# AEC PROJECT*

Shaik Affan Adeeb

Roll No: 2022102054
*ECE*
*IIIT Hyderabad*
shaik.affan@students.iit.ac.in

V.V.S.R Chetan Krishna

Roll No: 2022102047
*ECE*
*IIIT Hyderabad*
chetan.vellanki@students.iiit.ac.in

***Abstract*—The project focuses on the implementation of a prototype quadrature down converter (QDC) for wireless receivers (RX) used in modern communication systems such as Bluetooth, Wi-Fi, and WLAN. The primary objective is to mitigate interference and enhance communication quality. The QDC plays a crucial role in improving wireless communication and offers potential benefits in various applications.**

***Index Terms*—quadrature oscillator, mixer,opamps,IF (Intermediate Frequency),MOSFET,NMOS**

## 1. QUADRATURE DOWN OSCILLATOR

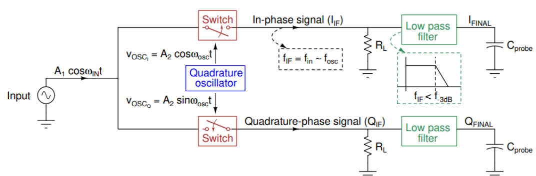


Fig. 1: QDC

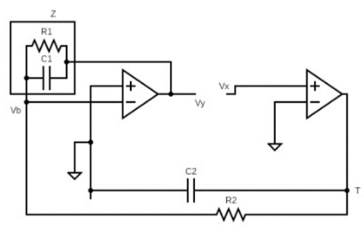


Fig. 2: Circuit for open loop gain

*1) For phase shift condition:*

$$\frac{V_{in}}{R_1} = \frac{-V_{out}(1 + SC_1R_2)}{R_2} \tag{1}$$

$$\frac{V_{out}}{V_{in}} = -\frac{R_2}{R_1}\frac{1}{(1 + SC_1R_2)} \tag{2}$$

$$\text{Phase shift} = -\tan\text{inverse}(\omega CR_1) \tag{3}$$

Identify applicable funding agency here. If none, delete this.

*2) For loop gain condition:* Applying KCL at node T

$$I = \frac{AV_x - V_b}{R_2} = \frac{V_y - V_b}{Z} \tag{4}$$

where

$$Z = \frac{R_1}{1 + j\omega R_1C_1} \tag{5}$$

$$V_b = V_y - V_z \tag{6}$$

$$I = \frac{AV_x - V_y}{R_2 - Z} \tag{7}$$

$$\frac{AV_x}{\frac{1}{SC_2}} + \frac{AV_x - V_y}{R_z - Z} = 0 \tag{8}$$

$$\frac{A}{\frac{1}{SC_2}} + \frac{A - loopgain}{R_2 - Z} = 0 \tag{9}$$

Input Signals: The Gilbert Cell Mixer takes two input signals: a. Local Oscillator (LO) Input: This is the signal that provides the desired frequency and phase information. b. Reference Input: This is typically a fixed frequency signal used as a reference for phase comparison.

Differential Mixing: The LO signal is split into two equal phases using a quadrature network, usually composed of passive components such as capacitors and inductors. The quadrature network ensures that the two resulting signals have a 90-degree phase difference (cosine and sine relationship).

In a Quadrature Down-Conversion (QDC) oscillator, the integrator and phase shifter are crucial components that work together to generate quadrature (90-degree phase-shifted) signals. These signals are essential in various applications, including frequency synthesis, modulation, and demodulation.

Integrator: The integrator is responsible for integrating the incoming signal, typically a square wave, to produce a triangular wave. It acts as a low-pass filter, smoothing out the sharp edges of the square wave.

The integrator consists of an op-amp and a capacitor. The input square wave is connected to the inverting input of the op-amp, and the output of the op-amp is connected to the junction of the capacitor and a resistor.

When the input square wave transitions from low to high, the op-amp tries to maintain the inverting input at the same potential as the non-inverting input (usually grounded). The op-amp output rises, causing the capacitor to charge through the resistor.

As the capacitor charges, the voltage across it increases linearly, generating a ramp-like waveform. This ramp waveform represents the integrated version of the input square wave.

