EGB240: Electronic Design

Assessment 2: Digital Voice Recorder

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# Executive Summary

The aim of this project is to document the implementation of an input conditioning circuitry for a digital voice recorder on a Teensy 2.0 board. Due to real world limitations implementation of the analogue signal conditioning cannot be done therefore its process is documented.

A series of filters are designed in which the output of the microphone is passed through. The signal is first passed through a high pass filter was used it was then passed though the 6th order Chebyshev filter designed on MATLAB and ltspice.

Before implementation of the filter the components value and other parameters were calculated and simulated in MATLAB. These steps will be covered in more detail with in this design documentation

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# Introduction

This report Is a technical documentation of the design process, methodology and other research that took place to complete the designated task.

The task given was to simulate input analogue conditioning circuitry for the Digital Voice Recorder (DVR). The task is to be carried out on the Teensy 2.0 microcontroller board which is provided by QUT. The analogue input conditioning circuitry that is designed will be interfaced to the microcontroller via the analogue to digital converter (ADC) peripheral as shown below. [1] The analogue input condition circuitry is based on the TL974 operational amplifier which has also been provided.

A close up of a map

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Fig. 1 Development board [1]

# Background/Literature review

## About Human Speech

A screenshot of a cell phone

Description automatically generatedThe general human hearing range is from 20 – 20kHz the female voice and male voice ranges however are between the ranges 350Hz to 17kHz and 100Hz to 8kHz respectively. Microphones are designed to measure frequencies from as low as 50Hz up to 20kHz. [2] The figures shown below show the characteristics of human hearing and human speech

A close up of a map

Description automatically generated Fig. 2 Human hearing [3]

Fig. 3 Human speech [6]

The human voice produces sound which is a form of energy and oscillates and vibrates which can be converted to voltages form using a microphone.

## Analog and Digital signals

Analog signals are varying amounts of information against time. These include audio, video and other forms of data. The characteristic of analog waves is that the signals are continuous [4]. Digital signals however are discrete in value and in time and are represented by binary numbers and consistent of different voltage values.

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Fig. 4 Differences between signals [5]

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Fig. 5 Comparing analogue and digital signals [5]

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Fig. 6 ADC sampling [1]

## Op-amps

Operational amplifiers also known as op-amps are voltage amplifying devices [7]. It’s inputs consist of a non-inverting input with voltage (V+) and an inverting input with voltage (V−) as shown by the diagrams below.

A screenshot of a cell phone

Description automatically generatedA picture containing clock

Description automatically generated

Fig. 7 Operation amplifier [7] Fig. 8 Operation amplifier [1]

Operation amplifiers can be structed in a few ways such as inverting, non-inverting, summing, differential etc. The ones used in this task are mentioned below.

1. Inverting amplifier

A picture containing clock

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* inverting amplifier inverts the input signal and produces a gain equal to –R2/R1 [1].

Fig. 9 Inverting amplifier [1]

1. A picture containing object, clock

   Description automatically generatedNon-inverting amplifier

* It amplifies the input signal without inverting the signal [1].

Fig. 10 Non-inverting amplifier [1]

1. Unity gain follower

* A picture containing clock

  Description automatically generatedUsed as a buffer because of its isolating properties [1].

Fig. 11 Unity gain follower [1]

## Filters

Filters can be categorised as

1. Active filters
2. Passive filters

Passive filters are made using passive components such as resistors, capacitors and inductors. These filters cannot amplify a signal. Active filters use active components such as transistors and op-amps and need a power supply so they can amplify the signal [1].

Filters can also be classified as low pass, high pass and band pass filters. For this task we are using an active low pass filter. Specifically, a Chebyshev filter.

## Chebyshev and Butterworth filters

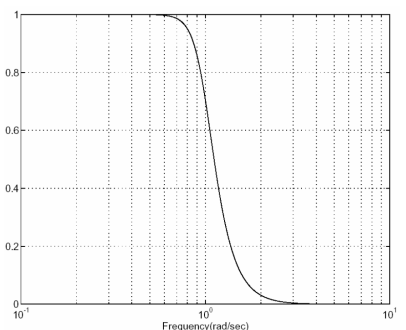
Butterworths exhibit a flat passband with no ripple. The roll off is smooth and has a good phase response. Shown below is a diagram of a Butterworth filter [9].

