ECE 3042 Microelectronics Laboratory

Laboratory Report

The Two-Resistor Voltage Divider

Date Performed: October 25, 2012

Date Submitted: November 19, 2012

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AD Login: abc123

Georgia Institute of Technology

School of Electrical and Computer Engineering

ECE 3042 Electrical and Electronic Circuits Laboratory Verification Sheet

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NAME:____ SECTION:___________________________

AD LOGIN:__________________________________

INVERTER Oscillator

Procedure	Time Completed	Date Completed	Verification (Must demonstrate circuit)		
Bode Plot of Filter					
Time Domain Screen Shot of Oscillator Output					
Spectra of Output of Oscillator					

Enter your critical frequency below:

Last Digit of GTID	

SIGNATURE:___________________________________ DATE:____________________________________

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Pledge of Academic Honesty

On my honor I

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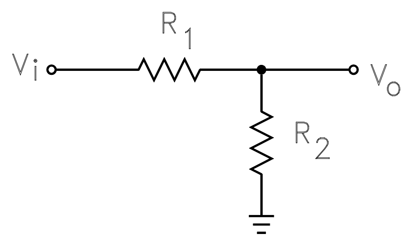
pledge that all work that appears in this document is mine. I have not copied from another student nor supplied materials to another student. Only the assistance of Drs. Brewer and Robinson or the staff of the Coleman Family Undergraduate Communication Studio has been solicited in the preparation of this document. I understand that if I do not sign this pledge and include it on the 3rd page of the laboratory report that I will receive a zero on the assignment.

Object

The object of this experiment is to design, simulate, assemble, experimentally evaluate and document a two-resistor voltage divider.

Theory

Shown in Fig. 1 is a two-resistor voltage divider.



Two-resistor voltage divider.

There are two voltages associated with this circuit, viz. an input voltage and an output voltage. The input voltage is V_i and the output voltage is V_o. By properly selecting the resistor R_1 and R_2 the output voltage may be made a specified fraction of the input voltage. The complex transfer function is given by

$$T(s) = \frac{V_o}{V_i} = \frac{R_2}{R_1 + R_2} \tag{1}$$

where s is the complex frequency variable. The complex input impedance is

$$Z_i(s) = \frac{V_o}{V_i} = R_1 + R_2 \tag{2}$$

and the complex output impedance

$$Z_o(s) = \left.\frac{V_o}{I_o}\right|_{V_i=0} = R_1 \| R_2 \tag{3}$$

Neither three of these network functions are frequency dependent. Indeed, they are purely real constants at all frequencies.

Design

Design Specifications

Design a two-resistor voltage divider that has an input impedance of $10\,\text{k}\Omega$ and an attenuation of $20dB$ at all frequencies. There is no specification for the output impedance. Use standard values of resistors if possible.

Solution

An acceptable solution is to pick $R_1 = 9\,\text{k}\Omega$ and $R_2 = 1\,\text{k}\Omega$. This will result in an gain of

$$20 \log \left| \frac{R_2}{R_1 + R_2} \right| = -20dB$$

which is therefore an attenuation of $20dB$. The $1\,\text{k}\Omega$ is a standard 5% resistor value and the $9\,\text{k}\Omega$ resistor may be implemented using either two $18\,\text{k}\Omega$ resistors in parallel or three $3\,\text{k}\Omega$ resistors in series.

Simulation

The design was simulated with SPICE, viz. Multisim 12.0. Calculations were made with Mathcad 15. These results are presented in Appendix A.

Procedure

The circuit was assembled in the laboratory and appropriate measurements were made. The circuit is shown in Fig. 2.

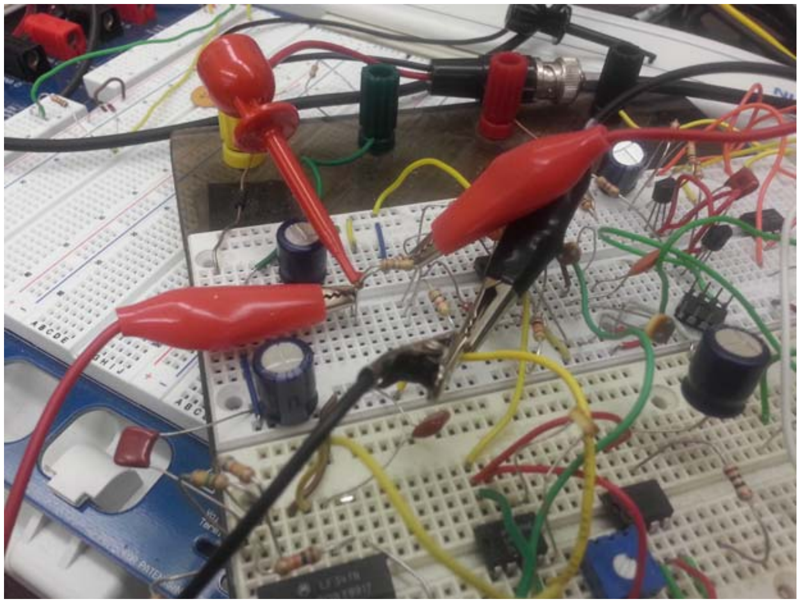


Figure 2. Two-resistor voltage divider circuit.

