Design of 2-8 GHz Ultra-Wideband LNA Using 0.18 µm CMOS Technology

[1]Kusuma MS, [2]Dr S Shanthala

[1]Department of Electronics and Communication Engineering
[1]Govt. S.K.S.J.T. Institute, Bangalore, India.

[2]Department of Telecommunication Engineering
[2]Bangalore Institute of Technology,Bangalore, India.

***Abstract*— This paper presents a Low Noise Amplifier (LNA) using Common Gate (CG) topology for use in Ultra Wide Band (UWB) Wireless Sensor Networks (WSN). The matching network is composed of series L_{s1}-R_{s1} in series with a parallel L_{s2}-R_{s2} to enhance the bandwidth at the input of the circuit. The high gain (S_{21}) is achieved by using the inductor L_C and the peaking inductor L_{D2}. In addition, low NF is achieved. The LNA circuit is implemented using the 0.18µm process and the simulated result of S_{11} is below -8.0dB while a maximum forward gain (S_{21}) of 18.6dB is achieved. The supply voltage for the LNA is 1.2V and has minimum Noise Figure (NF_{min}) of 2.649dB. The output reflection coefficient S_{22} is below -10dB.**

Keywords—LNA, common gate, wireless sensor networks, UWB, S-parameters, noise figure.

I. INTRODUCTION

The overwhelming technological advancements have reduced the CMOS device dimensions considerably [1]. As Moore's Law carries on, we can expect to continue doubling transistor density every two years for the next several years. We will evolve from integrating multiple cores on a chip to integrating many cores. Power consumption will continue to be a primary consideration. The new era of scaling is one where material and structure innovation are just as important as dimensional scaling [2]. Hence, for system-on-chip (SOC) designs, the ability to integrate digital, analog and RF building blocks with low power consumption is an acute necessity.

The Federal Communications Commission in USA (FCC) has defined an UWB device as any device with a –10 dB fractional bandwidth, greater than 20% or occupying at least 500MHz of the spectrum and authorized this technology for commercial use in 2002 [3]. UWB has been the emerging broadband wireless technology that promises connectivity within the 3.1–10.6 GHz band. It has been of great significance for the academic and industrial communities to explore better methods to realize UWB transceiver using the "continually shrinking" CMOS technologies.

A more recent approach to UWB is a multiband system. The Multiband OFDM (MB-OFDM) and alliance (MBOA) were formed in June 2003 to support an UWB specification based on OFDM. According to the MBOA and WiMedia specification, the UWB spectrum is segregated into 14bands, each having a bandwidth of 528MHz. The first 12 bands are then congregated into four band groups comprising of three bands each, and the last two bands are grouped into a fifth band group, as shown in Fig. 1.

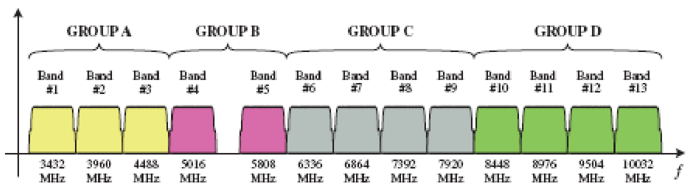

Fig.1 UWB frequency plan.

Low Noise Amplifier (LNA) is an inevitable component of a wireless receiver required to provide adequate gain, wideband input and output matching and low Noise Figure (NF). The various UWB LNA topologies like the distributed, feedback and common gate (CG) [4] amplifiers have been reported to meetthe aforementioned needs of a desired system.The CMOS UWB LNA architectures using common gate technology achieve wideband input match and absorb less parasitic capacitances and are less affected by process variations. The CG LNAs have better linearity, low power consumption and better input-output isolation when compared to the common-source LNAs. The proposed CG LNA architecture consists of new Input Matching Network (IMN) with series L_{s1}-R_{s1}in series with parallel L_{s2}-R_{s2} to enhance the input matching bandwidth.

This paper is organized into following sections where a brief introduction of wireless sensor networks is given in section II followed by the principle and functioning of common gate input matching technique with the circuit design in section III. The simulation results of the LNA are tabulated in section IV which are obtained using Advanced Design System.

