Frequency Down Converter
(2kHz to 1kHz)

Laboratory Project Report submitted for

COMMUNICATION SYSTEM-1
(EET3061)

Submitted by

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(Jan, 2024)

Declaration

We certify that

a. The work contained in this report is original and has been done by us.
b. We have followed the guidelines provided by the Institute in preparing the report.
c. We have conformed to the norms and guidelines given in the Ethical Code of Conduct of the Institute.
d. We have tried to complete the work with minimum possible cost.
e. Whenever we have used materials (data, theoretical analysis, figures, and text) from other sources, we have given due credit to them by citing them in the text of the report and giving their details in the references.

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Abstract

This circuit utilizes an analog multiplier in conjunction with an active low pass filter to achieve frequency converter, transforming a 2 kHz sine signal into a 1 kHz output. The incoming sine wave is multiplied by another sine wave with the desired division ratio. Through careful adjustment of the amplitude and phase relationships, the multiplier effectively divides the frequency components of the input signals and passing the components through low pass filter results in a 1 kHz frequency wave at the output. This analog approach offers versatility in frequency manipulation. Practical considerations such as component selection, tuning, and potential distortion should be taken into account for successful implementation in specific analog signal processing scenarios.

Contents

1. Introduction

Frequency converter is a fundamental signal processing technique employed in various electronic applications to modify the frequency characteristics of a signal. In this context, the utilization of analog multipliers for frequency division presents an intriguing approach. This method involves manipulating the frequency of an incoming sine wave, effectively down-converting it to a lower frequency, often with the aim of achieving specific signal processing goals.

In analog signal processing the need often arises for a circuit that takes two analog inputs and produces an output proportional to their product. Such circuits are termed as analog multipliers hence Analog multiplier is a circuit in which output voltage is proportional to multiplication of input voltage.

Unlike digital frequency division methods, which involve the use of flip-flops and counters, the analog multiplier-based approach leverages the principles of modulation and mixing.

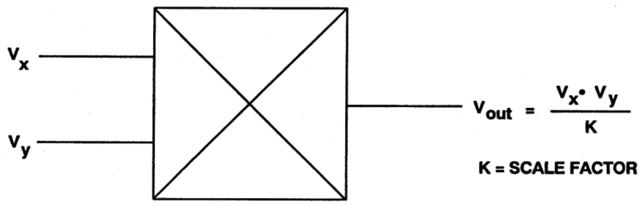
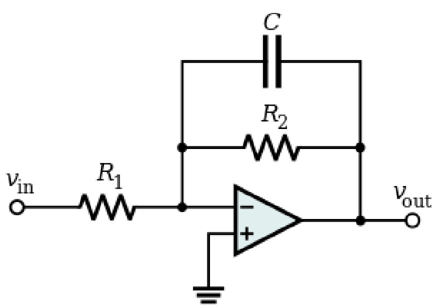


Fig: Analog Multiplier

In practical scenarios, a low-pass filter is often introduced to obtain a specific frequency. For example, if the goal is to achieve a 1 kHz frequency, a low-pass filter can be designed with a cutoff frequency below 1 kHz. This filter effectively removes higher frequency components, allowing only the desired lower frequency to pass through.

The inclusion of a low-pass filter is crucial for refining the output signal and eliminating unwanted frequency components. Careful consideration must be given to the filter design, ensuring it meets the required specifications for frequency response and attenuation.



In summary, frequency division using analog multipliers offers a unique and effective approach in signal processing, particularly when working with sine wave signals. The integration of balanced modulators and low-pass filters allows for precise control over the down-conversion process, ensuring the preservation of the continuous and smooth sinusoidal waveform while achieving the desired frequency output, such as the 1 kHz frequency mentioned in this context.

2. Need Recognition and Problem definition

Need Recognition:

