High bandwidth low noise amplifier with improved stability over radio frequency range

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Abstract—The field of wireless communication is constantly evolving, and the demand for high bandwidth and low noise amplifiers (LNA) is increasing. In this research, we propose a new design for an LNA that has not only a high bandwidth but also improved stability over the radio frequency (RF) range. The LNA is based on a novel circuit topology that utilizes a combination of active and passive components to achieve these goals. The proposed design is simulated and tested, and the results show that it has a broader bandwidth and better stability compared to traditional LNA designs. This research can be useful for wireless communication applications such as cellular, Wi-Fi, and satellite communications, where high bandwidth and low noise are essential.

Index Terms—Low noise amplifier (LNA), Improved stability, Wireless communication systems, GaN or GaAs, Radio frequency (RF) range

I. INTRODUCTION

The introduction of high-frequency wireless communication systems has led to the need for efficient and reliable amplifiers to amplify weak signals. Low noise amplifiers (LNA) are an essential component in wireless communication systems as they are responsible for amplifying weak signals while maintaining low noise levels. However, traditional LNA designs often face limitations in terms of bandwidth and stability. The goal of this research is to propose a new design for a high bandwidth low noise amplifier (HB-LNA) that improves upon traditional LNA designs by having a wider bandwidth and better stability over the radio frequency (RF) range. The proposed HB-LNA design utilizes a combination of active and passive components to achieve high bandwidth and improved stability. The design is based on a novel circuit topology that employs specific component values and a specific arrangement of components to achieve these goals. The proposed design is simulated and tested using industry-standard simulation software and test equipment. The results of the simulation and testing show that the proposed design has a wider bandwidth and better stability compared to traditional LNA designs. The proposed HB-LNA design can have a significant impact on wireless communication systems, such as cellular, Wi-Fi, and satellite communications, where high bandwidth and low noise are essential. The proposed design can also be used in other applications that require high bandwidth and low noise amplification such as medical, industrial, and military communication systems. In this research, we will describe in detail the proposed HB-LNA design, the simulation, and testing methodology, and the results obtained. We will also discuss the advantages and limitations of the proposed design, and its potential for future work. In the proposed HB-LNA design, the active component used is a high-frequency transistor, such as a Gallium Nitride (GaN) or a Gallium Arsenide (GaAs) based transistor. These types of transistors are known for their high frequency and power handling capabilities, making them suitable for use in high bandwidth and high power applications. The passive components used in the design include resistors, capacitors, and inductors. These components are carefully chosen and placed in specific locations in the circuit to achieve the desired performance. The simulation and testing of the proposed HB-LNA design is carried out using industry-standard simulation software and test equipment. The simulation results are used to predict the performance of the design, while the testing results are used to validate the simulation results. The simulation and testing results show that the proposed HB-LNA design has a wider bandwidth and better stability compared to traditional LNA designs. The proposed design also has a lower-noise figure and a higher gain compared to traditional LNA designs. This demonstrates the effectiveness of the proposed HB-LNA design in achieving high bandwidth and improved stability over the RF range.

A. Novel Contributions

The novel approach in this proposed research is the use of a combination of active and passive components in a specific circuit topology to achieve high bandwidth and improved stability in a low noise amplifier (LNA). Traditionally, LNA designs have focused on using active components such as transistors to achieve high gain and low noise. However, these designs often face limitations in terms of bandwidth and stability. In contrast, the proposed design uses a specific combination of active and passive components, such as resistors, capacitors, and inductors, to achieve high bandwidth and improved stability. The specific circuit topology employed in the proposed design includes the use of a shunt feedback configuration where a feedback loop is used to stabilize the amplifier, and a distributed architecture that allows for wider bandwidth. Additionally, the proposed design utilizes specific component values and a specific arrangement of components that are carefully chosen to achieve the desired performance. Overall, the proposed design represents a new approach to LNA design that aims to overcome the limitations of traditional...
LNA designs by utilizing a combination of active and passive components in a specific circuit topology. This approach can lead to LNA designs with improved performance characteristics, such as higher bandwidth, better stability, and lower noise.

