ELEC2004 Design Challenge Report

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Abstract

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1 Introduction

1.1 Problem Description

A black box containing a circuit of unknown composition was given for the group to analyse and design a reciprocal circuit which would negate the effects of the box. This meant that the desired output of the combination of the blackbox and the student designed circuit would be the same as the input into the combined circuits.

The input signal to the circuit was a sinusoidal wave of 20V peak to peak, the frequency of which was between DC and 20 kHz. The only output load on the circuit was an oscilloscope of high impedance. The group was given three two hour sessions to design and test the proposed circuit, using a range of components supplied in the lab.

1.2 Approach Taken

The process of the design of the circuit involved several steps. First, the black box was analysed to find its transfer function. Once this had been determined, a circuit was designed to give the inverse of this transverse function so as to reverse the effects of the black box. The components that best matched the calculated requirements were then selected from the supplied components in the lab. Testing was then undertaken on the circuit to ensure that it worked as expected. Minor tweaks to the values of the components used were made to better satisfy the conditions of the project.

The circuit that best reversed the effects of the black box was a non inverting amplifier with a purely real feedback impedance and a complex dividing impedance. This circuit will be further explained later in the report.

1.3 Report Breakdown

This report will cover the following topics:

- The background knowledge required to understand and replicate the results obtained;
- The experimental method used to obtain the results;
- The experimental results obtained;

- The design goals, method and outcome; and
- A discussion about the design process and outcome.

2 Background

2.1 Complex Impedance

2.2 Transfer Functions

3 Experimental Method and Results

3.1 Analysing the Black Box

3.1.1 Experimental Method

The apparatus used to analyse the black box was:

- The black box;
- A wave generator; and
- An oscilloscope.

The properties of the wave generated by the wave generator was set using the oscilloscope to ensure they were known and suitable for use in the experiment. Specifically, the wave was set to be a sinusoidal wave with a peak to peak voltage of 20V and no offset.

The input of the black box was connected to the output of the wave generator. This input signal was also connected to one port of the oscilloscope to measure the voltage into the black box. The ground of the black box was connected to both the ground of the wave generator and the oscilloscope to ensure a constant reference. The output of the black box was connected to the input of the oscilloscope.

Starting at a frequency of 1 Hertz, the input and output of the black box was recorded at regular intervals up to and including a frequency of 20 kiloHertz. This data can be seen and analysed in the following section of the report.

3.1.2 Experimental Results

3.2 Testing designed circuit

3.2.1 Experimental Method

The apparatus used to test the designed circuit was:

- The blackbox;
- The circuit;
- A wave generator; and
- An oscilloscope.

As with the analysis of the black box, the properties of the generated wave were set to be sinusoidal of peak to peak voltage of 20V and no offset.

The input of the black box was connected to the output of the wave generator. This input signal was also connected to one port of the oscilloscope to measure the voltage into the black box. The ground of the black box was connected to the ground of the wave generator, the ground of the oscilloscope and the ground of the designed circuit. The output of the black box was connected to the input of the designed circuit, and the output of this circuit was connected to the input of the oscilloscope.

Starting at a frequency of 1 Hertz, the input and output of the black box was recorded at regular intervals up to and including a frequency of 20 kiloHertz. This data can be seen and analysed in the following section of the report.