The response at a frequency of 1 kHz was obtained by connecting a function generator to the input and plotting the input and output waveforms that appear on the oscilloscope as shown in Fig. 3.

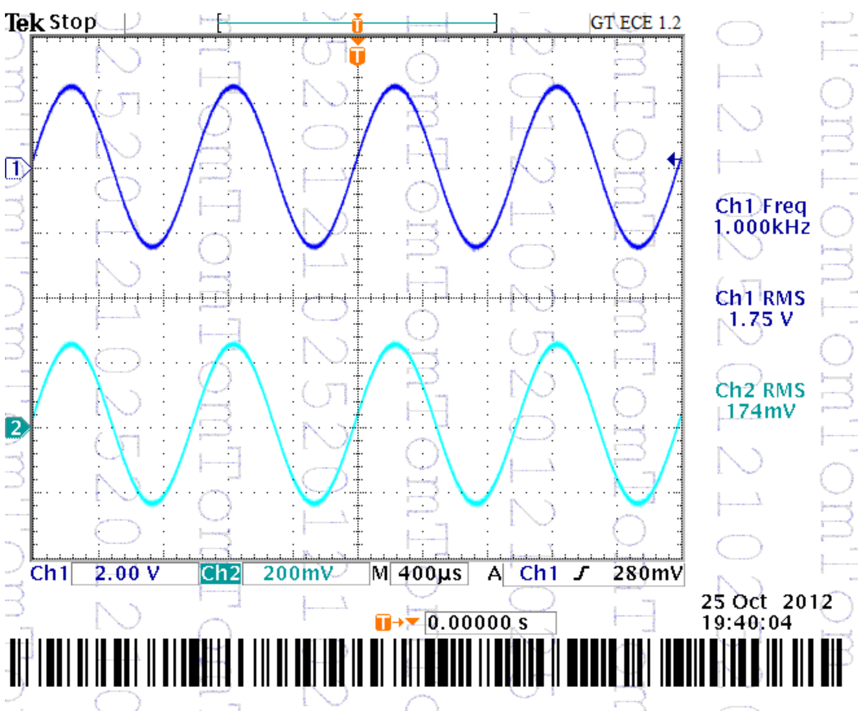


Figure 3. Sine wave response.

The frequency response was obtained with Agilent VEE and is presented in Appendix B.

Conclusions

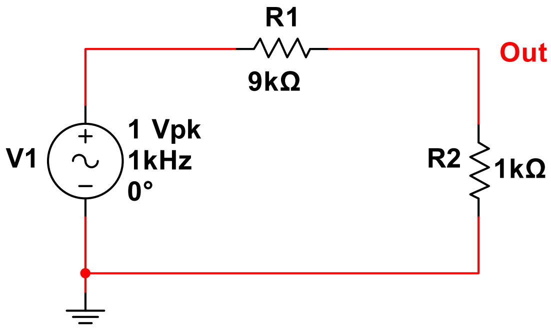
The agreement between the design specifications, the simulation results, and the experimental results is superb. Any difference between them may be attributed to the use of 5% resistors, instrument loading caused by the finite input impedance of the oscilloscope ($1\,\mathrm{M\Omega}$ resistor in parallel with a $13\,\mathrm{pF}$ capacitor), and that the instruments used in instructional laboratories are rarely calibrated. These minor sources of error did not cause a significant degradation of the results. The results obtained are independent of frequency for the ranges for which measurements were made.

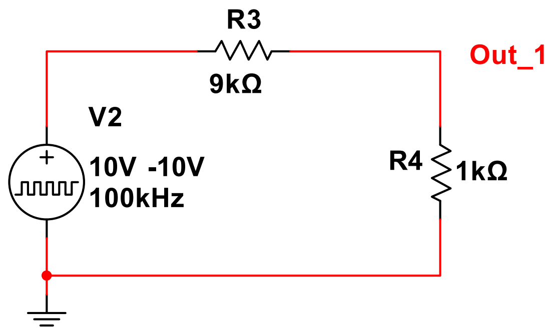
Thus the two-resistor voltage divider is an absolutely invaluable element in circuit design and fabrication. It may be used by both tyros and experts to implement an almost endless list of tasks. This experiment was an invaluable exercise in that it illustrated that this circuit is one of the foundations of society for now and until the end of time.

Appendix A.

