

Design and Development of Resistor Capacitor (RC) Bode Plot for Filters

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Abstract

The aim of this work is to design and develop a Resistor Capacitor (RC) bode plotting and system for use in the laboratory on which several circuits and filters of different topologies can be analyzed and tested after construction. The maximum measuring frequency for this work will be limited to Audio frequencies, since common op-amps use analogue circuit design and have a maximum unity gain bandwidth of 1Mz. In this design, we were able to analyse systems whose operating frequencies are limited to less than 22KHz. This involves the generation of an electrically tunable sine wave generator whose frequency can be automatically tuned by the computer. Sine waves were used due to low harmonic content, this ensures that the figures which we obtained have minimal distortions as expected from an ideal sine wave source. The system was based on 8-bit microcontroller, which generally gives a low resolution output. In order to improve the system's resolution, we used relatively low reference voltages. The 8052 micro-controller can operate at a maximum frequency of 33 MHz, by operating at this maximum available frequency, we were able to improve our system processing speed, thus ensuring that measurements and readings are obtained in almost real time. The system's graphical user interface was developed with the **VISUAL BASIC.NET** program and will run on Microsoft operating system. On completion of the work, the design and developed device provides actual frequency response as compared to the ideal response provided by a software-based Bode Plotter for a passive filter.

1. Introduction

A **Bode plotter** is a test and measurement device that is able to plot the graph of the transfer function of a linear, time-invariant electronic circuit system on a computer screen. This device is able to give us the actual frequency response of such a system as opposed to the ideal and can thus be used to compare as well as analyze variations from the ideal system. Most electronic systems operate in environments with varying temperatures, and the constituting electronic components deviate from the ideal, under these environmental variations. With a bode plotter, the overall system's response can be analysed during these varying environmental conditions, with a view to improving system performance as well as reliability. The bode plotter is a typical example of a closed loop control system, because it sends electrical impulses to an external system's input (i.e. the system being analysed), receives the resulting impulses from the system's output, initiates automatic gain controls to ensure that the system is operated within allowable bounds, takes the feedback from such a system, and then converts the resulting feedback signals to visual graphs which can be displayed on a computer screen and then analysed. As a test and measuring equipment, the system being analysed is considered to be a two-port network, and an attempt is made by the bode plotter to characterize the network from measurements obtained at the network terminals (input and output) without regard however to the contents of the network. Such a system is indispensable in any electronic system design laboratory, and thus falls into a category of network analyzers [1,2]. Bode plots are important in electronic feedback systems design because they are easy to measure and work with at low frequencies than other kinds of plots. They are conceptually simple, analytically convenient, and capable of providing a great insight into most low frequency measurement or design problems. Examples of such design problems occur in signal processing filters (low and high order filter designs), sound amplifier designs, sensor designs such as in determining microphone and several ultra-sonic transducers, actuator designs and countless other applications. [3]

In this design work, we build a bode plotter with an operating range of 0 – 22 KHz which is sufficient to cover the analysis of most audio and ultra-sonic networks. We have selected to work with the Intel's 8052 micro-controller, which has a UART to communicate with an external computer and the Intersil's ICL8038 function generator, which can generate very low distortion sine waves.

Bode plots today are a very useful way to represent the gain and phase of a system as a function of frequency. This is referred to as the frequency domain behavior of a system. These days several software and mathematical tools exist, that provide frequency domain analysis for system designers. These tools are very necessary at the design stage of a system, that is the stage when the system is idealized and are often regarded as

theoretical tools. They however cannot be used to provide tests for actual system networks. The bode plotter like any other network analyzer, is able to provide such tests and measurements for systems whose internal network components are not known.

1.1 Statement of Problem

Most communication system which requires electronic filters are face with the problem of determining their actual frequency response. Therefore, this work will enable us determine the actual frequency response of electronic filters as compared to their ideal response.

1.2 Review of Related Work

Bode Plot Generator was designed by **E. J. Mastascusa**[4]. He developed a software base applications which can be used to draw the bode plot of filters. This software requires the user to input the coefficients of the transfer function of the numerator and denominator of the filter and also the frequency scale. When the start button is pushed ON, it displays a frequency of Gain(dB) against frequency. This software has some Limitations. The users of this Bode plot generator is expected to calculate the transfer function of the filter or system required to be plotter. Therefore, this software will not be able to display the bode plot of filters which the values of their components are not known.

There is another software application designed for Bode plot analysis. It is called BodePlotGui. It was written in the MATLAB® programming language by **E.A Cheever (2005-2013)**[5]. It takes a transfer function and splits it into its constituent elements, then draws the piecewise linear asymptotic approximation for each element. The BodePlotGui program is a versatile program for teaching and learning the construction of Bode diagrams from piecewise linear approximations. It has the following limitations: It does not calculate the phase associated with a time delay. It cannot be used for a system or filter whose transfer functions is unknown

Another bode plotter in literature is Multisim Electronic Workbench is a simulation software that has a Bode Plotter incorporated in to its application. [6,7,8]. In order to analyse a filter using Multisim Electronic workbench the filter to be analysed is drawn on the graphical interface and the values of various components of the filter is inputted on the circuit been drawn. The input and output of the filter are then connected to the inbuilt plotter in the Electronic workbench. By turning ON the Bode plotter, it displays the frequency response showing the gain versus the frequency on the screen. In this application the transfer function of the system or filter is not required on the circuit component properly draw and connected to the bode plotter in the electronic workbench.

The limitations to this software is that it provides an ideal frequency response for the device been analyzed and requires that the Electronic filter to be analysed be drawn before it can analysed the bode plot of the system. The tolerance value of the individual components of the systems is not taken into consideration. Therefore the plotter provides an ideal response which may not be true in real life.

This bode plotter hardware been design and constructed will be able to provide actual tests and measurements of frequency response for systems whose internal network components are not known.

2 Design Consideration

The design of the Bode plot system was carried out according to the functional blocks namely:

- (i) Power Supply Unit
- (ii) A Signal Generator Unit
- (iii) Frequency Voltage Control Unit
- (iv) A signal Attenuator
- (v) Microcontroller
- (vi) Computer Software interface

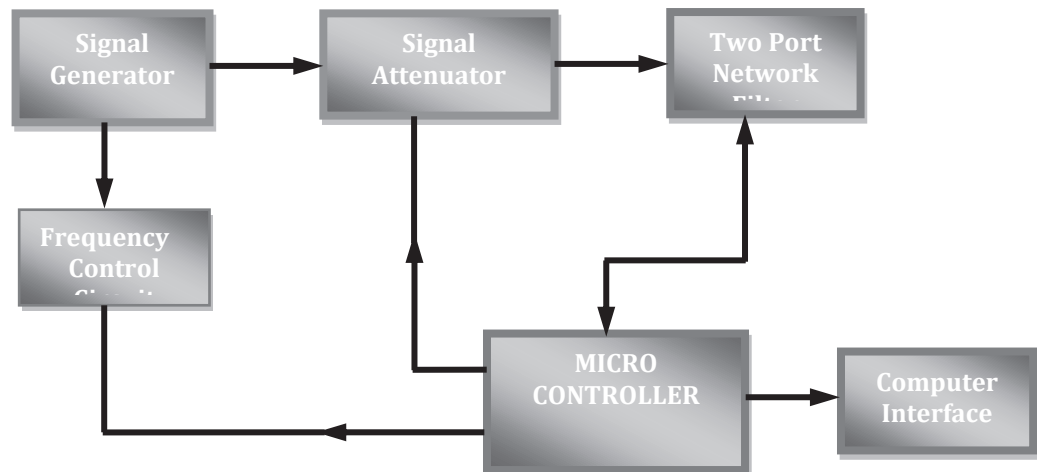


Figure 1. The bode plotter block diagram

2.1 Design of the Power Supply Unit

The circuit comprises of several digital and analog components which require different operating voltages. The digital components work with +5volts, the ICL8038 works with a voltage of +12volts and -12volts, the analog switches used for the signal attenuator work with +5volts and -5volts. Therefore for a perfect operation of our circuit, we will require four operating voltages namely +5volts, -5volts, +12volts and -12volts.

