Volume 3, Issue 10, October 2013 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

The Cascade and Cascode Resistive Feedback Low Noise Amplifier for UWB Applications

Mehri Emami Nigjeh [*], **Mahrokh Maghsoodi**
Department of Electrical Engineering,
University of Guilan

Abstract—this paper present two different resistive feedback low noise amplifiers. The benefits of using mentioned resistive feedback is to enhance the bandwidth and provide wideband input matching characteristics. These two low noise amplifiers (LNAs) are compared with each other and compared with previous designs. Results of simulations show that our LNAs have better performance than conventional works. The first resistive feedback LNA demonstrates a flat 11 dB voltage gain and S11<-14 dB over frequency range of 3.1-10.6 GHz. Noise figure in this range is 2.4-4 dB and this circuit consumes 26 mW. The second resistive feedback LNA has a noise figure of 2.7 dB, 17 dB flat gain and input impedance matching parameter, S_{11}, is lower than -10 dB over the UWB frequency band. It consumes 26 mW.

Keywords— Low Noise Amplifier; Resistive Feedback; Ultra Wide Band; Cascade; Cascode

I. INTRODUCTION

The ultra wide band system is a wireless communication technology approved by the federal communication commission (FCC) for commercial applications. FCC has allocated frequency range of 3.1-10.6GHz for UWB applications [1]. UWB has attracted much attention from both industry and academia. With such a large bandwidth, UWB technologies promise to offer low power and high data rate wireless connectivity for future short range communication systems.

The main purpose of the LNA is to amplify the received signal with minimum additional noise. The essential challenges in LNA design are flat and high gain, low NF, low power consumption and 50 Ω wide band impedance matching [2]. Good impedance matching can minimize the return loss in the receiver chain. In recent years the demand of wireless applications has increased dramatically which lead to new solution of wireless communication technology. Several techniques have been adopted to improve the frequency bandwidth of low noise amplifiers, including distributed amplifier, that consume large power and area so is not appropriate, using a third-order chebyshev band-pass filter [3], using a multi section LC ladder matching network to achieve wideband matching and low noise figure and low power consumption simultaneously [4] and other techniques. Resistive feedback is an effective technique in designing amplifiers particularly wide band amplifiers. Of course it is hard to obtain the flat gain and low noise simultaneously in the UWB band[5]. This paper proposes two resistive feedback LNA with acceptable high and flat gain and low NF in large bandwidth of 3.1 -10.6 GHz. In the first designed LNA the structure of one stage cascode amplifier in common source topology is used, that operates with a 1.8 V power supply. In second circuit, a cascade resistive feedback LNA with a 1.5 V power supply is presented.

II. CIRCUIT DESIGN

The principle of resistive shunt feedback LNA can be explained by referring the simple shunt-series amplifier shown in Fig. 1. This topology uses resistive feedback R_f to power match source impedance Rs, and offers a wideband real input impedance.

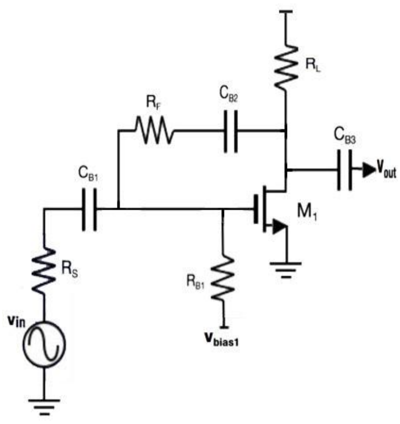

Fig. 1. Common Source Resistive Feedback LNA

Thermal noise contribution from R_f with noise current $I_n = 4kT/R_f$ directly injected to input referred node. This noise current can be quite significant compared with other components in the circuit. However, in presence of Miller effect the impedance across the gate and drain of MOSFET M_1 is divided by the Miller effect factor. That is to say actually the equivalent resistance looking from input node, $R_{eq} = R_f/A$, while A is the forward voltage gain from input to output. Since R_{eq} is forced to be equal to R_s, R_f can be very large if A is designed to be large and the noise contribution from R_f could be greatly minimized.