SPICE Simulations

Mathcad Calculations





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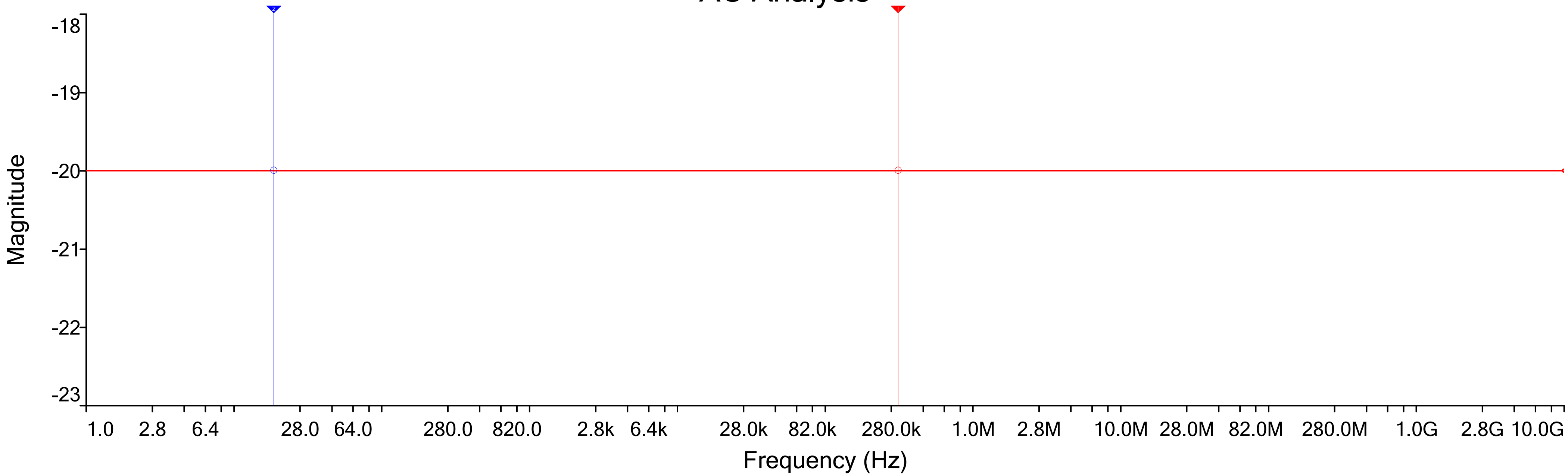
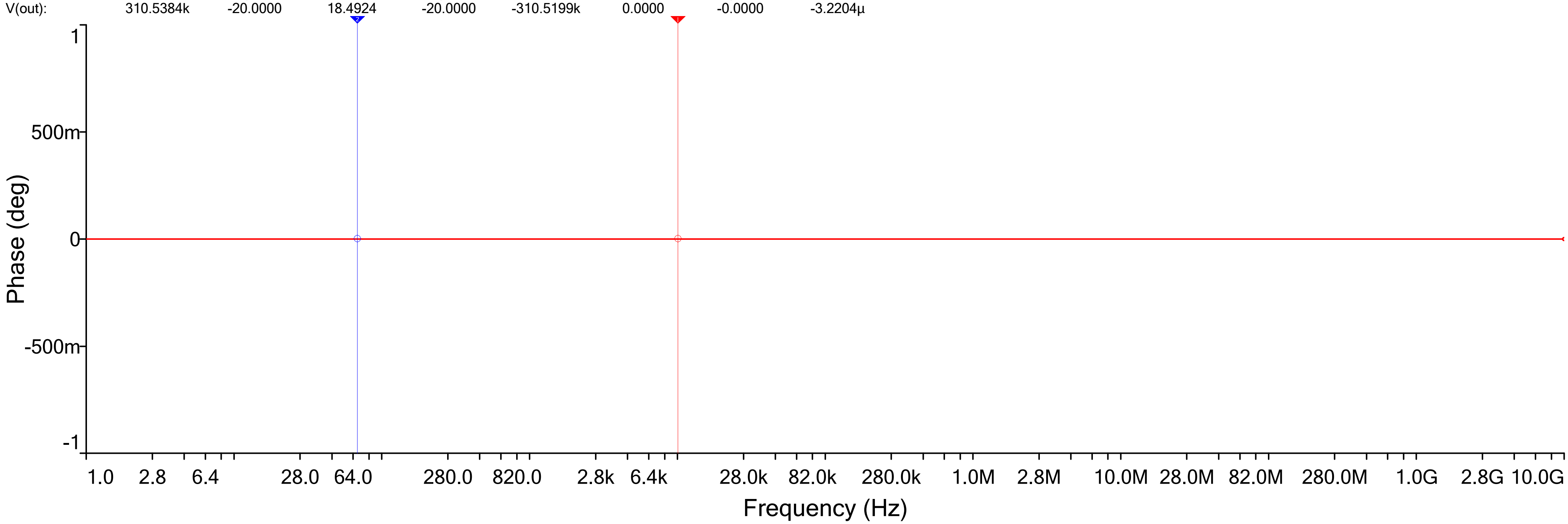
AC Analysis



