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HIGH FIDELITY LOW-NOISE AND LOW-POWER AMPLIFIERS (HIFI-LNLPA) FOR DIFFERENT RECEIVERS: A REVIEW

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ABSTRACT
Low Noise Amplifiers (LNA)are the basic building blocks of different communication systems, instrumentation and computation systems.To sense the weak signal with high fidelity, low noise amplifiers plays vital role. Low noise amplifiers have variety range of applications in different receivers. For LNA design,Noise Figure, Gain, Bandwidth, Proper Biasing Conditions, Selection of Transistor, Third Order Intercept Point, Good Sensitivity, Good Linearity and Good Dynamic Range are considered. In this paper, we present different low-noise, low-power amplifier circuit'stopology and corresponding parameters comparison review for different receiver applicationsin different fields with low noise, low power, excellent gain and linearity

Keywords: *LNA, TIA, LIDAR, High-Fidelity (Hi-Fi), MPI, LADAR, CRCI, CdZnTe, PSRR.*

I. INTRODUCTION

Every receiver application requires high-fidelity (Hi-Fi) reception feature in communication systems, Instrumentation and computation systems. The high fidelity is achieved with low noise, high gainand low power consumptionparameters for any receiver operation.Optical communication systems solve the bottleneck problem of data rates in many communication systems but with high fidelity optical receivers which is the main device of the entire optical fiber communication link or networks. A Pre-amplifier is designed with high bandwidth, low power consumption, low noise and is fabricated on 0.18um SiGe BiCMOS process for optical receivers [1]. In linear laser detection and ranging (LADAR) systems, light signal is transmitted onto the target and reflected back to the detector with very minimum amplitude of micro amperes which has to be amplified further to process with the trans-impedance amplifier. An eight-channel inverter voltage-mode trans-impedance amplifier is designed in 0.18µm CMOS technology for the applications of linear laser detection and ranging (LADAR) systems with excellent gain, bandwidth, noise, crosstalk, and good power consumption parameters [2].

Photo detectors (Phototransistors, PINdiodes and Avalanche photo diodes) can convert optical signal to electrical signal, but signal amplitude is weak in amplitude, so the signal can be amplified by a trans-impedance amplifier (TIA) which amplifies the signal and the amplified signal is in the form of current and conversion of the current to voltage is performed.A design with an equivalent input noise current of 3 pA per is considered and madethis design suitable for low noise LIDAR applications [3]. In high-speed wireless communications systems like wireless LAN or wireless PAN, an integrated technology should be considered to provide high data rates for transmitting audio, video and high bandwidth data at low cost and power in ultra wide band range. A combination of a common source and common gate stage is one of the best suitedoptions for ultra wide band (UWB) based IEEE802.15.3a wireless LAN (WLAN) applications and is fabricated on0.18 µm standard RF CMOS technology [4]. A design scenariowhich is used for ultra-wide-band applications with good stability, linearity, low noise characteristics are achieved by considering RC feedback in low noise amplifier (LNA) structure and is fabricated on0.18 radio frequency CMOStechnology[5].Achieving high-sensitivity of Magnetic Particle Imaging (MPI) receiver coil using BJT amplifier is minimum, but with the FET amplifier low noise and large bandwidth matching can be achieved.

A reasonable compromise between low noise figure (NF) and usable bandwidth is required from afront-end amplifier design process, in which noise-matched at abandwidth of 250 kHzto a high-inductance, high-sensitivity MPI receiver coil for Magnetic Particle Imaging (MPI) and is realized with 32 parallel ADA4817 operational amplifiers[6].In implantable integrated neural recording systems, observing neurons extracellular activities requires low input noise current and also low power and thermal dissipation amplifiers.A topology that combines supply sensitive single ended first stage with a shared reference channel and a differential second stage to cancel out feed-in noise uses low power of single-ended amplifiers with improved supply rejection and is fabricated on 90nm CMOS process[7].In preamplifier shaper circuit's design, capacitive detectors are used for signal amplification and also shaping by converting received photon energy to charge. A low-noise and low-power circuit is designed for Cadmium Zinc Telluride (CdZnTe) detectors and is fabricated in a 0.13μm CMOS technology for Medical Imaging, Security, and Astrophysics applications [8].

This paper is organized as follows: review of various research methodologies used to reduce noise figure, increase gain and bandwidth, and minimization of powerconsumption using various low noise and low power amplifiers are described in Section II.