3.2.2 Experimental Results

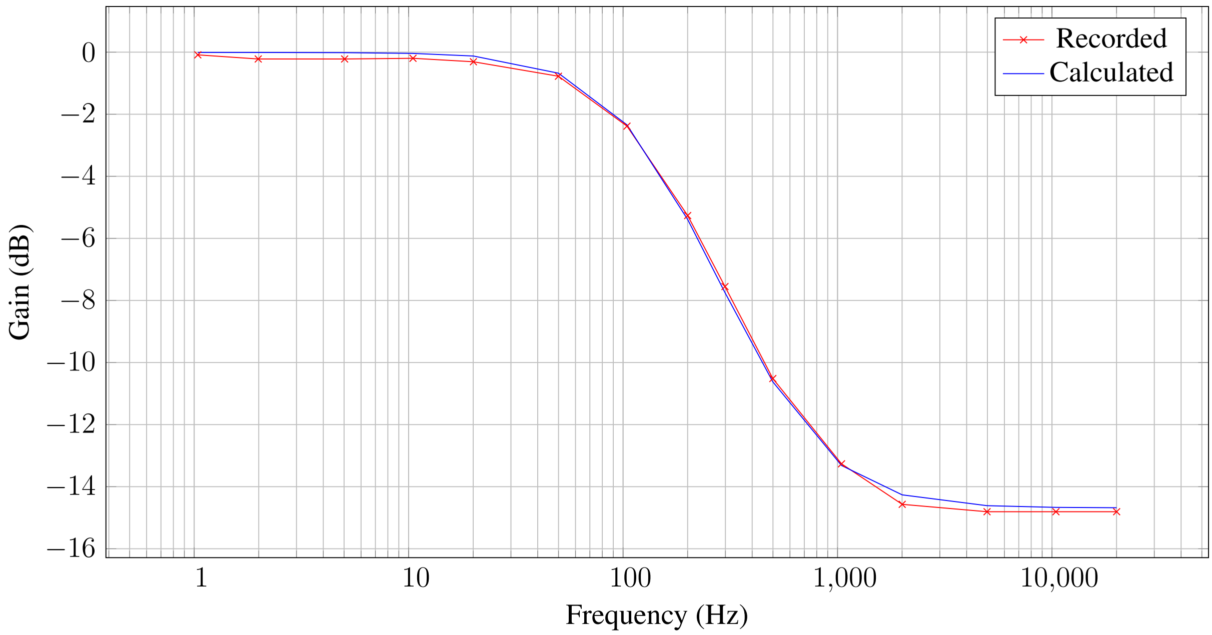

Figure 1: Blackbox

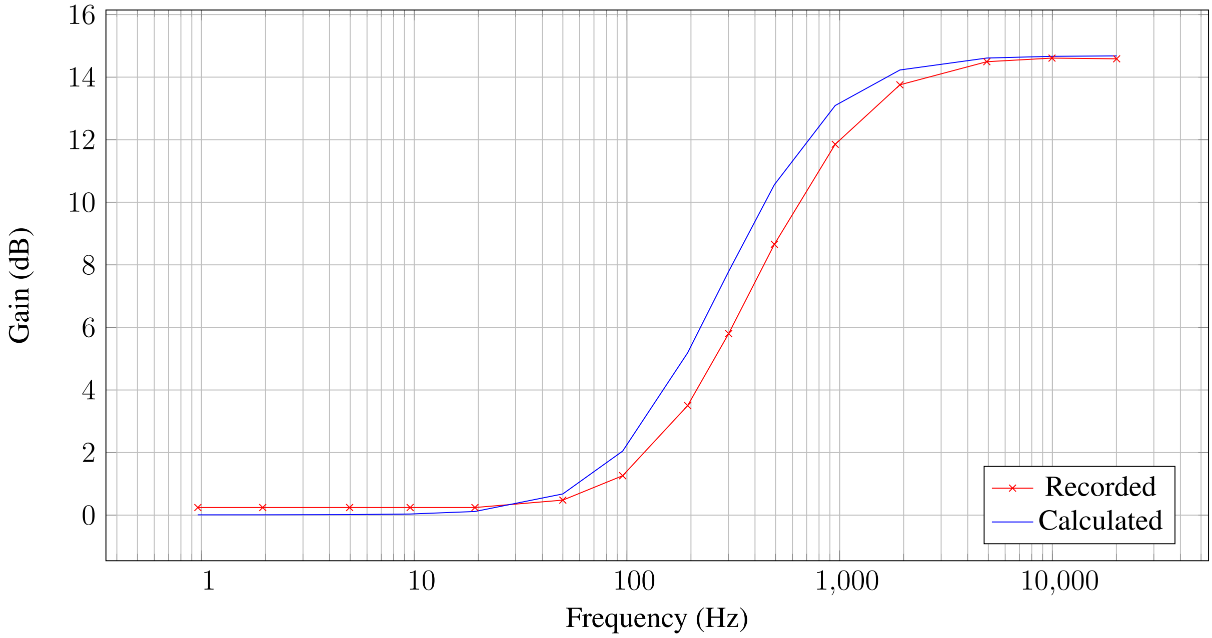

Figure 2: Designed

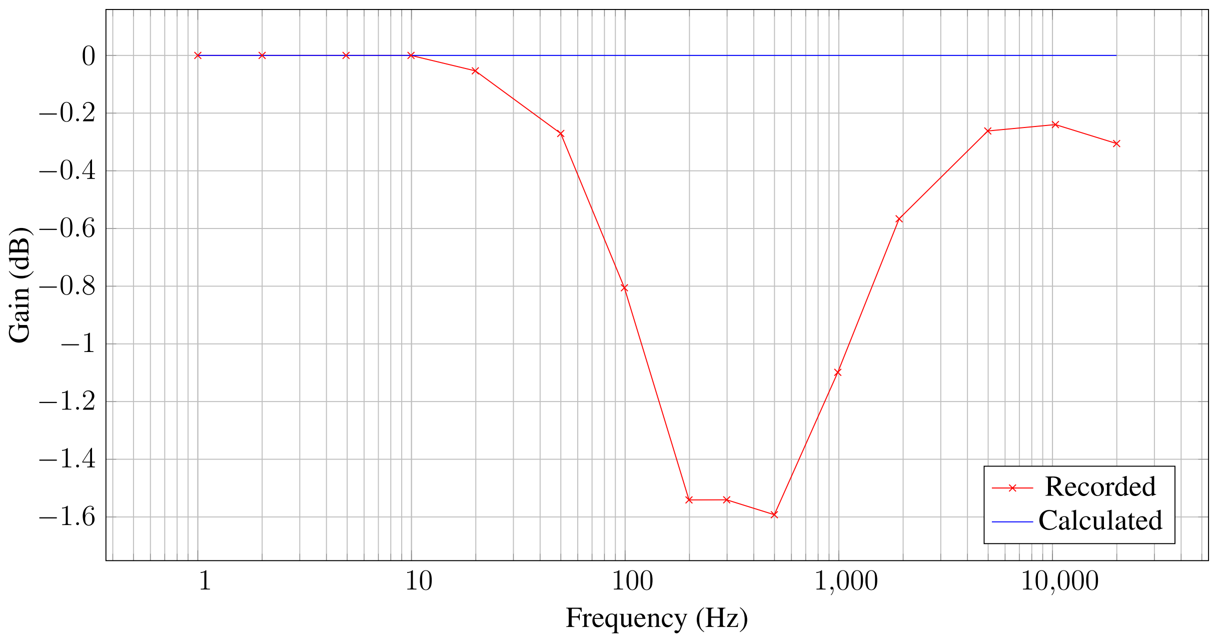

Figure 3: Combined

4 Design

4.1 Goals

4.2 Method

4.3 Outcomes

