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A LOW POWER 2.4 GHz LOW NOISE AMPLIFIER BYPASS SWITCH WITH CURRENT REUSE TECHNIQUE

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Abstract
Low-noise amplifier (LNA) is an electronic amplifier used to amplify possibly very weak signals. An LNA is a key component which is placed at the front-end of a radio receiver circuit. The growing demand for low-cost and low-power CMOS radio frequency (RF) transceivers in the application of wireless body sensor networks and RF identification encourages research on low-power and ultralow-power RF circuit design techniques such as current reusing. A typical example of a current-reusing technique is stacking one current-hungry module on top of another to share their dc bias current, thus, the power consumption can be reduced significantly. In this project a low power 2.4 GHz Low-noise amplifier bypass switch is proposed to reduce the power consumption and improving linearity. This is single ended input and differential output low noise amplifier used in WLAN RF front end. The designed LNA based on 0.13µm CMOS technology demonstrates a 25.27dB gain (S21), noise figure 2.65dB, input and output return loss (S11 and S22) -10.078dB and -10.427dB respectively at 2.4GHz frequency with voltage supply of 1.2V.

Introduction
The low-noise amplifier is used in RF front end of a wireless communication receiver system. It dominates the total noise of the receiver. However, it takes the cost of requiring more power for the high-gain LNA. It is more difficult to make tradeoffs between the performance of gain, noise figure, and linearity of the LNA when transistors operate at low power consumption and low supply voltage. In this paper, we are employing current reuse technique at the common-source transistor of the cascode stage to achieve the high voltage gain. This CMOS LNA will be planned to work at ISM 2.4-GHz frequency band. For the design and simulation, the advance design system (ADS) is used. The frequency and technology selected for this design is 2.4 GHz and 0.13um CMOS respectively. The other important parameters of low noise amplifier design are gain, input return loss, output return loss, noise figure and stability.

The Low Noise Amplifier (LNA) is the first gain stage of a receiver. It must meet several specifications at the same time, which makes its design challenging. The signals coming from the receiver antenna are very small, usually from -100 dBm (3.2 V) to -70 dBm (0.1 mV), therefore signal amplification is needed before it is fed into the mixer. This process sets the requirement of a certain gain to the LNA. The received signal should have a certain Signal to Noise Ratio (SNR) in order to allow proper detection. Therefore, noise added by the circuit should be reduced as much as possible. A large signal or blocker can occur at the input of LNA. The circuits should be sufficiently linear in order to have a reasonable signal reception. For portable and mobile applications, reasonable power consumption is another constraint.

i. **RF concepts:** RF behavior of any system regarding different applications is based on the following parameters –
a. Reflection: There are a number of performance parameters that show what extent of impedances are matched. Firstly the Reflection Coefficient which by definition is the ratio of reflected wave to incident wave which expressed in terms of impedances. It is a complex entity that describes not only the magnitude of the reflection but also the phase shift. ΓL = Reflected wave/Incident wave

$$= (Z_L - Z_S) / (Z_L + Z_S)$$

A closely related parameter is the voltage standing wave ratio (VSWR), which is commonly talked about in transmission line applications. The VSWR is defined as the ratio of the maximum to the adjacent minimum voltage of the standing wave.

$$VSWR = |V|max/|V|min = (1+|\Gamma L|) / (1-|\Gamma L|)$$

b. Scattering parameters: Scattering parameters or s-parameters are complex numbers that exhibit how voltage waves propagate in the radio-frequency (RF) environment. In matrix form they characterize the complete RF behavior of a network.

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Figure: A 2 –port with incident waves a_1 and a_2 and reflected waves b_1 and b_2.

