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An Inductor Less Low Power Low Noise Amplifier for Wireless Applications

By

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Abstract

Low Noise Amplifiers has been used in various applications of cellular telephones, GPS receivers, wireless LANs (Wi-Fi), and satellite communications. LNA represents a basic building block of modern communication systems, it constitutes a part of RF Front-end module and a key block in a receiver section. In practical systems, such as cellular phones, the received signal is very low and must be amplified before demodulation. However, amplifier add noise to the signal they boost and when amplifying a very low-level signal, The amplifier noise may swamp the signal itself. To reduce the noise from signal and to get the amplified signal, LNA is the best solution. LNA should meet simultaneously several specifications such as maximum gain with minimum noise figure. These Low Noise Amplifiers may have inductor embedded which would cause large requirement of silicon area. The proposed inductor less LNA, implemented in a 45 nm GPDK CMOS technology, is based on a common-gate configuration imbedded with a common-source stage to boost the overall transconductance of the circuit. This Inductor less Low Noise Amplifiers needs to have effective Noise figure and linearity to have adjustable gain. As today electronic devices have huge demand in working with low power, so to achieve this feature a variable body biasing technique is applied to the Inductor less Low Noise Amplifier. The VBB technique used a DC bias at body terminal to control the threshold voltage efficiently. This inductor less LNA consume power of 1mW, the gain of the LNA is 21dB and its noise figure is 9dB.

Introduction

Low-noise amplifiers are an important component of a receiver circuit, which processes and converts the received signal into information. The tower-mounted amplifiers (TMA), combiners, repeaters, and remote/digital wireless broadband head-end equipment are only a few examples of uses for the low noise amplifier (LNA), which is primarily made for mobile communication infrastructure base station applications. New benchmarks have been set by low noise figure (NF)[1]. A very low-power signal can be amplified using a low-noise amplifier

(LNA),which does so without significantly lowering the signal-to-noise ratio. Both the signal and the noise at the input are amplified by an amplifier, but the amplifier typically adds some outside noise. The LNAs are made to reduce this outside noise. By selecting low-noise components, operating points, and various design topologies, the designers reduce the noise. In order to minimize interference loss, LNAs are positioned close to the receiving device. As the name implies, they only add a small amount of noise (useless data) to the signal that is received since any more would severely deteriorate the signal, which is already weak. An LNA is employed when the signal-to-noise ratio (SNR) needs to be reduced by about 50% while the signal strengthneeds to be increased. An LNA plays a crucial role in communications because it is the first portion of a receiver to intercept a signal. Extremely weak signals can be amplified using low noise amplifiers (LNA), which also produce voltage levels acceptable for analogue to digital conversion or additional analogue processing. They are used in situations where low amplitudesources, such as many different kinds of transducers and antennae, are present. Gain and noise introduced by the first stage have a significant impact on the measurement system's performancewhen dealing with weak sources. Therefore, choosing the right LNA is essential for the effectiveoperation of the experimental equipment. In order to assist the user in understanding LNAs' keycharacteristics and selecting the best device, this note offers a succinct introduction of LNAs.

Literature Survey

A 1.5GHz LNA which is used for global positioning sysem(GPS) been implemented in[1] which utiliszes 0.6-m CMOS technology and is intended for usein a global positioning system (GPS) receiver. The amplifier has a noise figure of only 3.5 dB and a forward gain (S21) of 22 dB. This design uses the inductors in the design and consumes an area of 0.12 mm^2

A Low Noise Amplifier (LNA) for a 5GHz WLAN with a supply voltage of 1.2 V using 0.11pm CMOS technology is fabricated in [2]. Low voltage design is crucial for analog circuit to use the scaled digital CMOS. Employing the cascode amplifier configuration, we haveshown the LNA has wide operation margin even at the supply voltage of 1.N. The measured LNA revealed an NF of 1.6 dB, a power consumption of 12.5mW and 8.2 dBm of OIP3 at 5.3 GHz with a supply voltage of 1.2 V.