The power supply is comprised of four voltage regulators which provide all the required DC voltages. C2 and C4 are the input capacitors while C1, C3, C5 and C6 are the output capacitors. The regulators used are fixed voltage regulators which do not require any external component settings to regulate the output voltages. They are namely: 7805 for +5V output voltage, 7812 for +12 output voltage, and 7905 for -5V output voltage, 7912 for -12V output voltage.

However certain calculations must be made to determine the input and output capacitances. TR1 is a step-down center tapped transformer, it steps down the voltage from the ac mains from the typical 220 volts (AC) to two 15 volts (AC) output. BR1 is a full wave bridge rectifier arrangement. It rectifies the stepped down ac voltage to a dc level which has a peak value shown in equation 1.0

$$V_{peak} = V_{sec} \times 1.414 \quad (1.0)$$

$$\text{Where } V_{peak} = 15 \times 1.414 = 21.21 \text{ volts}$$

However the second half of the supply will give an equal but opposite voltage magnitude of -21.21 Volts. C2 and C3 are the input filter capacitors, whose value can be derived from equation 2.0

$$V_{ripple} = I / (f \times C) \quad (2.0)$$

Where

V_{ripple} = Ripple voltage

I = Maximum current drawn by the circuit

f = Frequency

C = Value of the input capacitance

A stiff design rule is to ensure that the ripple voltage is at least a third of the peak input voltage

$$\text{This implies that } V_{ripple} = V_{peak} / 3 \quad (3.0)$$

$$= 21.21 / 3 = 7.07 \text{ volts}$$

The maximum current the circuit can draw is limited to the maximum current the regulators can supply, which is 1.5Amps [Paul H and Hill W. 1989].

The frequency of a full wave rectified voltage is normally twice the input frequency of 50Hz i.e $2 \times 50\text{Hz} = 100\text{Hz}$

Substituting for f, V_{ripple} and I in the above equation yields

$$C = I / f \times (V_{ripple}) = 1.5 / (100 \times 7.07) = 2121.64 \mu\text{F}$$

Nearest preferred value for the input capacitances = 2200 μF

C1, C3, C5 and C6 are the output capacitances; their function is to improve the transient response of the DC output voltages. It is typical to have an output rise time of about 50 μsec for a micro-controller circuit. The rise time is dependent on the output capacitance and the output equivalent resistance of the voltage regulator.

To obtain a minimum rise time of 50µsec, we will design with reference to the voltage of least absolute value, which is 5volts. The equivalent output resistance for a 5volts fixed regulator, which can supply a maximum current value of 1.5 Amps is given as $R_{out} = 5 / 1.5 = 3.3\Omega$

$$\text{Output rise time} = R_{out} \times C2 \quad (4.0)$$

Therefore $C2 = 50\mu\text{sec} / 3.3\Omega = 15.15\mu\text{F}$

Nearest preferred value = 10µF; Therefore $C1 = C3 = C5 = C6 = 10\mu\text{F}$

The fixed voltage of +12 volts and +5 volts can be derived by placing the fixed regulators 7812 and 7805 respectively at the cathode ends of the bridge rectifier. Similarly -12volts and -5volts can also be derived by placing the fixed regulators 7912 and 7905 respectively at the anode ends of the bridge rectifier.

2.2 Design of the Signal Generator Unit

The signal generator is a voltage source that produces sinusoidal waves. The frequency range for our signal generator is designed to cover the audio frequency range, and must be capable of producing low distortion sine waves.[9,10] The signal generator used in their project is built around the ICL8038. The ICL8038 is a monolithic integrated circuit (IC) capable of producing highly accurate sine wave. Its frequency can be selected externally using either resistors or capacitors and frequency sweeping can be accomplished with an external voltage. The electrical circuit configuration used for this design is shown in Figure 2.0

Since the wave generator operates from 20HZ-25KHZ the schematic are obtained from the datasheet of the ICL8038.

The resistor at pin 4 and 5 and the capacitor at pin 10 are used to determine the maximum obtainable frequency according to the following relationship.

$$\begin{aligned} \text{Maximum frequency} &= \frac{1}{(R_1 + R_2) \times C_2} \quad (5.0) \\ &= \frac{1}{(4700 + 4700) \times 3.9 \times 10^{-9}} = 27.277\text{KHz} \end{aligned}$$

Thus, the maximum frequency = 22.277KHz

The output waveform can be varied by a ratio of 1000 to a maximum frequency (i.e from $(F_{max}/1000)$ to F_{max}). V_{in} is varied from 0V to -12Volts.

The R8 resistor is a 1KΩ resistor that acts as a source resistor. R8 is connected between pins 1 and 8 of the TCS81 operational amplifier. It is used to adjust the op-amp IC1.

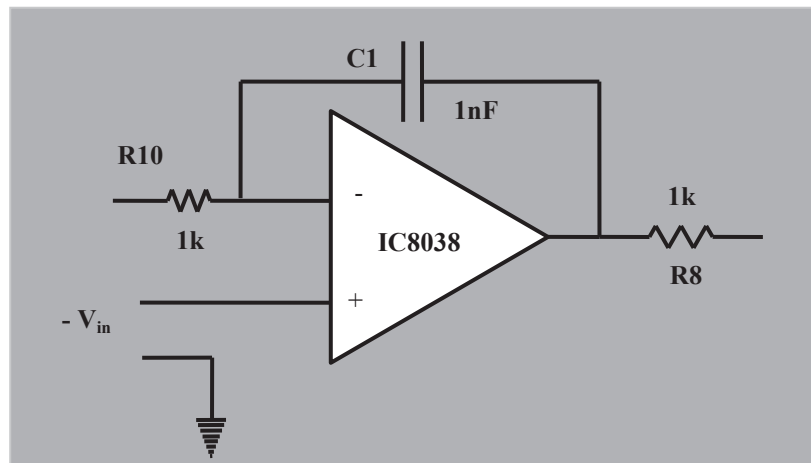


Figure. 2.0 Control Voltage Source

Its function is to provide the control voltage for the ICL8038. The resistor R4 is a recommended 100k variable resistor used to reduce the distortion of the output sine wave. Resistor R3 is used to adjust the duty cycle of the output waveform.

Capacitor C3 is a 47µF coupling capacitor. It couples the sine wave to the buffer amplifier op-amp IC3.

However, the combination of C3 and R7 represent a first order high pass filter at the input of the Op-amp. It ensures that the output waveform from the ICL8038 is properly coupled to the next stage buffer.

