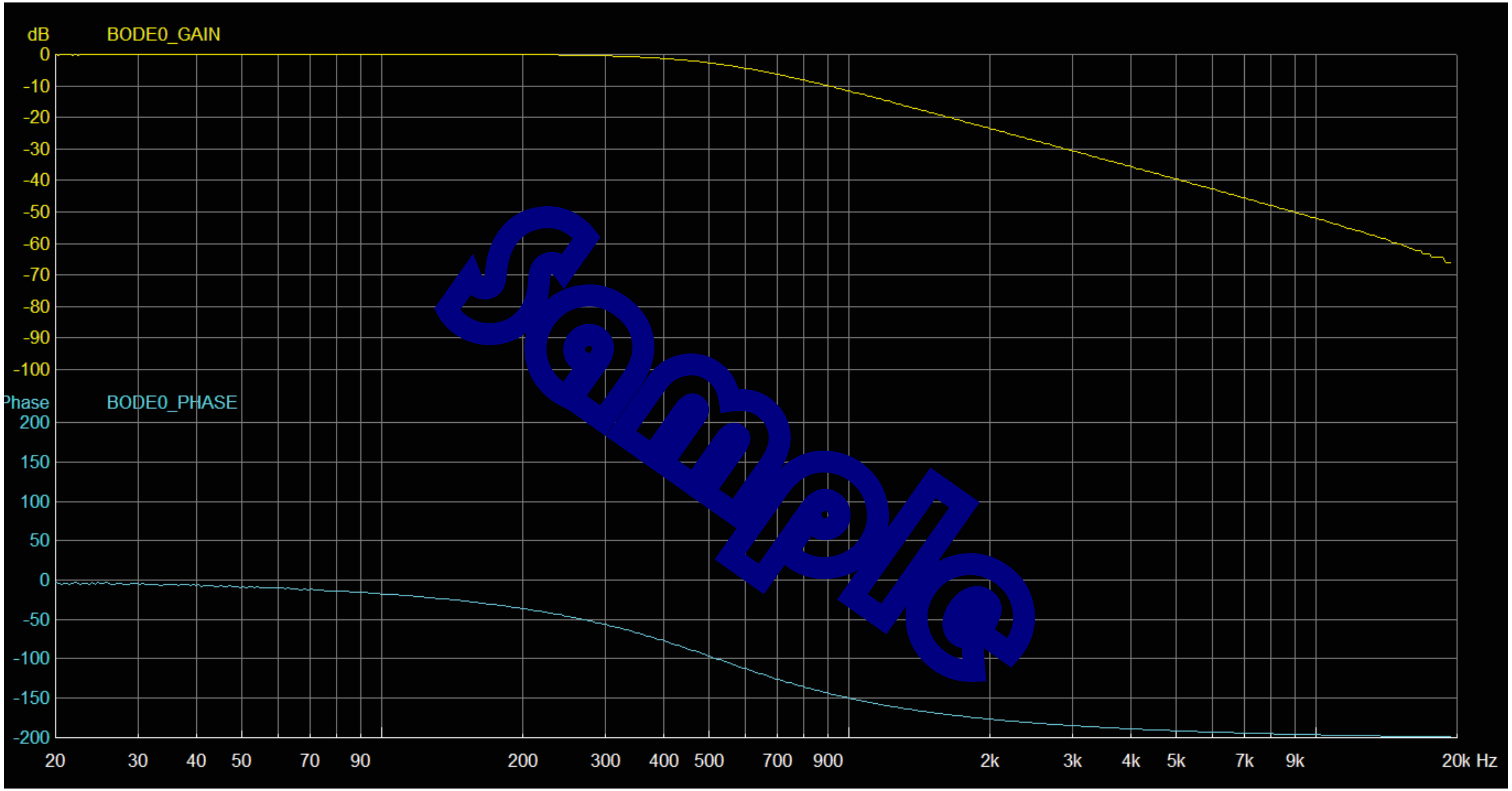

dB
BODE0_GAIN
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Phase
BODE0_PHASE
200
150
100
50
0
-50
-100
-150
-200
20
30
40
50
70
90
200
300
400
500
700
900
2k
3k
4k
5k
7k
9k
20k Hz
Sample