Using the small-signal model in Fig. 2, the voltage gain of the amplifier can be given as:

$$A_V = \frac{V_{out}}{V_{in}} = -(g_m - \frac{1}{R_f})(\frac{R_f R_L}{R_f + R_L}) \tag{1}$$

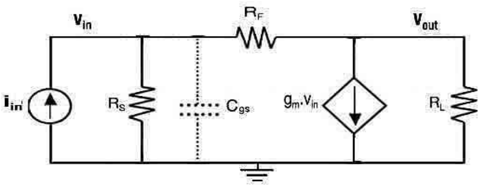

Fig. 2. Small signal model of shunt-shunt feedback amplifier

Feedback analysis can be done by opening the loop and determining the open loop transresistance gain and the feedback factor, shown as follows [6]:

$$a = -(g_m - \frac{1}{R_f})(\frac{R_f R_L}{R_f + R_L}) \tag{2}$$

$$f = -\frac{1}{R_f} \tag{3}$$

The voltage gain given by feedback analysis is:

$$A = -g_m(\frac{R_f R_L}{R_f + R_L}) \tag{4}$$

The discrepancy between (1) and (4) is because the feed forward path through R_f is ignored in the feedback analysis. This difference is negligible if:

$$g_m \rangle\rangle \frac{1}{R_f} \tag{5}$$

Shunt–shunt feedback reduces the input impedance of the amplifier by a factor of (1+af). The input resistance of the amplifier is given by:

$$R_{in} = (\frac{R_f R_s}{R_f + R_s}) \approx \frac{Rs}{1+af} \tag{6}$$

For reasons related to NF, which will explained later, R_f should be larger than R_s ($R_f \rangle\rangle Rs$) and approximation is correct. For noise figure calculation the contribution of each noise source to the total output noise is evaluated. The NF is then calculated by evaluating the ratio of the total output noise to the output noise due to Rs as follows [7]:

$$NF = 1 + \frac{\gamma g_m}{R_s g_m} + \frac{1}{R_s R_L g_m{}^2} + \frac{4R_s}{R_f}(\frac{-1}{1 + \frac{R_F + R_s}{(1+g_m R_s)R_L}})^2 \tag{7}$$

At low frequencies parasitic capacitance can usually be ignored, but in high frequency circuits it can be a major problem limit the performance of broadband amplifiers so we use shunt and series peaking bandwidth extension technique for CMOS amplifier That use inductors to trade off bandwidth versus peaking in the magnitude response.

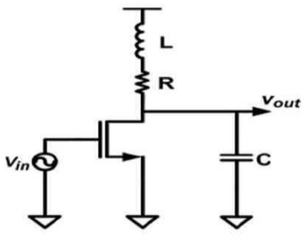

Fig. 3. A common-source amplifier with shunt peaking

From small signal model fig. 2, the gain is simply the product of the Z(s) and the transconductance g_m.

$$Z(S) = \frac{R + SL}{1 + SRC + S^2 LC} \tag{8}$$

The inductor introduces a zero in Z(s) that increases the impedance with frequency, compensates the decreasing impedance of C, and thus extends the bandwidth. From [8] by Substituting the bandwidth of the reference common source amplifier, W_0=1/RC, and the variable $m=R^2C/L$ into Eq. (8) and normalizing to the impedance gives:

$$z_N(S) = \frac{1 + \frac{S}{mw_o}}{1 + \frac{S}{w_o} + \frac{S^2}{mw_o^2}} \tag{9}$$

For $m = \sqrt{2}$ bandwidth of amplifier is 1.84 fold with 1.5 dB of peaking. A maximally flat gain is achieved for $m = 1 + \sqrt{2}$ but bandwidth extension of amplifier is reduced (1.72). In this circuit we add a capacitor shunt with the inductor that should be large enough to negate peaking but small enough to not significantly alter the gain response shown in Fig.4.