For a coupling high pass filter, it is recommended to design for a cut off frequency which is (far less than) the minimum signal frequency.

$$\text{For a minimum frequency of } f_{max}/1000 \quad (6.0)$$

$$= \frac{27.22}{1000} \text{ KHz} = 27.22 \text{ Hz}$$

A cut-off frequency have to be chosen such that $f_{cut\ off} \ll 27.277 \text{ Hz}$

$$f_{cut-off} = \frac{1}{2\pi R_7 C_8} \quad (7.0)$$

Designing a cut-off frequency of $f_{max}/100$

$$f_{cut-off} = \frac{27.277}{100} = 0.272 \text{ Hz}$$

This implies that from the cut-off frequency relationship

$$R_7 = \frac{1}{2\pi \times f_{cut-off} \times C_8} = \frac{1}{2\pi \times 0.272 \times 47 \times 10^{-6}}$$

$$R_7 = 12.449 \text{ k}\Omega;$$

Preferred value for $R_7 = 15 \text{ k}\Omega$

2.3 Design of the Frequency Voltage Control Circuit

The circuit is built such that its frequency can be varied from an electrically controlled voltage. As the control voltage is varied, the output frequency will also vary. In order to achieve this, the micro-controller is connected to a Digital to analog converter to provide the analog voltage require to control the frequency of the output signal. The Digital to analog converter is used to generate the control voltage which is to be fed into the voltage control pin 8 of the ICL8038. The circuit is also a standard circuit obtained from the data sheet of the DAC0808. The voltage at pin 13 is a dual supply voltage of +5Volts. It operates on a dual supply voltage source with the negative voltage (V_{EE}) of -12volts connected to pin 3 of the digital to analog converter. The digital to analog converter is an 8- bit type. Hence, its output voltage can be varied over 256 discrete steps

Where, number of discrete steps = $2^{[\text{no of bits}]} = 2^8 = 256$

The output voltage can be defined by the following relationship

$$V_{OUT} = V_{REF} \left[\frac{A_1}{2} + \frac{A_2}{4} + \frac{A_3}{8} + \frac{A_4}{16} + \frac{A_5}{32} + \frac{A_6}{64} + \frac{A_7}{128} + \frac{A_8}{256} \right] \quad (8.0)$$

2.4 Design of the Signal Attenuator

The 4066 IC is an analog switch. When a voltage is applied to any of the point A, B, C or D, the voltage at the input of the analog switch appear at its output. The system is design to have a maximum gain of -2. R_{11} has been chosen as a fixed resistor value of $10 \text{ k}\Omega$

$$\text{Maximum gain} = -2 = \frac{R_{16}}{R_{11}} \quad (9.0)$$

$$\Rightarrow R_{16} = -2 \times -10 \text{ k}\Omega = 20 \text{ k}\Omega$$

A minimum gain of -0.01 is also designed for. This implies that the minimum resistor on the feedback network should be at least 0.01 of the minimum value.

$$\text{Max. Resistor} = R_{16} = 20 \text{ k}\Omega$$

$$\text{if } R_{12} \text{ is the minimum resistor} \Rightarrow R_{12} = 0.01 \times 20 \text{ k}\Omega = 200 \Omega$$

$$\text{Preferred value} = 220 \Omega$$

We can choose values that increase by a certain ratio

$$R_{13} = 5 \times R_{12} = 220 \times 5 = 1100 \Omega \quad \text{Preferred value} = 1 \text{ k}\Omega$$

$$R_{14} = 5 \times R_{13} = 5 \times 1000 = 5000 \Omega \quad \text{Preferred value} = 4700 \Omega$$

$$R_{15} = 5 \times R_{14} = 5 \times 4700 = 23,500 \Omega \quad \text{Preferred value} = 20 \text{ k}\Omega$$

The following values resistors have been obtained for the attenuator circuit:

$$R_{12} = 220 \Omega, R_{13} = 1 \text{ k}\Omega, R_{14} = 4.7 \text{ k}\Omega, R_{15} = 20 \text{ k}\Omega, R_{16} = 20 \text{ k}\Omega$$

There are 16 possible states for the control voltage A, B, C, D and their corresponding gains. The corresponding states are shown below; 0000, 0001, 0010, 0011, 0100, 0101, 0110, 0111, 1000, 1001, 1010, 1011.

The gains of the attenuator can be calculated for each of the states.

$$\text{Gain} = \frac{f_B}{R_{11}} \quad (10.0)$$

$$\begin{aligned} \text{State (0000)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{16}}{R_{11}} = -2 \\ \text{State (0001)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{15} // R_{16}}{R_{11}} = \frac{20k\Omega // 20k\Omega}{10k\Omega} = -1 \\ \text{State (0010)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{14} // R_{16}}{R_{11}} = \frac{4.7k\Omega // 20k\Omega}{10k\Omega} = -0.38 \\ \text{State (0011)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{14} // R_{15} // R_{16}}{R_{11}} = \frac{4.7k\Omega // 20k\Omega // 20k\Omega}{10k\Omega} = -0.32 \\ \text{State (0100)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{15} // R_{16}}{R_{11}} = \frac{1k\Omega // 20k\Omega}{10k\Omega} = -0.0218 \\ \text{State (0101)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{15} // R_{15} // R_{16}}{R_{11}} = \frac{1k\Omega // 20k\Omega // 20k\Omega}{10k\Omega} = -0.0215 \\ \text{State (0110)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{15} // R_{14} // R_{16}}{R_{11}} = \frac{1k\Omega // 4.7k\Omega // 20k\Omega}{10k\Omega} = -0.0792 \\ \text{State (0111)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{15} // R_{14} // R_{15} // R_{16}}{R_{11}} = \frac{1k\Omega // 4.7k\Omega // 20k\Omega // 20k\Omega}{10k\Omega} = -0.0796 \\ \text{State (1000)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{12} // R_{16}}{R_{11}} = \frac{220\Omega // 20k\Omega}{10k\Omega} = -0.0218 \\ \text{State (1001)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{12} // R_{15} // R_{16}}{R_{11}} = \frac{220\Omega // 20k\Omega // 20k\Omega}{10k\Omega} = -0.0215 \\ \text{State (1010)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{12} // R_{14} // R_{16}}{R_{11}} = \frac{220\Omega // 4.7k\Omega // 20k\Omega}{10k\Omega} = -0.0208 \\ \text{State (1011)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{12} // R_{14} // R_{15} // R_{16}}{R_{11}} = \frac{220\Omega // 4.7k\Omega // 20k\Omega // 20k\Omega}{10k\Omega} = -0.0206 \\ \text{State (1100)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{12} // R_{14} // R_{16}}{R_{11}} = \frac{220\Omega // 4.7k\Omega // 20k\Omega}{10k\Omega} = -0.0179 \\ \text{State (1101)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{12} // R_{15} // R_{15} // R_{16}}{R_{11}} = \frac{220\Omega // 1k\Omega // 20k\Omega // 20k\Omega}{10k\Omega} = -0.0173 \\ \text{State (1110)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{12} // R_{15} // R_{14} // R_{16}}{R_{11}} = \frac{220\Omega // 1k\Omega // 4.7k\Omega // 20k\Omega}{10k\Omega} = -0.0172 \\ \text{State (1110)} \quad \text{Gain} &= \frac{f_B}{R_{11}} = \frac{R_{12} // R_{15} // R_{14} // R_{16} // R_{16}}{R_{11}} = \frac{220\Omega // 1k\Omega // 4.7k\Omega // 20k\Omega // 20k\Omega}{10k\Omega} = -0.0171 \end{aligned}$$

2.5 Design of the Micro-Controller Circuit

The Micro-controller is the heart of the enter system. It coordinates all the actions between all the blocks in the system. The micro-controller used in their circuit is the PIC16F877A and it is driven by an internal program. The following flowchart has adopted to realize the entire design. It has the following internal features:

- (i) **UART(Universal Asynchronous Receiver and Transmitter)** which allows the microcontroller to be able to communicate with a computer via a RS232 connection
- (ii) **Internal Analog-to-digital Converter.** The PIC16F877A has an inbuilt 10-bit Analog-to-digital converter. The analog to digital converter converts the analog voltages fed into the micro-controller to 10-bit digital values which can be processed by the micro-controller and the computer.

