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Implantable Devices with Reconfigurable Biosensing Analog Front End

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Abstract. This paper, have a tendency to develop a reconfigurable analog front end for wireless body sensing element nodes and implantable devices with reduced size. By converting voltage in to current the effort to achieve the area efficiency is taken. Because these are bio implantable chips if the numbers of transistors are reduced it will reduce lots of power and area, the circuit operation is also quick. In the proposed system, narrow swing current mirror circuit is used in the low pass filter region. By using the current mirror the same input current can be obtained at the output. At the same time the area of the chip used in the devices gets reduced. The active space of the chip is 157μm^2.

Keywords: Wireless Body Sensing element Nodes (WBSNs), Implantable Devices, Biopotential signals, Transconductance Low Pass Filter.

1. Introduction

Wireless Body Sensing element Nodes (WBSNs) are the sensor nodes which is used for monitoring the health condition of the human body without the use of wire connection. These Wireless Body Sensing element Nodes are able to be implanted in to the body or can also wearable. Sensing element in WBSNs monitors the actions and the activities of human in a continuous manner. In medical field, WBSNs are used for different applications such as patients can be monitored at home, hospital, or at any places.

Physical and Physiological sensors of WBSNs are mostly used by physical condition devotee who likes to know about their health and to increase their health. This type of sensor can worn by athlete can be used to observe the bodily behaviour of the athlete by the coach while performing the cardiovascular exercise. WBSNs have a spacious range of applications in the military. The sensing elements and actuators, which are worn on the soldiers body helps the commander to know about the location of the soldiers when they are in the theatre of war and can be also be used to send commands to the soldiers in concurrent.

In reconfigurable Analog Front End, biopotential signals with diverse bandwidths and amplitudes will be captured by WBSNs from various parts of the body. The Analog Front End region is used for collecting the clear details about the information done by biopotential signals. For an ultralow power AFE the most important design factor is amplifier linearity. The amplitude of biopotential signals varies from tens of micro volts to few mill volts. The area of the chip used for implantable devices and for Wireless Body Sensing element Nodes should be as small as possible. When the area of the chip is reduced the power consumption of the chip will also be automatically reduced. The input current remains constant due to the characteristics of the narrow swing current mirror.

With the purpose of the challenges which are mentioned above, this paper says about the reconfigurable Analog Front End which has its benefits over the Wireless Body Sensing element Nodes which will be used for most of the implantable devices.

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The remaining portion of this paper is prearranged as follows: Part 2 describes about the survey of recent researches on field. Part 3 details the proposed work. Part 4 says about the results and related discussions. And finally conclusions are said in Part 5.

2. Survey of Recent Researches on Field

Targeted Muscle Reinnervation (TMR) and Time Division Multiple Access (TDMA) [1] are used inorder to control the upper limb for wireless prosthesis control system. This prosthesis is an implantable device which is used in the recovery of the upper limb. The drawback found here is that it has lower lifetime and it can transmit less amount of data at a time. Radio Frequency Identification (RFID) Technology along with Electromyography (EMG) [2] can also be used in prosthetic arm. But here it is used only for a particular muscle. Due to the usage of these techniques it has somewhat larger size; by using antenna decoupling method the size can be reduced. A separate gain stage is added to improve the sensitivity of the receiver. Electrocardiography (ECG) and Capacitive Feedback Chopper Stabilized Instrumental Amplifier (CCIA) [3] are mainly used in the heart region. It is designed with 2 cm for the heart of the sheep and for human it is about 5 cm. The main disadvantage found over here is the quality of the signal gets degraded due to the impedance change which occurs due to the movement of the body occurs between patch and the skin.

Electrocardiography (ECG) acquisition Chip with fully integrated lossless compression engine [4] has only one application that it can be used only for wearable devices. It cannot be used in implantable devices. Since it has the applications over wearable devices it consumes large amount of power. Multi-node Synchronization uses Time Division Multiple Access (TDMA) protocol [5] is mainly used for measuring temperature in the abdominal region. These are battery less and while harvesting the energy they received signals and the received signals are transmitted to the base station. The application of this system can be verified only by using the temperature of the abdominal region under room temperature. Magnetic Resonant Coupling Method [6] is used for transferring the power without the use of wire. Since it is a wireless method it is applicable only for a fixed distance and for where it gets directed. That is the efficiency of the system gets reduced rapidly when the receiver is stirred left from its most favourable working spot.