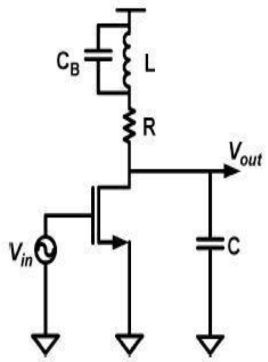

Fig. 4. A common-source amplifier with shunt peaking self and capacitor

From [7] we have:

$$z_N(S) = \frac{1 + (\frac{1}{m})\frac{S}{w_o} + (\frac{K_B}{m})\frac{S^2}{w_o^2}}{1 + \frac{S}{w_o} + (\frac{K_B + 1}{m})\frac{S^2}{w_o^2} + (\frac{K_B}{m})\frac{S^3}{wo^3}} \tag{10}$$

Where $K_B=C_B/C$, w_0=1/RC, and $m=R^2C/L$. Compared to Eq.(9), C_B introduces another pole and zero in Z_N(S). Fig. 5, shows the schematic of cascode resistive negative feedback LNA. The cascode is a two-stage amplifier consists of two parts, a transconductance amplifier and a current buffer. In comparison to a single stage amplifier, this combination has these advantages: higher input impedance, high output impedance, higher gain or higher bandwidth and higher input-output isolation as there is no direct coupling from the output to input.

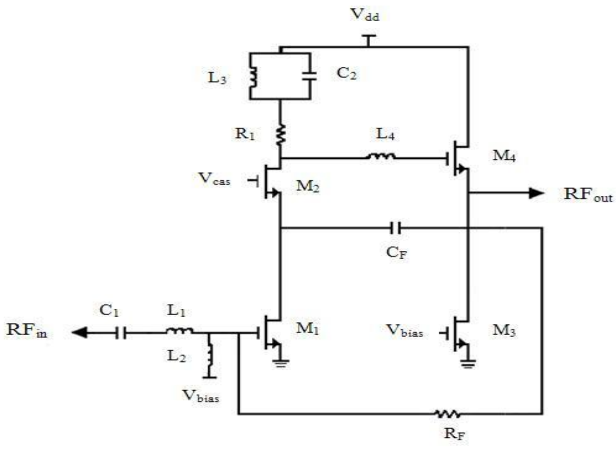

Fig. 5. The circuit schematic of ultra-wideband resistive feedback LNA

This eliminates the Miller effect and thus contributes to a much higher bandwidth. It was first used in an article by F.V. Hunt and R.W. Hickman in 1939, in a discussion for application in low-voltage stabilizers [9]. M_1 is the transconductance transistor and M_2 is a cascode transistor to increase the output impedance and improve the isolation between input and output ports. The value of the feedback resistor is determined by the source impedance (50Ω) and AV (voltage gain).

$$R_f = R_S\,(1+|A_v|) \tag{11}$$

In proposed a classical filter topology with a multi section LC resonant configuration is used to match the input impedance to 50 Ω in the full band. Noise and linearity of a LNA are affected by the gate width (M_1 & M_2) and Vgs of common source transistor. The transistor M_1 dominates the noise performance. However, the transistor M_2 contributes to the linearity performance as well as the improvement of the reverse isolation due to high output impedance.We also use a voltage current feedback to enhance wideband performance that is suited for the CMOS LNA since the input impedance of MOSFETs is large and mostly capacitive. Voltage current resistive feedback configuration has lower R_{in} in comparison to amplifiers without feedback. This is helpful to the reduction of input resistance of a MOSFET and means that the input impedance can be controlled and set by feedback. Negative feedback configuration can extend the bandwidth because the product of gain and bandwidth is constant and feedback resistance reduces gain [10]. The value of the feedback capacitor, which is used for biasing purposes, was set large enough to not have a significant effect on feedback. Fig. 6 presents the schematic structure of second proposed resistive feedback LNA. In a cascade low noise amplifier, the output of the first stage amplifying transistor is fed as input to the second amplifying device, whose output is fed as input to the third, and so on until adequate signal amplification has been achieved.