S-parameters measurements are carried out by measuring wave ratios while systematically altering the termination to cancel either forward gain or reverse gain according to following equations:

$S_{11} = b_1/a_1 | a_2=0$

$S_{12} = b_1/a_2 | a_1 = 0$

$S_{21} = b_2/a_1 | a_2=0$

$S_{22} = b_2/a_2 | a_1=0$

Conclusively, the S-parameters relate the four waves in the following fashion:

$b_1 = S_{11} a_1 + S_{12} a_2$

$b_2 = S_{21} a_1 + S_{22} a_2$

Input return loss(S_{11})- Input return loss(RL in) is a scalar measure of how close the actual input impedance of the network is to the nominal system impedance value and, expressed in logarithmic magnitude .

$RL\ in = |20\log_{10}|S_{11}||dB$.

Output return loss (S_{22}) - The output return loss (RL out) has a similar definition to the input return loss but applies to the output port (port 2) instead of the input port.

$RL\ out = |20\log_{10}|S_{22}||dB$

The s-parameters not only give a clear and meaningful physical interpretation of the network performance, but also form a natural set of parameters for use with signal flow graphs.

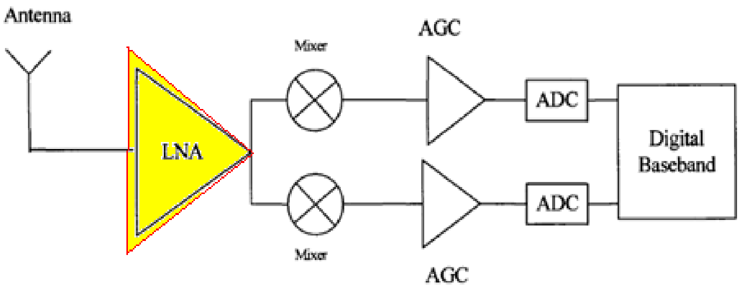
c. The Quality Factor: The Quality Factor (Q) is a descriptive parameter of the rate of energy loss in complete RLC networks or simply in individual inductors or capacitors.

$Q_{RLC} = \omega\ Etot/ Pavg$

$QL = XL/R= \omega L/R$

$QC = |XC|/R= 1/\omega CR$

ii. **Low Noise amplifier Strategy:**



The receiver features a Low Noise Amplifier (LNA) followed by a mixer (demodulator). The mixer removes the carrier from the received radio frequency signal. Usually there is an automatic gain control block between the mixer and the Analog to Digital Converter (ADC). The purpose of this block is to balance the amplification or attenuation of the received signal in a way that it utilizes the maximum range of the ADC. The analog to digital converter then converts the analog signals to digital data which is fed to the DSP to process the transmitted data. The signal is then fed to the DSP block for baseband processing. In this context it is clear that an ultra-wideband LNA should pass all the frequencies between 3.1 to 10.6 GHz. Such an amplifier must feature wideband input matching to a 50 Q antenna for noise optimization and filtering of the out-of-band interferers. Moreover, it must show flat gain with good linearity and minimum possible noise figure over the entire bandwidth.

a. Amplifier's gain: There are two criteria that affect the gain performance of any RF amplifier: the RF transistor itself and the input output matching network.

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Power Gain = (Available power at output) / (Power at input)

b. Noise performance: The noise performance of an RF amplifier is represented by its noise factor or noise figure. The noise factor accounts for the degradation of the signal's SNR due to the amplifier. It is defined as the SNR at the input of the network divided by the SNR at the output of the network.

F = (SNRin /SNRout)
Where SNRjn and SNRout are the SNRs at the input and output of the amplifier, respectively. The noise factor represents the signal's quality in terms of noise before and after the network. The noise figure is the same as the noise factor expressed in dB;
NF (dB) = 10log F

Proposed Circuit Design

The whole schematic is designed in agilent's Advance digital system software (ADS).As it provides the function to choose the parameters automatically for the user, provided that it gives the optimization target. In a word, agilent's ADS are powerful for the circuit design at RF frequency. LNA designing needs to put several aspects into consideration, such as high gain, low noise figure, good input and output matching, stability and linearity. These factors are not independent from each other, and the unconditional stability often need to sacrifice part of the gain as compensation, and high linearity usually require high-current, and minimum noise figure is obtained at a lower current.