Local Data Processing and 12-bit Successive Approximation Analog to Digital Converter [7] are designed with Bluetooth protocol which is used for ECG monitoring system which is portable. In this artifacts may occur, the presence of these artifacts may lead to poor quality of signal and wrong experimental analysis. Neural Probe technology [8] contains active electrodes of count 455 and parallel recording channels of about 52. By using this Neural Probe Technology the implantable devices can be inserted in neurons. Since, the insertion is done in the brain it will damage many neurons during the insertion. Microsystems Integration and Packaging skills [9] were used for fetching information for deepest part of the brain. For neural activities, this wireless neural recording is quite critical since the signals should be recorded from hundreds of neurons.

3. Proposed Work

The block diagram of the chip which is used in the proposed system is shown in Figure 1. The structure consists of three blocks. They are Power Management Unit (PMU), Analog Front End (AFE) and a clock. These blocks are connected with an electrode. The Power Management Unit contains Band gap Reference (BGR) circuit, voltage regulators with 1.4 V and 1V and along with this Bias Current Reference is also present. The Analog Front End region contains Low Noise Amplifier (LNA), a Programmable Gain Amplifier (PGA) and G_m-C Low Pass Filter (LPF). The electrodes are connected with low noise amplifier which is followed by programmable gain amplifier. This programmable gain amplifier is connected with the G_m-C Low pass filter. The clock oscillator consists of a process compensator, a clock and a divider. The Analog Front End and the clock oscillator are interconnected by a Successive Approximation Register (SAR) ADC. The main goal for designing ADC is low region occupation.

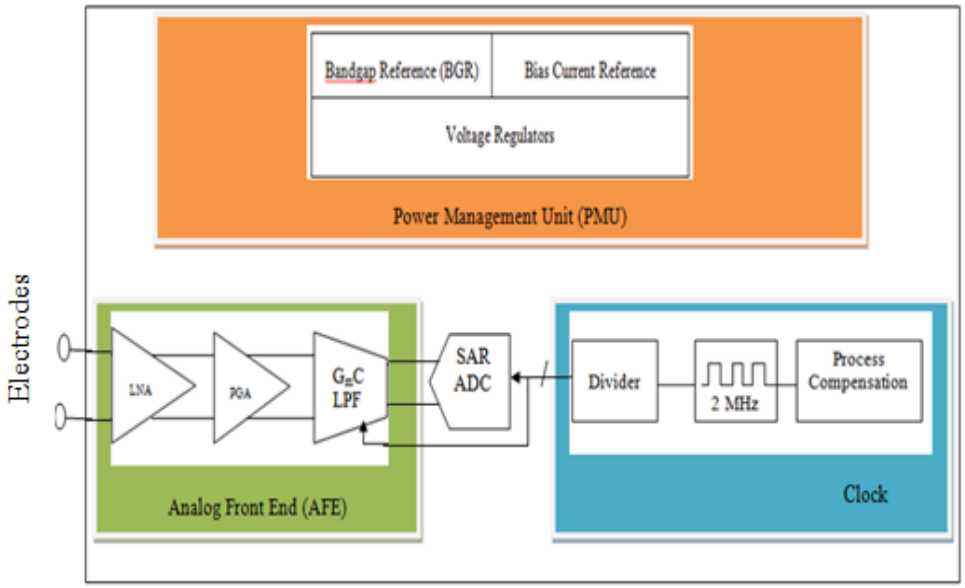


Figure 1. Block diagram for the chip used in implantable devices.