The time constant of the integrator circuit, determined by the resistor and capacitor values, influences the rate at which the integration occurs. It affects the slope and frequency response of the integrated waveform.

Phase Shifter: The phase shifter is responsible for shifting the phase of the integrated waveform by 90 degrees. This is achieved by utilizing a high-pass filter, often implemented with resistors and capacitors.

The phase shifter consists of two resistors and two capacitors arranged in a specific configuration. The integrated waveform from the integrator is connected to the junction of the two resistors. The output is taken from the junction of the two capacitors.

The resistors and capacitors are chosen such that the RC time constants of the two paths differ by a factor of four. This configuration creates a phase shift of approximately 90 degrees between the input and output waveforms.

The high-pass filter characteristic of the phase shifter allows higher-frequency components of the integrated waveform to pass through, while attenuating the lower-frequency components. This phase shift is introduced by the frequency-dependent phase response of the high-pass filter.

By adjusting the values of the resistors and capacitors in the phase shifter, you can fine-tune the amount of phase shift introduced.

When combined, the integrator and phase shifter in a QDC oscillator generate two signals: the original integrated waveform and a phase-shifted version of it. These signals are typically used as the quadrature (cosine and sine) signals required in various applications, such as in-phase and quadrature (I/Q) modulation or demodulation schemes.

It's important to note that the specific circuit configurations, component values, and design considerations may vary depending on the oscillator topology or architecture being used. Different oscillator architectures may employ different techniques to generate quadrature signals, and the integrator and phase shifter may have different implementations based on the specific design requirements.