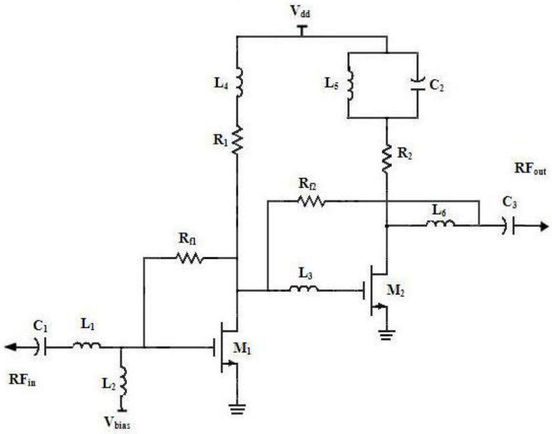

Fig. 6. The circuit schematic of proposed ultra wideband resistive feedback LNA

For input stage, a common source amplifier with resistive shunt feedback is used. The feedback resistance supplies feedback current to the input so that a suitable value of shunt feedback resistor (R_{f1}) can be selected to achieve input matching, a low NF, and also broadband gain, simultaneously. To fulfill input matching a two section LC resonance configuration is used to match the input impedance to 50Ω in the full band [10]. This topology has good potential for input impedance matching and low noise figure. The benefit of Inter stage circuit consists of series inductor, L_3, is to enhance the gain at high frequency. The next stage is common source with shunt inductive peaking L_4 to achieve high gain at higher frequency, also have resistive shunt feedback (R_{f2}) to extend the bandwidth and flattens the gain. The output tank circuit is used for increase gain and decrease output return loss S_{22}.The component values of two circuits are shown in Table I.

TABLE I. COMPONENTS VALUES OF TWO LNAs

Components for cascode LNA		Components for cascade LNA	
L_1	0.9nH	L_1	1.3nH
L_2	2.4nH	L_2	3nH
L_3	1nH	L_3	1.4nH
L_4	1.5nH	L_4	3nH
R_f	340Ω	L_5	4nH
C_1	900fF	L_6	1nH
C_f	400fF	R_{f1}	450Ω
		R_{f2}	500Ω
		R_1	100Ω
		R_2	30Ω
		C_1	700fF
		C_2	500fF
		C_3	1000fF

III. SIMULATION RESULTS

The wideband resistive feedback LNAs are designed in 0.18µm CMOS process. Fig. 7 shows the simulated power gain of cascade and cascode LNAs in one graph. The measured power gain achieves a maximum of 11dB flat gain for cascode resistive feedback LNA over the bandwidth of 3.1 – 10.6 GHz and a maximum of 17 dB flat gain for cascade resistive feedback LNA over the bandwidth of 3.1 – 10.6 GHz.

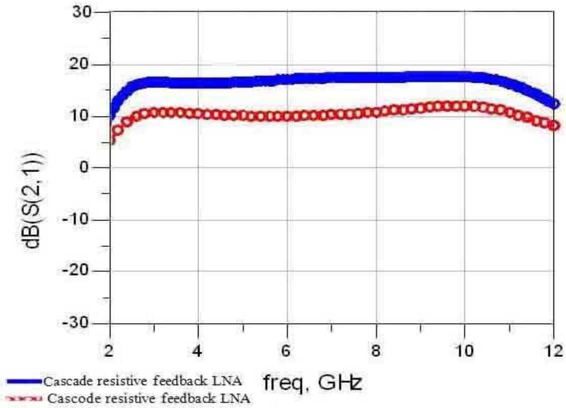

Fig. 7. Simulated power gain

The simulated input return loss is presented in Fig. 8 for both LNAs. The input return loss is better than -14dB in the UWB bandwidth for cascode resistive feedback LNA and is better than -10 dB in the 3.1-10.6 GHz for cascade resistive feedback LNA.

