Disposal Techniques of Offset Applied to Biomedical Instrumentation

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ABSTRACT

This article presents some Offset reduction/ elimination techniques, something undesirable and present in operational amplifiers. The work focuses on the importance of operational amplifiers in applications such as biomedical instrumentation that uses electrical signals from the human body for analysis and development of instruments that assist professionals in the medical field diagnosis and detection of pathologies. For example, Offset, may impair the reading of such signals. Therefore, it is necessary to study the techniques and that Chopper stabilization, among the mentioned techniques, presented better results in the elimination of noise.

KEYWORDS

Offset, Amplifiers, Instrumentation

1 INTRODUCTION

Concerning the analysis of biomedical signals, since they are signals with low amplitude and frequency, with approximate values between 5 and 10 mV [1], interferences caused by external means such as noises caused by the equipment or by signs of muscles in the Makes the signal processing more complex. Because of such problems, there has been a need to use biopotential amplifiers, which are electronic circuits capable of amplifying the potentials produced by the body cells, as well as rejecting the inherent interferences of the measurement process, whose aim is to raise the voltages to Levels suitable for their processing and / or storage, where such potentials are captured by electrodes positioned under the biological tissue [2].

The use of amplifiers was due to the fact that ideally it has peculiar characteristics, among them one can cite [3]:

- Infinite input impedance;
- Output impedance null;
- Gain in infinite open mesh;
- Rejection in infinite common mode;
- Infinite frequency response bandwidth.

In this way, the signals from the measurement process can be more pure and accurate, resulting in the analysis and development of more accurate systems. However, the production of ideal amplifiers becomes impossible, since in the manufacturing and packaging process the same is subject to mismatch between the components internal to them [4]. Consequently, the amplifiers have a set of limitations as well as imperfections such as finite gain, finite input impedance, non-zero output impedance, and imperfections that for low frequency signal analysis can negatively influence, such as thermal noise that occupies the broadband Frequency, pink noise (1/ f) and the offset voltage (Offset) which are low-band narrow-frequency signals [5].

Thus, to solve such problems, a bibliographic study was carried out to identify some of the techniques for reducing Offset as well as to perform a comparative analysis between them in order to verify which technique stands out, specifying its advantages and disadvantages.

This paper is organized as follows: In section II, the topologies applied for offset elimination / reduction are presented. In section III, the comparative analysis between the techniques discussed in section II and finally, in section IV are presented the conclusions of the work.

2 OFFSET ELIMINATION / REDUCTION TECHNIQUES

2.1 Offset

Offset voltage or displacement voltage is the term used when grounding both inverter and non-inverting inputs in an amplifier, it has a voltage at the output, usually caused by transistor mismatch in the differential stage of the operational amplifier, which ideally Should be identical, resulting in an unbalance of the currents in the circuit [6].

In Fig. 1, a basic differential amplifier circuit is present internally in an operational amplifier, whose main characteristic is to give great gains when the input signals have opposite polarities, when compared to the same polarity gain [7]. Considering the identical transistors Q1 and Q2 and the resistors RC1 = RC2 as well as the voltages V1 = V2, it is observed that the output Vo, ideally equals 0. However, if any mismatch between these transistors occurs, an imbalance is caused due to The difference between the base-emitter voltage of transistors Q1 and Q2, VBE1 and VBE2 respectively, whose module of difference we call Offset.

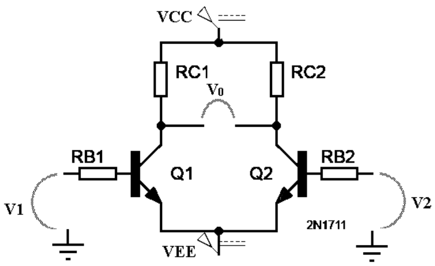

Fig. 1. Differential amplifier.

It has been noted previously that there is a voltage V0, even with both grounded inputs, which we call output offset. By dividing the output voltage by the gain of the amplifier, we obtain the input Offset voltage. [3]. Thus, in circuits whose accuracy is important, such displacement can become a problem. To solve this problem, some methods for elimination / reduction of Offset will be discussed later among them we have:

- Cancellations by Offset pins;
- External Resistive Circuit;
- Auto-zeroing;
- Auto-zeroing with output Offset Storage;
- Auto-zeroing with input Offset storage;
- Chopper Stabilization;

2.2 Cancellations by Offset pins

Some operational amplifiers such as LM741, as shown in Fig. 2, proposed by Texas Instruments are provided with two additional terminals, pins 1 and 5, in which a circuit can be connected to zero the output voltage dc caused by Offset, [3].