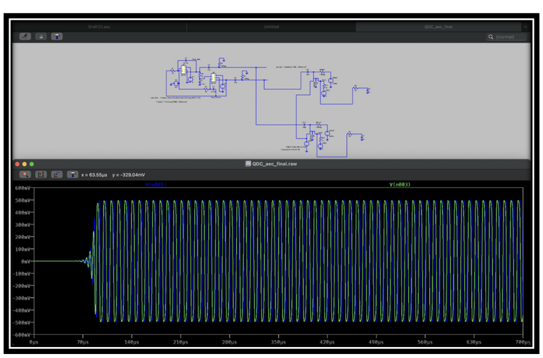

Fig. 2: Wave generated

## HARDWARE IMPLEMENTATION OF MIXER:

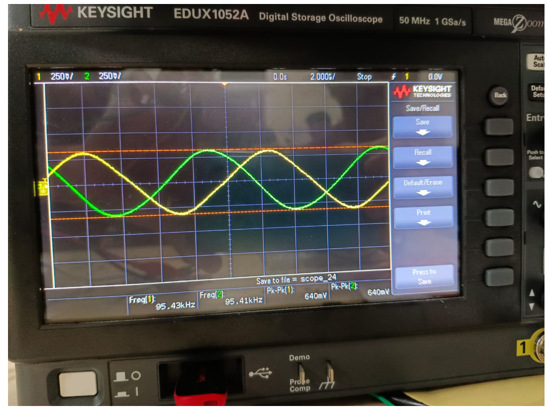


Fig. 3: In phase and quadrature phase output

## 2. SWITCH (MIXER)

### *A. Mixing of Two Cosine Wave Signals for Fin=98k and Fosc=100k*

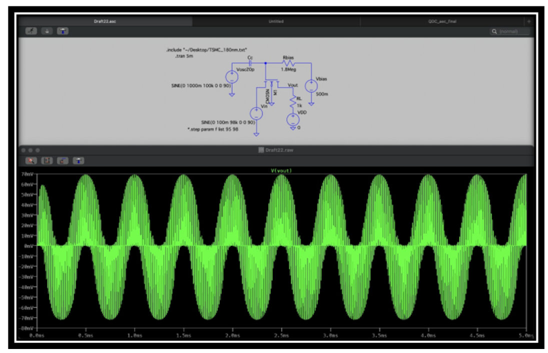

Fig. 4: Mixing of two cosine wave signals

### *B. FFT Plots for Fin=98k and Fosc=100k*

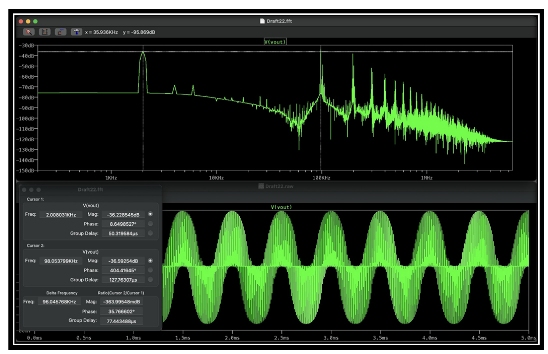

Fig. 5: First peak at 98kHz

Fig. 6: Second peak at 198kHz

### *C. Mixing of Two Cosine Wave Signals for Fin=95k and Fosc=100k*

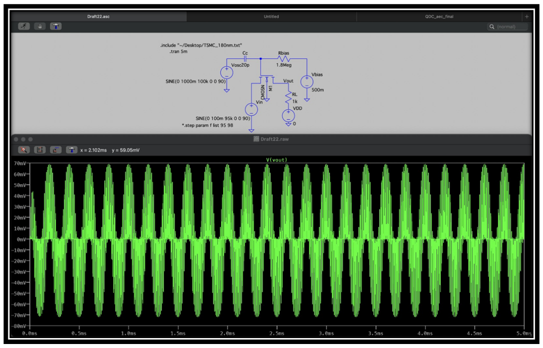

Fig. 7: Mixing of two cosine wave signals

### *D. FFT Plots for Fin=95k and Fosc=100k*

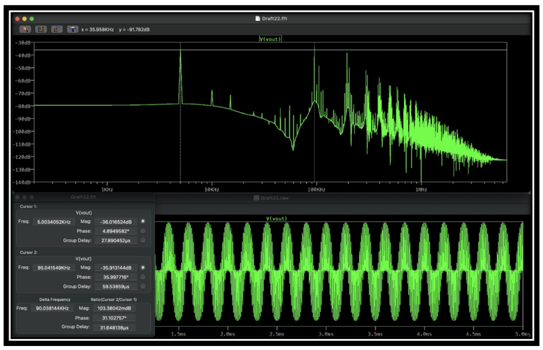