3.1 Analog Front End

The size reduction of the chip can be achieved by designing the apparatus such as Low Noise Amplifier, Low Pass Filter and Programmable Gain Amplifier. The involvement of amplifier is higher than the other stages. Low Pass Filter removes the signal errors related to the speed of Low Noise Amplifier. Inorder to reduce the size of the chip, theconcentration will be only on Low Noise Amplifier and the Low Pass Filter block. These blocks are discussed in detail below.

3.1.1. *Low Noise Amplifier*

The schematic diagram of Low Noise Amplifier is shown in Figure 2. It consists of two parts. One is Folded Cascade Operation Transconductance Amplifier (FC OTA) and the other part is Common Mode Feedback Circuit (CMFB).

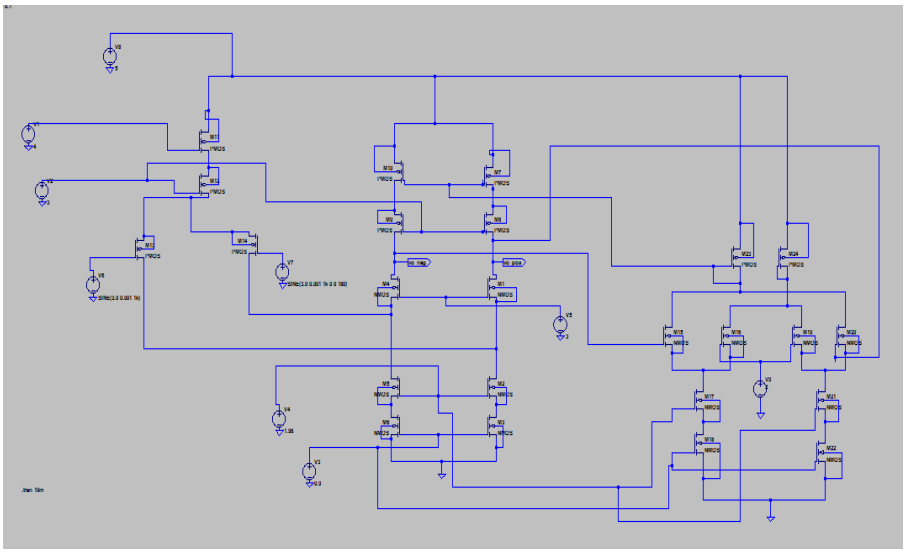


Figure 2. Schematic diagram of Low Noise Amplifier.

The transconductance of the input differential transistors M_1 and M_2 has to be maximized. At the same time, the transconductance of the transistors M_5, M_6, M_{13} and M_{14} has to be minimized. By using cascade transistors such as M_{11} and M_{12}, the effective transconductance can be increased more by boosting the impedances. This will be more useful for eliminating the use of bulky source degeneration resistors which is used by current sink transistors. By the elimination of these resistors

will lower the area which it actually occupies.