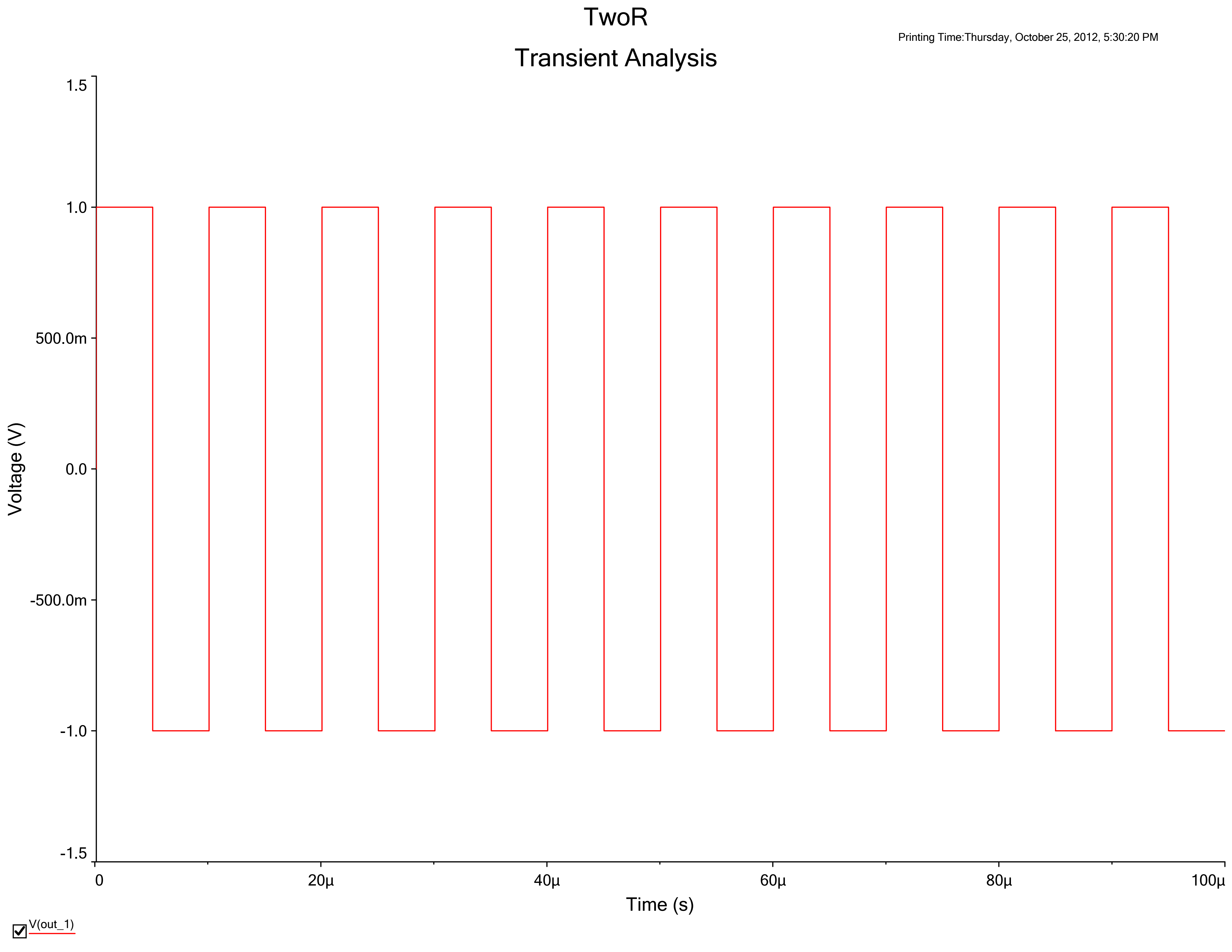
V(out)

	x1	y1	x2	y2	dx	dy	dy/dx	1/dx
V(out):	310.5384k	-20.0000	18.4924	-20.0000	-310.5199k	0.0000	-0.0000	-3.2204µ



V(out)

	x1	y1	x2	y2	dx	dy	dy/dx	1/dx
V(out):	10.0502k	0.0000	68.0014	0.0000	-9.9822k	0.0000	-0.0000	-100.1782µ



TwoR
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Transient Analysis
Voltage (V)
1.5
1.0
500.0m
0.0
-500.0m
-1.0
-1.5
0
20µ
40µ
60µ
80µ
100µ
Time (s)
V(out_1)

