MEDICAL IMPLANT ELECTRONIC SYSTEM FOR DEEP BRAIN STIMULATION

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Abstract

Due to the gradual growth in the industry of medical devices especially in Implantable Medical Devices (IMD), the research in this area has grown in the past few years. A number of studies have demonstrated the potency of Deep Brain Stimulation (DBS) for dystonia, Parkinson's disease etc. Therefore, DBS is now a significant option when medical therapy fails. This paper presents a sensing structure requiring minimal power consumption. While this paper focuses on the key sensing features it shows that the scaled silicon technologies coupled to the shorter interconnect, give significant advantage for resolution and power consumption of the initial sensing.

Keywords: Implantable Medical Device, DBS, Low Power Devices, Interface, Coupling.

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1. Introduction

In 1780, Luigi Galvani proposed that nerves were electrical conductors. This theory discarded the earlier theory proposed by Descartes. The new discovery by Galvani helped the development of electrophysiology, a science of electrical properties of biological tissues (Collomb-Clerc & Welter, 2015; Jiang et al., 2014; Miocinovic et al., 2013; Wang et al., 2017). In human brain, the neurons are excited by complex electrochemical processes. However, scientists discovered that excitation of the neurons is possible by artificial means as well. Thus, a new field of research was born namely neuromodulation. In this technique, electrical signals are provided to the brain to excite the neurons artificially. This approach has provided a means to manipulate the excitation of neurons externally, in a controlled manner. The effect of electrical signals is useful for the treatment of several chronicle diseases for example Parkinson, Epilepsy, tremors, movement disorders, pain and psychiatric disorders. Neuromodulation is the process of release of a matter from the neuron tissue; which may alter the basic behaviour of glial cell or synaptic transmission(Andersson et al., 2018; Lozano et al., 2019). Through this process, a selected neuron is able to affect the properties of other bunch of neurons. This technique is another form of therapy in which electrical signals are used to modify the behaviour of central nervous system (CNS).

In this section biasing circuits are discussed which are useful for separating DC and AC components. Normally, DC signals are used as bias to produce AC signals. Thus, the sum of the DC bias current and the AC signal current will flow into the circuit. As the AC signal is only small compared to the DC current (~10%), these two currents have to be separated again to be able to properly process the signal efficiently with respect to power consumption. A single ended, voltage output circuit is as shown in Figure 1.

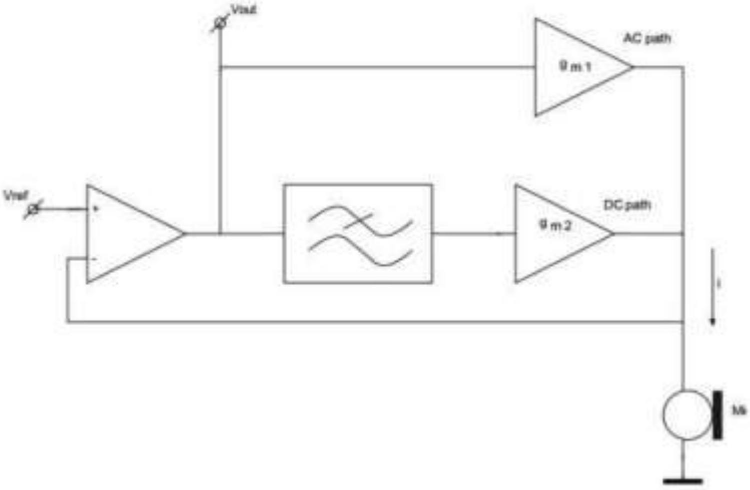

FIGURE 1: Single-Ended, Voltage Output Biasing Circuit

The circuit can be split in an AC and DC path. The DC path has a low-pass filter in its loop. Also, the gm of the AC path is lower than the gm of the DC path. This results in the DC path having a high gain for low-frequency (out of the band of interest) signals, while it has a low gain for in band signals. The AC path has a high gain in the signal band (Howell et al., 2015; Stieglitz, 2007; Zierhofer et al., 1995). To generate an output-current from this voltage, another gm can be added. The low-frequency corner frequency needed for the low-pass filter can be generated by the means of switched-capacitor techniques. One of the drawbacks of this circuit is the fact that it is not differential. Another disadvantage is that the AC signal still contains a DC component, and this DC component is dependent on the microphone bias current. This results in a DC component that is different for each different microphone, which is not desirable.

