ABSTRACT

Two Stage Stagger Tuned Amplifier

Problem Statement:

Conventional single tuned amplifiers suffer from narrow bandwidth, limiting their effectiveness in communication systems. This creates a challenge in achieving both high gain and wide bandwidth. Stagger tuned amplifiers address this by using stages tuned at slightly different frequencies to obtain a broader response. This project designs and simulates a two-stage stagger tuned amplifier using eSim to achieve improved bandwidth and analyze its performance against a single tuned amplifier.

Theory/Description:

A stagger tuned amplifier is a multi-stage tuned amplifier designed to overcome the bandwidth limitation of conventional single tuned amplifiers. While single tuned amplifiers offer high selectivity, they suffer from narrow bandwidth, making them less suitable for modern communication systems. This creates a trade-off between gain and bandwidth, which is addressed using stagger tuning.

In a stagger tuned amplifier, multiple amplifier stages are cascaded, and each stage is tuned to a slightly different resonant frequency. The resonant frequency of each tuned circuit is given by:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

where $L$is the inductance and $C$is the capacitance of the LC tank circuit. By selecting different capacitance values in each stage, the resonant frequencies are intentionally shifted (staggered).

The circuit implemented in this project consists of two common-emitter amplifier stages using BC547 transistors. Each stage incorporates an LC tuned circuit connected at the collector. The first stage is tuned to one frequency, while the second stage is tuned to a nearby frequency. The individual responses of each stage exhibit peak gain at their respective resonant frequencies.

When these stages are cascaded, their responses overlap, producing a combined frequency response that is wider and smoother compared to a single tuned amplifier. This results in improved bandwidth and a near flat-top response, while still maintaining adequate gain.

Stagger tuned amplifiers are widely used in RF and intermediate frequency (IF) stages of communication systems, where both selectivity and bandwidth are critical requirements.

The circuit is simulated using ngspice through eSim. The frequency response data is extracted from ngspice and plotted using Python (NumPy and Matplotlib) to obtain accurate stage-wise and overall responses. This ensures compliance with the required simulation methodology instead of relying on the native KiCad simulation panel.

Reason to reproduce with eSim:

1. eSim enables easy simulation of frequency response and tuning effects in amplifier circuits.
2. Being open-source, it provides a cost-effective alternative to proprietary tools.
3. It supports ngspice-based simulation for accurate circuit-level analysis.
4. It allows clear visualization of stage-wise outputs and easy data analysis using Python plotting.

Expected Outcome/outputs:

1. Amplified output with wider and flatter frequency response than a single tuned amplifier.
2. Each stage shows peak response at slightly different resonant frequencies.
3. Combined output exhibits staggered effect with improved bandwidth.
4. Performance validated using ngspice AC analysis and Python plotting.

The resonant frequency of each tuned stage is:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

For two-stage stagger tuning:

$$f_1 = \frac{1}{2\pi\sqrt{L_1C_1}} \qquad f_2 = \frac{1}{2\pi\sqrt{L_2C_2}}$$

where:

- $f_1 \neq f_2$
- both frequencies are chosen close to each other

The voltage gain is:

$$A_v = \frac{V_{out}}{V_{in}}$$

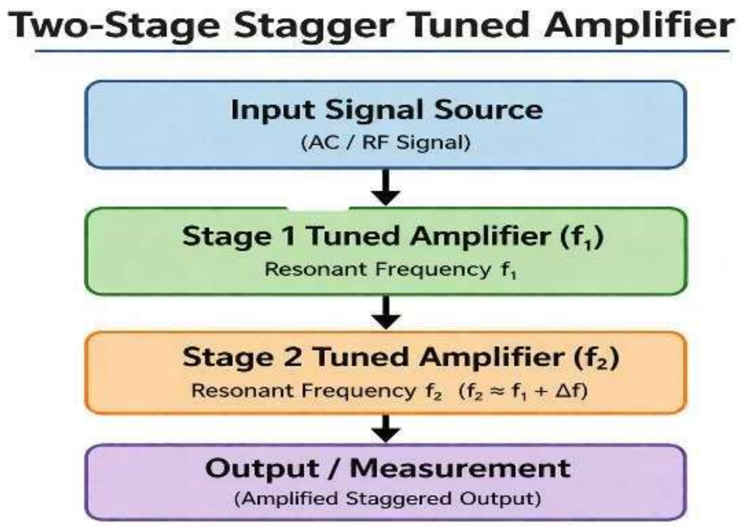
For frequency response in dB:

$$G_{dB} = 20\log_{10}\left(\frac{V_{out}}{V_{in}}\right)$$

These ngspice commands extract the input, stage 1, and stage 2 output data and save it to a file for Python-based analysis and plotting.

```
run
let vinmag = mag(v("Net-_C1-Pad2_"))
let vstage1 = mag(v("Net-_C4-Pad2_"))
let vstage2 = mag(v("Net-_C7-Pad2_"))
set filetype=ascii
wrdata F:\esim\stagger\clean_data.txt frequency vinmag vstage1 vstage2
```

Block Diagram:



Circuit Diagram:

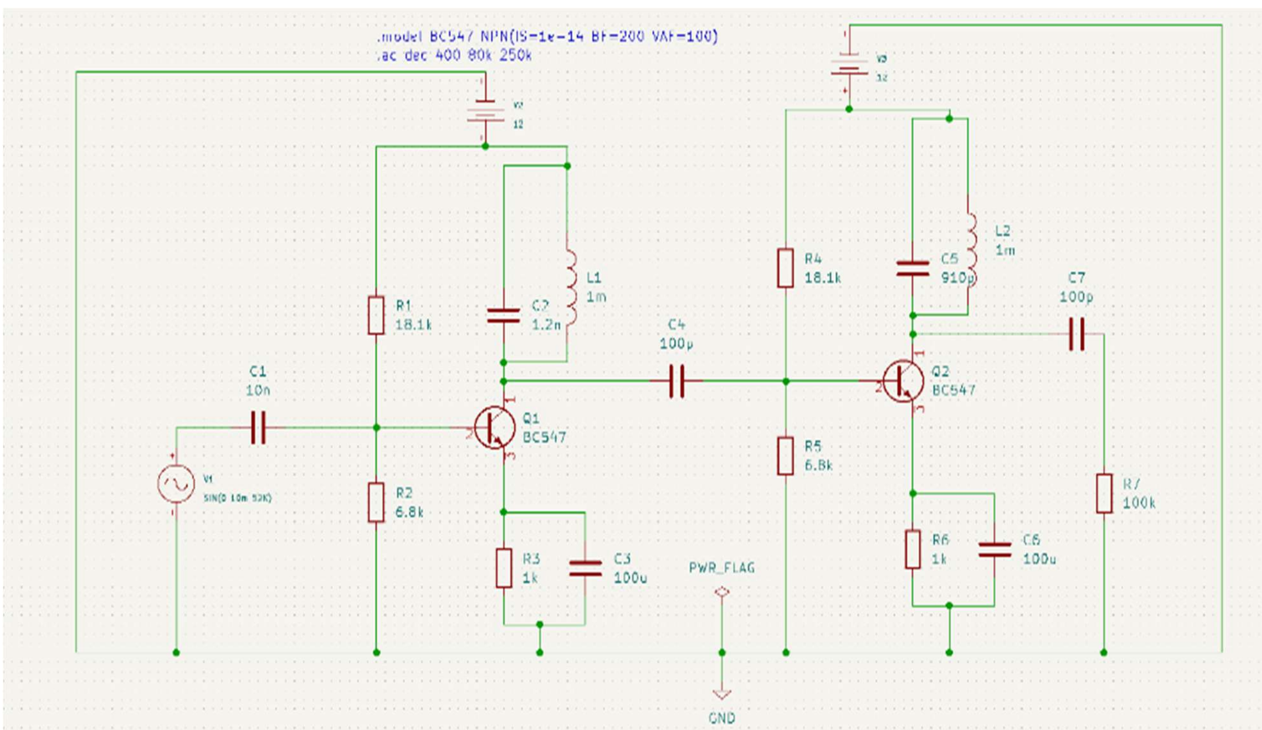


Fig: Circuit diagram of Two-Stage Stagger Tuned Amplifier implemented in eSim

Expected Results (Input, Output waveforms and/or Multimeter readings) :