Two-Resistor Voltage Divider

Specified Attenuation   20dB

Specified Input Impedance   10kΩ

$$\frac{R_2}{R_1 + R_2} = 10^{\frac{-20}{20}}$$

$$R_1 + R_2 = 10k\Omega$$

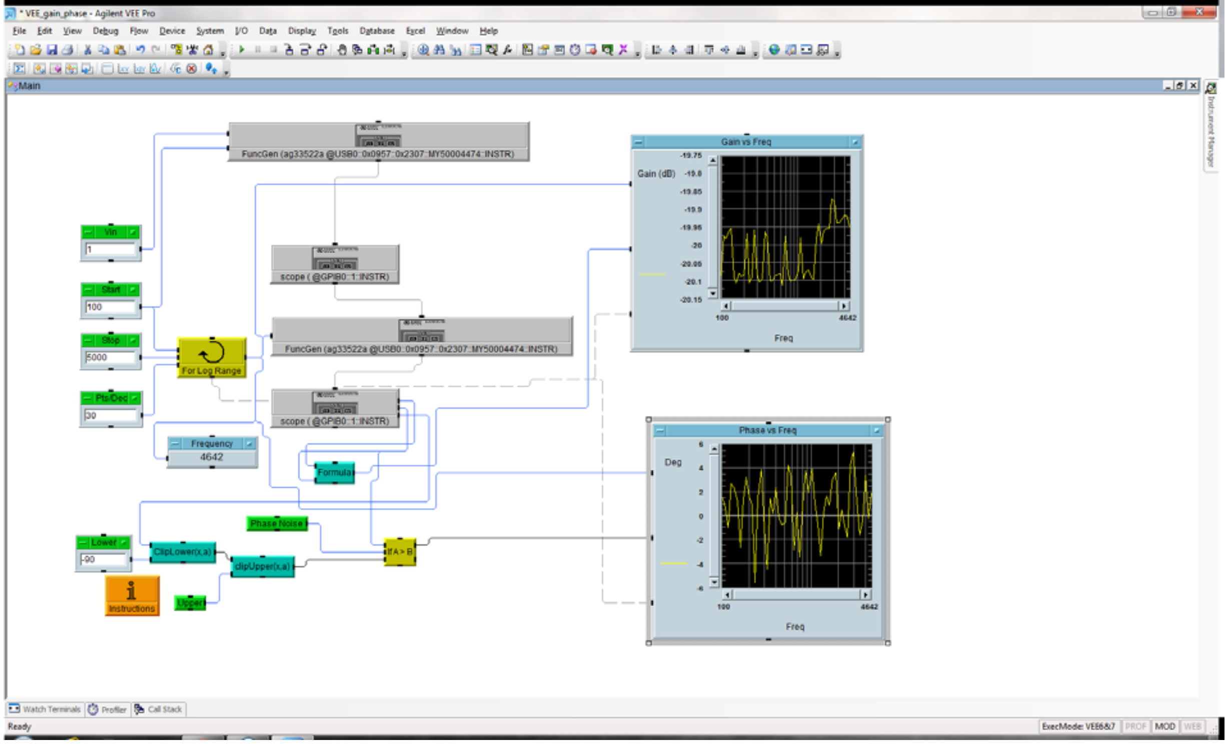