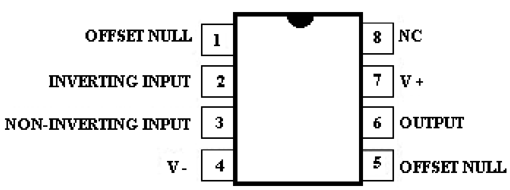

Fig. 2. LM741.

It is common to couple a 10 kΩ potentiometer connected to the amplifier's Offset pins and the potentiometer's central terminal is connected to one of the amplifier's power pins as shown in Fig. 3. The cancellation occurs due to the fact that when connecting the Potentiometer, it will be connected to the differential input and with this it is possible to balance the collector currents and consequently to equal the voltages V_{BE1} and V_{BE2}.

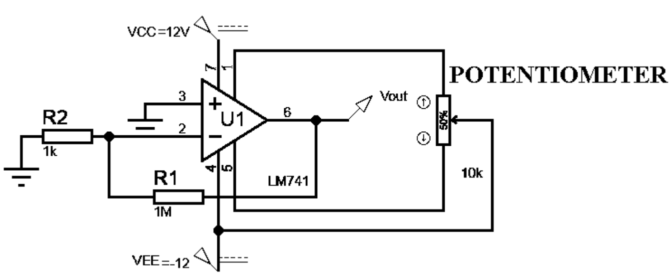

Fig. 3. Offset null Pin Offset Cancellation.

However, some considerations must be taken into account, including the fact that not all amplifiers have pins for adjusting the offset, as is the case of the LM307, being necessary to couple an external circuit, as well as fact of putting a potentiometer may not be Enough to eliminate the offset stresses, since such stress can be caused by other factors such as temperature, mismatch of β values which is an intrinsic parameter to the component [5].

2.3 External Resistive Circuit

Similarly to Offset voltages, it is common to occur in amplifiers what we call Offset currents which is the difference between the input bias currents between the signal inputs, V + and V-, which are required for the amplifier to operate. However, offset currents can be corrected by introducing a resistance in series with the non-inverting input terminal whose value is equal to the parallel of the inverter input resistances, [3], see Fig. 4.

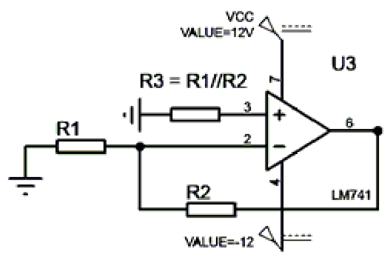

Fig. 4. Reduction of Offset by R3.

Theoretically, the reduction performed by an external balancing is interesting, however adjusting the resistance of R3 so that it is the parallel of R1 and R2 is not a simple task because they are not ideal components. In addition, as mentioned previously, internal mismatches to the component can occur generating an undesirable Offset at the output [4].

2.4 Auto-zeroing

One of the ways to block a cc component of a signal to compensate for the Offset is to use a technique known as Auto-zeroing which consists of coupling a capacitor to store the Offset signal and eliminate it, in which we can Analyzing this topology in two moments: a self-zero sampling phase in which the Offset of a system is measured and stored in the capacitor, and a signal phase in which the signal is amplified and the previously stored Offset is subtracted from the signal [8].

According to [9] there are three basic topologies for Auto-zeroing of which two consists of storing the Offset output, input and canceling closed-loop Offset using an auxiliary amplifier, where the first two will be covered in this article.

2.4.1 Output Offset Storage. To illustrate, we will analyze the circuit of Fig. 5, shown below, also called open loop displacement, which can be analyzed in two moments, the sampling phase F2 and the signal phase F1 [8].

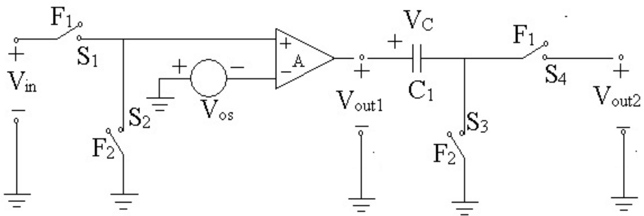

Fig. 5. Auto-zeroing with output Offset Storage.