II. Wireless Sensor Network

A sensor network is an infrastructure comprised of sensing i.e. measuring, computing, and communication elements that gives an administrator the ability toinstrument, observe, and react to events and phenomena in a specified environment. The environment can either be the physical world, a biological system, or an Information Technology (IT) framework [5].

A Wireless Sensor Network can be defined as a network of devices or sensors, represented as nodes, which are able to sense the surrounding environment and communicate the gathered information from the field under check. The data is sent, possibly via several hops, to a sink which on occasions is represented as a monitor or controller that can use it in the vicinity or is connected to other networks such as the Internet through a gateway for instance. The nodes can be stationary or moving. They can either be aware of their location or not even they can be homogeneous or not [6].

The goal of wireless sensor network engineers is to developa standards orientedinexpensive wireless networking solution that has low power consumption, supports low-to-medium data rates, high forward gain and guarantees security and reliability.

III. Circuit Design

Fig. 2 shows the proposed CMOS UWB LNA utilizing the Common-Gate (CG) topology [9]. The CG LNAs have become popular because of their simple input matching network, better linearity and low power consumption. A parallel inductor (L_{S1}) is used as the IMN of a CG LNA. The inductor L_{s1}resonates with the gate source capacitance (cgs1) of the CG input transistor at high frequency of ω_0. The wideband input impedance matching at frequencies around $\omega_0$can be achieved if the transconductance (g_{m1}) of the CG input transistor is roughly equal to the inverse of the source resistance (20 mS). Since L_{S1}exhibits a nearly zero voltage drop at DC and g_m(or gate width) is relatively small, low power consumption can normally be achieved.

The drawbacks of using L_{S1}only in IMN of CG LNA are the poor input impedance matching at low frequencies and the not-flat-enough NF over the particular range of frequencies.The low-power, flat and high S_{21}, flat and low NF, and wideband input impedance matching can be achieved for a CG LNA with the new architecture, in which theinput matching network consisting of a series L_{S1}-R_{S1}in series with a parallel L_{S2}-R_{S2}, is used to enhance the input matching bandwidth.This is mainly attributed to the inputmatching improvement at low frequencies due to the non-zeroinput impedance at DC (about 20.6 Ωin current work). In addition flat and high gain is achieved by using the connecting inductor $L_C$and the peaking inductor $L_{D2}$to compensate the gain loss at medium-frequency and highfrequency, respectively.

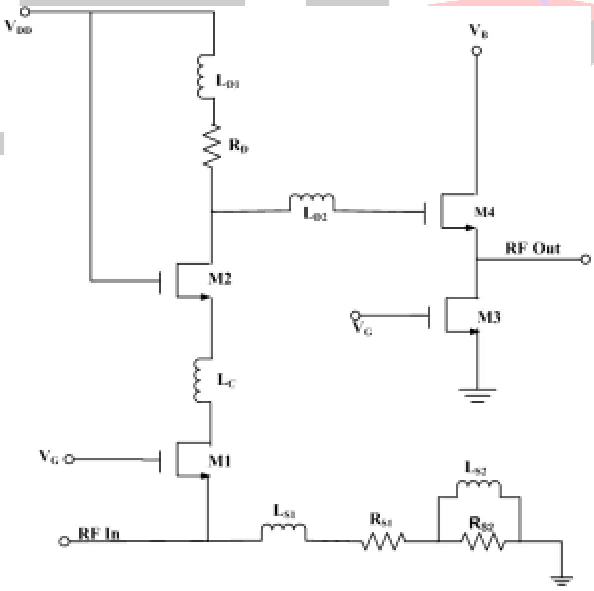

Fig.2 Proposed LNA circuit.

IV. Simulation Results

The proposed Low Noise Amplifier is simulated using CMOS 0.18µm process. By employing common gate topology for IMN in the LNA, the supply voltage V_{DD} = 1.2V. The bias voltage $V_B = V_{DD}$ = 1.2V and V_G = 0.7 V. All the LNA results are simulated using Advanced Design System Tool Version 2016.01 from KEYSIGHT TECHNOLOGIES.