Fig. 12 Butterworth filter response [9]

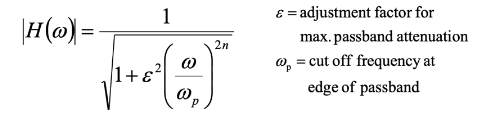
The frequency response of a Butterworth filter can be calculated by the equation shown below.

Fig. 13 Equation for frequency response of Butterworth filter [1]

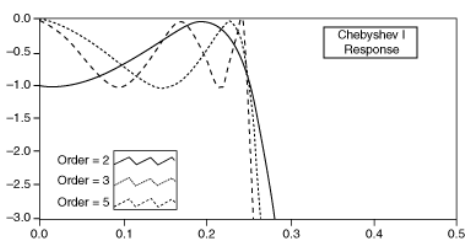
Chebyshev filters are analog filters that has a faster roll-off by allowing ripple in the frequency response. As the ripple increases the roll-off becomes sharper. The con of using a Chebyshev is that they have poor phase response.

Fig. 14 Chebyshev filter frequency response [8]

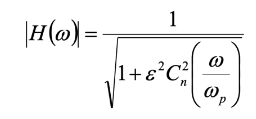
The frequency response of a Chebyshev filter can be calculated by the equation below.

Fig. 15 Equation for frequency response of Chebyshev filter [1]

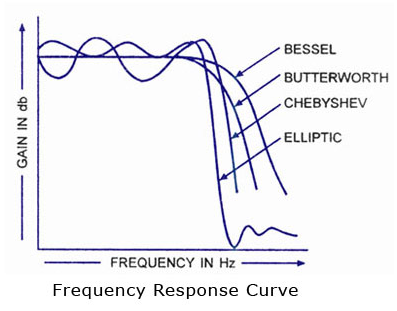
Chebyshev filters produce better results than the Butterworth filter for this task because it has a step roll-off response than a Butterworth filter as shown in the diagram below.

Fig. 16 Graph of different filter types [9]

# Task

## Input filter

As mentioned above the use of a Chebyshev filter was considered over a Butterworth filter. Specifically, a 6th order filter. This filter was implemented in MATLAB to receive proper values. The equations shown below were used for the MATLAB calculations

Stop band frequency as per Shannon Nyquist theorem,

Maximum attenuation in the stop band

A screenshot of a cell phone

Description automatically generatedA screenshot of a social media post

Description automatically generatedTo find the coefficients to use for the spice simulation the function shown below was used in MATLAB.

## A close up of a map Description automatically generatedA close up of a map Description automatically generated

A screenshot of a social media post

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Description automatically generated

Figs. 17 MATLAB simulations

As shown by the images above the cheby function was used to calculate the coefficients to be used with the filter along with the components values which were determined using the excel sheet found in appendix A.