In the sampling phase F2, the switches S2 and S3 are closed, while the switches S1 and S4 are opened. Thus, the voltage on the capacitor can be expressed as the gain of the circuit, A, multiplied by the input voltage, in this case the Offset voltage, Vos, that is:

$$Vc = Vout1 = A.Vos \quad (1)$$

In signal phase F1, keys S2 and S3 are opened, while keys S1 and S4 are closed. Thus, the output Vout2 is given by:

$$Vout1 = (Vos + Vin) * A \; e \; Vout2 = Vout1 - Vc \quad (2)$$

$$Vout2 = Vos * A + Vin * A - A * Vos \quad (3)$$

$$Vout2 = Vin * A \quad (4)$$

2.4.2 Input Offset Storage. Similar to the previous case, we have an Auto-zeroing circuit, however the capacitor was coupled to the inverter input of the amplifier. In this way, we will analyze the circuit shown in Fig. 6, in two moments, the signal phase and the sampling phase [8].

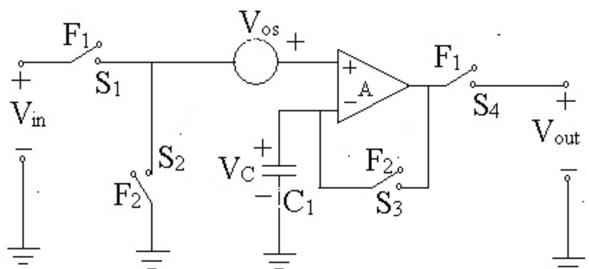

Fig. 6. Input Offset Storage.

In the sampling phase F2, the switches S2 and S3 are closed, while the switches S1 and S4 are opened. Thus, the voltage across the capacitor can be expressed as an RC circuit, whose transfer function can be given by:

$$Vc = \frac{A}{A+1}.Vos \quad (5)$$

In signal phase F1, keys S2 and S3 are opened, while keys S1 and S4 are closed. In this way, the output Vout2 is given by:

$$Vout = (Vin + Vos - Vc) * A \quad (6)$$

$$Vout = \left(Vin + Vos - \frac{A}{A+1}.Vos\right) * A \quad (7)$$

$$Vout = \left(Vin + -\frac{1}{A+1} * Vos\right) * A \quad (8)$$

Thus, by analyzing the equation above, it is noted that the greater the gain given to the circuit, the greater the difference between the input signal and the circuit. However, some problems can arise from this topology, mainly by the use of CMOS technology, which is a reference when designing analog circuits, which because it is more economical, allows the integration of digital signal processing of low power making possible the realization of systems of complex mixed signals [8].

However, by the use of MOS technology, in the switching, there is a charge injection of the capacitance, - Qinj and + Qinj, when opening and closing keys respectively, influencing a residual offset increase, however this can be solved by increasing the capacitance in both cases.

2.5 Chopper Modulation

Unlike the self-zeroing, previously shown where we coupled a capacitor to capture the displacements, the Chopper stabilization aims to put the signal of interest and the Offset to different frequencies and filtered so that the output of the system is only the desired signal [8].

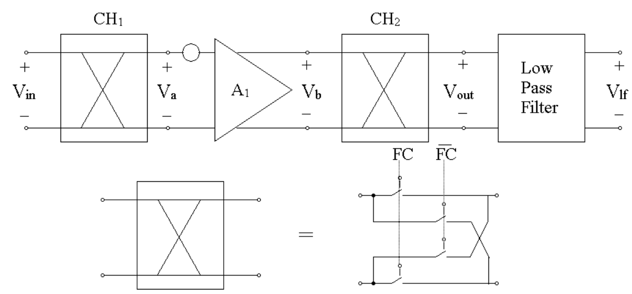

Fig. 7. Chopper Circuit.

The Chooper Stabilization, shown in Fig. 7, can be analyzed in 4 stages. The first stage, CH1, consists only of modulating the input signal in order to get high frequency. In the second stage, A1, the modulated signal is amplified, whose output consists of the modulated signal and next to the Offset. In the third stage, CH2, the demodulation of the signal and the modulation of the displacement takes place. In the fourth stage, LPF, consist only of a low pass filter that filters signal, whose output will be the desired amplified signal.