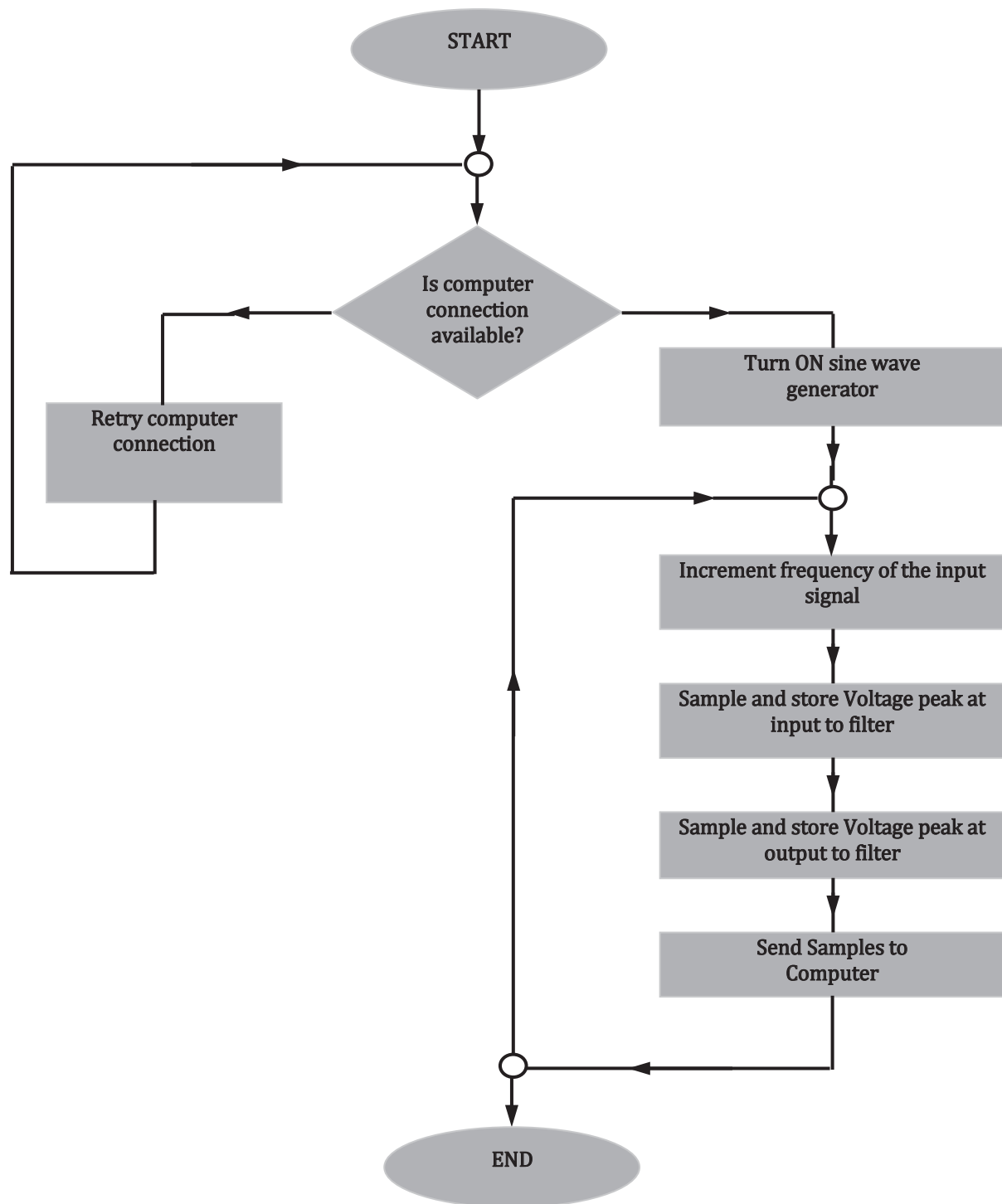


Figure. 3.0 The flow chart diagram of the program structure

2.6 Design of Graphical User Interface

The Bode plotter has a graphical user interface which allows the operator to observe the frequency response curves being plotted by the system. The graphical user interface communicates with the hardware via the RS232 Serial Connector and the program is written in **Visual basic.Net**.

The computer detects when the Bode plotter has been connected and sends a command to the micro-controller to start generating signals in discrete frequency steps. Note that the network to be analyzed must be connected to the bode plotter's hardware. The computer then receives frequency, input voltage and output

voltage data from the micro-controller. With these data, the computer can generate frequency versus gain plots for any attached network.