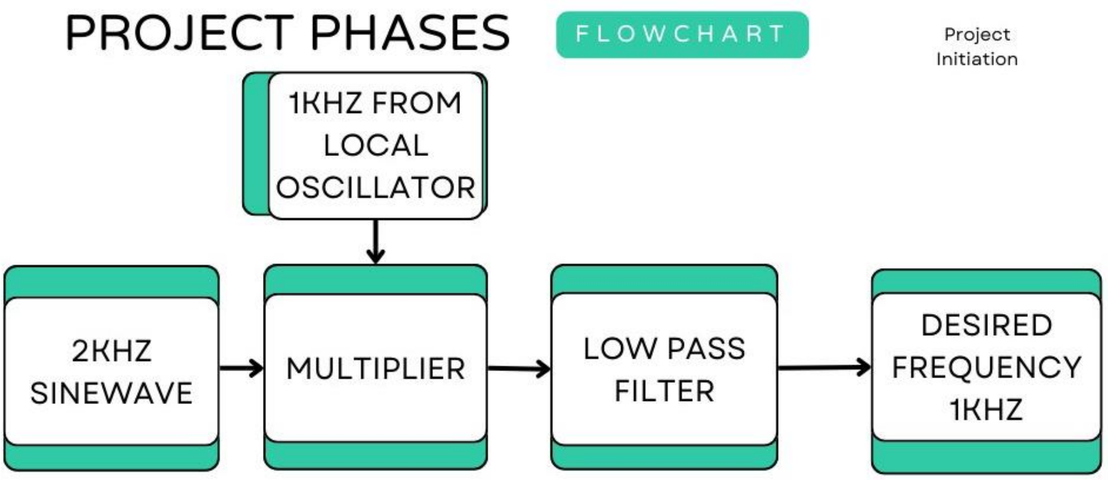
The need for frequency converter using analog multipliers arises from the demand for versatile and precise signal processing techniques. Traditional methods of frequency division often involve digital circuitry, introducing quantization and potential waveform distortion. Analog multipliers and filters present an alternative approach that allows for continuous and smooth frequency manipulation.

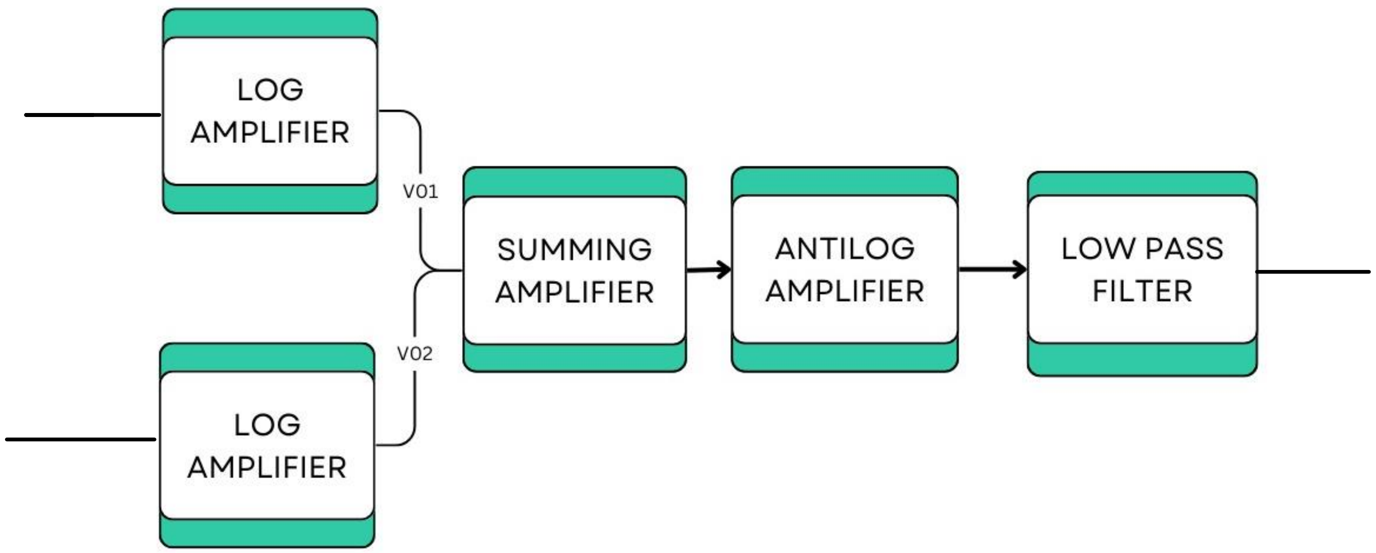
Problem Definition:

Given the identified needs, the specific problem to be addressed involves developing and implementing an analog multiplier and filter-based frequency converter circuit for down-converting a 2kHz frequency to 1kHz.

3. Function Decomposition

BLOCK DIAGRAM:





4. Concept Generation

The described process outlines a frequency down-conversion method using analog circuits such as log amplifiers, summing amplifiers, antilog amplifiers, and low-pass filters. There are alternative concepts and methods for down-converting a 2 kHz signal to 1 kHz, and here are a couple of alternative approaches:

Heterodyne Mixing:

Heterodyne mixing involves multiplying the input signal with a locally generated oscillator signal to produce sum and difference frequencies.
In this case, you would use a local oscillator (LO) signal with a frequency of 1 kHz. By multiplying the 2 kHz input signal with the 1 kHz LO signal, you get both the sum (3 kHz) and the difference (1 kHz) frequencies.
A bandpass filter can then be used to isolate the desired 1 kHz frequency component.