Fig. 8: First peak at 95kHz

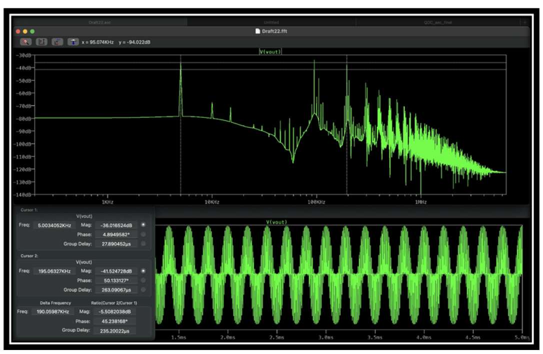

Fig. 9: Second peak at 195kHz

### *E. Mixing of Sine and Cosine Wave Signals for Fin=98k and Fosc=100k*

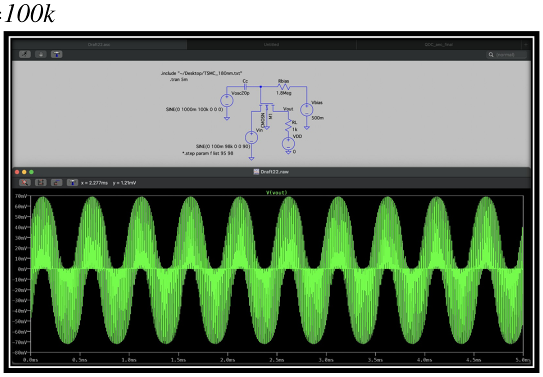

Fig. 10: Mixing of sine and cosine wave signals

### *F. FFT Plots for Fin=98k and Fosc=100k*

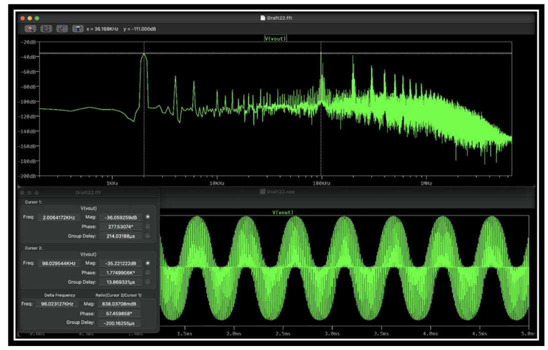

Fig. 11: First peak at 98kHz

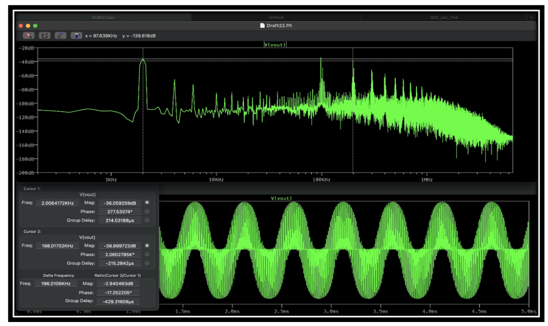

Fig. 12: Second peak at 198kHz

## HARDWARE IMPLEMENTATION OF MIXER:

### *G. Mixing of Two Cosine Wave Signals for Fin=98k and Fosc=100k*

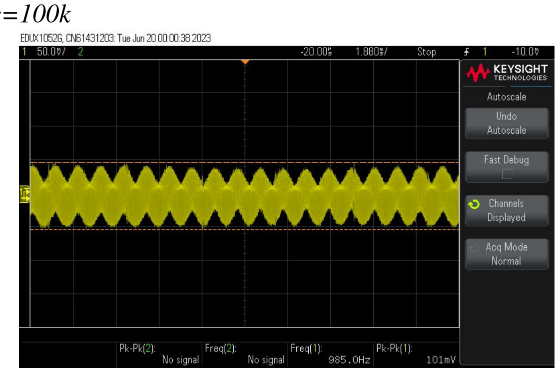

Fig. 13: mixing of cosine input with quadrature phase output of oscillator using switch(mixer)