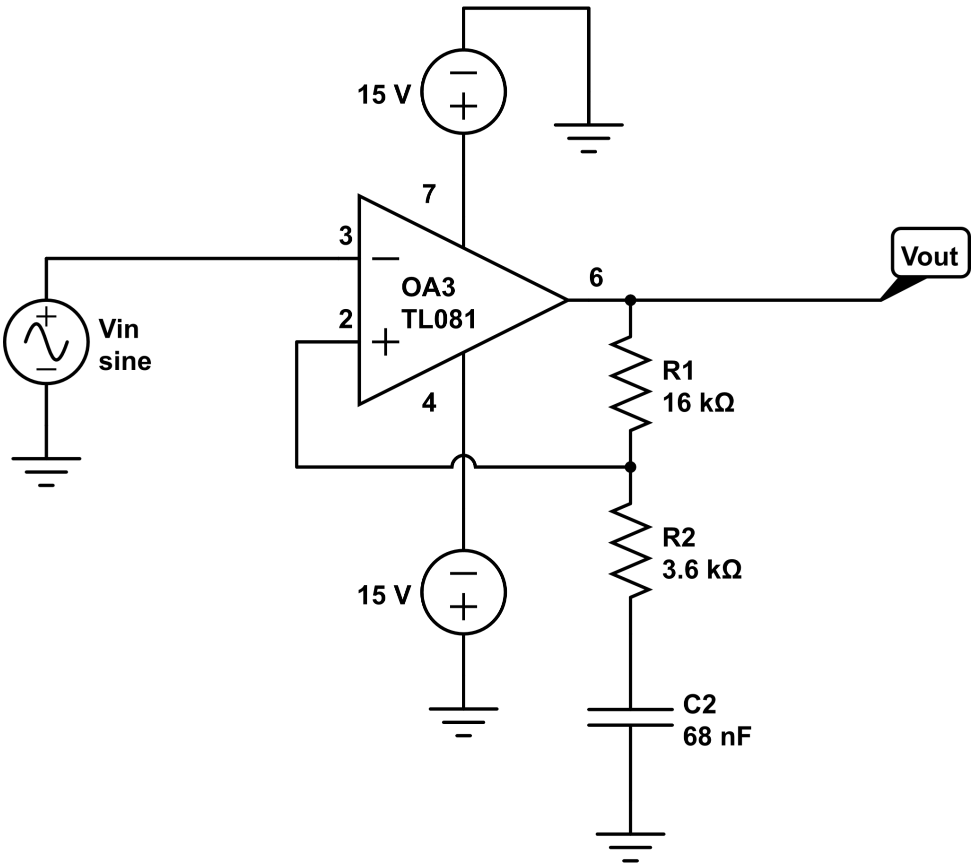

Figure 4: Circuit schematic

5 Discussion

More text.

6 Conclusion

More text.

7 Bibliography

References

[1] S. W. McDougall, "Programming paradigms." `http://world.std.com/~swmcd/steven/programming/paradigms.html`, 1993. Accessed 11/08/2014.