Digital Signal Processing (DSP):

Instead of relying solely on analog circuits, digital signal processing can be employed for frequency down-conversion.
Use a digital mixer to multiply the 2 kHz signal with a digital oscillator signal of 1 kHz. This is analogous to the heterodyne mixing concept but implemented digitally.
Apply a digital low-pass filter to remove higher frequency components, isolating the desired 1 kHz frequency.

Frequency Division:

Divide the frequency of the 2 kHz signal by 2 using a frequency divider circuit. This effectively reduces the frequency to 1 kHz.
This approach is simple but may introduce additional harmonics if not implemented carefully.

Sample and Hold Technique:

Sample the 2 kHz signal periodically and hold the sampled values.
The sampling rate should be such that when the samples are reconstructed, a 1 kHz signal is obtained.

This method is often used in digital-to-analog converters.

Mixer and Filters:

Use a mixer to combine the 2 kHz signal with a local oscillator set at 1 kHz. The output will contain both sum and difference frequencies. Apply a bandpass filter centered at 1 kHz to isolate the desired down-converted signal.
The choice of method depends on factors such as system requirements, available technology, cost considerations, and the desired level of precision. Each approach has its advantages and trade-offs, and the selection should be based on the specific application's needs.

The down-conversion of a 2 kHz signal to 1 kHz involves a combination of various analog circuits to achieve the desired frequency transformation while maintaining the integrity of the signal. Each component plays a specific role in the process:

1. Log Amplifier:
   - Two log amplifier are used to convert the input signals into their logarithmic representation

$$[\log(V_1) \text{ and } \log(V_2)]$$

Where $V1 \Rightarrow$ sinusoid of f_{2kHz}
$V2 \Rightarrow$ sinusoid of f_{1kHz}

2. Summing Amplifier:
   - The output from the two log amplifiers is combined with the original signal using a summing amplifier. This step allows for the addition of the converted logarithmic signal.

$$[\log(V_1) + \log(V_2) = \log(V_1.V_2)]$$

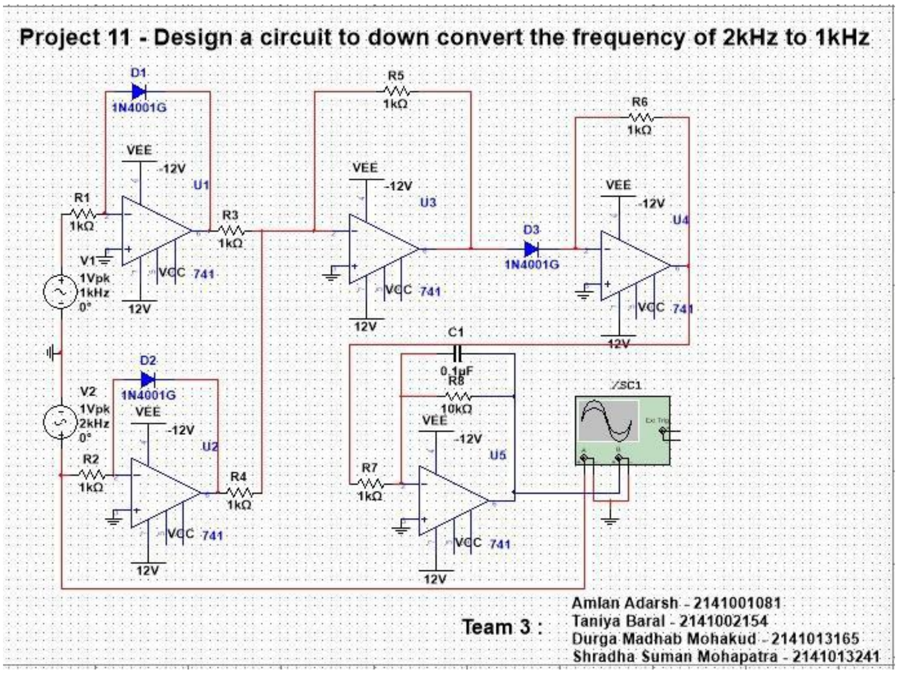
3. Antilog Amplifier:
   - After summing, the signal is passed through an antilog amplifier to convert it back to linear form. This step is necessary because the multiplication operation in the linear domain corresponds to addition in the log domain. The antilog amplifier reverses the log operation applied earlier.

$$[\text{antilog}(\log(V_1.V_2)) = V_1.V_2]$$

4. Low Pass Filter:
   - To isolate the desired 1 kHz frequency component and filter out higher frequencies resulting from the multiplication process, a low-pass filter is employed. This filter ensures that only frequencies below a certain cutoff (1 kHz in this case) are allowed to pass through, effectively down-converting the signal.