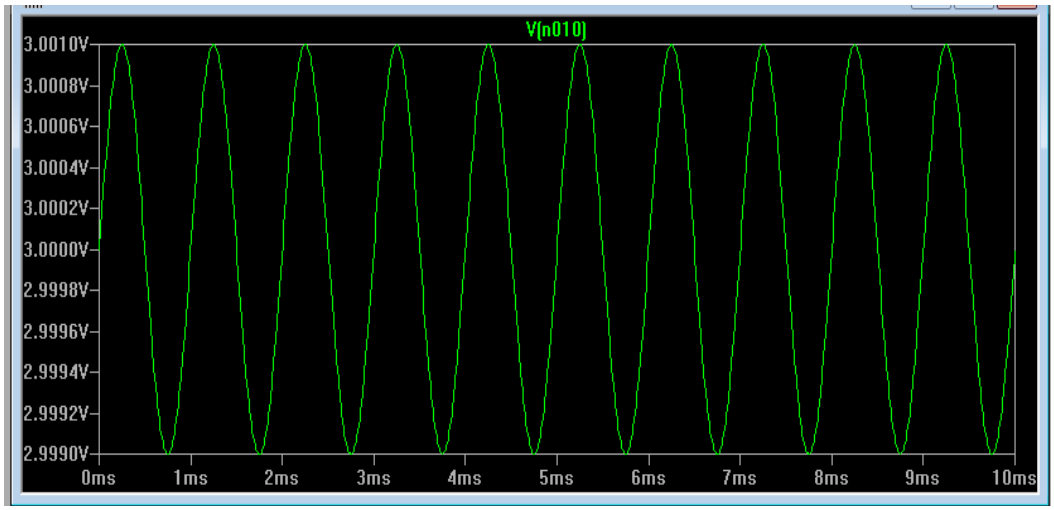


Figure 2.a. Input Voltage of LNA

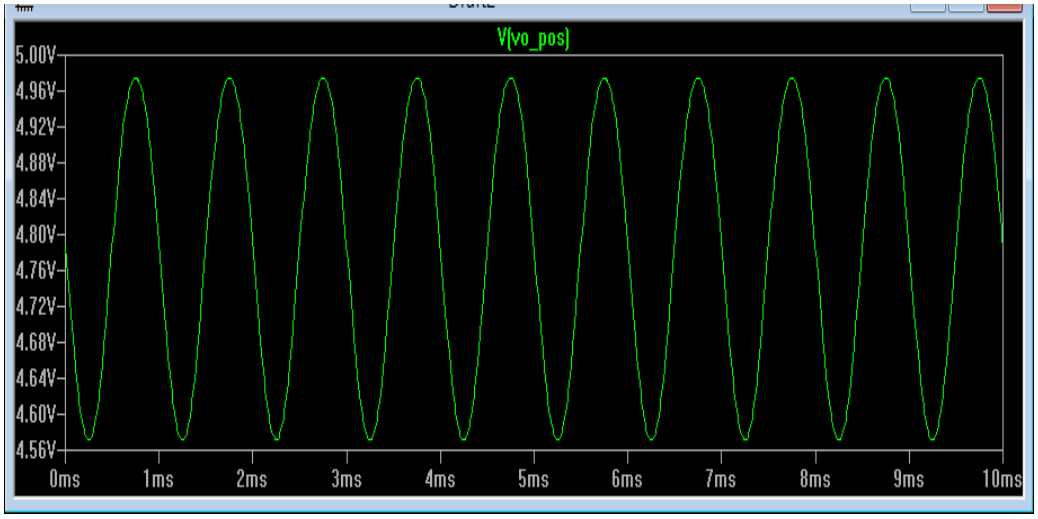


Figure 2.b. Output Voltage LNA

3.1.2 Programmable Gain amplifier

Programmable Gain Amplifier (PGA) contains Folded Cascade Operation Transconductance Amplifier same as that of low noise amplifier. But in PGA the cascade devices such as M_{11} and M_{12} are not incorporated. But at rest current scaling is used inorder to minimize the total amount of power consumption by the Analog Front End.