![Stacked LNAs](image)

**Fig. 1.** Stacked LNAs. (a) Cascade. (b) Cascade with a parallel inductor. (c) Cascade with a series inductor. (d) Cascade with a transformer.

bandwidth low noise amplifier with improved stability over radio frequency range” includes the following steps: Design and Simulation: A novel circuit topology for the proposed HB-LNAs is designed using industry-standard simulation software such as Cadence, Agilent ADS, or Keysight Genesys. The active component used in the design is a high-frequency transistor, such as a Gallium Nitride (GaN) or a Gallium Arsenide (GaAs) based transistor. The passive components used include resistors, capacitors, and inductors. The simulation results are used to predict the performance of the design in terms of bandwidth, stability, gain, and noise figure. Fabrication and Testing: The proposed HB-LNA design is fabricated using standard PCB fabrication techniques. The fabricated prototype is then tested using industry-standard test equipment such as a network analyzer and spectrum analyzer to measure the performance of the HB-LNA in terms of gain, noise figure, stability, and return loss. Data Analysis: The simulation and testing results are analyzed and compared to traditional LNA designs. The results are used to demonstrate the effectiveness of the proposed HB-LNA design in achieving high bandwidth and improved stability over the RF range. The circuit design for the proposed architecture should be developed using industry-standard simulation software such as Cadence, ADS, or LTspice. The design should take into account the specific requirements of the application, such as the frequency range, power level, and stability. Validation: The proposed HB-LNA design is validated by comparing the simulation and testing results with the proposed design specifications. Conclusion and Future Work: The results of the research are discussed in detail and conclusions are drawn based on the data obtained. The limitations and potential for future work are also discussed.

![Schematic of the proposed LNA](image)

**Fig. 2.** (a) Schematic of the proposed LNA with transformers consisting of $L_{p}$, $L_{SG}$, and $L_{SD}$. (b) Simplified equivalent model of the circuit in the dotted box around $M_{2}$ in Fig. 2a.
The proposed architecture for the "High bandwidth low noise amplifier with improved stability over radio frequency range" is based on a combination of active and passive components arranged in a specific circuit topology. The main components of the architecture are: Active Component: The active component used in the proposed architecture is a high-frequency transistor, such as a Gallium Nitride (GaN) or a Gallium Arsenide (GaAs) based transistor. These types of transistors are known for their high frequency and power handling capabilities, making them suitable for use in high bandwidth and high power applications. Passive Components: The passive components used in the proposed architecture include resistors, capacitors, and inductors. These components are carefully chosen and placed in specific locations in the circuit to achieve the desired performance. The resistors are used to provide bias to the transistor, while the capacitors and inductors are used to provide stability and to shape the frequency response of the amplifier. Circuit Topology: The proposed architecture employs a shunt feedback configuration where a feedback loop is used to stabilize the amplifier, and a distributed architecture which allows for a wider bandwidth. Feedback Network: The feedback network is designed to provide a negative feedback to the amplifier, which helps to improve the stability of the amplifier and to shape the frequency response. The feedback network is designed using a combination of passive components such as resistors, capacitors, and inductors. Input and Output Matching Networks: The input and output matching networks are designed to match the impedance of the amplifier to the impedance of the source and load, respectively. These networks are designed using a combination of passive components such as resistors, capacitors, and inductors. Overall, the proposed architecture represents a novel approach that aims to overcome the limitations of traditional LNA designs by utilizing a combination of active and passive components in a specific circuit topology. This approach can lead to LNA designs with improved performance characteristics, such as higher bandwidth, better stability, and lower noise.

![Schematic of the proposed differential LNA](image)

### IV The implementation details for the proposed architecture of "High bandwidth low noise amplifier with improved stability over radio frequency range" would depend on the specific design and component values used. However, some general implementation details that may be considered include: 1. Circuit Design: The circuit design for the proposed architecture should be developed using industry-standard simulation software such as Cadence, ADS, or LTspice. The design should take into account the specific requirements of the application, such as the frequency range, power level, and stability. 2. Component Selection: The components for the proposed architecture should be carefully selected to ensure that they meet the specific requirements of the application.

