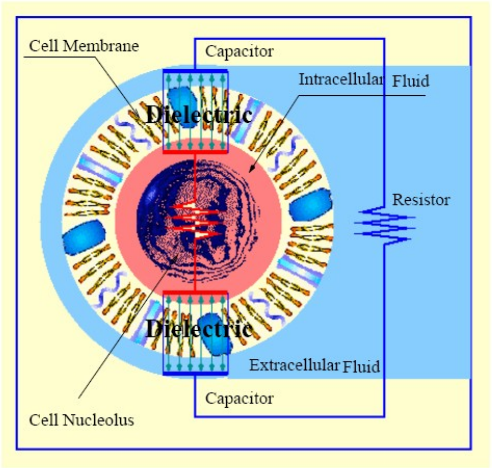
Wide band frequency Fixed current source for BIT and BIA

A. H. Ar-Rawi, M. Moghavvemi, W.M.A Wan-Ibrahim
Faculty of Engineering / University of Malaya

Abstract— **High frequency bioelectrical impedance analysis devices are mostly used in Bioimpedance tomography and blood analysis. Nowadays 50 – 100 KHz bioelectrical impedance devices are commonly used for body composition analysis.**
AD8130 or AD 8129 deferential op-amp is used in this paper. These two op-amps offer high output impedances at low frequencies because of the amplifiers' good low-frequency CMRR (common-mode-rejection ratios). At higher frequencies, decreasing CMRR, inherent output capacitances, and slew-rate limitations prevent realization of high-quality current sources.
170 mV sine wave signal is used as input voltage considering the current should be no more than 1 mA. Four frequencies of 100 KHz, 1 MHz, 2 MHz and 3.2 MHz are applied to the circuit and by changing the load resistor, the current is measured. The result shows the current stable during the load resistor changing.

I. INTRODUCTION:

Bioelectrical Impedance tomography (BIT) and Bioelectrical Impedance Analysis (BIA) are two main techniques using Bioimpedance measurements. Bioimpedance are widely used in many applications such as tissue characterization, physiological measurement, disease detection, biosensing, etc. It has many advantages like it is not expensive, easy in use and can be portable. It also can be used for imaging (BIT) however it is low resolution apart from being cheap and portable [1-2].



The outer boundary of the cell is a plasma membrane of phospholipid molecules that become a dielectric to form an electrical capacitor when a radio frequency is introduced to the cells environment.

Fig. 1 The electrical explanation for the body cell

All living things are made of cells. Cells are membrane bounded compartments filled with a concentrated solution of chemicals and salts. Groups of cells perform specialized functions and are linked by an intricate communications system. The cell membrane maintains an ion concentration gradient between the intracellular and extracellular spaces figure 1. This gradient creates an electrical potential difference across the membrane which is essential to cell survival. Electrical gradients are necessary to support movement of oxygen, carbon dioxide, and nutrients. Therefore, the cell membrane has electrically insulating qualities to maintain an electrical gradient. Damage to the cell membrane, and its functions, is as lethal to the cell as direct damage to the nucleus itself (Fig. 1). Moreover the electric equivalent circuit for body tissue cells is as in figure 2 [3]. Because of the nature of the tissue cell we can see the real and imaginary parts of the total impedance are frequency dependent. The higher the frequency, the lower is the impedance. Furthermore, the current pathway in the tissues is different for the varied frequency. Therefore, mean wide band frequency fixed current source is required to get more information from the cell.

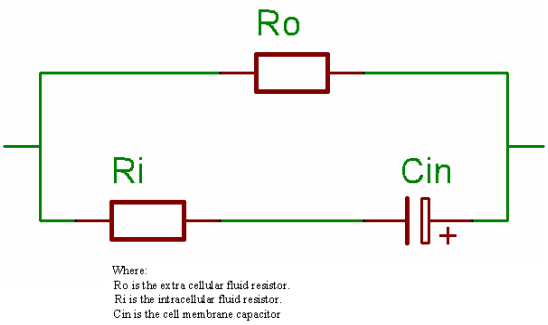


Fig. 2 the equivalent circuit for the tissue cell

The main function of "Current pumps ", "voltage to current" or "fixed current" circuits is to feed fixed current to the load and there are two main types i.e AC and DC circuits. The AC fixed current circuit with very low current between 500 uAmp and 1mAmp are normally used in the bioelectrical impedance analyses (BIA) and bioelectrical impedance tomography (BIT) applications. Ramon et. el.[4] has built the current source by using three operational amplifiers and his circuit is up to 1 Mhz., moreover this circuit is very complicated.
Zhang Shuai et. el. [5] and Kuo-Sheng et. el. [6] have built complete Bioimpedance system for BIT by using the enhanced Howland current source. The howland current pump is quite a stable circuit up to 1 – 2 Mhz., however this circuit needs very accurate balanced bridge resistors. And this circuit also needs very high frequency band op-amp. The voltage supply required more than 10 volt to be able to work at frequencies above 3 MHz due to the multi feedback method.