3.1.3 Variable g_{mf} stages used in the LPF core

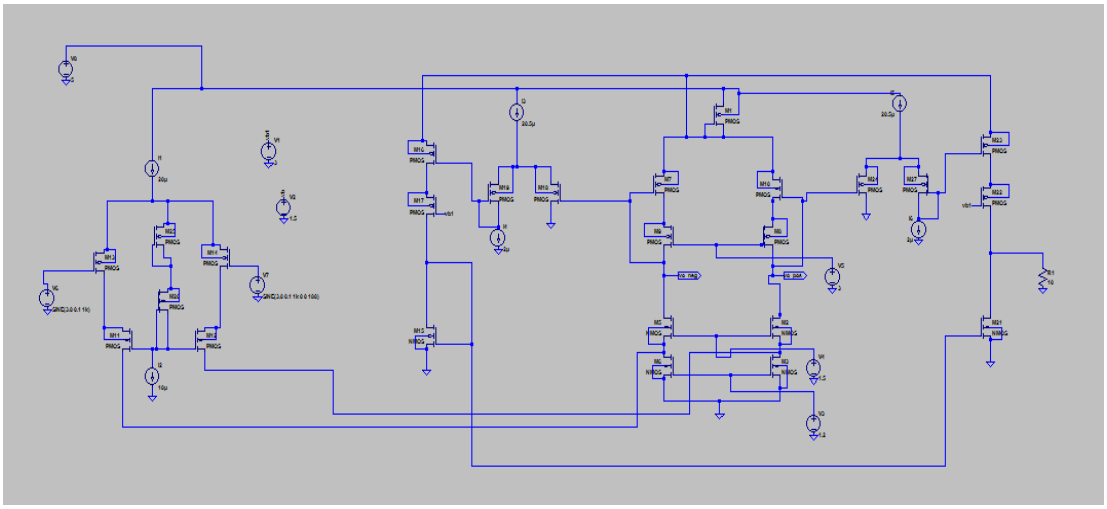


Figure 3. Proposed schematic for variable g_{mf}-stages used in LPF Core

In order to reduce the size of Wireless Body Sensing element Nodes, the method to be implemented is done mainly in the Low Pass Filter core region. The proposed schematic for g_{mf} stage used in LPF Core is shown in Figure 3. By using these proposed schematic the size of the chip can be reduced.

The output resistance of the transistors M_3 and M_4 are in the saturation mode. These transistors serve as the source degeneration resistor for the transistors M_5 and M_6. Voltage to Current conversion is the primary operation of these transistors. The main goal of this circuit is the voltage to current conversion. In the voltage to current conversion method the input is given as the voltage and the output can be obtained as current.

$$\frac{V_{op}(s) - V_{on}(s)}{V_{ip}(s) - V_{in}(s)} = \frac{(1/b)(^{g_{mf}}/_{C})^3}{\left\{s^2 + \left(^{g_{mf}}/_{aC}\right)s + (^{g_{mf}}/_{C})^2\right\}\left\{s + (^{g_{mf}}/_{bC})\right\}}$$

Here, g_{mf} is the transconductance. This is in differential mode since it contains the replica of transistors such as M_{16}, M_{17}, M_{18} and the replica is M_{21}, M_{22}, and M_{23}. And the transistor M_{19} is equivalent with the transistor M_{27}. In the existing system, the wide swing current mirror circuit is used. The common source stage passes the signal to the common gate stage. If the input voltage contains fluctuations then the current will reaches the saturation region. This is the main problem occurs over here. When it reaches the saturation region the circuit will stop its operation.

So, inorder to make the circuit work even it contains fluctuations Common Mode Feedback (CMFB) circuit is added at the output region.