Simultaneous solution yields

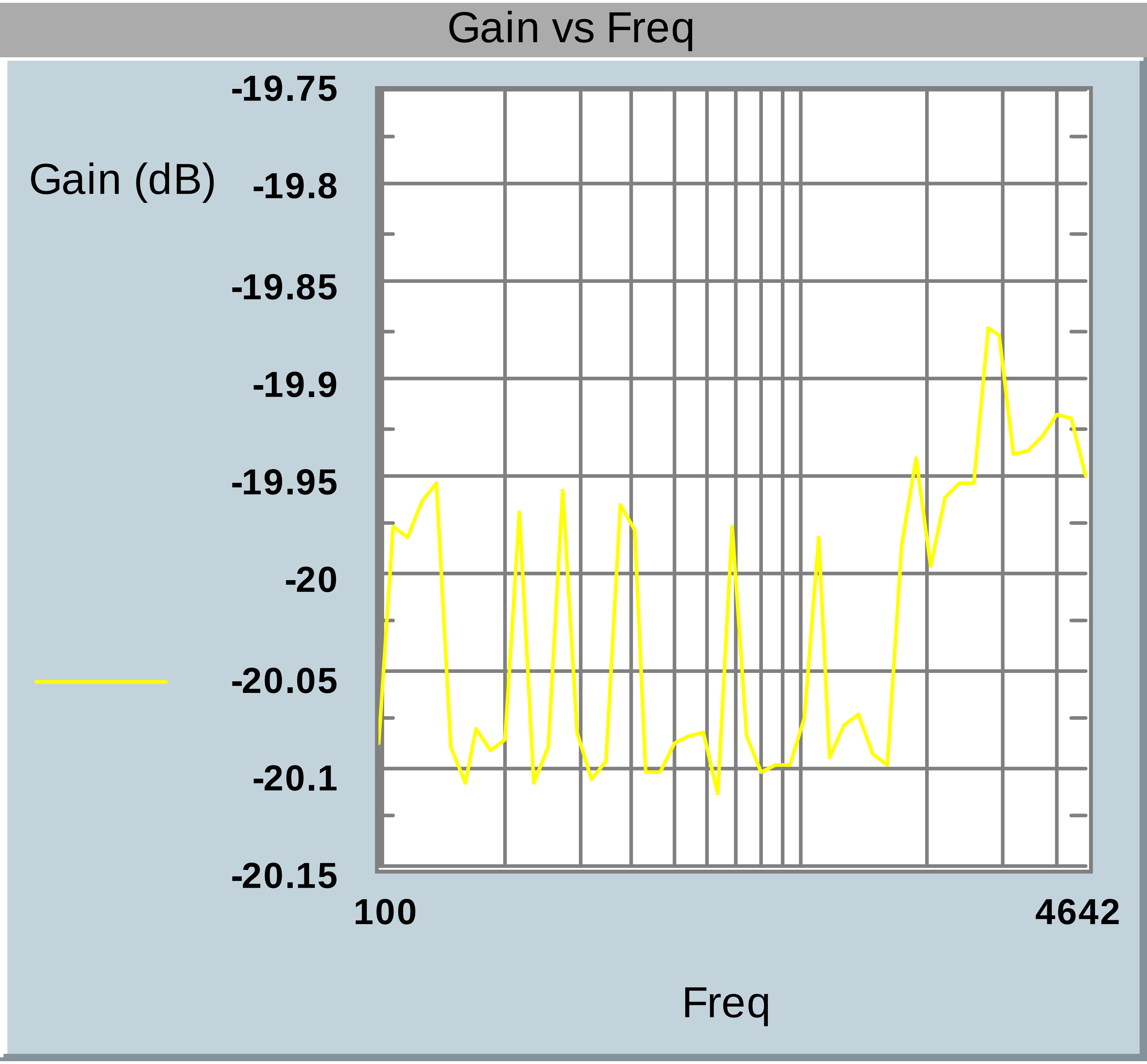
$R_1 := 9k\Omega$ $R_2 := 1k\Omega$

"brewer.bmp"

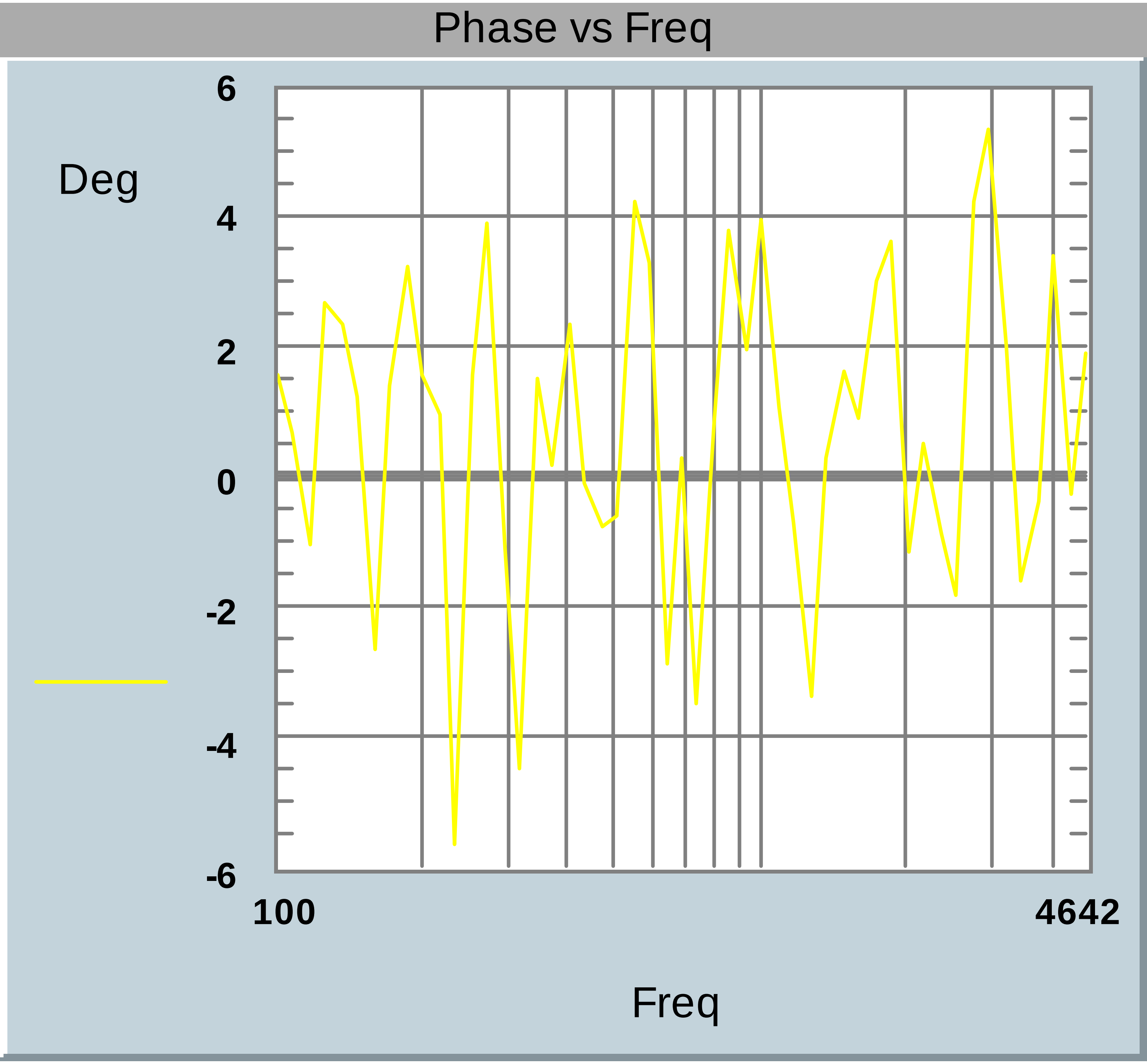
Appendix B.