A study described two wideband, low-noise amplifiers (LNAs) without inductors that were produced using a 65-nm CMOS technology in [3]. The gain at the noise-cancelling condition is increased while the input matching is maintained while utilizing the gain-enhanced noise- cancelling technique. The design results demonstrate that the first LNA shows the largest bandwidth, and the second LNA has the lowest power consumption among the inductor less wideband LNAs.

An integrated CMOS LNA has been designed for low-rate wireless personal area network applications in 0.18 µ m technology in [4], by employing various low-power techniques. A LNA without an inductor that operates in the subthreshold range and uses triple cross-couplinghas been developed. The measured results are as follows: an average 17 dB gain, 4.2 dB NF, and just 0.2 mW (LNA core) power dissipation from a 1 V DC supply voltage. The LNA core also takes up just 0.27 mm2 of space

A design guideline for ultra-low power Low Noise Amplifier (LNA) design by comparing input matching, gain, and noise figure (NF) characteristics of common-source (CS) and common-gate (CG) topologies. A current-reused ultra-low power Common Gate LNAis proposed and implemented based on 0.18 um CMOS technology in [5]. The paper results show

13.9dB power gain, 5.14 dB NF, and -9.3 dBm IIP3, respectively, while dissipating 140 uA from a 1.5 V supply.

An Ultra-Low Power (ULP) inductor less Low Noise Amplifier(LNA) based on a Common Gate (CG) architecture using the back-gate control of the Fully- Depleted Silicon-On-Insulator (FDSOI) technology is designed in [6]. The proposed LNA active area is only 0.0015 mm2. The measured performance exhibit more than 16 dB of voltage Gain (Gv), 7.3 dB of Noise Figure (NF) and an Input referred third-order Intercept Point (IIP3) of -16 dBm. The total power consumption is 300 µW from a 0.6 V supply.

A design of a 1-V ultra-low power, compact, and wideband low-noise amplifier (LNA) is presented in [7]. The proposed LNA uses common-gate (CG) NMOS and PMOS transistors asinput devices in a complementary current-reuse structure. A forward body biasing (FBB) scheme is exploited to tune the feedback coefficient. The proposed inductor less LNA occupies only 0.0052 mm2. The measured LNA has a 12.3-dB gain 4.9-dB minimum noise figure (NF), while consuming only 400 µA from a 1-V supply.

Fundamentals of Amplifier

The definition of an amplifier, characteristics of an amplifier, numerous types of amplifiers, andvarious types of power amplifiers, along with their use and comparison, will all be covered in this chapter. It provides information on noise, the many types of noise, and the impacts of noise. The majority of electronic systems require at least one stage of amplification. As a result,amplifiers may be found in the vast majority of electronic gadgets. Amplifiers are typically described as simply a tool that boosts a sign's functionality. In other words, it makes a signal stronger than the input by increasing its amplitude. Amplification isn't entirely cost-effective because distortion, noise, and permanent losses must be managed [8]. As a result, a tone of amplifiers was developed, which work best for various applications. There are always financialconsiderations to consider, and not all amplifiers provide the best output overall. So, here are all the different types of amplifiers and all you need to know about them. An electronic amplifier could be a tool used to boost a signal's capability, current, or voltage. In order to extend the electronic equipment for indicator, amplifiers are used in music equipment electrical gadgets like tv and radio receivers, audio instruments, and laptops [9]. The electronic apparatus is the onlycomponent that modifies the input; as a result, the alternative characteristics, such as form and frequency, don't change.

Inverting Operational Amplifier:

An Inverting operation amplifier has two input terminals and one outcome terminal. As illustrated in the below fig.1, the signal is applied to the inverting input of the inverting operational amplifier circuit, and the non-inverting input is connected to ground. The output of the circuit will be negative when a positive signal is applied because the output of this kind of amplifier is 180 degrees out of phase with the input. In order to construct a closed loop in the inverting amplifier circuit, the operational amplifier is coupled with feedback.