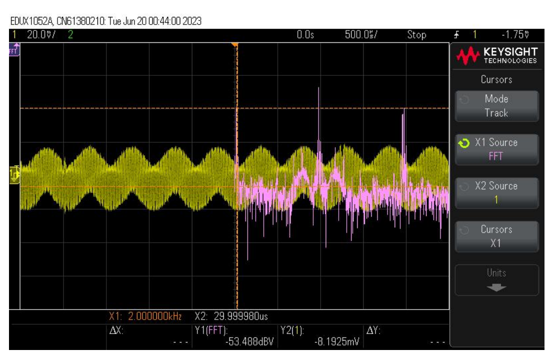

Fig. 14: peak at 2kHz

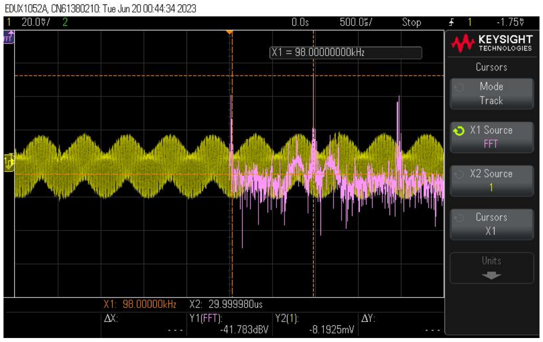


Fig. 15: peak at 98kHz

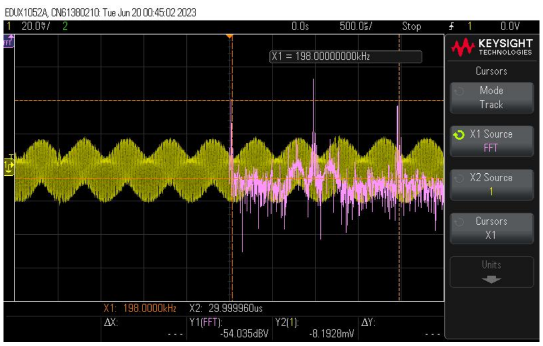


Fig. 16: peak at 198kHz

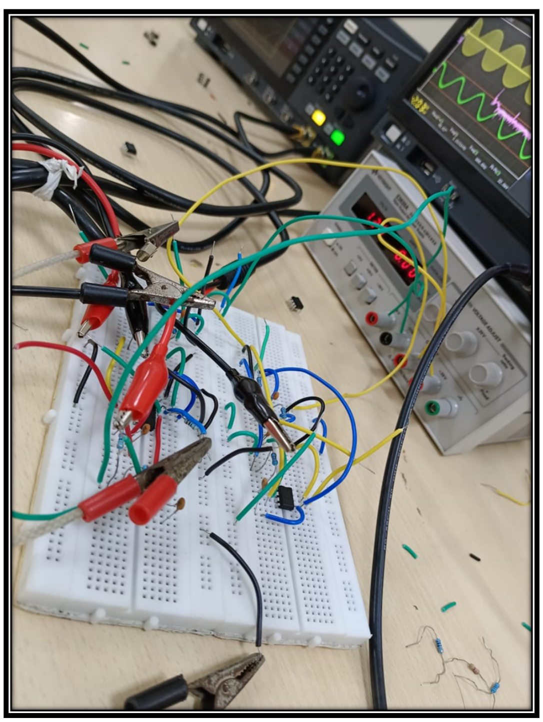

Fig. 17: Circuit performed in lab

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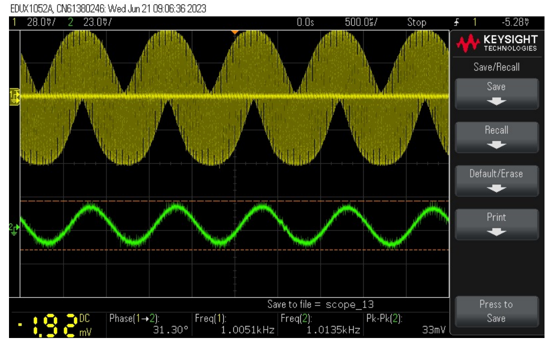


Fig. 18: Filter output on mixing in phase quadrature output and given cosine input

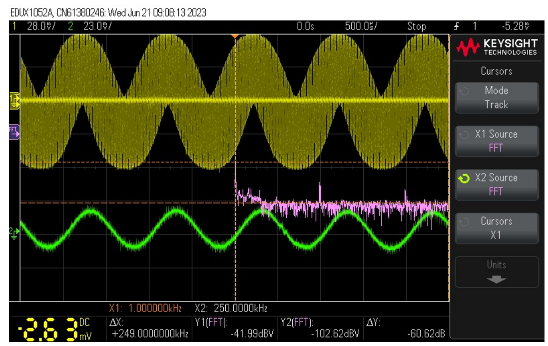


Fig. 19: peak at f1-f2 has maximum strength

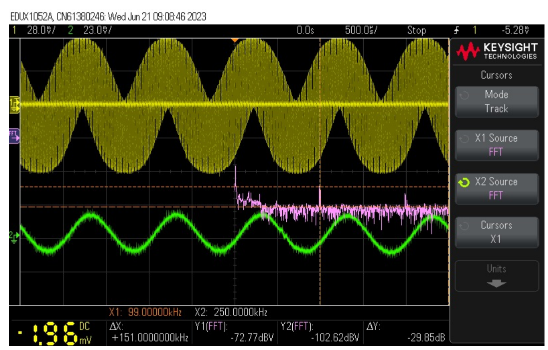


Fig. 20: peak representing input frequency

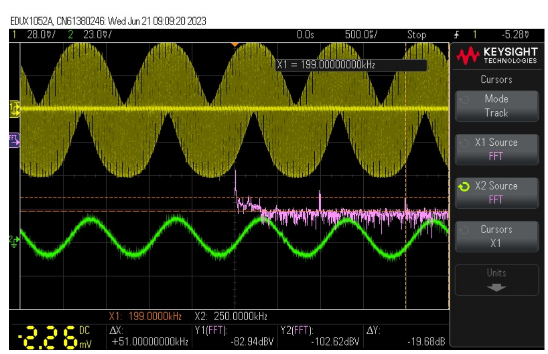


Fig. 21: peak representing f1+f2 frequency

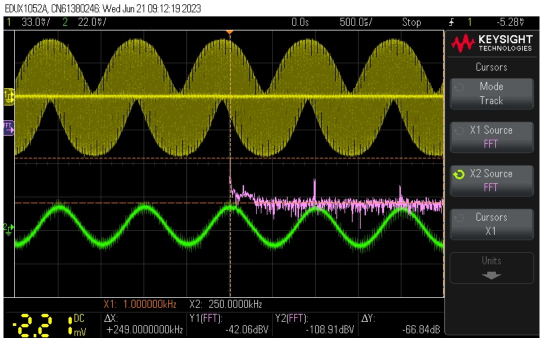


Fig. 22: Filter output on mixing out phase quadrature output and given cosine input, also peak at f1-f2 has maximum strength