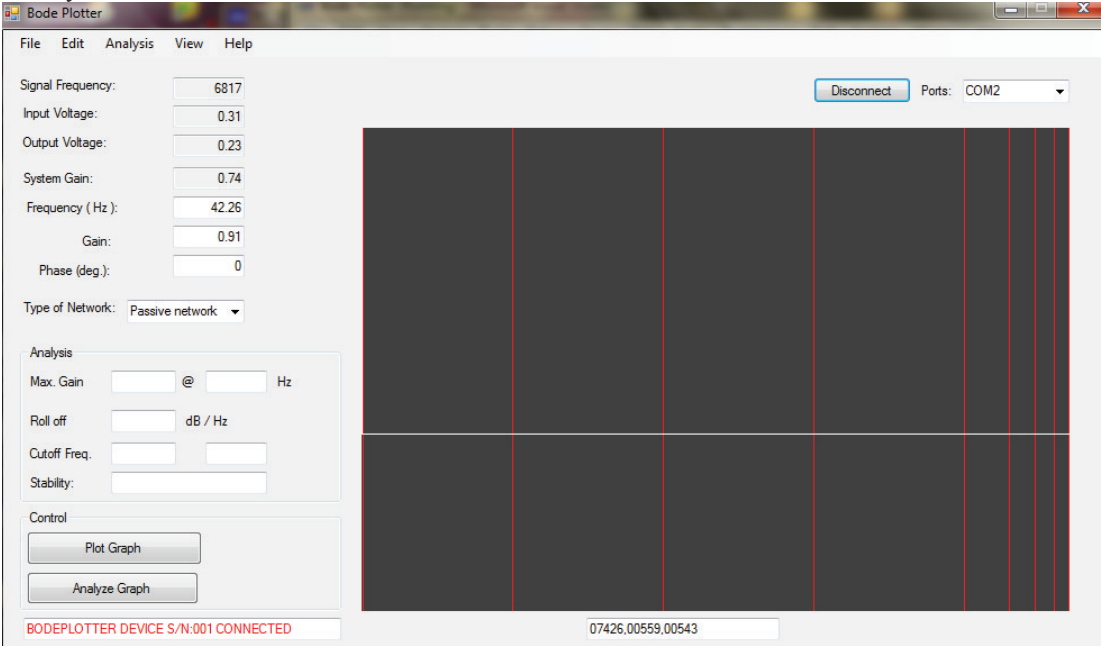


Figure 4. Graphical user interface for bode plotter

3 Flowchart of Graphical User Interface Program

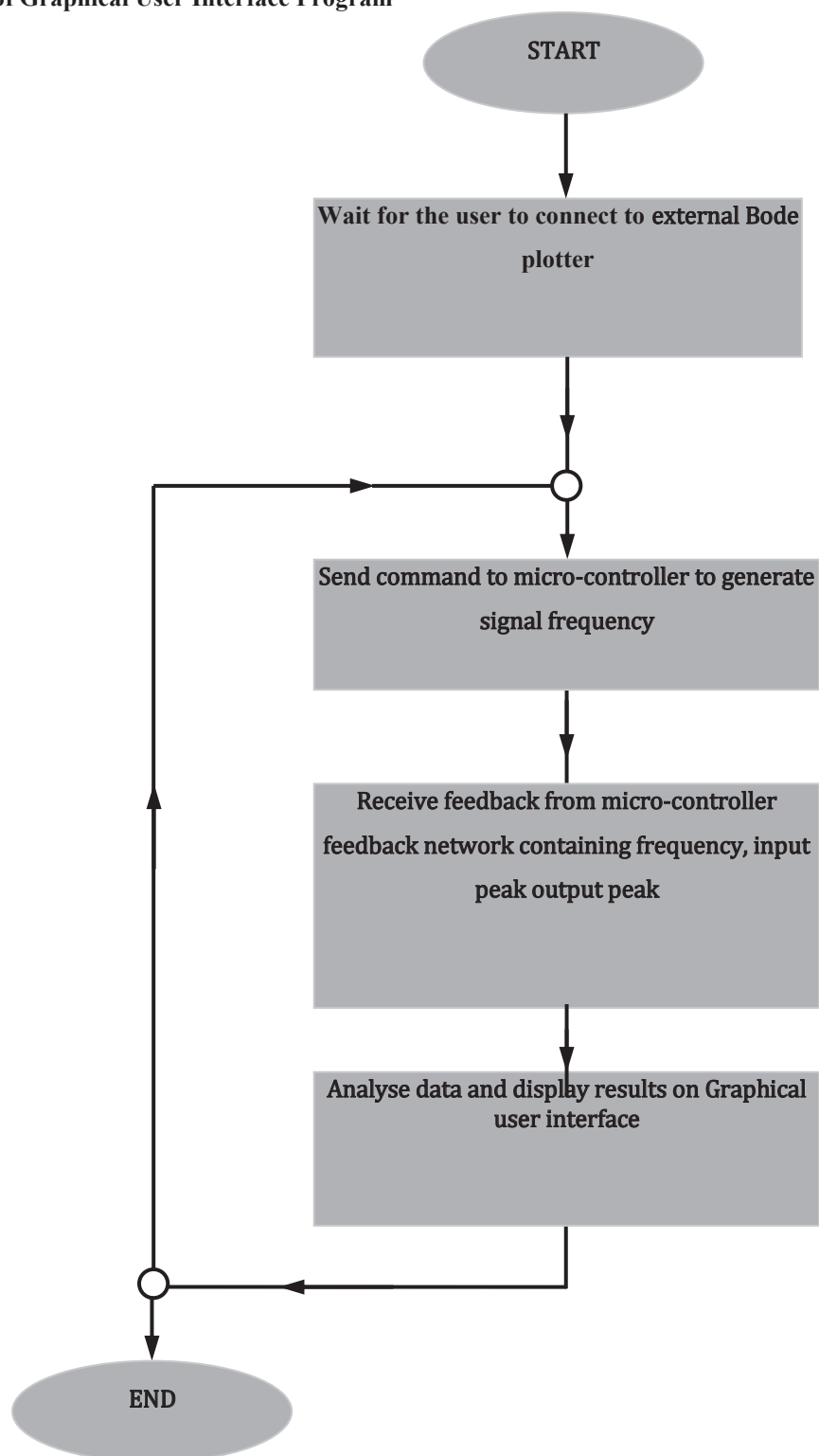


Figure 5. Flow chart of the Graphics User interface

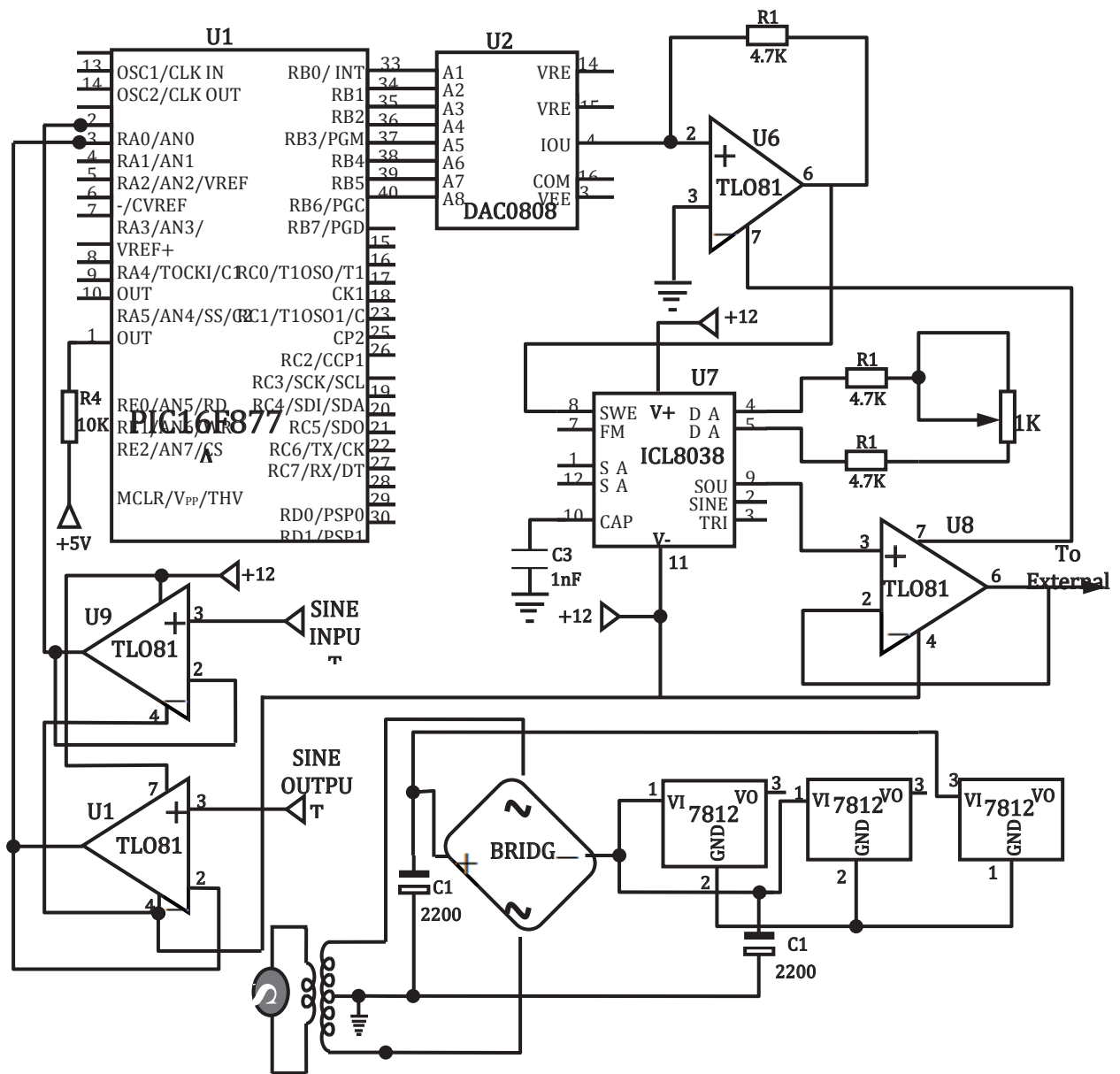


Figure 6. Circuit Diagram of a Bode Potter

4 Testing

After the circuit was constructed, the system was tested using the interface software built for it. Figure 7.0 is a screen capture of the circuit performance without a filter connected to the output.