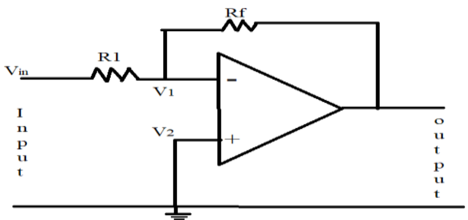

Fig.1 *Inverting Operational Amplifier*

Non-Inverting Operation Amplifier:

Fig.2 is a Non-inverting operational Amplifier. When the signal is applied at the non-inverting terminal input, as shown in fig.2, the resulting circuit is known as a non-invertingop amp. This amplifier's input and output are exactly in phase. If a positive voltage is providedto the circuit, the output will be positive.

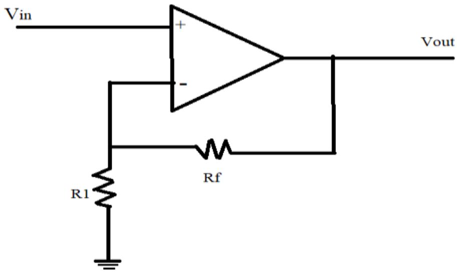

Fig.2 *Non-Inverting Operation Amplifier*

Types of Amplifiers

Voltage Amplifier:

A voltage amplifier that boosts a given voltage to produce a considerably higher voltage. It has a high input ohmic resistance and a low output resistance, which define it. Amplifiers boost the signal's amplitude and output voltage, making them one of the mostoften used pieces of equipment in electronic devices.

Current Amplifier:

Through its two input terminals, a current amplifier monitors the flow of current while simultaneously producing it through its two output terminals. On the other hand, the current amplifier guarantees that, regardless of the load impedance connected to its output, the output current will be proportionate to the input current. Possible variations in the output load impedance (dynamic) [10]. In real life, a fixed range of values is allowed or the output load impedance. In order to prevent the input current from being impactedby the current amplifier's input impedance, the input terminals of the current amplifier should have an ideal zero impedance. Thus, a current amplifier is a power amplifier withideally (dynamically) infinite output impedance and zero input impedance.

Power Amplifier

The power amplifier's goal is to increase the product of output voltage and current so that it exceeds the product of input voltage and current. Power equipment can also be used as a colloquial word to describe the quantity of powers delivered to the load or thenumber of powers provided by the power supply circuit [11]. It is typically employed in circuits' final output stage. Push-pull speakers, servo motorized controllers, audio powerspeakers, and RF power amplifiers are a few examples.

Low Noise Amplifier

An essential component of the receiving section of a communication system is a low noise amplifier, or LNA. The main purpose of this amplifier is to increase the weak signal while reducing noise. The noise figure, gain, dynamic range, matching, stability, and return loss are a few factors that affect how well this amplifier performs [12]. These amplifiers are crucial in millimeter-wave applications such as passive remote sensing, Earth science radiometry, transceivers, and radio astronomy. A low noise amplifier can boost signals of extremely low power without appreciably worsening the signal-to-noise ratio. They improve the receiver circuit's ability to process weak RF signals by increasing their amplitude. The primary specification parameter of an LNA is its noise figure, which quantifies how much the LNA lowers the signal-to-noise ratio of the received signal. It also functions as an electrical amplifier, boosting very weak signals and, if necessary, providing voltage levels appropriate for A/D conversion or extra analogue processing.