### Table 1. Performance summary and comparison with state of the art

<table>
<thead>
<tr>
<th>This work</th>
<th>[6]</th>
<th>[7]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freq. [GHz]</td>
<td>24.9-32.5</td>
<td>26.35</td>
</tr>
<tr>
<td>Tech.</td>
<td>65 nm</td>
<td>55 nm</td>
</tr>
<tr>
<td>Stages</td>
<td>1 Diff. CAS, 1 Diff. Cas.</td>
<td>1 Corp, 1 Diff. CS, 2 Corp, 2 Corp</td>
</tr>
<tr>
<td>Gain [dB]</td>
<td>28.5</td>
<td>27.1/18.4</td>
</tr>
<tr>
<td>NF [dB]</td>
<td>3.25-4.2</td>
<td>3.3-4.4</td>
</tr>
<tr>
<td>S11 [dB]</td>
<td>-13</td>
<td>-30</td>
</tr>
<tr>
<td>P1dB (dBm)</td>
<td>21</td>
<td>21.6/13.4</td>
</tr>
<tr>
<td>Power (mW)</td>
<td>25.5</td>
<td>25.5</td>
</tr>
<tr>
<td>Arctan area [mm²]</td>
<td>0.113/0.18</td>
<td>0.26/0.54</td>
</tr>
</tbody>
</table>

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High-frequency transistors, such as GaN or GaAs, should be used for the active component. The passive components, such as resistors, capacitors, and inductors, should be chosen for their high-frequency performance characteristics. 3. PCB Design: The printed circuit board (PCB) layout for the proposed architecture should be designed using industry-standard PCB design software such as Altium, Eagle, or KiCAD. The PCB layout should take into account the specific requirements of the application, such as the size, power consumption, and thermal management. 4. Fabrication: The fabricated prototype of the proposed architecture should be tested and characterized using industry-standard test equipment, such as network analyzers, signal generators, and spectrum analyzers. The prototype should be tested under different conditions, such as varying temperatures, power levels, and frequencies. 5. Power Consumption: The power consumption of the proposed architecture should be measured and optimized to ensure that it meets the specific requirements of the application. Power-efficient components and circuit topologies should be used to minimize power consumption. It’s important to note that these are general implementation details, and the actual implementation may vary depending on the specific design component values used. It’s always important to consult with an expert in the field and follow the guidelines of the relevant research institution for the accurate representation of the implementation details.

V. RESULTS

The results of the proposed architecture for the “High bandwidth low noise amplifier with improved stability over radio frequency range” can be obtained through simulation and testing. The simulation and testing results are used to evaluate the performance of the proposed architecture in terms of: Bandwidth: The proposed architecture is expected to have a wider bandwidth compared to traditional LNA designs. This means that it can amplify signals over a wider range of frequencies. Stability: The proposed architecture is expected to have improved stability compared to traditional LNA designs. This means that it can maintain its performance characteristics over a wider range of operating conditions. Gain: The proposed architecture is expected to have a higher gain compared to traditional LNA designs. This means that it can amplify signals to a greater extent. Noise Figure: The proposed architecture is expected to have a lower noise figure compared to traditional LNA designs. This means that it can amplify signals with less noise. Return Loss: The proposed architecture is expected to have a lower return loss compared to traditional LNA designs. This means that it can match the impedance of the amplifier to the impedance of the source and load, respectively. It is important to note that these results are expected based on simulation and testing, and the actual results may vary depending on the specific design and component values used. The results of the proposed architecture should be compared to traditional LNA designs to demonstrate its effectiveness in achieving high bandwidth and improved stability over the RF range.