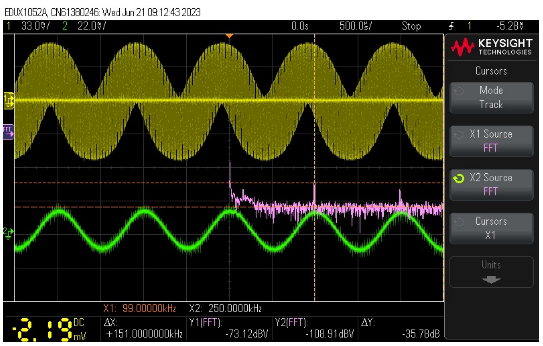


Fig. 23: peak representing input frequency

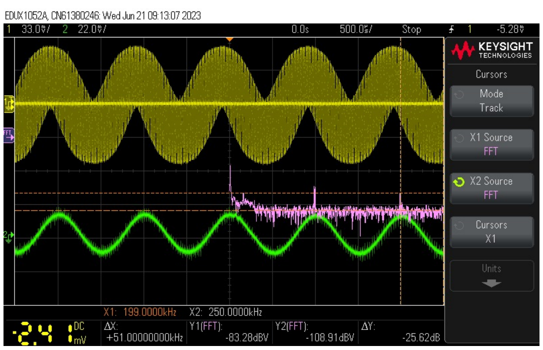


Fig. 24: peak representing f1+f2 frequency

## Working of mixer:

An IR (Intermediate Frequency) switch mixer is a type of mixer circuit used in radio frequency (RF) applications. It is designed to combine or mix two input signals to produce an output signal at a different frequency. Input Signals: a. Source Input (cos): This is the signal you want to mix or modulate. b. Oscillator Input (sin): This is the local oscillator signal operating at a known frequency. c. Gate Input (cos): This is a control signal that determines when the mixing operation occurs.

Switching Operation: The IR switch mixer utilizes a switching mechanism to control the flow of signals. The gate input signal is responsible for turning on and off the switch.

Mixing Operation: When the gate input signal is high (cos(gate) = 1), the switch is turned on, allowing the source input (cos) and the oscillator input (sin) to pass through.

The switch mixes or multiplies these two input signals together. The mixing operation is achieved by multiplying the instantaneous values of the source and oscillator signals at each point in time.

Output Signal: The output signal is taken at the drain of the IR switch mixer. The drain acts as the output port of the mixer.

The mixing process generates new frequencies, including sum and difference frequencies. The output signal at the drain typically consists of the sum and difference frequencies of the source and oscillator signals.

The frequency of the output signal depends on the frequency of the source input and the frequency of the oscillator input. The desired output frequency is usually the difference between the source and oscillator frequencies.

It's important to note that the IR switch mixer may also introduce harmonic and spurious products due to the nonlinear characteristics of the mixing process.

Overall, the procedure in an IR switch mixer involves switching on and off the mixer circuit based on the gate input signal, multiplying the source and oscillator inputs during the on phase, and obtaining the output signal at the drain, which consists of the mixed frequencies.

| Parameters | Simulated | measured |
|---|---|---|
| Oscillator Frequency | 100KHz | 95.4KHz |
| Oscillator Amplitude (I-phase) | 1V | 640Mv |
| Oscillator Amplitude (Q-phase) | 1V | 640mv |
| Input frequency | 98KHz | 96KHz |
| IF | F1=98KHz ,F2=100KHz =>F1+F2=198KHz, F1-F2=2KHz | F1=96KHz F2=95.4KHz So F1+F2=191.4KHz F1-F2=600Hz |
| Supply | For mixer 0V | 0V |
| VBIAS | =Vth=500mV | =Vth=1.12V |
| CC | 20pF | 1nF |
| Rbias | 1.8Meg ohm | 1Meg ohm |

Fig. 25: Mixer parameters

## I. Low Pass Filter Design

In a low-pass RC filter, frequencies below the cutoff frequency pass through the filter with minimal attenuation, while frequencies above the cutoff frequency are attenuated. The -3 dB cutoff frequency represents the frequency at which the output magnitude is reduced by 3 dB, which corresponds to approximately 70.7% of the input signal power.