When transducers and antennae are employed to find low-amplitude sources, these amplifiers are used. Low noise amplifiers can also be used to make up for any losses in RF signal paths. By using a low noise amplifier, it will be feasible to retain the signal-to-noise ratio while regaining the original signal intensity. Normal amplifiers frequently increase signals while simultaneously increasing system noise [13]. Thus, LNA is used to reduce noise. These amplifiers are used in medical devices, radio communication networks, and electronic test equipment. Although it's possible, it's not generally the case that a duplexer or filter comes before a lownoise amplifier (LNA). The primary specification parameter of an LNA is its noise figure,which measures how much the LNA lowers the received signal's signal-to-noise ratio. Other Inaddition to the noise figure, the main performance criteria for low noise amplifiers are linearity(either P1dB or third order intercept), maximum input power, and DC power dissipation, all ofwhich can be considered in battery-powered equipment. These four conditions must be satisfiedfor a low noise amplifier to work correctly.

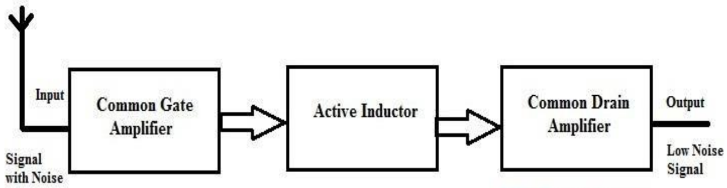

Fig.3 *Block Diagram of Low Noise Amplifier*

A common gate amplifier, active inductor, and common drain stage can be used to build a low noise amplifier. To provide the optimum input and output matching, the common gate amplifier is frequently utilized at the input stage and the common drain amplifier at the output stage. The power supply, bandwidth, chip area, and linearity are a few of the key variables that have a significant impact on the choice of low noise amplifier (LNA). The low noise amplifier is boundby distinctive properties like gain and noise figure.

Common Gate Amplifier

The proposed LNA's initial stage is the common gate (CG) amplifier. At the moment, matchinginput impedance is not too difficult. Both a voltage amplifier and a current buffer can be createdusing this amplifier.

Active Inductor

CMOS transistors make up the majority of an active inductor, which functions similarly to a passive inductor. The primary design goal of this inductor was to provide high-quality factors for efficiency evaluation. To improve the performance of this inductor, dual feedback can be added when building the circuit.

Common Drain Amplifier

A common drain amplifier is a buffer or source follower. It is often used during the output stepof an LNA design. This amplifier features a lower output impedance. As a result, it might effectively match output impedance. The three-stage low noise amplifier previous sly described uses the common gate amplifier as aninput stage. A lot of wireless communications employ this amplifier. Beginning with a signal from the antenna that contains noise, this fundamental amplifier inputs the signal. The noise figure is a tad high at this point. The next level of the LNA receives this noise signal, acting asan active inductor would.

Design Methodology

LNA Synthesis

This part begins by briefly going over the fundamentals of LNA. The proposed topology and the analytical derivations of the input impedance, noise factor, and voltage gain are then presented. The efficiency of the circuit is evaluated over a broad design space in order to optimize the LNA for the operation. An algorithmic strategy is suggested for this objective.