The Low Noise Amplifier operates in 3-6GHz band and has an input reflection coefficient S_{11} below -8dB over the frequency band of interest as shown in Fig. 3 which indicates reasonably acceptable input matching.The forward-gain S_{21} of the Low Noise Amplifier is found to have a maximum value 18.797dB at a frequency of 3.66GHz which is shown in Fig. 4.

Fig. 4 also depicts the achieved noise figure of the proposed low noise amplifier. The minimum noise figure obtained for the LNA is 2.649 dB at 3.445GHz and the noise figure is below 4dB in the frequency band of interest. The output reflection coefficient $S_{22}$is also shown in Fig. 3. The output reflection coefficient S_{22} is below -11dB in the desired frequency band. The LNA provides very good reverse isolation as the use of the CG topology removes the Miller effect.

Table 1 shows the summary of simulated wideband LNA and the other UWB LNAs reported in the literature. Compared to other work this CMOS LNA has larger gain and lower NF. The result shows that the proposed CG LNA architecture is suitable for 2-6 GHz wideband frequency wireless system applications.

TABLE1. Performance comparison.

Parameter	**This Work**	[7], 2008	[8], 2008	[9], 2013	[10], 2014
Technology	**0.18µm**	65nm	0.18µm	0.18µm	0.18µm
Supply Voltage(V)	**1.2**	1.2	1.8	1.2	1.8
Frequency(GHz)	**2-6**	0.2-5.2	2-6	3.6-11.2	3-10
S_{11}(dB)	**<-8**	<-10	<-10	<-10.2	<-10.7
S_{21}(dB)	**10-18.6**	13-15.6(0.2GHz-5.2GHz)	12	11-14.5	13.7±1.5
NF_{min}(dB)	**2.64-3.3**	3.5-4.0 (0.1GHz-6GHz)	4.4-6.7	3.72	2.3±0.1

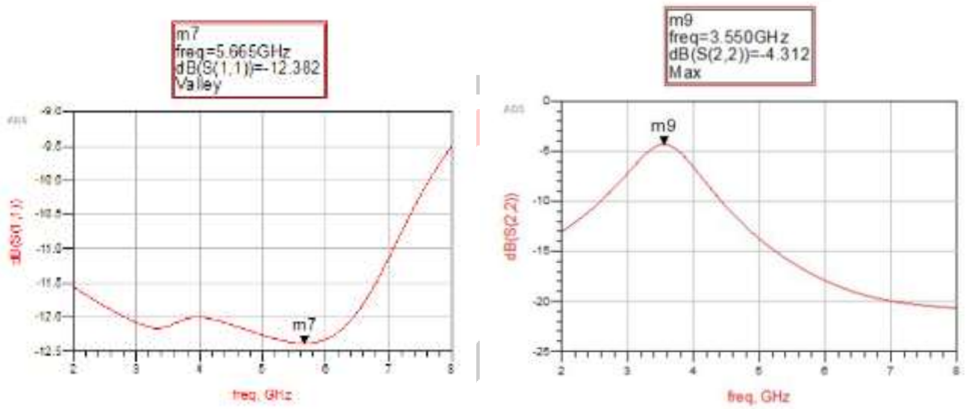

Fig. 3 Input Reflection Co-efficient (S_{11}) and Output Reflection Coefficient (S_{22}).