Measured Frequency Response


* VEE_gain_phase - Agilent VEE Pro
File Edit View Debug Flow Device System I/O Data Display Tools Database Excel Window Help
Main
FuncGen (ag33522a @USB0::0x0957::0x2307::MY50004474::INSTR)
Gain vs Freq
Gain (dB)
Vin
1
Start
100
scope (@GPIB0::1::INSTR)
Stop
5000
For Log Range
FuncGen (ag33522a @USB0::0x0957::0x2307::MY50004474::INSTR)
Freq
Pts/Dec
30
scope (@GPIB0::1::INSTR)
Frequency
4642
Formula
Phase vs Freq
Deg
Phase Noise
Lower
-90
ClipLower(x,a)
clipUpper(x,a)
If A > B
Instructions
Upper
Freq
Watch Terminals
Profiler
Call Stack
Ready
ExecMode: VEE6&7
PROF
MOD
WEB
Instrument Manager



Gain vs Freq
Gain (dB)
-19.75
-19.8
-19.85
-19.9
-19.95
-20
-20.05
-20.1
-20.15
100
4642
Freq


Phase vs Freq
Deg
6
4
2
0
-2
-4
-6
100
4642
Freq

Guidelines for Formal Laboratory Reports

This is a technical paper and must meet the standards for such a document. It is both a report of the results of the experiment and an exercise in technical writing. It will be graded for both content and style.

The communication of the results of an experiment is as important as the care taken in performing the experimental work. No matter how important the findings of an engineer may be, they are useless unless he/she can communicate them to others. Consequently, much of an engineer's time is spent in writing reports on his/her own work or the work of the technicians or junior engineers working under him/her. Therefore, it is necessary to cultivate the ability to write a clear technical report.

The purpose of writing laboratory reports in instructional laboratories is twofold: first, to develop a report-writing ability; second, to assemble the information gathered in the laboratory into a form in which it can be easily remembered by the writer and presented to the reader. It should be emphasized to students taking an instructional laboratory course that they are being evaluated on both their experimental techniques and their ability to write acceptable technical reports.

There is no "best" way to write a laboratory report; rather, there are many good ways. A report should reflect careful organization, proper English, neatness, and attention to detail. The 5 C's of excellent technical communication are the following:

1. Clarity
2. Conciseness
3. Correctness
4. Consistency
5. Comprehensiveness

Indeed, excellent technical communication should be clear, concise, correct, consistent, and comprehensive. A guiding principle to keep in mind throughout report writing is that any outsider with a technical background similar to the report writer's should be able to duplicate the entire experiment, data, and conclusions by reading the report. Do not trust memory to fill in details—after a few days the experiment may be a mystery even to the report writer.