fig.10

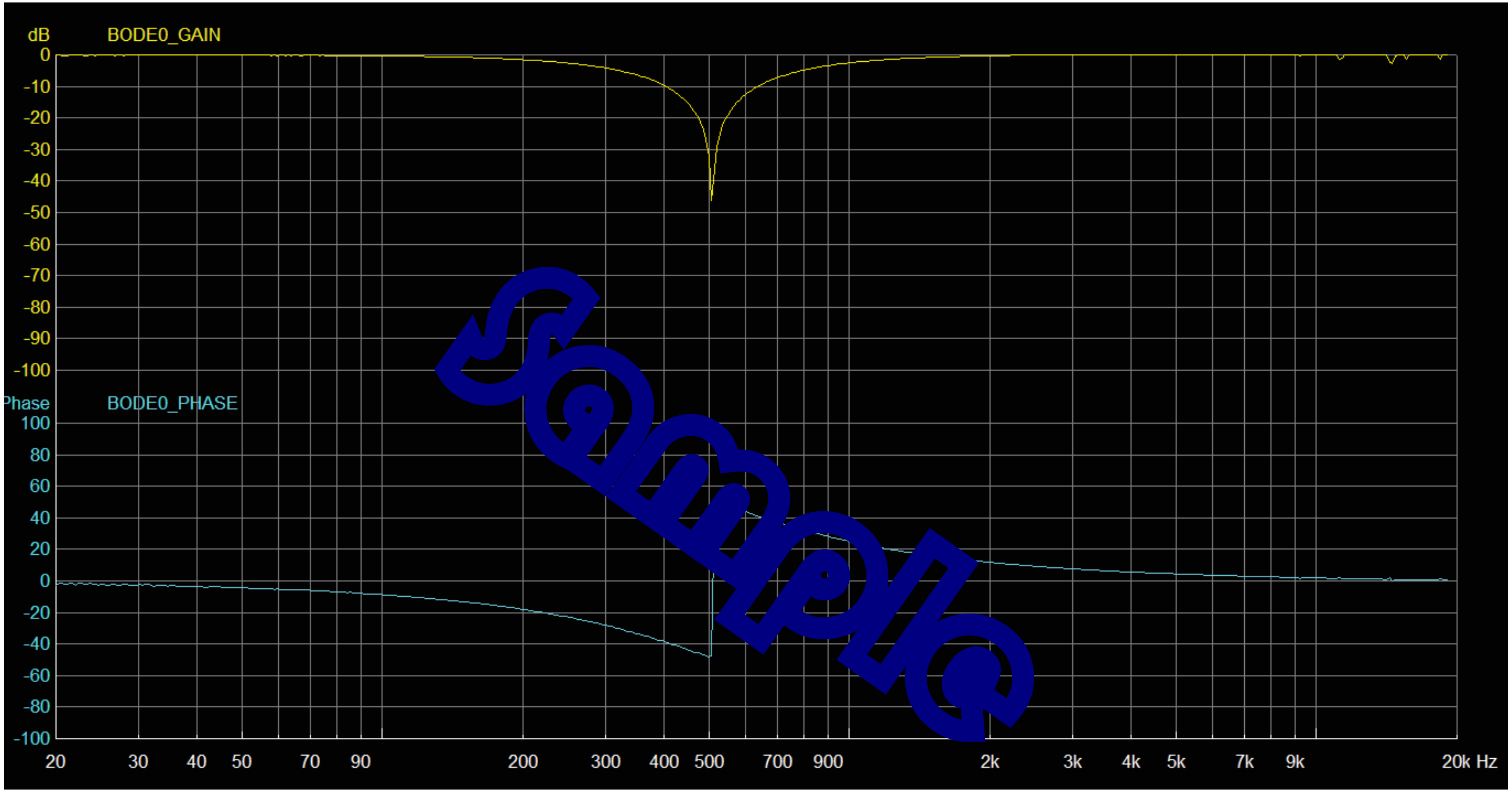

dB
BODE0_GAIN
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Phase
BODE0_PHASE
100
80
60
40
20
0
-20
-40
-60
-80
-100
20
30
40
50
70
90
200
300
400
500
700
900
2k
3k
4k
5k
7k
9k
20k Hz
Sample

fig.11