The current-reuse technology may provide the best combination of high power gain, low noise figure, and low power consumption, making it a viable candidate for use in LNA designs. This is single ended input and differential output low noise amplifier used in WLAN RF front end.

A Balun is a device which converts balanced impedance to unbalanced and vice versa. Baluns can take many forms and their presence is not always obvious. Sometimes, in the case of transformer baluns, they use magnetic coupling but need not do so. Common-mode chokes are also used as baluns and work by eliminating, rather than ignoring, common mode signals.

A Single Pole Double Throw (SPDT) switch is a switch that only has a single input and can connect to and switch between 2 outputs. This means it has one input terminal and two output terminals.

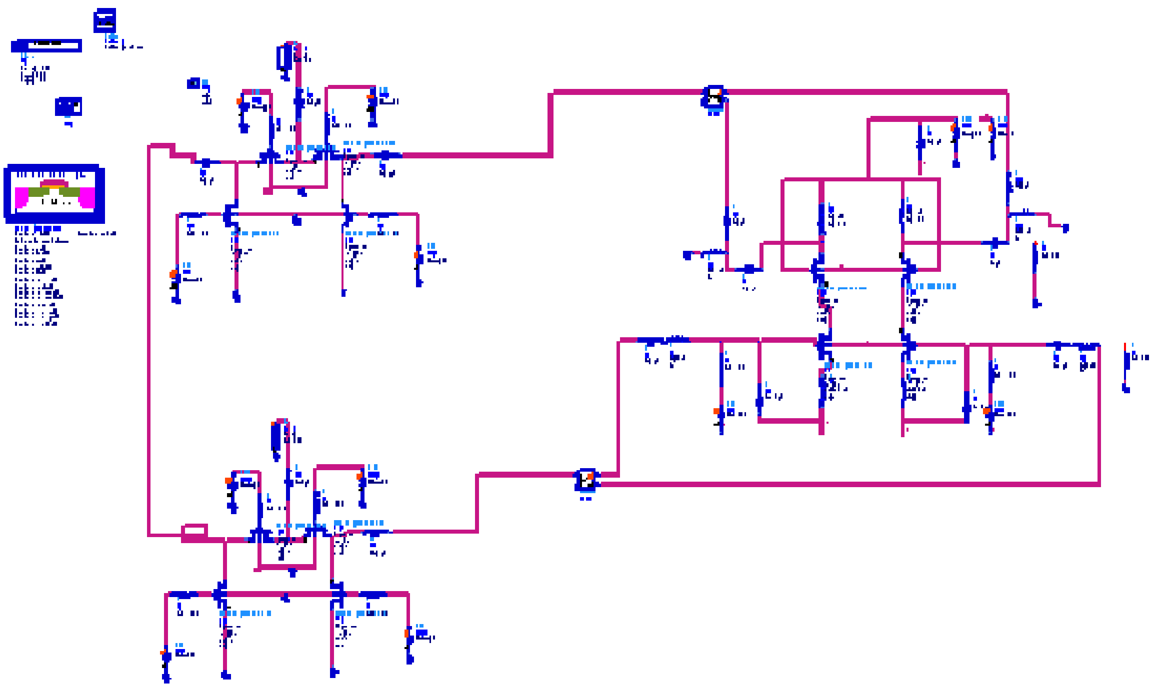

Fig. 1 The Schematic of LNA circuit

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Simulation Results

The proposed current-reusing LNA is designed and simulated in the Taiwan Semiconductor Manufacturing Company Ltd., 130-nm RF CMOS process with a supply voltage of 1.2 V. The forward gain S21 is measured to be 25.274dB at the frequency of 2.4GHz. Input reflection coefficient (S11) and the output reflection coefficient (S22) are -10.078dB, -10.427dB, respectively at the frequency of 2.4GHz. The noise figure plotted is about 2.653dB at 2.4GHz. The device is unconditionally stable and the stability factor is 2.246.