A good report should be carefully and concisely written and should be free from grammatical errors and misspelled words. A suggested outline is as follows:

1. Each experiment must have a cover sheet or title page which contains the name of the course, the section, the day of the week and the hours for the laboratory section, the name of the experimenter, the semester, the date the experiment was performed, and the date the report was submitted. This cover sheet or title page is the page in the report that appears first. The cover page is the attention grabber that entices someone to actually read the report.
2. The Verification Sheet. It must have appropriate signatures for all sections.
3. The Pledge of Academic Honesty is placed immediately after the Verification page. It must be signed with the student's name or the report will not be graded.
4. The first part of the laboratory report is to be an overall Objective, and the final part is to be the General Conclusions, Conclusions, or Summary. (Any appendixes follow the General Conclusions. Each laboratory report has a least one appendix, which is the rough data sheet signed and dated by the laboratory instructor.) This is so that a reader can tell what the experiment was about by a glance at the Objective section of the laboratory report and what degree of success the experimenter achieved by a glance at the General Conclusions section of the laboratory report. The Objective, Introduction, Purpose of the Experiment, Abstract, or whatever name is chosen for this initial section should appear as the first item on page 1 (it is not necessary to number page 1). The Conclusions or Summary should appear on the last numbered pages prior to the appendices.

5. The report should be a concise, intelligible, and readable account of what was done. It should never contain a personal pronoun. It should never contain statements such as: "I did...," "We did," "Lee Roy measured the voltage...," or "Do". Instead, the wording should be as follows: "The circuit was connected as shown in Fig. 3, and the following data was taken," etc. Anthropomorphisms such as "the oscilloscope didn't feel well" are not acceptable—don't attribute emotions or feeling to inanimate objects. The report should be prepared on a word processor. Microsoft Office is recommended. Curves and diagrams must be drawn with a CAD system. Computer simulations such as SPICE should be included as an appendix. Results from simulations should be placed in the main body of the report when appropriate. The following are some common mistakes made when writing laboratory reports:

- Cover page missing information. The cover page should contain all the information requested. This is the first thing that a reader sees; thus, it should also be free of formatting errors and misspellings. Make certain that it includes the "College of Engineering" and the "School of Electrical and Computer Engineering". Chose font sizes and spacing that make the cover attractive, impressive, and informative.
- Pledge of Academic Honesty not included or not signed. The report will not be graded. The student must resubmit the report and receive a penalty for a late report.
- Circuit diagram not included with SPICE simulations.
- Inadequate conclusions. Pertinent conclusions should appear at the end of each section of the report, as well as those at the end of the report. The word "pertinent" means that some sections of the report may not be important enough to require a conclusion.
- Improper use of tenses. The Objective and Procedure sections are written in the past tense. The experiment was performed in the past and, therefore, the description of the procedure used for the accumulation of data, etc. should be in the past tense. The theory, data, simulation, and conclusion sections are written in the present tense. Stating fundamental scientific and engineering principles in the present tense does not constitute a tense change.
- Improper use of pronouns. Personal pronouns are not acceptable in a laboratory report and are not used. Besides, it is not necessary to say "I" or "we" performed anything; the names of the experimenter is on the title page, which removes any ambiguity about who performed the steps in the procedure. Correct usage is, "the function generator was connected to the oscilloscope" and not, "I connected the function generator to the oscilloscope."
- Casual and Imprecise Language. "This Agilent meter worked pretty good," or "I couldn't get the plots to print right, so I sketched them by hand," or "It looked to me like," or "the percent error was reasonable," are not acceptable. Be specific and exact.
- No labels for tables, graphs, circuits, and/or calculations. All tables, graphs, circuit, calculations, and other non-text figures should be clearly and logically labeled. The label should not only include a sequential number, but also a description of what is being labeled. Examples Circuit 3, Nonelectronic Voltmeter; Calculation 7, Example of Percent Error Calculation; Table 2, Theoretical and Measured Voltage with Percentage Error; and Graph 6, Voltage vs. Frequency for RCL Circuit of Circuit 5. Labeling something with the step in the procedure which uses it is not acceptable—Example: Step 6 would not be a appropriate title for a graph.
- Improper table format. Tables must have lines clearly separating rows and columns. Furthermore, decimal points should be aligned if the word processor being used is capable of this. All circuit diagrams, tables, sample calculations, figures, etc. should appear in the body of the report with the procedure step with which they are first associated.
- Graph format incorrect or inadequate. All graphs and/or figures should be computer generated. Axes should be properly labelled, as should multiple plots per graph. The graph should have a logical title that describes what is being graphed, not just the procedure step with which the graph is associated.
- Raw data just stapled to report. Raw data should be included as an "Appendix" to the report, not just stapled on at the end without a title or page numbers. Each report should contain at least one

appendix (the raw data with the signature or initials of the laboratory instructor). The pages of an appendix should be numbered with a letter prefix indicating the appendix. If there are multiple pages in an appendix, they should be numbered with Arabic numerals following the appropriate letter prefix.

- Number pages. All pages of the report should be numbered including any appendices except for the first page in the main body of the report. The sections prior to the Objective, if any, should be numbered with lower case Roman numerals. The Objective should begin a new page—although this is page 1 of the report, no number appears on this page. It is not necessary to have a Table of Contents or List of Figures in a short document.
- Other examples of laboratory reports can be obtained by doing a web search on "electrical engineering laboratory reports" which show similar formats.