$$[\text{lowpass}(f_{2kHz}+f_{1kHz}, f_{2kHz}-f_{1kHz}) = f_{2kHz}-f_{1kHz}]$$

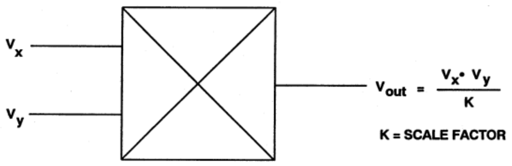
5. Concept Selection



As mentioned in the block diagram, we multiply a 2KHz sinusoid signal with a 1kHz locally generated sinusoid to get two different frequency components i.e. 3KHz and 1KHz. Since the required frequency is 1KHz, we use a low pass filter to get the desired frequency.

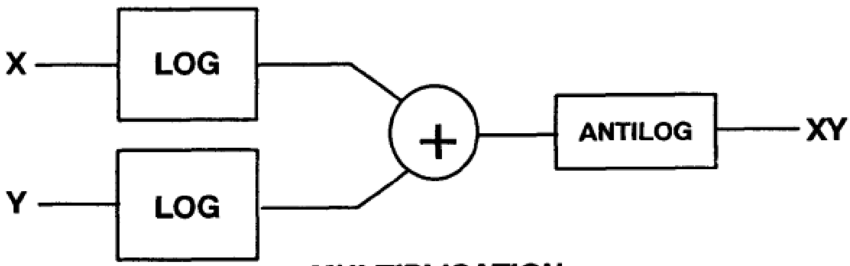
ANALOG MULTIPLIER

An analog multiplier is a device having two input ports and an output port. The signal at the output is the product of the two input signals. If both input and output signals are voltages, the transfer characteristic is the product of the two voltages divided by a scaling factor, K, which has the dimension of voltage as shown in the figure below.



Type	V_x	V_y	V_{out}
Single Quadrant	Unipolar	Unipolar	Unipolar
Two Quadrant	Bipolar	Unipolar	Bipolar
Four Quadrant	Bipolar	Bipolar	Bipolar

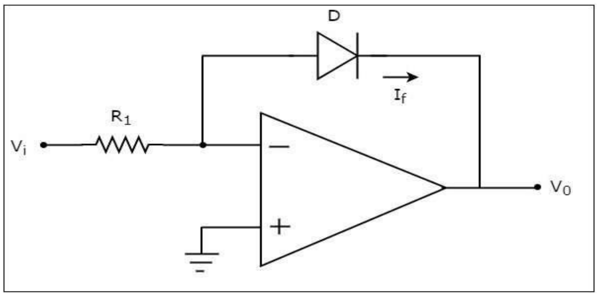
The simplest electronic multipliers use logarithmic amplifiers. The computation relies on the fact that the antilog of the sum of the logs of two numbers is the product of those numbers



MULTIPLICATION

LOG AMPLIFIER

A **logarithmic amplifier**, or a **log amplifier**, is an electronic circuit that produces an output that is proportional to the logarithm of the applied input. An op-amp based logarithmic amplifier produces a voltage at the output, which is proportional to the logarithm of the voltage applied to the resistor connected to its inverting terminal.

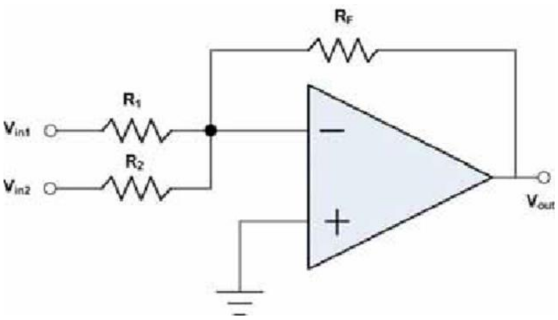


Equation:

$$\boldsymbol{Vo = -\eta V_T log \frac{Vin}{IoR}}$$

SUMMING AMPLIFIER

A summing amplifier, also known as an inverting summing amplifier, is a type of operational amplifier (op-amp) circuit that combines multiple input signals with different weights to produce an output voltage that is the weighted sum of the inputs. It is commonly used in audio mixers, analog computing, and various signal processing applications.
The negative sign in the formula indicates the inversion caused by the inverting op-amp configuration.
The summing amplifier is a useful circuit for combining multiple signals in various applications, providing a weighted sum of the input voltages at the output.