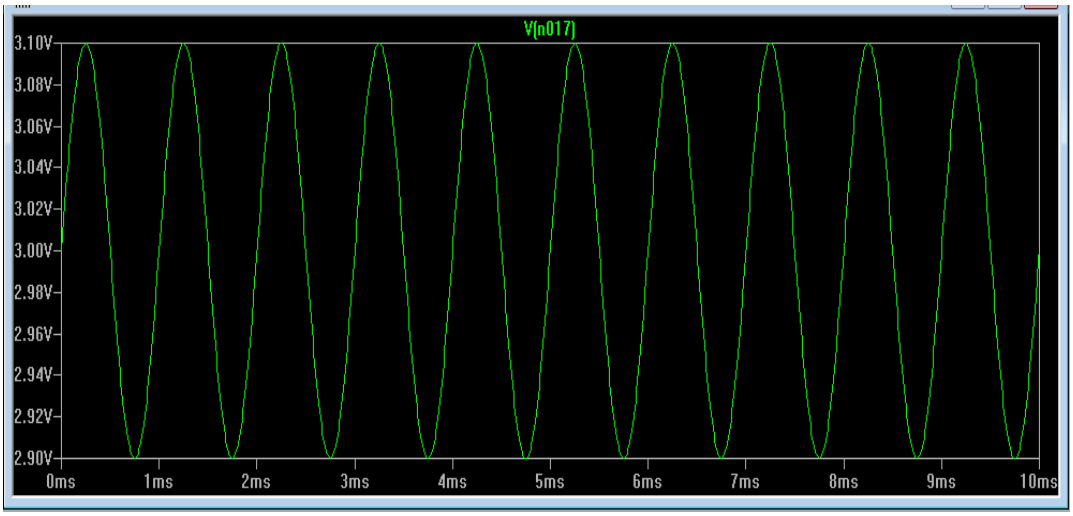


Figure 3.a. Input Voltage for the variable g_{mf}-stages used in the LPF

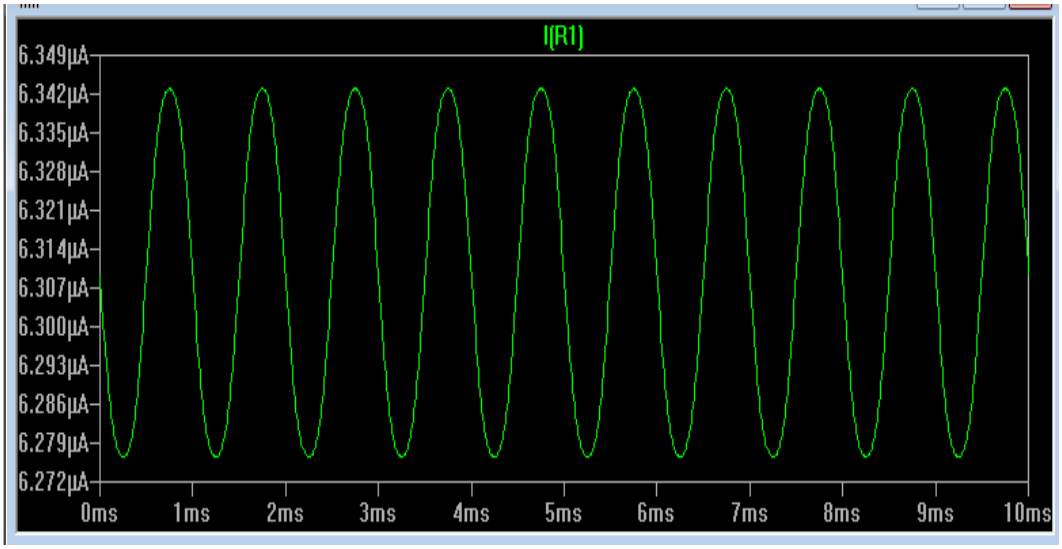


Figure 3.b. Output current for the variable g_{mf}-stages used in the LPF

4. Results and Discussion

Table 1 shows the range of voltage differences in the input region and in the output region. It clearly shows the minimum voltage and the maximum voltage range in the input region and in the output region.

Table 1. Input and Output Voltage Range of LNA

Input Voltage Range		Output Voltage Range	
Minimum Voltage (v)	Maximum Voltage (v)	Minimum Voltage (v)	Maximum Voltage (v)
2.9	3.01	4.56	5

Figure 3 acts as narrow swing current mirror circuit. The functionality of wide swing current mirror and narrow swing current mirror are same. By converting voltage to current the area efficiency is required to be achieved because these are bio implantable chips if the number of transistors is reduced it will reduce lots of power and area. And the circuit operation is also quick. So, in comparison with the existing system, the wide swing current mirror is replaced with the narrow swing current mirror but achieves the same efficiency.

In comparison with the existing system, the area of the chip gets reduced in our proposed system. When the size of the chip is reduced the power consumption of the chip will also be reduced. Table 2 shows the comparison of chip area with the existing system.

Table 2. Comparison of Chip Area with Existing System

Method	Chip Area
Proposed Circuit	157 μm^2
Existing Circuit	159 μm^2

5. Conclusion

Reconfigurable analog front end for wireless body sensing element nodes and implantable devices with reduced size are obtained in our proposed system. The wide swing current mirror is replaced with the narrow swing current mirror but achieves same efficiency. By converting voltage to current the area efficiency is tried to achieved because these are bio implantable chips if the number of transistors are reduced it will reduce lots of power and area, the circuit operation will also be quick. The active space of the chip is 157 μm^2.

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