O. Dössel and W.C. Schlegel (Eds.): WC 2009, IFMBE Proceedings 25/II, pp. 522–524, 2009.
www.springerlink.com

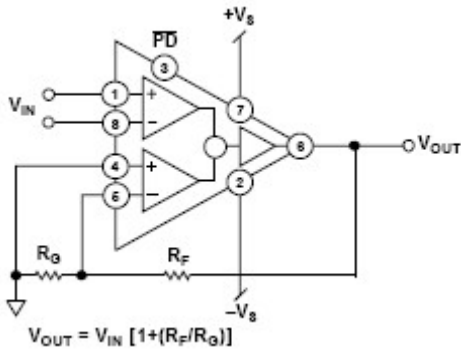


Fig. 3 the basic circuit of AD8130

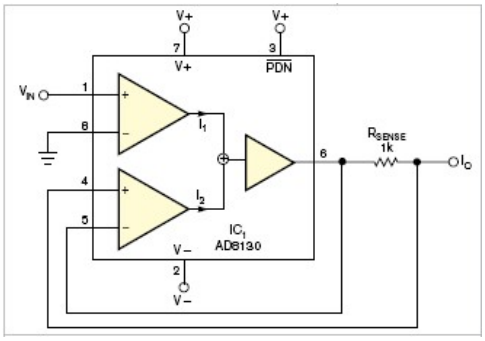


Fig. 4: The basic circuit for the current source where Rsense is placed in series with the load

II. METHODOLOGY:

AD8130 [8] differential op-amp is used in this circuit as shown in Fig. 3, showing the basic circuit and gain function.

Fig. 4 shows the basic circuit for the current source where Rsense is placed in series with the load and feedback to pins 4 and 5. The over all equation will be:

$$i_{out} = \frac{v_{in}}{R_{sense}} \text{ ---------- } 1$$

And for a constant Vin , a constant output current is recorded for Rsense constant.

The load resistor up to 3.5 KOhm is utilized because of the supply 10 Vp-p. For this range of supply, the maximum output voltage 7Vp-p is obtained after that the waveform is distorted.

III. RESULTS:

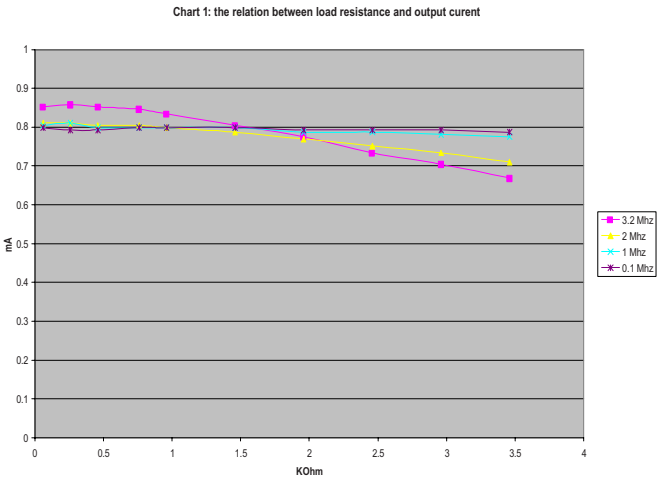


Chart 1 the current changing Vs load resistor

Chart 1 shows the changes of load resistor from 0-3.5 KOhm with different frequencies from 100 Khz – 3.2 Mhz. At frequencies of 100 KHz and 1 MHz the system is quit stable and fix in at about 800 uA. However the system is less stable at 2 Mhz and 3.2 Mhz.
The results above show that the simple cheap circuit with wideband frequency can be used in different bioelectrical impedance applications.

IV. Discussion

Normal voltage to current convertors or current source circuits offer very high output impedance at low frequencies because of the amplifiers' good low-frequency CMRR (common-mode-rejection ratios). The affection of output capacitance and slew rate limitations which inhere the decreasing of CMRR at higher frequencies will prevent realization of high quality current sources. And the high frequency is needed in the bio-impedance analysis devices.

AD8130 differential amplifier is used to overcome the problems. The circuit in figure 4 shows that a very simple circuit (only one IC) could be designed to generate a fixed current pump greater than 3 MHz. The another benefit is that the load is grounded not floating because of the current sensing is in the upper side of the load.

The results from the chart 1 show that the current is stable for different load values until up to 1 MHz. However,

from 1 MHz to 3.2 MHz, the current linearity is less due to the decreasing in the CMRR at these frequencies. The percentage of the nonlinearity is small and it is within an acceptable levels.

V. REFERENCES:

1. A. De Lorenzo, A. Andreoli, J. Matthie, and P. Withers, “Predicting body cell mass with bioimpedance by using theoretical methods: a technological review,” J. Appl. Physiol. Vol. 82, pp. 1542-1558, 1997.
2. D. S. Holder, Electrical Impedance Tomography, Methods, History and Applications, Institute of Physics Publishing, 2005.Ramon Brag&, Javier Rose11 and Pere Riu, "A wide-band Ac-coupled current source for electrical impedance tomography", Physiol. Meas. 15 (1994) A91-A99.
3. Fatimah Ibrahim, Mohd Nasir Taib, Senior Member, IEEE, Wan Abu Bakar Wan Abas, Chan Chong Guan, and Saadiah Sulaiman.," A Novel Approach to Classify Risk in Dengue Hemorrhagic Fever (DHF) Using Bioelectrical Impedance Analysis (BIA)", IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, VOL. 54, NO. 1, FEBRUARY 2005
4. Zhang Shuai, Xu Guizhi, Wu Huanli, Geng Duyan, and Yan Weili, " Multi-frequency EIT Hardware System Based on DSP", This work was supported by the Natural Science Foundation of Hebei Province , China under Grant No. E2004000054 and E2005000047
5. Kuo-Sheng Cheng, Senior Member, IEEE, Cheng-Yu Chen, Min-Wei Huang, and Chien-Hung Chen, " A Multi-Frequency Current Source For Bioimpedance Application",
6. "A Comprehensive Study of the Howland Current Pump", National Semiconductor Application Note 1515 Robert A. Pease January 29, 2008
7. Data sheet for AD8130-AD8129 Analog device.