The behavior of a filter before the cutoff frequency involves a transition band where the magnitude response gradually decreases from the passband to the stopband. In an ideal scenario, the filter's output magnitude should closely match the input magnitude below the cutoff frequency. However, due to the filter's transfer function, this transition region occurs before reaching the exact cutoff frequency. As a result, we observe a slight decrease in the output magnitude before reaching the cutoff frequency of 2 kHz. This characteristic behavior is related to the roll-off of the filter and introduces a gradual decrease in the output magnitude as the frequency approaches the cutoff.

The rate at which a low-pass RC filter attenuates the signal beyond its cutoff frequency depends on the filter's roll-off characteristics, which are determined by its design. Commonly used designs, such as first-order RC filters, exhibit a slope of -20 dB/decade or -6 dB/octave after the cutoff frequency. As the frequency increases beyond the cutoff, the filter's response gradually attenuates the signal at this rate. In other words, for every tenfold increase in frequency beyond the cutoff, the signal's amplitude reduces by approximately 20 dB or 90%.

## II. Circuit Diagram

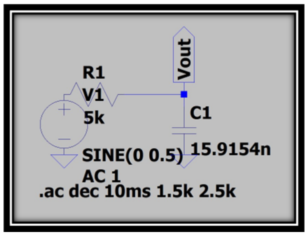


Fig. 26: Circuit diagram of RC filter

## III. Frequency Response (Output Magnitude vs Frequency) from AC Analysis

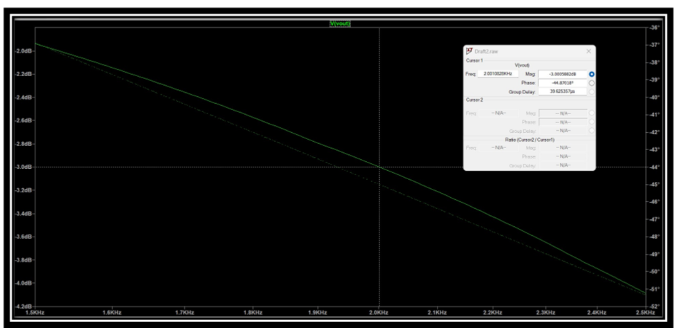

Fig. 27: Frequency response of RC filter

## IV. Transient Response

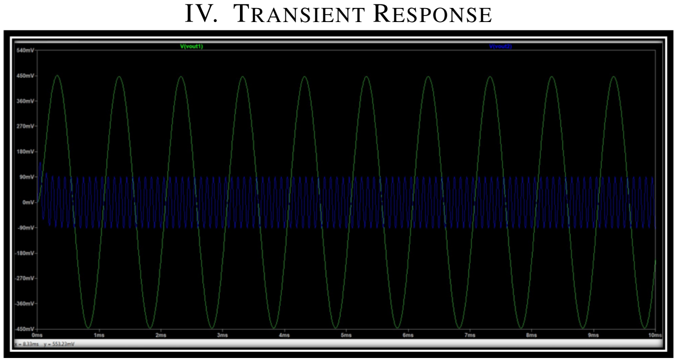

Fig. 28: Transient response of RC filter (green=1kHz, blue=10kHz)

From the plot, we can see that the amplitude for 10kHz is reduced as for frequencies after the cutoff frequency (2kHz), the amplitude of the output signal reduces, and for 1kHz, the output amplitude is 0.5V, which is equal to the input voltage.

Cut-off frequency: $f_{\text{CUT OFF}} = 2\,\text{kHz}$

Simulated values of R and C: $R = 79\,\text{k}\Omega$ $C = 1\,\text{nF}$

Experimental values of R and C: $R = 90\,\text{k}\Omega$ $C = 1\,\text{nF}$