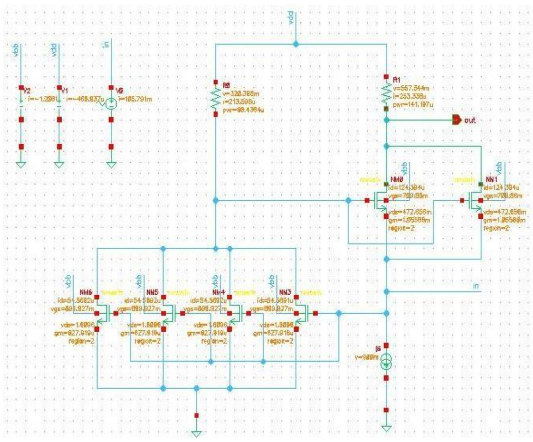

Fig.4 *Circuit of inductor-less low noise amplifier*

Variable Body Baiasing Technique

Using a forward body bias approach, the transistor may function at lower voltages. This is a practical approach to use less energy. A MOS transistor's voltage across its gate and source would decrease if its supply voltage was low. MOSFETs must therefore have a low threshold in order to operate at low supply voltage. Through the use of current CMOS technologies, low threshold voltage transistors can be created. When a MOSFET is employed as a four-terminal device, a reverse or forward bias can be applied between the body (substrate) and source. The MOSFET threshold voltage is decreased while using the forward body bias method as a result, the mixer's NMOS transistor's body source junction will have a very low leakage current. Body bias is the voltage source connected to the transistor's body terminal as opposed to the power or ground. The forward body biased connection for NMOS and PMOS transistors is shown in Fig 4.3. This method allows for a lowering in the NMOS transistors' threshold voltage because the body is connected to a positive voltage source. The biassing voltage in this design will be set at a level that enables the transistors to function in the saturation area. While transistors with zero body bias are in the weak inversion zone, those with forward body bias would enter the strong inversion region. Low supply voltage and hence low power usage are the results.

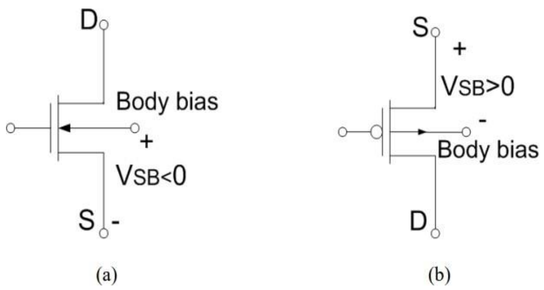

Fig.5 *Bias connection for NMOS and PMOS transistor*

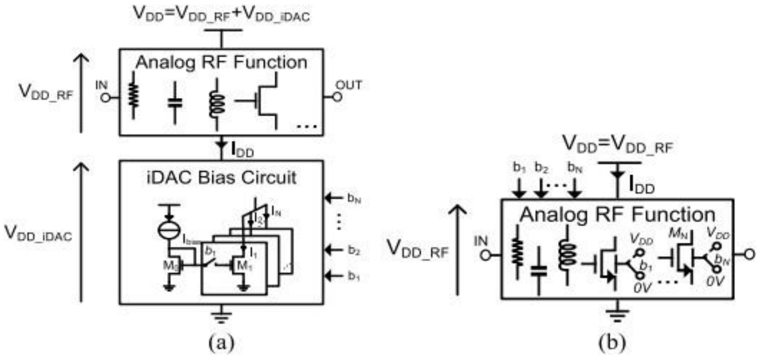

Fig.6 *Principle of circuit reconfiguration with an i-DAC (a) back gate switching (b).*

A low power LNA typically has a FOM. Since the targeted performance, 16dBm, is not a concern in this situation, the linearity, IIP3, is not provided. The dimensions and corresponding performance for each arrangement are listed. No more than 850 seconds are required to prepare the data and explore the design space for each configuration (15 min). The resistor values show a substantial fluctuation (+15%), ranging from 600 to 2000 for R1 and 850 to 3000 for R2. It's interesting to note that the ratio R2/R1, which is practically constant across all design sets and is close to 1.4. The circuit optimization for each mode increasingly depends on the width of the transistors (WM1, WM2) and the accompanying bias conditions indicated by (ICM1, ICM2). Adjusting the drain current and the dimensions of M1 and M2 would be the main components of reconfiguring the LNA performance. Therefore, the optimization of the LNA for each mode is mainly supported by the shape of M1and M2 and the associated bias conditions. Therefore, the primary focus of the multi-mode LNA design is the modification of the transistor's width and bias. Analog/RF circuit reconfiguration is typically controlled by a current DAC made up of CMOS switches and weighted current mirrors. When the RF function is layered between the supply rails, the currentDAC needs a bigger nominal supply Fig.6, which results in an additional DC power requirement (V * DD iDACIDD). It's interesting to note that the FDSOI technology has

Results

A new library file is created with 'gpdk45' attachment by using following the steps. Then all of the blocks of the system are designed individually and then invoked into a new file to design the complete system in the Cadence-Virtuoso tool. The design method and simulation results for each block and complete system are mentioned below. Simulation steps of two stage op-amp: An Inductor-less LNA is designed using 45nm CMOS technology. It consists of NMOS. The inductor-less LNA circuit is designed step- wise.