## LTspice simulation

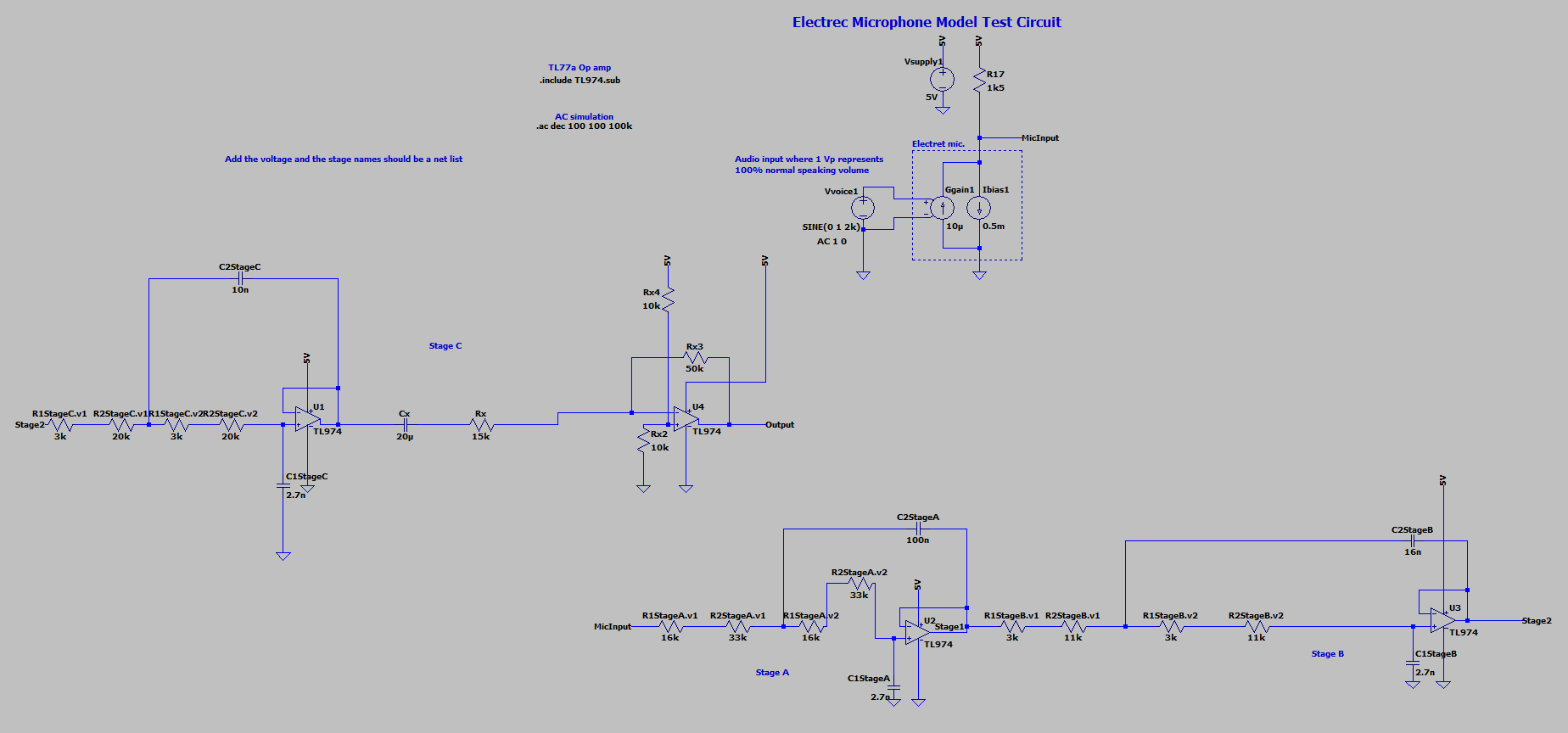
The calculated component values were set up in the LT psice simulation abd shown in the figure below. The first figure shows an overview of the 6th order cheybshev filter and the following figures show it’s components in more detail.