Then implementation of methodologies for different receiver applications have been discussed in section III, Comparison of some of recently used technologies is given in Section IV. Finally,the concluding remarks are been given in Section V.

II. RELATED RESEARCH METHODOLOGIES DESIGN CONCEPTS FOR DIFFERENT RECEIVER APPLICATIONS

A. Optical Receivers

In the design structures of the differential pre-amplifier of optical receiver, a high gain, high speed, low noise differential preamplifier, a three-stage differential post-amplifier and an output bufferstages are considered to obtain low noise parameter.

Preamplifier transforms the weak current signal generated by photo detector to voltage signal and amplifies it to override the noise of the next building block in the design structure. Post amplifier is designed to amplify the signal at the output of preamplifier to work with a clock and data recovery circuit.

B. LADAR Systems

In this design approach, voltage mode and current mode amplifiers are designed with different number of channels and concluded that voltage mode trans-impedance amplifier is best suited for the applications of linear laser detection and ranging (LADAR) system with very good gain, bandwidth, noise, crosstalk, and power consumption parameters.

C. LIDAR Applications

Anexcellent trans-impedance amplifier should possess high gain, high input resistance, ultra-low voltage and current noise, and low input capacitance. It should have a FET or MOS input stage to meet above mentioned requirements. The output of the trans-impedance amplifier is generally converted to a differential signal and amplified before analog to digital or digital to analog A-D or D-A conversion process.

D. Wireless LAN (WLAN) Applications

A design with low noise amplifier (LNA) performs the initial amplification in the radio frequency (RF) receiver and over an ultra-wideband (UWB) based on the 0.18 μm standard RF CMOS process technology and the noise from the process is decreased across the ultra-wide band and also using the derivative method, the third order intercept factor is improved further.

E. Ultra Wide-Band (UWB) Applications

For UWB systems, to obtain optimum gain and noise figure, a design with current resistor-capacitor (RC) feedback arrangement is provided in LNA stages. In the LNA design, comparatively with the bipolar configurations, FET configurations are well suited for UWB applications.

F. Magnetic Particle Imaging(MPI) Receiver

In view of the fact that the low resistance and highinductance of Magnetic Particle Imaging (MPI) receiver makes low Noise Figures (NF) difficult to achieve over a large bandwidth using BJT-based amplifiers due to high reverse saturation orcurrent noise, with the helpof low-noise FET amplifiers larger-bandwidth noise relation can be obtained.

G. Neural Recording in Medical Applications

A design strategy utilizing a Current-reuse complimentary-input (CRCI) topology and reference-sharing architecture is considered to achieve high power and good efficiency in the first stage but reduction in power supply rejection ratio (PSRR) but with second stage.

Also operational trans-conduction amplifier with capacitive feed-back improved PSRR can be achieved, which is suitable for implementing a neural recording amplifier array with ultralow-power low-noise operation.

H. Cadmium Zinc Telluride (CdZnTe or CZT) Detectors in Medical Imaging, Security, and Astrophysics

In this design process, the power consumption of the circuit is just below 1 mW from applied supply voltage of 1.2 V and the design is well suited for Medical Imaging, Security, and Astrophysicsapplications because of strict requirements of detector are needed for above mentioned applications. The design uses charged capacitor detector which performs the conversion of received photon energy to charge then after signal amplification and shaping.

III. IMPLEMENTATION OF METHODOLOGIES FOR DIFFERENT RECEIVER APPLICATIONS

The following methodologies and corresponding implementations are given with different technologies or topologies for different receiver applications by considering certain specifications as:

- For optical receiver application, 0.18µm SiGe BiCMOS technology is used at 13.22GHz and 15 GB/s, with power dissipation of 38mW and trans-impedanceof 87.3dBΩ.
- For LADAR systems using 8-channel TIA, 0.18µm CMOS technology is used at 1200MHz and 1.8Gb/s, with excellent cross talk of -23dB, good linearity and power dissipation of 10mW.
- For LIDAR applications using operational trans-impedance amplifier,LMH6624 wideband op-amp technology is used from DC to 150MHz with SNR of -27.43dB, noise current of 3pA, power dissipation around 0.85mW and also stability is optimized.
- For WLAN applications in ultra wide band, 0.18 µm standard RF CMOS technology is used from 3.1 to 10.6 GHz with power gain of 14 ± 0.8 dB, Noise figure of 2.66 to 3 dB, power consumption of 27.3 mW and 3rd order intercept point is also improved with technology.
- For Ultra wide-band applications, LNAs are designed in 0.18µm CMOS technology from 3 to 5GHz using current reuse and common source topology which offers power gain of 12.7dB, power consumption in the range of 11.7 to 12.5dB, noise figure of 2.3dB and with the use of common source topology in the second stage of the design stability and good linearity is improved.
- For Magnetic Particle Imaging Receiver, 32 parallel ADA4817 operational amplifiers are considered in the design at 250 KHz band width low voltage noise of 0.9 nV per 3dB, with the use of inductive sensor coils noise figure of 3.3dB at 250KHz and 11dB 600KHz is achieved and gain of 30.10dB.
- For Neural Recording Applications with Bio-potential Amplifier, 90 nm CMOS technology isused from0.49 KHz to 10.5 KHz with pass band gain of 58.7 dB, per channel power consumption of 2.85 µW(per channel), power supply rejection ratio greater than 50 and noise efficiency factor is 1.9 by using current reuse complimentary input topology, to improve efficiency of the design.
- For Medical Imaging, Security, and Astrophysics Applications,0.13-µm CMOS process is used, which offers power consumption of 1mW with 1.2v power supply, charge sensitive sensor amplifier dark current is in terms of less than 50nA and design uses pulse shaper circuit gives four different outputs varies from108ns to 1.1µs peak times.

IV. COMPARATIVE RESULTS FROM DIFFERENT TECHNOLOGIES

Table I demonstrates comparison between different technologies/topologies with Gain/SNR in dB, Noise current and voltage/Noise figure, power for different applications. From table, it is observed that power consumption varies from 1mW to 38.6 mW, Noise parameter is also very minimum and gain parameter varies from positive to negative in dB for different receiver applications.

Table I: Comparison Of Different Technologies/Topologies

S.No	Technology/Topology	Gain(dB)/SNR(dB)	Noise Current/ Noise Voltage/Noise Figure	Power (mW)	Application(s)	Ref.	Year
1.	0.13-µm CMOS process.	-30.79	50nA dark current	1	Medical Imaging, Security, And Astrophysics	[8]	2016
2.	90 nm CMOS Bio-potential Amplifier	58.7	$3.04\mu V_{rms}$	2.85 µW (per channel)	Neural Recording	[7]	2015
3.	32 parallel ADA4817 operational amplifiers	30.10	0.94 nV/3dB	30.8	Magnetic Particle Imaging Receiver	[6]	2015
4.	0.18µm CMOS low noise amplifier	12.7	3dB	11.7 to 12.5	Ultra wide-band applications	[5]	2014
5.	0.18 µm standard RF CMOS technology	14 ± 0.8	2.66 to 3 dB	23.7	WLAN applications	[4]	2014
6.	LMH6624 wideband op-amp	-27.43	3 pA	0.85	LIDAR	[3]	2014
7.	0.18µm CMOS technology	65	Cross talk = -23dB	10	LADAR Systems	[2]	2013
8.	0.18µm SiGe BiCMOS	87.3	1.71 µA	38.6	Optical Receiver	[1]	2012

V. CONCLUDING REMARKS

Review on different LNA/LPA with varying parameters is presented in this paper. We have reviewed different technologies/topologies used in different applications which include reduced noise currents/voltages, increased gain and decreased power consumption. Different technologies are used for implementing the different designs of LNA/LPA for different receiver applications have been given in the Table I.

- For Optical receiver, LADAR and LIDAR system's high performance, LNLPA's dark current and internal capacitance is to be considered.
- For UWB applications, in the design, input impedance improvement is done by considering instrumentation amplifier in the first stage of the design.
- For MPI receiver applications, noise figure in the design, for larger range may be improved by using stagger tuned amplification process.
- For Neural recording application, in the design, improvement in noise efficiency parameter may be improved by distributing supply voltage to many numbers of channels.
- For Medical Imaging, Security, and Astrophysics applications, in the design, capacitive sensor time constant also depends on the photo detector's internal capacitance, quantum limit, resposivity which affect the pulse shaper timings.

Finally, some of the mentioned Hi-Fi LNLPA technologies or topologies are provided with the optimal design specifications like low noise and low power, best suited for different receiver applications.

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