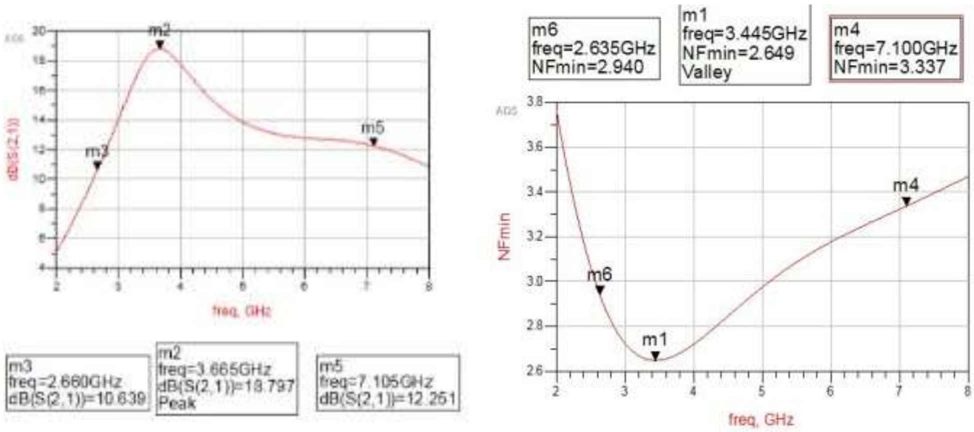

FIG.4 FORWARD GAIN (S_{21}) AND NOISE FIGURE (NF_{MIN}).

V. CONCLUSION

In this paper, a Low Noise Amplifier is presented for whose application is in the front end of RF receivers to be used in wireless sensor networks. The LNA is based on common gate technique with new matching network to enhance the input matching bandwidth. As discussed, the high S_{21} and low NF is achieved by connecting suitable values of L_c and L_{D2}. The proposed CG circuit architecture of low noise figure along with a high gain makes the LNA useful in ultra wide band wireless networks.

REFERENCES

[1] M. Khurram and S. M. R. Hasan, "A 3-5 GHz Current-Reuse g_m Boosted CG LNA for Ultrawideband in 130 nm CMOS," in *IEEE Transactions on Very Large Scale Integration (VLSI) Systems*, vol. 20, pp. 400-409, 2012. doi: 10.1109/TVLSI.2011.2106229

[2] Yuhua Cheng, M. Jamal Deen and C.H. Chen, "MOSFET Modeling for RFIC Design," in *IEEE Transactions on Electron Devices*, vol. 52, No. 7, July 2005, pp 1286-1303.doi: 10.1109/TED.2005.850656

[3] FCC, Washington, DC, "First report and order, revision of Part 15 of the commission's rules regarding ultra wideband transmission systems," DC ET Docket 98-153, 2002.

[4] K.-H. Chen, J.-H. Lu, B.-J. Chen, and S.-I. Liu "An Ultra-Wide-Band 0.4–10-GHz LNA in 0.18-μm CMOS", *IEEE Trans. Circuits Syst. II:* Exp. Briefs, vol. 54, no. 3, pp. 217-221, Mar. 2

[5] K. Sohraby, D. Minoli and T. Znati, "Wireless sensor networks" Hoboken, N.J.: Wiley-Interscience, 2007.

[6] C. Buratti, A. Conti, D. Davide, and R. Verdone, "An Overview on Wireless Sensor Networks Technology and Evolution in Sensors", vol. 9, no. 9, pp. 6869–6896. August 2009.

[7] S. C. Blaakmeer, E. A. M. Klumperink, D. M. W. Leenaerts and B. Nauta, "Wideband Balun-LNA With Simultaneous Output Balancing, NoiseCanceling and Distortion-Canceling", *IEEE J. Solid-State Circuits*, vol. 43, no. 6, pp. 1341-1350, Jun. 2008.

[8] Tommy K. K. Tsang, Kuan-Yu Lin, and Mourad N. El-Gamal, "Design Techniques of CMOS UWB Amplifiers for Multistandard Communications" *IEEE Transactionson Circuits and systems-II:* Express Briefs, Vol. 55, No. 3, March 2008. pp. 214-218.

[9] Chang C. T. and S. Wang, "A low-power CMOS low-noise amplifier for ultra-wideband applications" *in Electronic Devices and Solid State Circuits (EDSSC), 2013 IEEE International Conference*.

[10] Yo-Sheng Lin, Chien-Chin Wang, Guan-Lin Lee, and Chih-Chung Chen "High-Performance Wideband Low-Noise Amplifier Using Enhanced π-Match Input Network", *IEEE Microwave and Wireless Components Letters*, Vol. 24, No.3, March 2014, pp. 200-202

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