Fig. 18 LTspice simulation

Stage A and Stage B

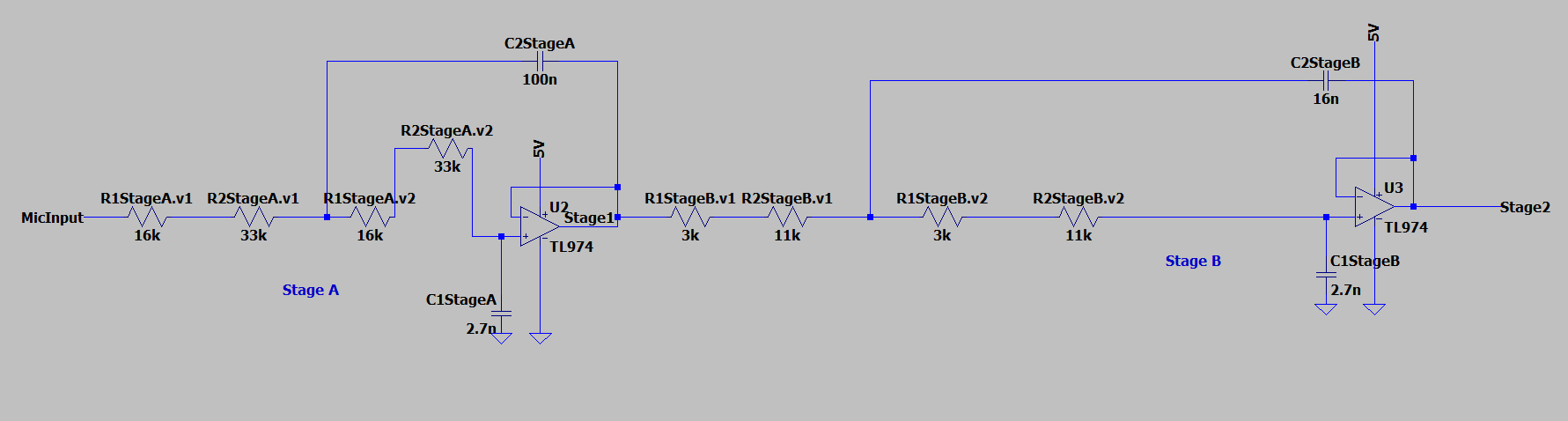


Fig. 19 LTspice simulation

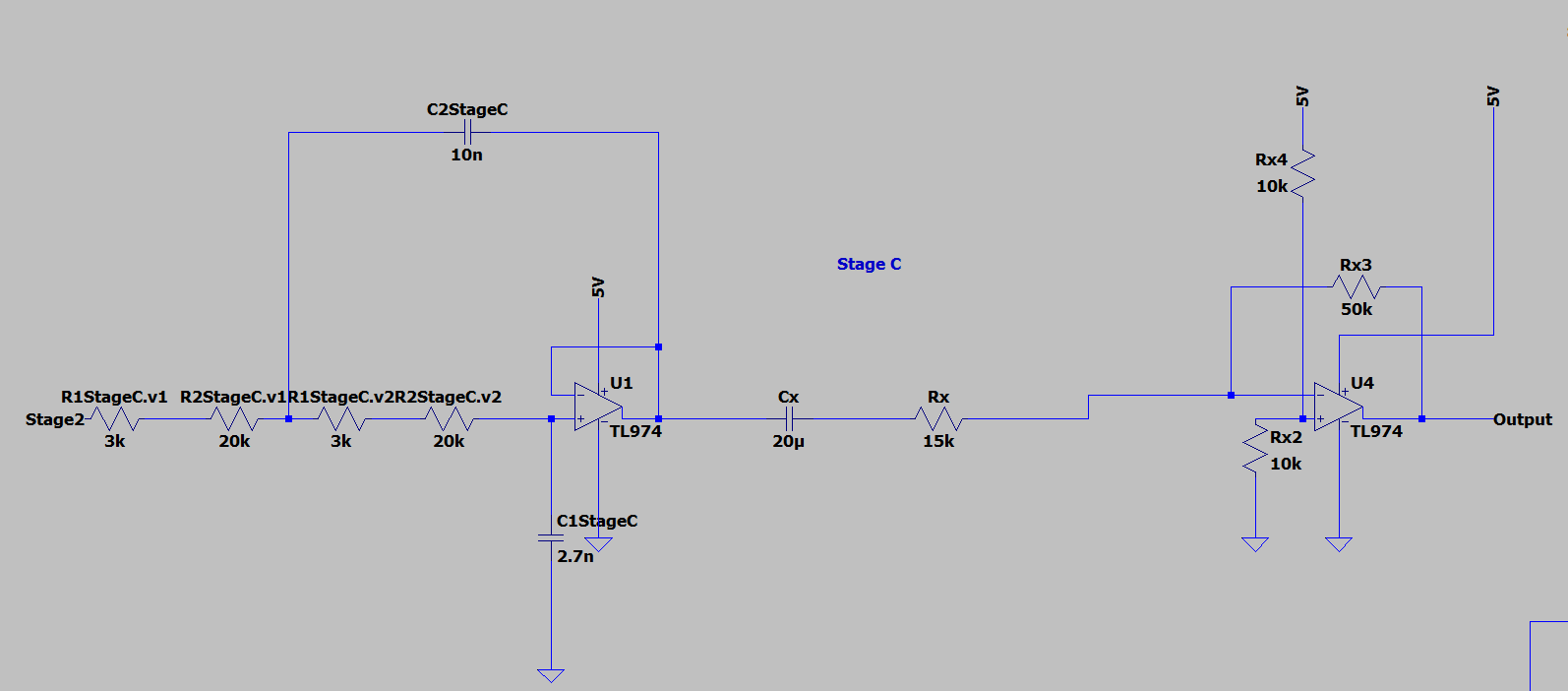
Stage C

Fig. 20 LTspice simulation

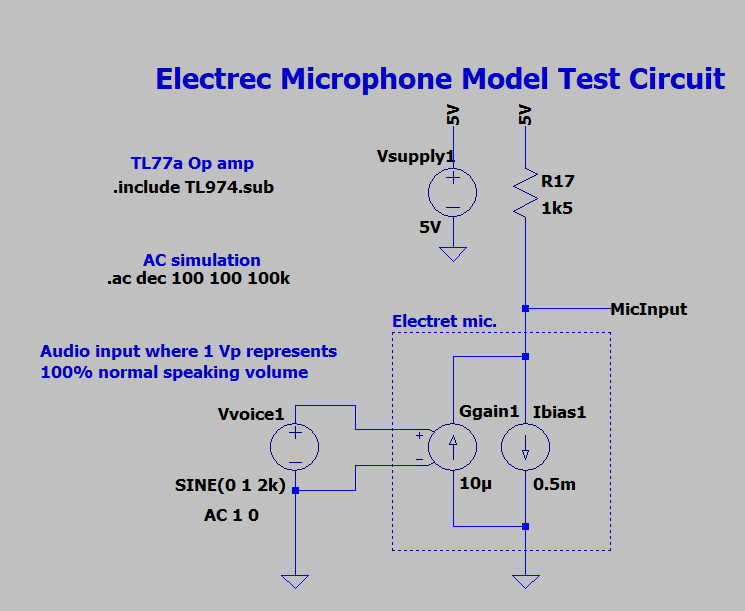
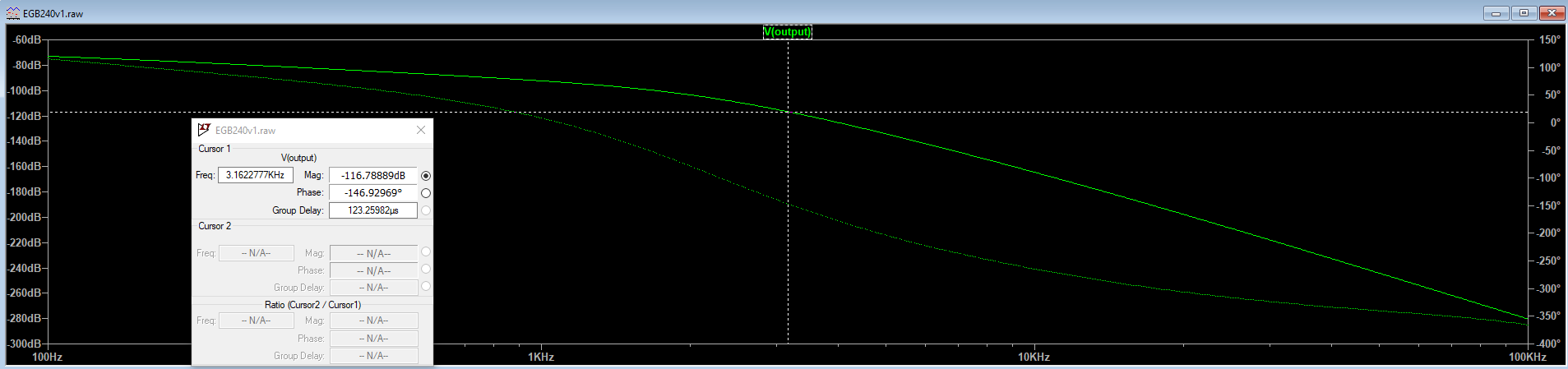
Microphone

Fig. 21 LTspice simulation

## Verification of simulation

The simulations performed in LTspice are shown below for the output, stage 2, the input and a final graph of all waveforms.

As seen by the results the filter works as intended.