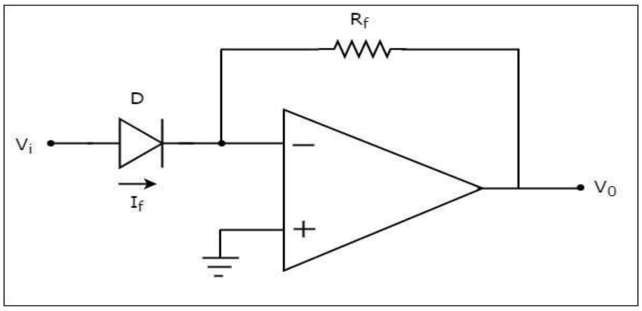


Here in the diagram the adder used has gain equal to 1(R_1=R_2=R_F).

ANTILOG AMPLIFIER

An **anti-logarithmic amplifier**, or an **anti-log amplifier**, is an electronic circuit that produces an output that is proportional to the anti-logarithm of the applied input.

An op-amp based anti-logarithmic amplifier produces a voltage at the output, which is proportional to the anti-logarithm of the voltage that is applied to the diode connected to its inverting terminal.



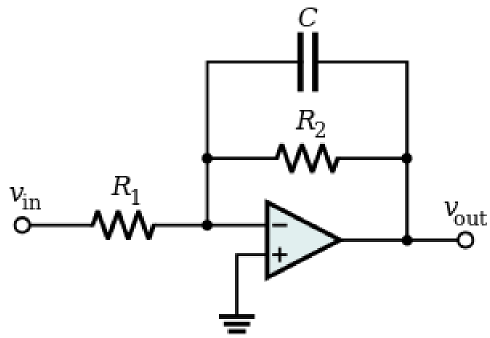
Equations:

$$\boldsymbol{Vo = -I_0 Rantilog \frac{V_{in}}{\eta V_T}}$$

Here we have taken two log amplifier and we have done multiplication of two signals further its output is given to summing amplifier and then its further cascaded through the antilog amplifier.

LOW PASS FILTER

A low-pass filter (LPF) is a circuit that only passes signals below its cutoff frequency while attenuating all signals above it. It is the complement of a high-pass filter, which only passes signals above its cutoff frequency and attenuates all signals below it.

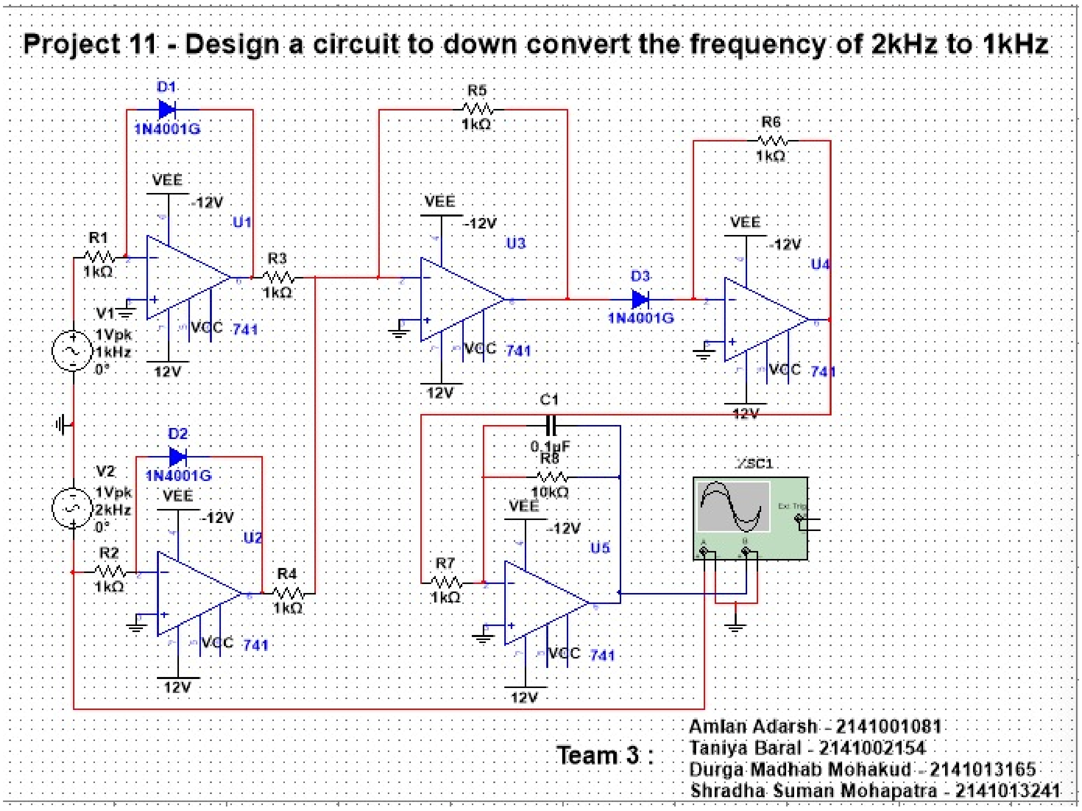


The resistor and capacitor in feedback determine the cut-off frequency i.e. $\omega = \frac{1}{CR2}$