Table 1: Circuit Simulation Results

Sr No.	Parameters	Value
1	Operating Voltage	1.2V
2	Stability factor	2.246
3	S (2,1) Gain	25.273 dB
4	S (1,1) Input Return Loss	-10.078 dB
5	S (2,2) Output Return Loss	-10.427dB
6	NF	2.653 dB

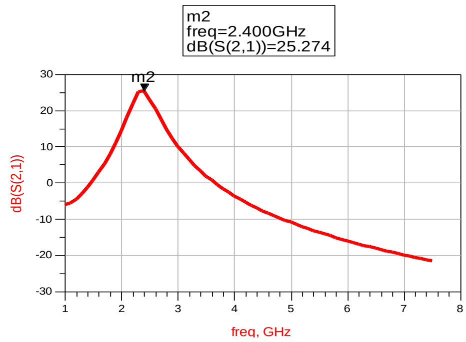

Fig 2 Gain of LNA

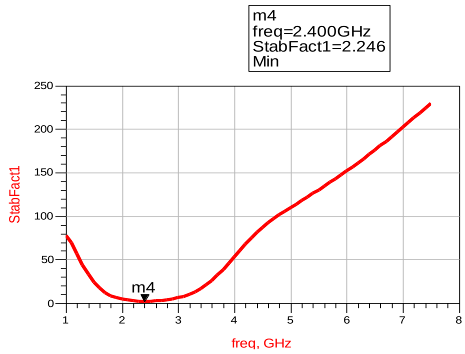

Fig 3 stability of LNA

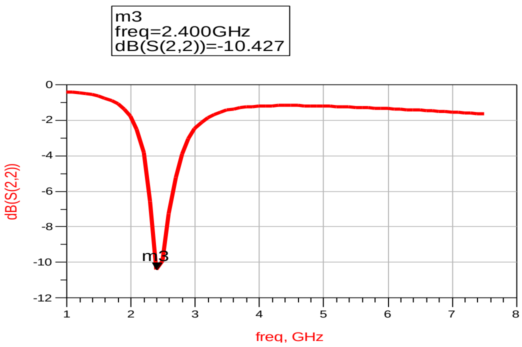

Fig 4 input return loss (S11)

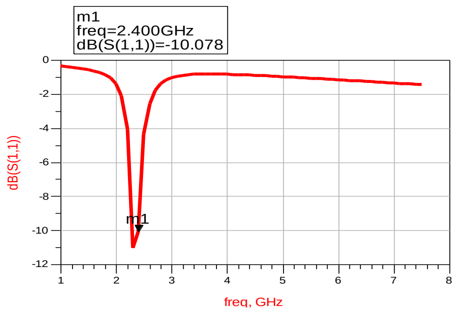

Fig 4 Output return loss

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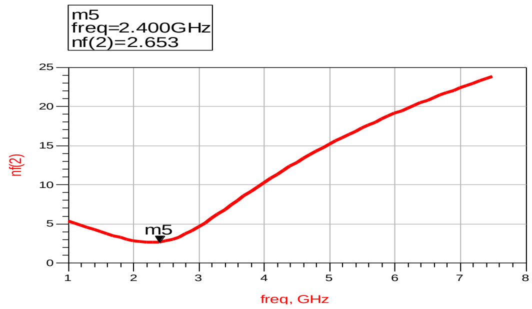

Fig 5 Noise figure of LNA

Conclusions

The amplifier is demonstrated with excellent gain, noise figure, and input/output return loss. The simulation results show that the integrated circuit can meet the requirements of LNA. Complete LNA schematic is simulated in Agilent's ADS through 0.13µm CMOS technology generates 25.274 dB voltage gain (S21), 2.653dB noise figure (NF), -10.078 dB input return loss (S11) and -10.427 output return loss(S22) also the stability factor is 2.246 at 2.4GHz frequency with voltage supply of 1.2V**.**

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