3 RESULTS AND DISCUSSIONS

When talking about precision systems in terms of frequency and amplitude, as in the case of biomedical systems, any interference may impair reading. Among the main problems mentioned, such as thermal noise, pink noise and offset, it is concluded that the first techniques mentioned, using the offset pins and external resistive circuits only reduce Offset without eliminating any other interference.

In the case of Auto-zeroing input and Auto-zeroing Output both have the same behavior in the output signal, however, the Auto-zeroing Input does not eliminate Offset, it eliminates the offset gain making it insignificant when compared to the signal of interest.

Therefore, because both presented the same behavior, the Auto-zeroing Output technique was chosen to compare it with the Chooper stabilization technique.

In order to demonstrate, in Fig. 8, an input signal of 10 mV amplitude and 200 Hz frequency, was analyzed at the output of a common gain amplifier 2 at two moments. In the first case, (Perfect_Signal), it was considered an ideal case where there is no noise and offset. In the second case, (Signal_Offset_Rose) this is a signal with an offset of 1 mv and a pink noise added to the input signal.

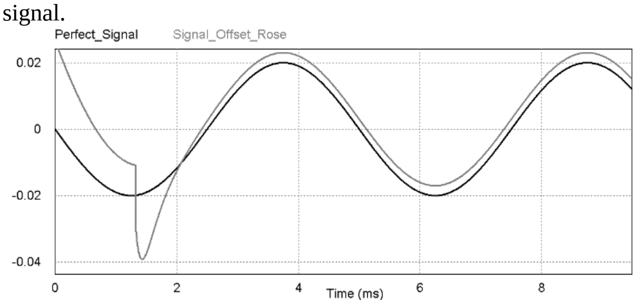

Fig. 8: Sample Sign and With Noise.

A small perturbation was noticed in the first milliseconds and a displacement that may not be of great importance to the naked eye, but for systems of great precision like biomedical systems the same can be a problem due to its sensitivity.

In Fig. 9, it shows that for a signal with noisy input the Chooper modulation, whose output, (Vout_Chopper), presents the best behavior, since besides eliminating the offset, it eliminates the effect of the pink noise, being neglected the thermal noise, by the In fact, the noise level of a Chopper amplifier is higher when compared to the thermal noise level [8].

The output of the Auto-zeroing circuit (Vout_AutoZero) has small peaks along the signal, which visibly is the one that distances itself from the ideal signal (Perfect_Signal) when compared to the Chooper circuit.

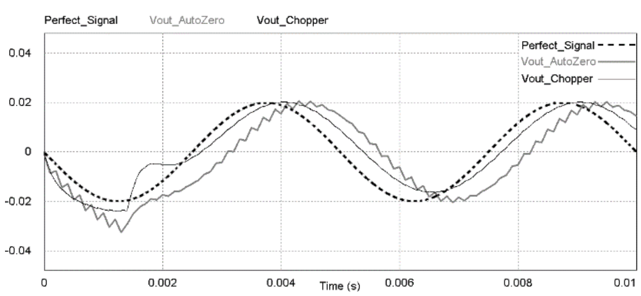

Fig. 9. Comparison.

Table 1, shown below highlights the main characteristics analyzed in this work.

Table 1: Comparison of Offset Reduction Techniques

Topologies	Eliminates Offset Voltage	Implantable with any AMPOP	HighGainPossibility	Injection of cargo Residual	Eliminates Noise 1 / f
Offset Pins	✓		✓		
Resistive Circuit		✓	✓		
Auto-zeroing output	✓	✓		✓	
Auto-zeroing input		✓		✓	
Chooper stabilization	✓	✓	✓		✓

4 CONCLUSIONS

Among the techniques and problems presented in Table I presents a comparison of the same ones showing that among all techniques of Chooper Stabilization presents a better performance when compared to the others both to eliminate the offset and pink noise. However, such a technique has a drawback which is the appearance of a small ripple which is characteristic of it.

It has been seen that Auto-zeroing output and Chopper techniques are both effective in eliminating Offset and based on the cases and signals to be analyzed, we can define which better choice, in the case of biomedical signals because they are low frequency applications and Low power and low baseband noise, Chooper modulation is a good choice.

In the future it is intended to analyze different Offset elimination techniques that complement the Chooper Stabilization and Auto-zeroing junction and methods of eliminating the ripple present in the Chooper modulation. And finally it is intended to couple to the instrumentation amplifier.

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