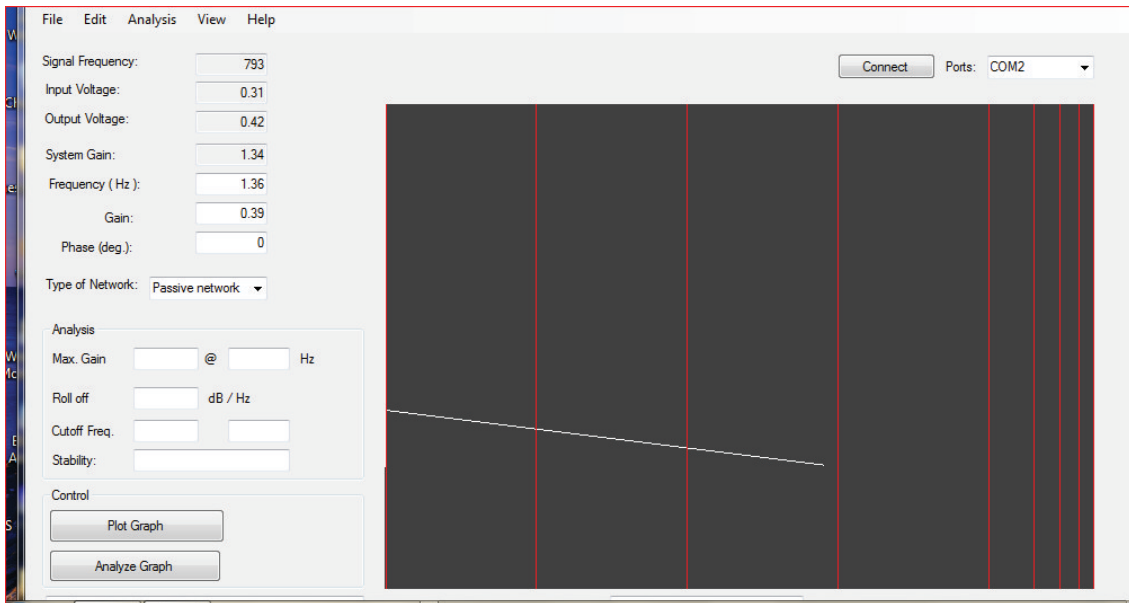


Figure 7. Graph of the frequency versus gain

The sloping white line is the graph of the frequency versus gain. It is supposed to be a horizontal line when no filter is attached, the sloppiness of the line is an indication of power supply problems. The unbalanced nature of the power supply was corrected and the new plot obtained and shown in Figure 9.0

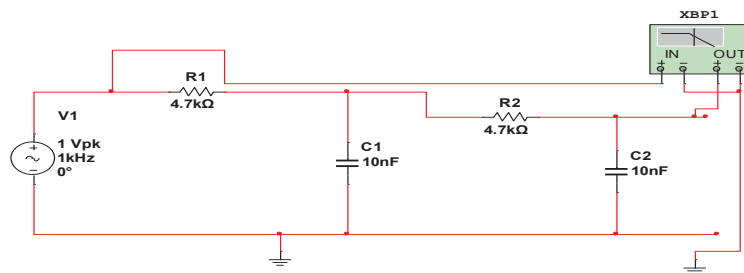


Figure 8. The Low pass filter (Test Circuit)