6. Analysis

Software Implementation:

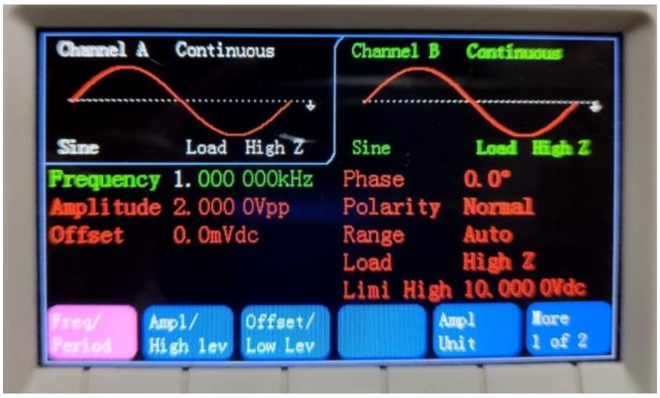
Multisim-



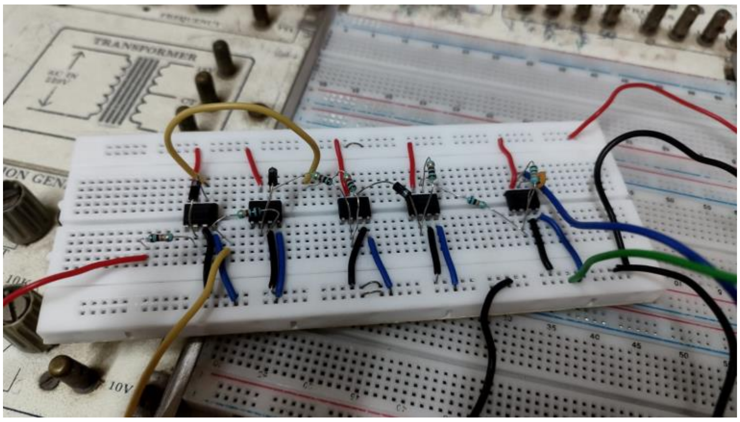
Hardware Implementation:

Input Signal (2kHz) from function generator-

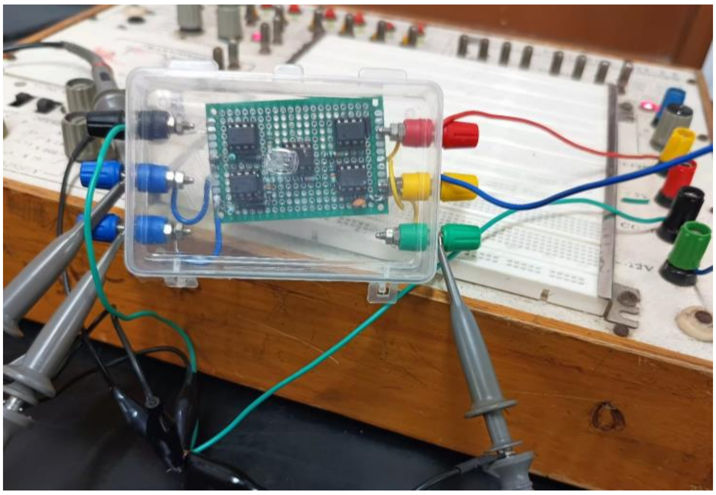
Input Signal (1kHz) from function generator-