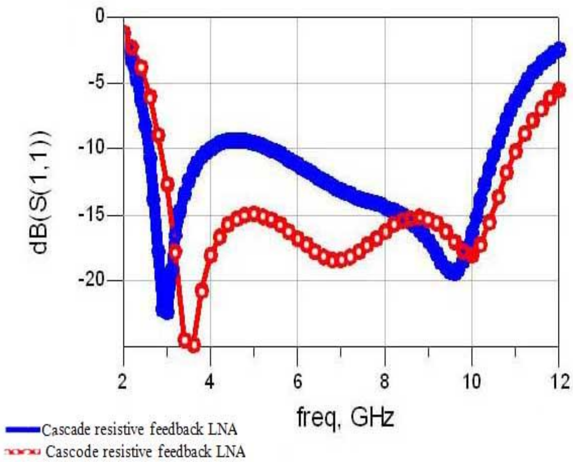

Fig. 8. Simulated input return loss (S_{11})

Noise figures are illustrated in Fig. 9. The simulated noise figure is from 2.4 to 4 dB across the bandwidth for cascode resistive feedback LNA and is 2.7 dB for cascade resistive feedback LNA.

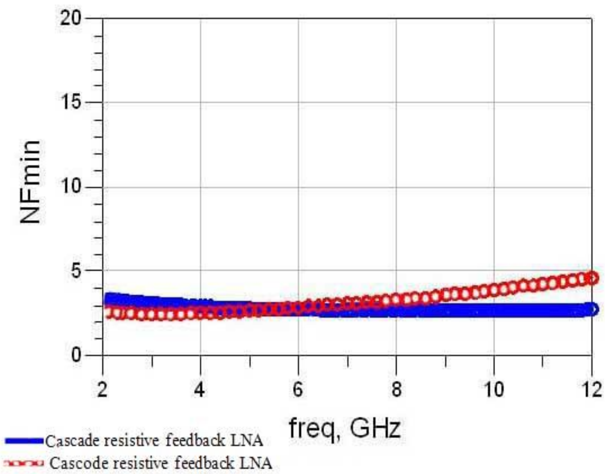

Fig. 9. Simulated NF

The simulated S_{12} that is a measure of reverse isolation is illustrated in Fig. 10 that is better than -20 dB in the bandwidth for cascode resistive feedback LNA and is better than -30 dB in the 3.1-10.6 GHz for cascade resistive feedback LNA.

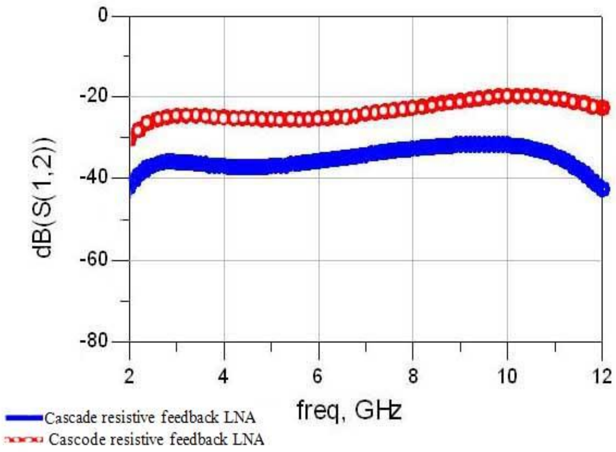

Fig. 10. Simulated S_{12}

TABLE II. COMPARISON OF THE PROPOSED UWB LNAS WITH EACH OTHER AND WITH OTHER REPORTED WIDEBAND LNA.

Ref.	**Tech**	**Bandwidth (GHz)**	**S_{21} (dB)**	**S_{11} (dB)**	**NF (dB)**	**Supply (v)**	**Power (mw)**
2007[9]	0.18(µm)	3.1-10.6	9.2-7.4	<-9.7	4.1-7	1	23.5
2008[11]	0.18(µm)	0.7-6.5	12.5	-11	3.5-4.2	1.8	-
2010[12]	0.18(µm)	3.1-10.6	15	<-7	4-4.4	1.8	21.5
2007[13]	0.18(µm)	3.1-10.6	9.7-7.5	<-11	4.5-5.1	1.8	29
2011[14]	0.18(µm)	3.1-10.6	6.8-10	-7	3-7.1	1.8	21.5
This work (cascade design)	**0.18(µm)**	**3.1-10.6**	**17**	**<-10**	**2.7**	**1.5**	**26**
This work (cascode design)	**0.18(µm)**	**3.1-10.6**	**11**	**<-14**	**2.4-4**	**1.8**	**26**

IV. CONCLUSIONS

In this paper two different resistive feedback LNAs have been designed and simulated in 0.18µm CMOS process. It is observed that in same power consumption, the gain of cascade resistive feedback topology is higher than cascode one. While the S_{11} parameter in cascode resistive feedback LNA is better. Both LNAs have good performance in terms of noise figure. The number of elements in the cascode LNA is less than cascade LNA.