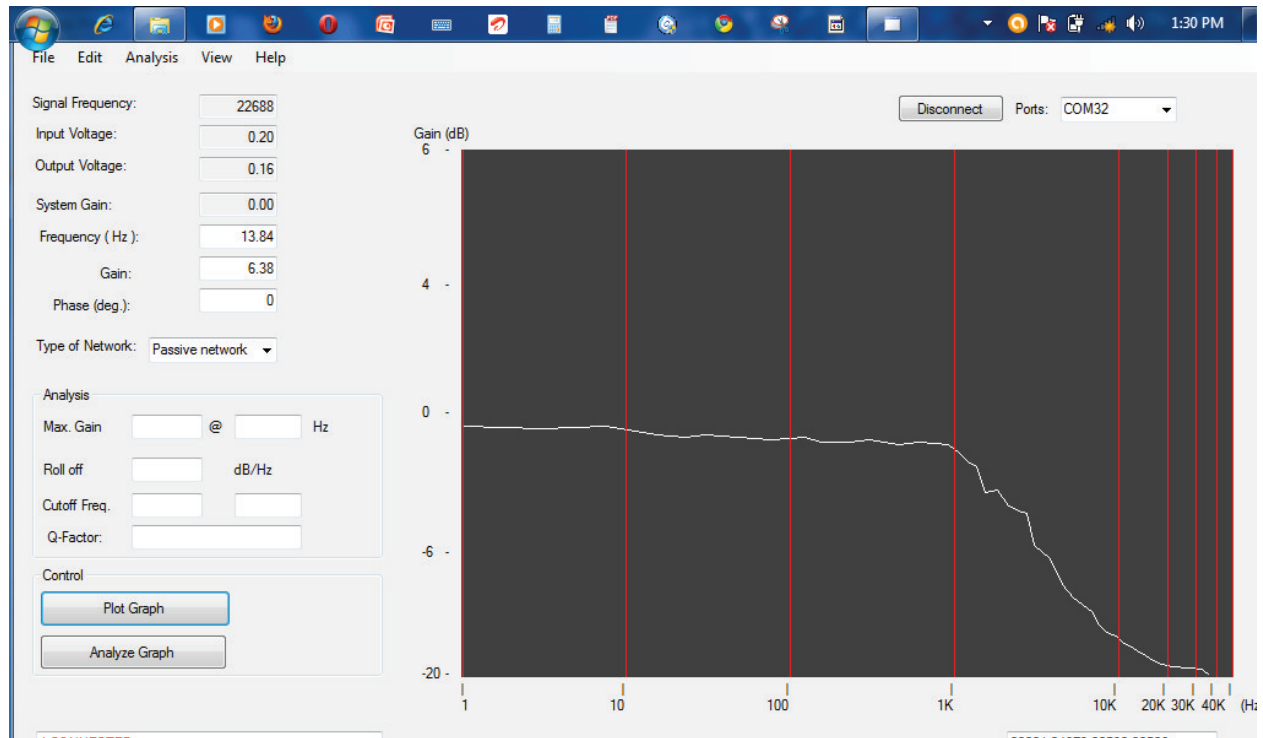


Figure 9. Actual Frequency response of a Low pass filter using a bode Plotter

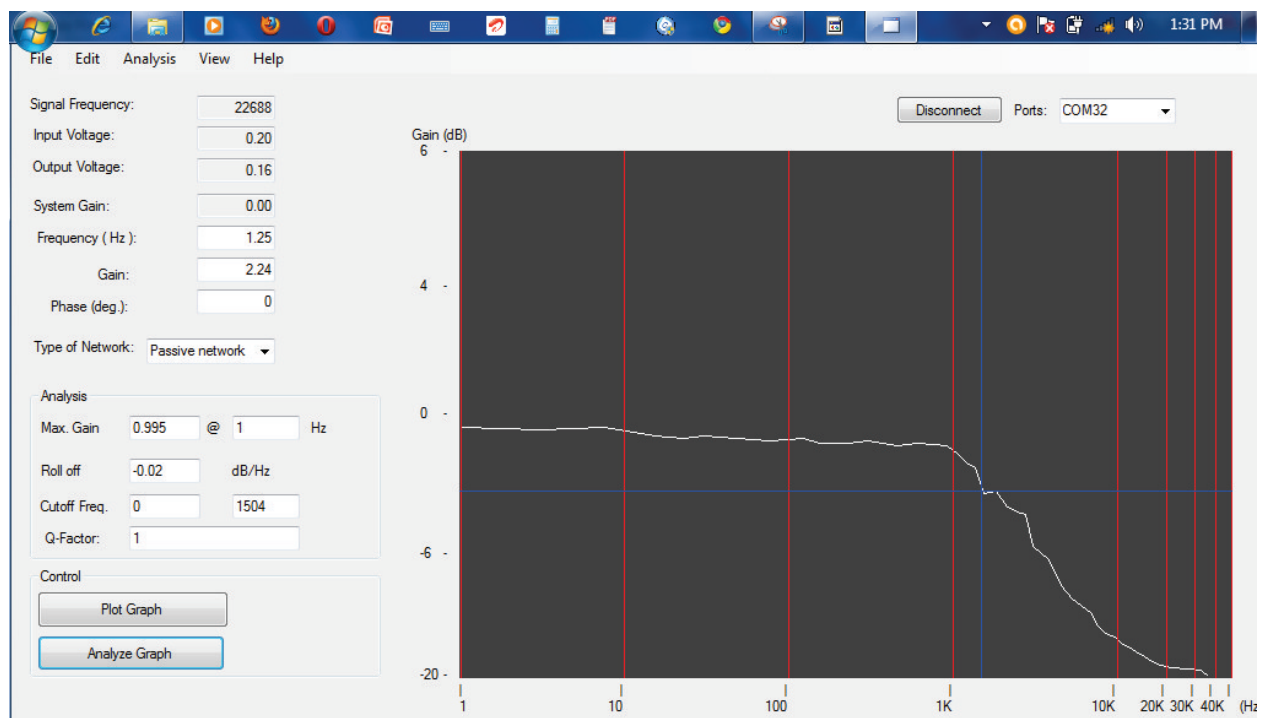


Figure 10. Actual Frequency response of the analyzed Filter

Using Multisim Electronic workbench to determine the ideal frequency response of the low pass filter in Figure 9 and the High pass filter in Figure. 10

Procedure:

1. Open Multisim by clicking on Start -> Programs -> National Instruments -> Circuit Design Suite 11.0 -> Multisim 11.0 .
2. Create a new file with File-> New->
3. Find the components using the command Place -> Components (Ctrl + W) or right-click a blank spot and go to Place Component. The AC source is in the “Sources” group (top left), “Signal Voltage

4. Choose an appropriate spot and click to place the component. Rotate components with Ctrl+R flip them with Alt+X and Alt+Y.
5. Next find the capacitor, in the “Basic” group and select the correct valued capacitor and resistor from the list or place one and double-click it and modify the value.
6. Wire the circuit by clicking on the end points of the components
7. To get a bode plot, place a Bode Plotter from the instruments toolbar and wire it as shown in the Figure. 9.0 above. Now choose an bode Plotter from the right hand toolbar (the Instruments toolbar)
8. Double click on the Bode plotter and set the frequency range to run from 100Hz to 1MHz. (Note that in the Bode plot set up mHz stands for milli-Hertz and MHz stands for MegaHertz.)
9. Final, run the simulation by pushing F5 and you will get the Bode plot shown in Figure. 13

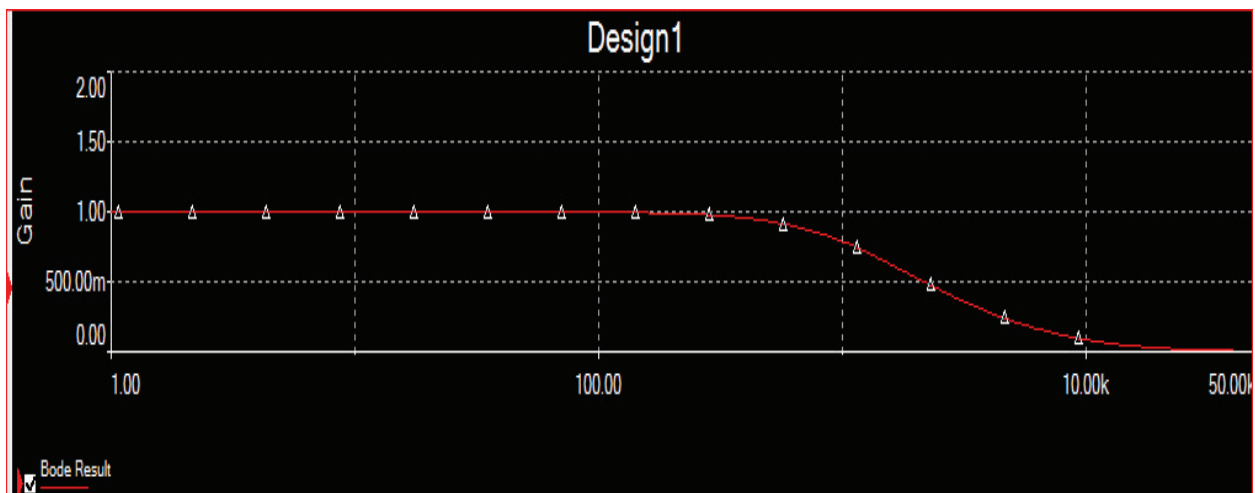


Figure 11 The Ideal Frequency response of a Low pass filter from a multisim workbench

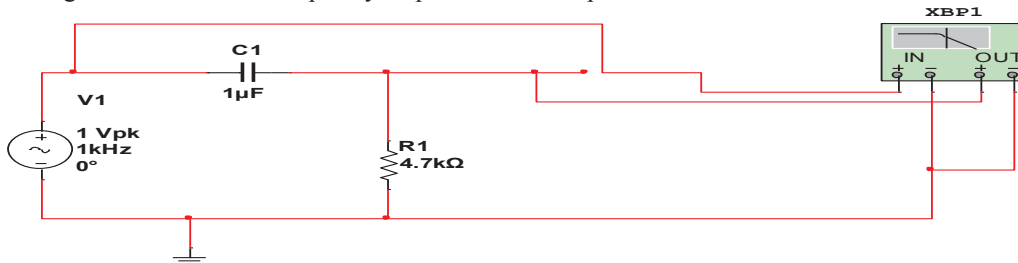


Figure 12.0 The High pass filter (Test Circuit)