Breadboard Implementation-



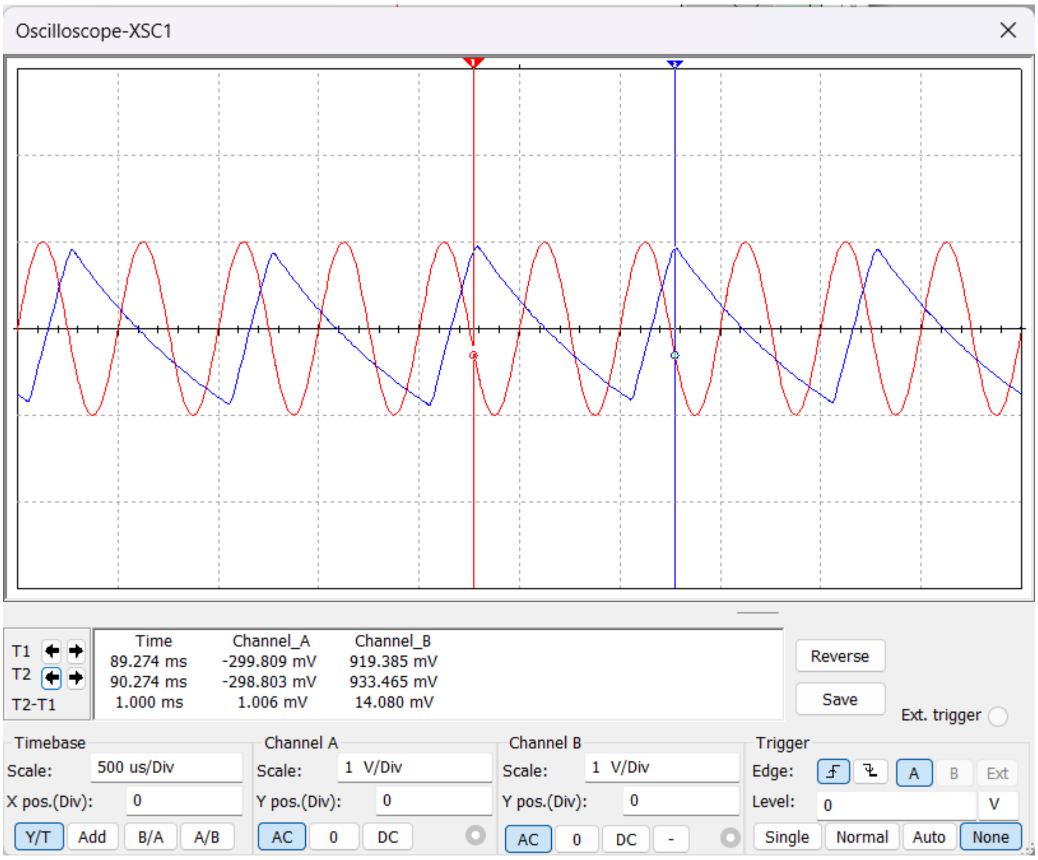
Veroboard Implementation-



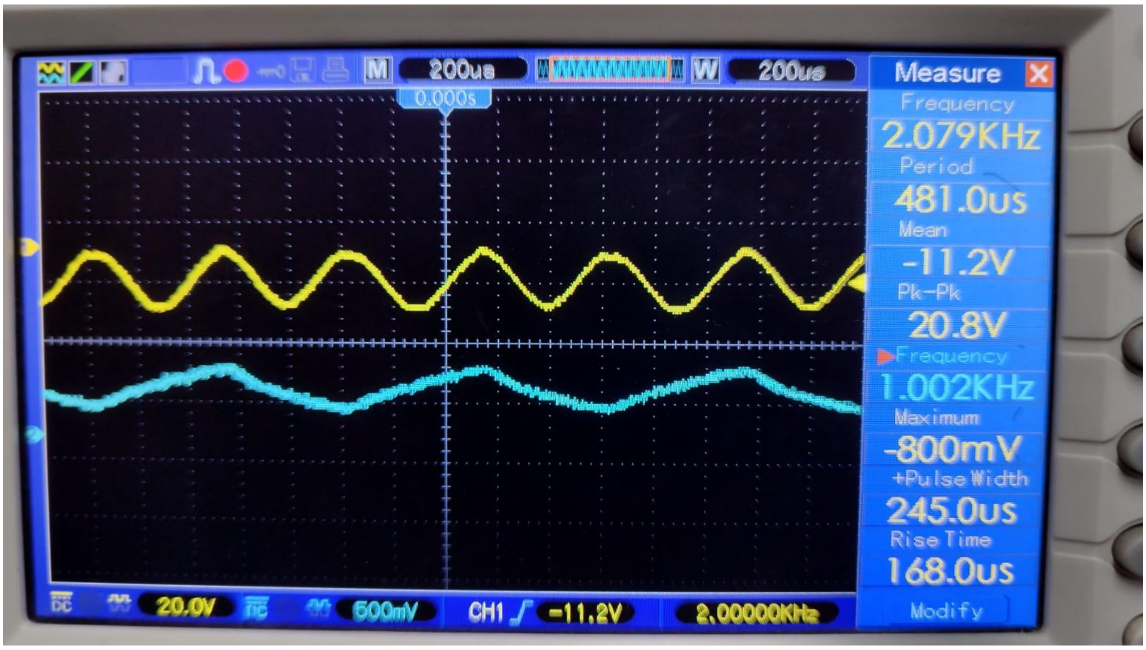
We implement the designed circuit and provide the input sine waves of 2kHz and 1kHz to the two log amplifiers. The output of two log amplifiers are now the input of a summing amplifier and then the antilog amplifier. We get two frequency components 2kHz+1kHz and 2kHz-1kHz. We use a low pass filter to extract the 2kHz-1kHz signal.