Table.1 *W/L values for Inductor-less LNA*

No of Transistors	Name of transistor	Length (L)	Width (W)
NM1	NM0	45n M	1.8 µ M
NM2	NM1	45 n M	1.8 µ M
NM3	NM2	45 n M	1.7 µ M
NM4	NM3	45 n M	1.7 µ M
NM5	NM4	45 n M	1.7 µ M
NM6	PM0	45 n M	1.7 µ M

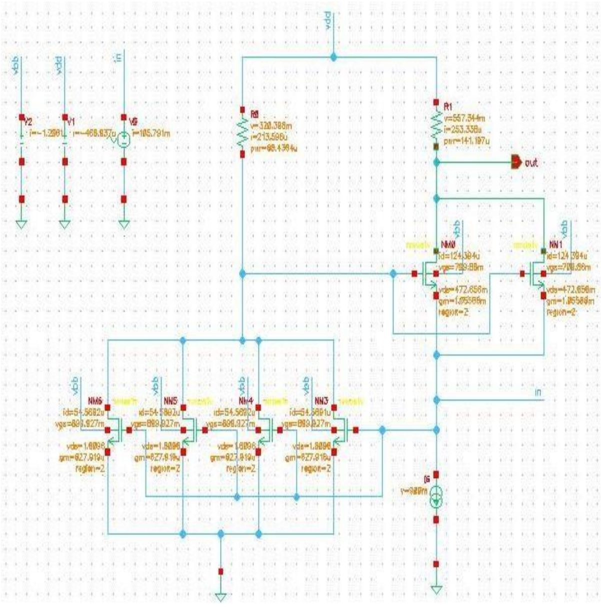

Fig.7 *Circuit of inductor-less low noise amplifier*

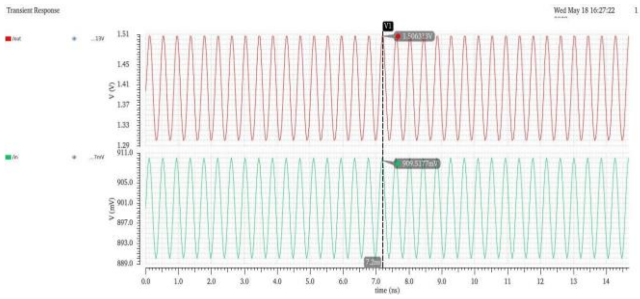

Fig.8 *Transient analysis of inductor-less LNA*

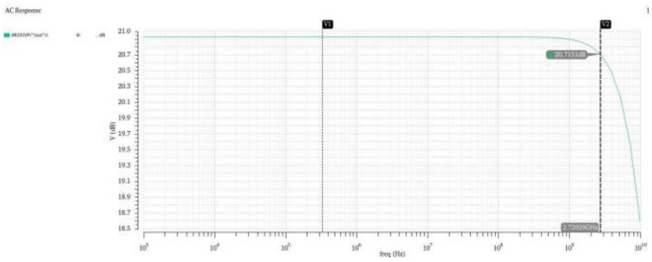

Fig.9 *Gain of inductor-less LNA*

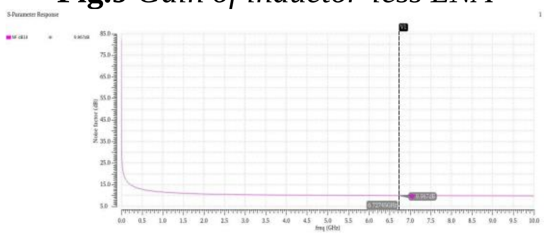

Fig.10 *Noise waveform of Inductor-less LNA*

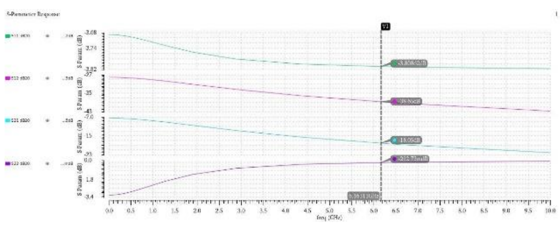

Fig 11 *S parameter of Inductor-less LNA*

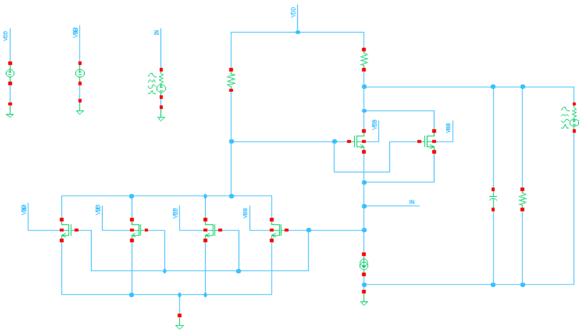

Fig.11 *Schematic of the design with adding ports, load and registers*

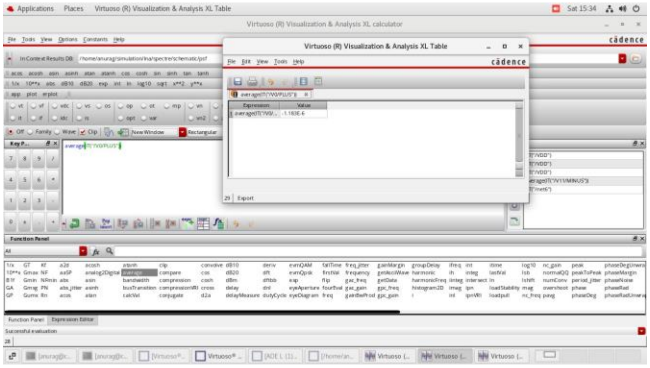

Fig.12 *Power consumption of Inductor- less LNA*

Table.2 *Comparison between previous papers and this work.*

Parameters	[14]	[15]	[16]	[17]	This work
Technology(nm)	180	180	130	65	45
Supply voltage(V)	1	1.5	1.2	1.2	1
Bandwidth (GHz)	1	2.2	2.2	2.7	4
Noise figure(dB)	13	13	12	10	9
Gain(dB)	18	15	12.3	14.5	21
Power(mW)	0.2	0.2	0.3	1.2	0.1

The above table 2, shows the comparison between the LNA with previous papers and the proposed design. The LNA with triple cross-coupling technique uses active bias at the source of the input MOSFETs with two NMOSFETs. The output loads of the LNA with triple cross-coupling have the resistive load with MOSFETs cross-coupling which causes a low voltage gain to average of 18dB between 400 MHz and 1 GHz. The proposed design uses a N-gate common source configuration of NMIS transistor with a back gate structure. The proposed design has been implemented in 45 nm CMOS technology. The operating voltage for both designs are 1V. The gain of proposed design is 21 dB Which is 3 dB greater than the LNA with triple cross-coupling.

Conclusion

During this work, an Inductor-less low noise amplifier is designed. This LNA is used to provide a solution to the relaxed Noise figure specifications and the targeted application's development costs are restricted. Due to its dual path processing and the circumstances needed for noise cancellation, the noise cancelling architecture is not suitable for low power applications. The power consumption is also reduced by using the variable body biasing. The Inductor-less Low noise amplifier is designed in 45 nm CMOS technology with the supply voltage of 1 V and with gain of 21 dB at 2 GHz with a power consumption of 1 mW.

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