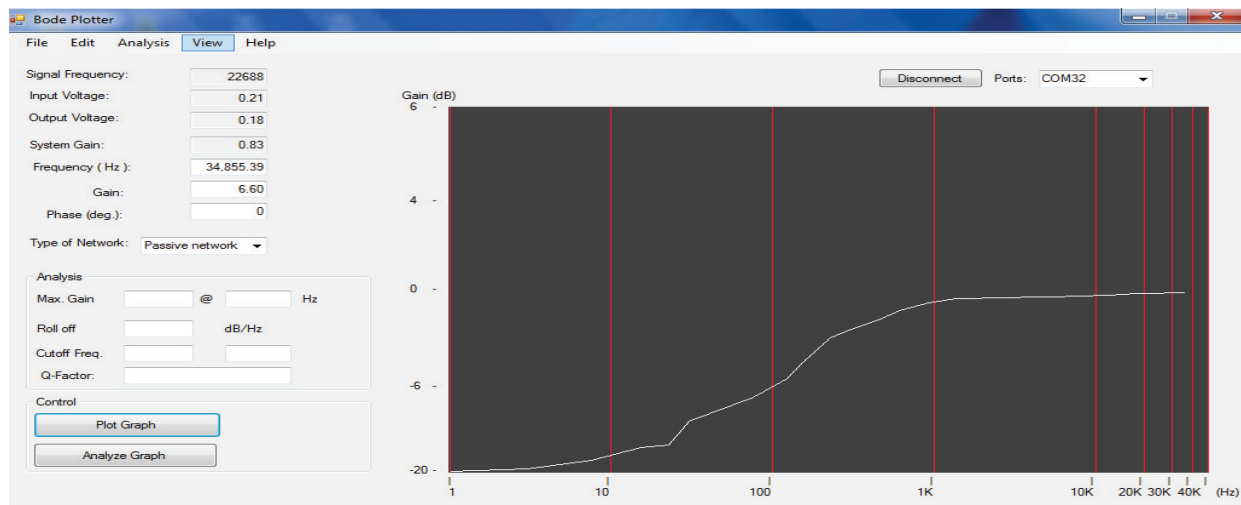


Figure 13.0 Actual Frequency response of a high pass filter using a bode

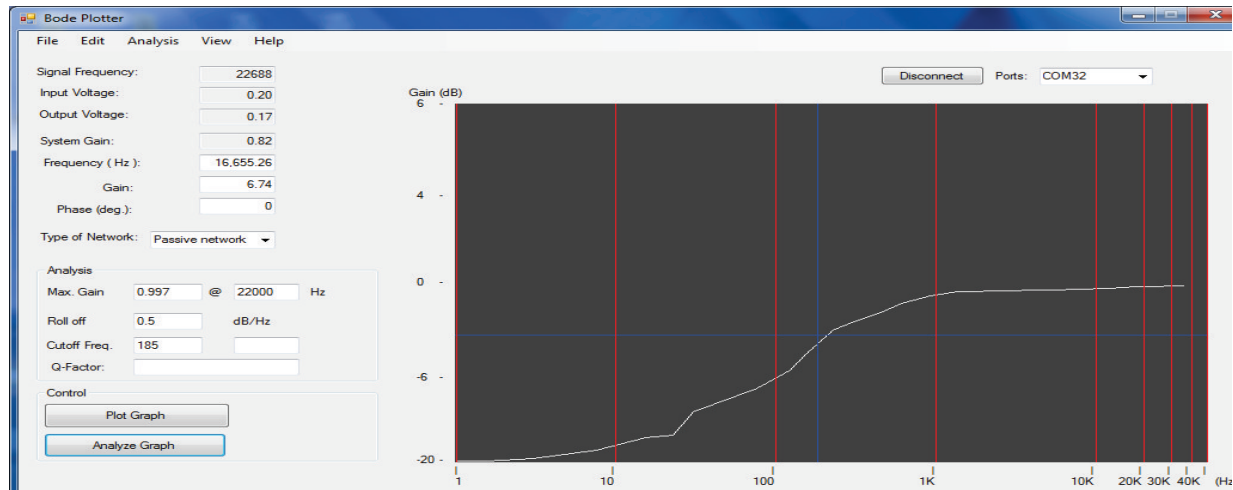


Figure 14.0 Actual Frequency Response of the analysed High Pass Filter

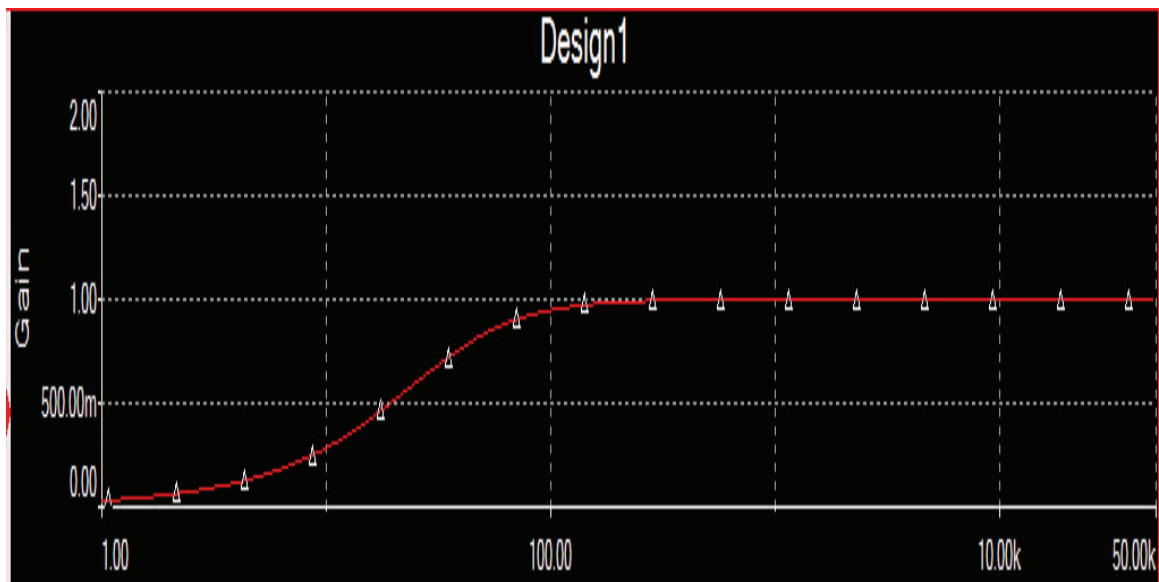


Figure 15.0 Ideal Frequency response of the analyzed High pass Filter from a Multisim workbench

Table 1 Results obtained from Figure. 13.0 and Figure. 14.

SYSTEM	Cut Off Frequency(F_C) from the Bode Plotter	Cut Off Frequency(F_C) from the Multisim Software
LOW PASS FILTER	1.504KHZ	1.25KHZ
HIGH PASS FILTER	185HZ	159HZ

6 Conclusion

It can be observed that the result of the plot gives the actual response of the filters been analyzed compared to the ideal response shown by the MULTISIM SOFTWARE. And this indicates that the system designed can be used to plot the gain versus the frequency response of the filter and also analyze the filter.

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