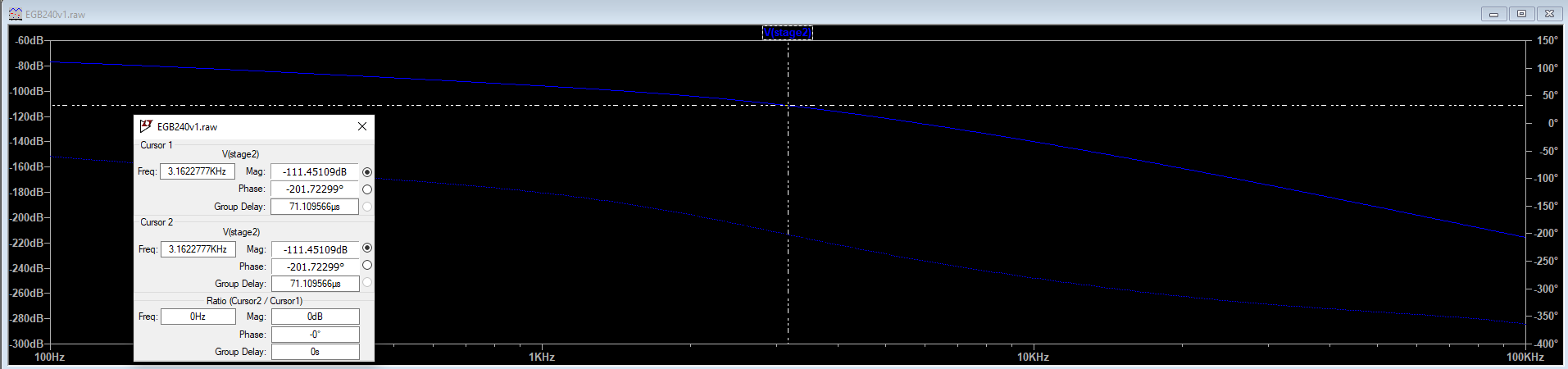
Fig. 22 LTspice simulation (output)

Fig. 23 LTspice simulation (stage 2)

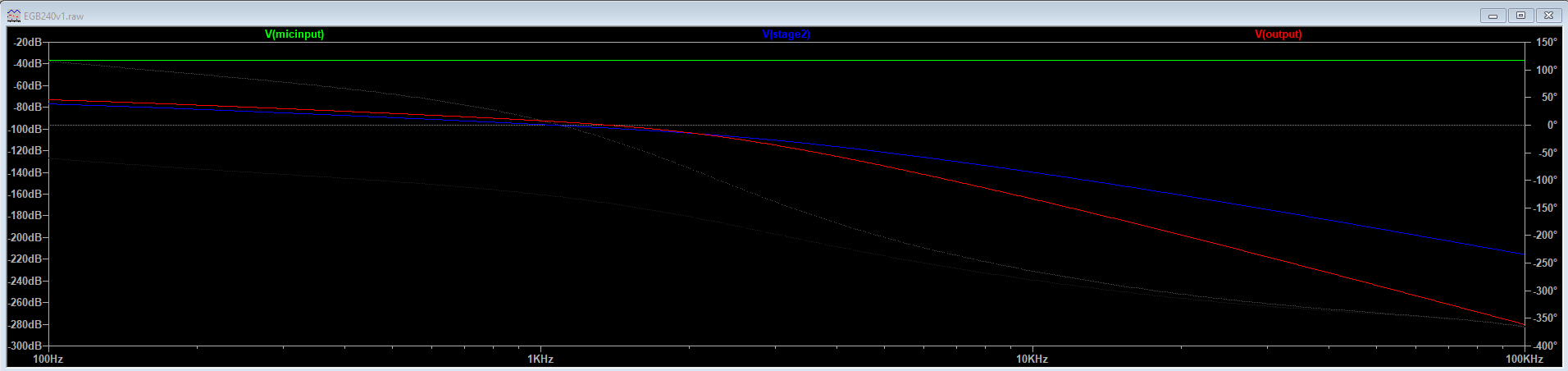
Fig. 24 LTspice simulation (input)

Fig. 25 LTspice simulation

# Conclusion

The filter works as intended but for future projects the used of a butterworth filter or different order of Chebyshev can be explored and different set ups so that less error occur throughout the process.

# References

[1]*QUT Blackboard*, 2020. [Online]. Available: https://blackboard.qut.edu.au/bbcswebdav/pid-8450378-dt-content-rid-30612278\_1/courses/EGB240\_20se1/EGB240\_Assessment2\_2020\_Rev1.pdf. [Accessed: 25- May- 2020].

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[5]"Difference Between Analog And Digital Signal in Tabular Form | BYJU'S", *BYJUS*, 2020. [Online]. Available: https://byjus.com/physics/difference-between-analog-and-digital/. [Accessed: 26- May- 2020].

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[9]*Ele.uri.edu*, 2020. [Online]. Available: https://www.ele.uri.edu/courses/ele314/handouts/YS06\_Classicfilters.pdf. [Accessed: 02- Jun- 2020].

# Appendices

## A screenshot of a cell phone Description automatically generatedA screenshot of a cell phone Description automatically generatedA screenshot of a cell phone Description automatically generatedA screenshot of a cell phone Description automatically generatedAppendix A – Excel sheets used

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## Appendix B – Extension