REFERENCES

[1] Revision of part 15 of the commission's rules regarding ultra-wide-band transmission systems. Federal Communication Commission, Washington, DC, First Report and Order, 2002.

[2] K. H. Chen, J. H. Lu, B. J. Chen, and S. I. Liu, An Ultra wideband 0.4-10 GHz LNA in 0.18µm CMOS, IEEE Transaction on circuits and systems, vol. 54, No. 3, March, 2007.

[3] S. S. Kim, Y. S. Lee, and T. Y. Yun, High gain wideband CMOS low noise amplifier with two stage cascade and simplified chebyshev filter, ETRI Journal, vol 29, No., October 2007.

[4] A. Bevilacqua and A. M. Niknejad, An ultra-wideband CMOS LNA for 3.1 to 10.6GHz wireless receivers, IEEE International Solid-State Circuits Conference, vol. XVII, pp. 382 - 383, Feb, 2004.

[5] Rozi Rifin, Mamun, Syedul Amin and Hafizah Husain, Design of an Inductor-Less LNA Using Resistive Feedback Topology for UWB Applications, Research Journal of Applied Sciences, 2012

[6] P. R. Gray, P. J. Hurst, S. H. Lewis, and R. G. Meyer, Analysis and Design of Analog Integrated Circuits, 4th ed. NewYork: Wiley, 2001

[7] Bevin G. Perumana, Jing-Hong C. Zhan, Stewart S. Taylor, Brent R. Carlton, Joy Laskar, "Resistive-Feedback CMOS Low-Noise Amplifiers for Multiband Applications," IEEE Transactions on microwave theory and techniques, , vol. 56, no. 5, May 2008

[8] Sudip Shekhar, S. Walling, David J. Allstot, Bandwidth Extension Techniques for CMOS Amplifiers, IEEE Journal of Solid-State Circuits, November 2006

[9] Hickman, R. W. and Hunt, F. V., "On Electronic Voltage Stabilizers," Review of Scientific Instruments, vol. 10, p. 6-21 (January 1939).

[10] Ruey-Lue Wang, Min-Chuan Lin, Chih-Cheng Lin, Cheng-Fu Yang, A 1V Full-band Cascoded UWB LNA with Resistive Feedback, IEEE International Workshop on Radio-Frequency Integration Technology, Dec 2007

[11] Jianyun Hu, Yunliang Zhu, and Hui Wu, An Ultra-Wideband Resistive-Feedback Low Noise Amplifier with Noise Cancellation in 0.18μm Digital CMOS, IEEE Topical Meeting on Silicon Monolithic circuits in RF Systems (SiRF), 2008.

[12] A. I. A. Galal, R. K. Pokharel, Haruichi Kanay, Keiji Yoshida, Ultra-wideband Low Noise Amplifier with Shunt Resistive Feedback in 0.18μm CMOS Process, IEEE Topical Meeting on Silicon Monolithic circuits in RF Systems (SiRF), 2010.

[13] Chih-Fan Liao, Shen-Iuan Liu, A Broadband Noise-Canceling CMOS LNA for 3.1–10.6-GHz UWB Receivers, IEEE Journal of Solid-State Circuits, vol. 42,no.2, pp.329-339, Feb. 2007.

[14] Pou-Tou Sun, Tzu-Wei Yang Ssu-Chieh Chan, Ying-jui Chuang, Using Shunt Resistive-Feedback to Design 3.1GHz-l0.6GH Ultra-Wideband Low Noise Amplifier with Shunt Resistive Feedback, Cross Strait Quad-Regional Radio Science and Wireless Technology Conference, 2011.