Stage 1 Maximum Voltage Gain (Av): 256.441608
Stage 1 Maximum Gain (dB): 48.17976982869632
Stage 1 Resonant Frequency: 139826.661 Hz
Stage 2 Maximum Voltage Gain (Av): 71613.9638
Stage 2 Maximum Gain (dB): 97.0999542478353
Stage 2 Resonant Frequency: 139826.661 Hz

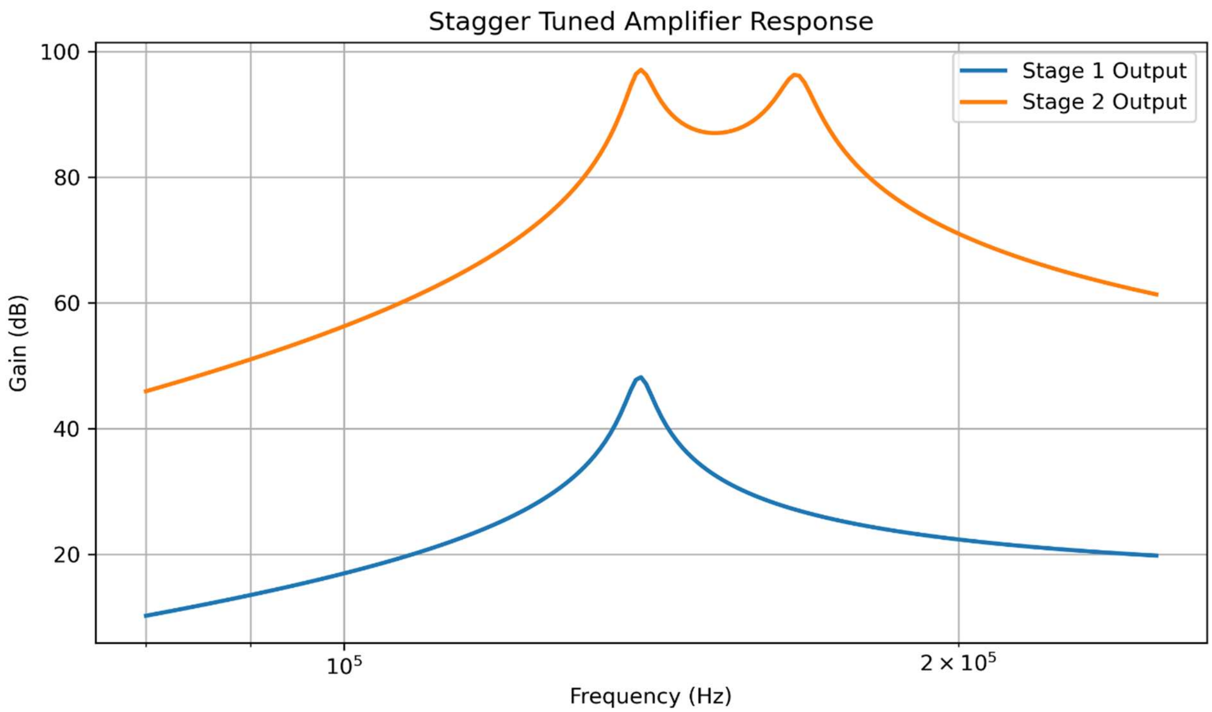


Fig: Frequency Response of Stage1 and Stage2

Research Paper/Journal/etc.:

Title: A Stagger-Tuned Transimpedance Amplifier
Author: M. H. Taghavi et al
Page No.:
LLink: https://ieeexplore.ieee.org/document/7275166

Source/Reference(s):

1.Millman, J., and Halkias, C. C., *Electronic Devices and Circuits*, McGraw-Hill

2.Sedha, R. S., *A Textbook of Electronic Circuits*, S. Chand

Conclusion:

The design and simulation of the two-stage stagger tuned amplifier clearly demonstrate the effectiveness of stagger tuning in overcoming the inherent bandwidth limitations of single tuned amplifiers. By intentionally offsetting the resonant frequencies of individual stages, a significantly wider and smoother frequency response is achieved without compromising overall gain. The simulation results validate the theoretical principles, showing improved bandwidth and a near flat-top response. This confirms that stagger tuned amplifiers are a reliable and efficient solution for modern communication systems where both selectivity and bandwidth are critical.