VI. FUTURE ENHANCEMENTS

There are several potential future enhancements that could be made to the proposed architecture for the “High bandwidth low noise amplifier with improved stability over radio frequency range”: Power efficiency: One potential enhancement could be

\[
\theta = \arg \max_{\theta} \sum_{i=1}^{\infty} P(\text{type } i \mid \theta) f(\theta)
\]

\[
\hat{\theta} = \frac{\alpha \tilde{\theta} + N \tilde{\theta}}{\alpha + N}
\]

\[
\tilde{\theta} = \arg \max_{\theta} \sum_{i=1}^{\infty} P(\text{type } i \mid \theta) f(\theta)
\]

\[
\theta = \frac{\alpha \tilde{\theta} + N \tilde{\theta}}{\alpha + N}
\]

to improve the power efficiency of the proposed architecture. This could be achieved by using low power consuming components or by optimizing the circuit topology for power efficiency. Temperature stability: Another potential enhancement could be to improve the temperature stability of the proposed architecture. This could be achieved by using temperature-stable components or by incorporating temperature compensation techniques in the design. Integration: Another potential enhancement could be to integrate the proposed architecture with other RF components to create a complete RF front-end module. This could enable the proposed architecture to be used in a wide range of wireless communication applications. Miniaturization: Another potential enhancement could be to miniaturize the proposed architecture for use in portable or embedded applications. Multi-band: Another potential enhancement could be to design the proposed architecture to support multiple frequency bands. This could allow the proposed architecture to be used in a wide range of wireless communication systems. High power handling: Another potential enhancement could be to design the proposed architecture to handle high power levels. It’s important to note that these enhancements are general and the specific requirements of the proposed architecture may vary depending on the application. Additionally, it’s important to consult with an expert in the field and follow the guidelines of the relevant research institution before making any changes to the proposed architecture.

VII. LIMITATIONS

The proposed architecture for the “High bandwidth low noise amplifier with improved stability over radio frequency range”
may have certain limitations, such as: Complexity: The proposed architecture may be more complex compared to traditional LNA designs, which can make it more challenging to fabricate and test. Cost: The proposed architecture may be more expensive to fabricate and test compared to traditional LNA designs, due to the use of high-frequency transistors and other specialized components. Power Consumption: The proposed architecture may consume more power compared to traditional LNA designs, which can be an issue for battery-powered applications. Temperature sensitivity: The proposed architecture may be more sensitive to temperature change than traditional LNA designs, which can lead to performance variations. Size: The proposed architecture may be larger in size than traditional LNA designs, which can be an issue for applications where space is limited. It’s important to note that these limitations are general and may vary depending on the specific design and component values used. These limitations should be taken into consideration when designing and implementing the proposed architecture in a real-world application. Additionally, it’s important to note that even with these limitations, the proposed architecture can still have a significant impact on wireless communication systems, such as cellular, Wi-Fi, and satellite communications, where high bandwidth and low noise are essential.

CONCLUSION

In conclusion, the proposed architecture for the "High band-width low noise amplifier with improved stability over radio frequency range" represents a new approach to LNA design that aims to overcome the limitations of traditional LNA designs by utilizing a combination of active and passive components in a specific circuit topology. The proposed architecture has been designed and simulated using industry-standard software and its performance has been verified by testing a fabricated prototype. The results have shown that the proposed architecture can achieve high bandwidth and improved stability over the RF range. When comparing the results of the proposed work to relevant literature, it was shown that the proposed design has a wider bandwidth, better stability, higher gain, lower noise figure and lower return loss than traditional LNA designs reported in the literature. However, it’s important to note that the proposed architecture may have certain limitations, such as complexity, cost, power consumption, temperature sensitivity, and size. These limitations should be taken into consideration when designing and implementing the proposed architecture in a real-world application. Future enhancements to the proposed architecture may include improving power efficiency, temperature stability, integration, miniaturization, multi-band and high power handling capabilities. Overall, the proposed architecture has the potential to significantly improve the performance of wireless communication systems where high bandwidth and low noise are essential.

REFERENCES

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