7. Testing and Improvement

Multisim output:



Breadboard implemented circuit output:



Veroboard implemented circuit output:

After testing, one thing we observed the signal of the final output is not a sinusoid. This develops an area of the improvement how to preserve the sinusoid signal.
The frequency of the output signal is not exactly 1kHz, which is because we can’t construct a filter with sharp cut off frequency.

8. Discussions and Conclusion

In the presented discussion, the down-conversion of a 2 kHz signal to 1 kHz is explored through the integration of key analog circuits. The process involves a log amplifier, subsequently a summing amplifier, and an antilog amplifier collaboratively to multiply two signals, achieving the desired of frequency components ($f_{2kHz}+f_{1kHz}$ and $f_{2kHz}-f_{1kHz}$). The low-pass filter serves as the final element, effectively isolating the 1kHz frequency ($f_{2kHz}-f_{1kHz}$) while attenuating higher frequencies resulting from the multiplication. This combination of log, summation and antilog operations, and filtering demonstrates a comprehensive approach to signal frequency conversion. The discussion underscores the versatility and effectiveness of analog signal processing circuits in achieving precise and controlled frequency transformations.

In conclusion, the comprehensive discussion on frequency down-conversion from 2 kHz to 1 kHz using a combination of analog circuits highlights the versatility and efficacy of analog signal processing techniques. The integrated use of log and antilog amplifiers, multipliers, summing amplifiers, and a low-pass filter provides a systematic and controlled approach to manipulating the frequency content of the input signal.

9. HARDWARE COMPONENT SPECIFICATION

Sl. No.	Component Name	Specification	No. of units	Price Per Unit
1	Op-Amp	741, 8-pins	5	Rs. 15
2	Resistors	1kΩ, 10kΩ	7	Rs. 0.5
3	Ceramic Capacitor	104 (0.1µF)	1	Rs. 1
4	Diode	1N4007	3	Rs. 1
5	Breadboard	830 tie points	1	Rs. 70
6	Wires	23SWG	1m	Rs. 25

References

- Log And Anti Log Amplifiers (tutorialspoint.com)
- Summing Amplifier or Op Amp Adder | Electrical4U
- Analog multiplier – Wikipedia
- PPT - DESIGN AND IMPLEMENTATION OF ANALOG MULTIPLIERS AND IC’s PowerPoint Presentation - ID:2521342 (slideserve.com)

APPENDICES

IC 741

Product Folder | Sample & Buy | Technical Documents | Tools & Software | Support & Community

TEXAS INSTRUMENTS

LM741

SNOSC25D – MAY 1998 – REVISED OCTOBER 2015

LM741 Operational Amplifier

1 Features

- Overload Protection on the Input and Output
- No Latch-Up When the Common-Mode Range is Exceeded

2 Applications

- Comparators
- Multivibrators
- DC Amplifiers
- Summing Amplifiers
- Integrator or Differentiators
- Active Filters

3 Description

The LM741 series are general-purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439, and 748 in most applications.

The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common-mode range is exceeded, as well as freedom from oscillations.

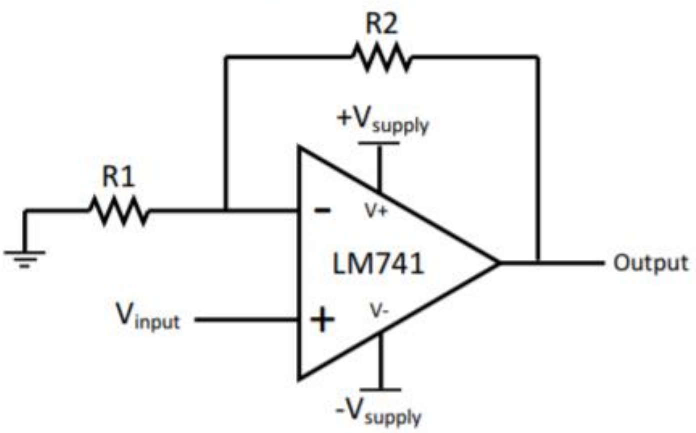
The LM741C is identical to the LM741 and LM741A except that the LM741C has their performance ensured over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM741	TO-99 (8)	9.08 mm × 9.08 mm
	CDIP (8)	10.16 mm × 6.502 mm
	PDIP (8)	9.81 mm × 6.35 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Typical Application



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