Proposed Medical Implant System

We have proposed a circuit (Figure 2) having solution to the non-differentially problem. The circuit from Figure 1 is reproduced below the microphone, connecting it differentially. gm1 and gm2 already have been replaced by transistors (T1 and T2, T3 and T4 respectively). V1 (V2) corresponds with Vout of the previous circuit. If it is assumed that the W/L of transistor T2 (T4) is nine times the W/L of transistor T1 (T3), the current through T1 (T3) will be the AC signal current + 1/10th of the DC bias current. To completely remove this DC component in the output signal of the circuit, and to create a differential output current, transistors T5, T6, T7 and T8 are added. Cascode transistors T9 and T10 (T11 and T12) are added to keep the Vds voltages of T1, T2, T5 and T6 (T3, T4, T7 and T8) approximately equal. This ensures an accurate copy of the current through T1 and T2 (T3 and T4). The current from T1 (T3) is copied to T5 (T8). 1/10th of the DC current is copied to T6 (T7). This results in an Iout of exactly the AC signal current, without any DC component. In Figure 2, the common-mode loop that controls the common mode output voltage is not shown. This loop is realized by two controlled current sources that are connected in parallel with T5 and T6. A differential amplifier senses the common-mode output voltage, and adjusts these current sources accordingly (Alonso et al., 2018; Orlov et al., 2017; Xu et al., 2018). One of the advantages of this circuit is that it is fully differential. The output can be used as a differential current-output simply by removing the output resistor. Another advantage is that in a Σ/Δ configuration, it would be possible to directly connect both the integrator capacitors of the first integrator and the DAC to this output.

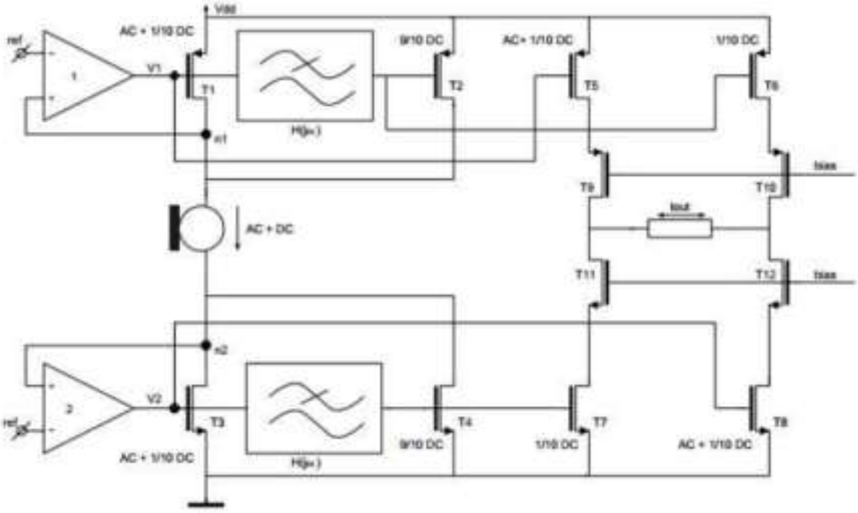

FIGURE 2: Proposed differential circuit with current-copying

The circuit discussed in the previous paragraph had two distinct problems: stability and a microphone-dependent DC current in the output stage. To overcome the stability- problem, care has to be taken not to control the voltage of two (or more) nodes that are directly influenced by each other. If a DC component that is microphone-dependent in our output stage is not desirable, only the AC signal from the microphone has to be allowed to flow into the output stage.

2. Results and Discussion

The main function of electronic circuits is to control the flow of current, signal processing and communication. In this work, differential electronic circuit for ac-dc separation is 96 considered and optimized. The volume population initiated in the brain tissue is dependent on the electric field through it. The field profile is dependent on the geometry of the microelectrode. A theoretical model for separating DC-AC signal segregation is discussed and proposed. The model has 12 transistors and 2 differential operational amplifiers. a dbs system is highly complex system and involves sophisticated electronic circuitry. The critical aspect of electronic circuitry is power consumption. It is always suggested to do power optimization for such system to increase their utility; brain implant system operates in the range of micro watt and even less. As dbs is implanted inside the brain; it is not possible to check them after implantation; many times old people are not able to undergo another surgery. Small electronic circuits are susceptible to ever present noise. Such noise pollutes the signal of interest. It is another area of research to optimize the dbs system for noise optimization.

3. Conclusion

An electronic model for separating ac-dc current in DBS system is proposed. The major advantage of the proposed system is to provide differentiability in the circuit. It is achieved by using more transistors in such a way to achieve the desired goal. Major advantages and limitations of the circuits are presented and discussed. The study presented here can help to understand electric current separation circuits and future developments. The addition of cascade transistors improves the performance of the overall circuit. The proposed circuit has stability problem and this aspect needs further investigation. Any case , electronic circuits need to judge for stability before actual application.

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