8 Appendices

$$1 + \frac{z_1}{z_2} = \frac{1 + j\frac{\omega}{p}}{1 + j\frac{\omega}{z}} \tag{1}$$

$$\frac{z_1}{z_2} = \frac{1 + j\frac{\omega}{p} - (1 + j\frac{\omega}{z})}{1 + j\frac{\omega}{z}} \tag{2}$$

$$\frac{z_1}{z_2} = \frac{j\frac{\omega}{p} - j\frac{\omega}{z}}{1 + j\frac{\omega}{z}} = \frac{j\frac{\omega}{240\pi} - j\frac{\omega}{1300\pi}}{1 + j\frac{\omega}{1300\pi}} \tag{3}$$

$$\frac{z_1}{z_2} = \frac{j\omega(\frac{1}{240\pi} - \frac{1}{1300\pi})}{1 + \frac{j\omega}{1300\pi}} \tag{4}$$

$$\frac{z_1}{z_2} = \frac{j\omega(\frac{53}{15600\pi})}{1 + \frac{j\omega}{1300\pi}} \tag{5}$$

$$\frac{z_1}{z_2} = \frac{j53\omega}{15600\pi + j12\omega} \tag{6}$$

$$\frac{z_1}{z_2} = \frac{53}{\frac{15600\pi}{j\omega} + 12} \tag{7}$$

$$R_1 = 53a, \quad R_2 = 12a, \quad C = \frac{1}{15600\pi a} \qquad \text{Where } a \text{ is an arbitrary constant} \tag{8}$$

$$C = 68 \text{ nF}, \quad a = 300.066 \tag{9}$$

$$R_1 = 15903.5\ \Omega, \quad R_2 = 3600.79\ \Omega \tag{10}$$

Freq	In	Out	Phase	Measured Gain (dB)	Expected Gain (dB)
1	8.15	8.15	1.18	0	0
2	8.15	8.15	1.1	0	0
4.94	8.15	8.15	1	0	0
9.95	8.15	8.15	-0.5	0	0
19.9	8.15	8.1	-1	$-5.35 \cdot 10^{-2}$	0
49.96	8.15	7.9	-3	-0.27	0
99.2	8.13	7.41	-5	-0.81	0
199	8.12	6.8	-4.8	-1.54	0
298.7	8.06	6.75	-2	-1.54	0
499.2	8.06	6.71	2	-1.59	0
989	8.08	7.12	4	-1.1	0
$1{,}916$	8.08	7.57	3	-0.57	0
$4{,}980$	8.08	7.84	-1	-0.26	0
$10{,}323$	8.08	7.86	-4.5	-0.24	0
$19{,}970$	8.1	7.82	-12	-0.31	0

Table 1: Combined

Freq	In	Out	Phase	Measured Gain (dB)	Expected Gain (dB)
1.04	20	19.8	-0.3	$-8.73 \cdot 10^{-2}$	$-8.96 \cdot 10^{-3}$
1.99	20	19.5	0.7	-0.22	$-9.8 \cdot 10^{-3}$
5.03	20	19.5	1.9	-0.22	$-1.6 \cdot 10^{-2}$
10.48	20	19.55	3.9	-0.2	$-4.05 \cdot 10^{-2}$
20.05	20	19.3	7.5	-0.31	-0.12
49.96	19.9	18.2	16.8	-0.78	-0.68
104.3	20	15.2	30.8	-2.38	-2.34
200.1	19.8	10.8	41.5	-5.26	-5.39
298.7	19.8	8.3	44	-7.55	-7.75
499.2	19.8	5.9	40	-10.52	-10.62
$1{,}044$	19.8	4.3	27	-13.26	-13.32
$2{,}003$	19.8	3.7	16	-14.57	-14.26
$4{,}980$	19.8	3.6	9	-14.81	-14.61
$10{,}436$	19.8	3.6	5.8	-14.81	-14.67
$20{,}024$	19.8	3.6	4.5	-14.81	-14.68

Table 2: BlackBox

Freq	In	Out	Phase	Measured Gain (dB)	Expected Gain (dB)
0.96	1.41	1.45	0	0.24	$8.92 \cdot 10^{-3}$
1.94	1.41	1.45	-0.2	0.24	$9.74 \cdot 10^{-3}$
4.97	1.41	1.45	1	0.24	$1.58 \cdot 10^{-2}$
9.57	1.41	1.45	2.8	0.24	$3.52 \cdot 10^{-2}$
19.3	1.41	1.45	4.9	0.24	0.12
49.96	1.41	1.49	12	0.48	0.68
95.5	1.41	1.63	24	1.26	2.05
193	1.41	2.11	38.5	3.5	5.19
300.8	1.41	2.75	43	5.8	7.79
493.4	1.41	3.82	42	8.66	10.56
953.2	1.41	5.52	35	11.85	13.09
$1,920$	1.41	6.87	22	13.75	14.23
$4,919$	1.41	7.48	7	14.49	14.61
$9,960$	1.41	7.58	-0.5	14.61	14.67
$20,055$	1.41	7.56	-10	14.59	14.68

Table 3: Designed