

RESEARCH ARTICLE**Comparison of Various Methods of Human Body Composition****¹Archana A. Pawar*, ²Prof. D. K. Kamat, ³Dr. P. M. Patil***¹Dept of EnTc, Sinhgad Academy of Engineering Pune, India***²Asst Prof Dept of EnTc, Sinhgad Academy of Engineering and Research Scholar SCOE Pune, India.**³Professor E&TC, JSPM's JSCOE, Pune, India***Received on: 25/10/2016, Revised on: 20/11/2016, Accepted on: 14/12/2016****ABSTRACT**

Body composition is not only used to give information about state of health but also it gives information about various diseases and methods to prevent health diseases. Body impedance analysis is used for body composition measurement purpose, which is low cost, non-invasive and easy to handle etc. With the help of body composition analysis we can measure the fat mass, total body water, fat free mass, extracellular water and intracellular water present in human body. Body composition analysis is done using single frequency measurement, dual frequency measurement and multifrequency measurement. For single frequency 50kHz, 1 and 100 KHz for dual frequency measurements and 5 to 500 KHz for multifrequency measurements. There are various methods, which are available to perform body composition like PDA based fat measurement module, AD5933, air-displacement plethysmography and AFE4300 etc. AD5933 is new chip used for impedance measurement. AD5933 allows four electrodes during impedance measurement. It requires low Sensitivity to interface impedance. There are various laboratory based body composition methods are available which include dual-energy X-ray absorptiometry, hydrostatic weighing, measurement of total body water by isotope dilution, measurement of total body potassium and multicompartments models. All these methods are regularly used and all of them have some inherent practical limitation. Whole body air displacement plethysmography method is used for body composition. BOD POD is an air displacement plethysmography which is used to determine body composition (fat vs. lean). It measures body mass using very precious scale and volume by sitting inside the BOD POD. In this paper we see all these methods also how the measurement of body composition is performed.

Keywords: body composition, body impedance analysis, PDA, Air displacement plethysmography, AD5933, AFE4300.

INTRODUCTION

Traditional technique used for body impedance analysis is isotope dilution technique. But isotope dilution method is more costly and consumes more time so that this method is not used mostly. After that more practical method is used for body composition analysis is plethysmography technique is used. But in that method only two needles are used for body impedance. One needle is placed on one hand and other on opposite foot. But due to two needles are used some technical restrictions are come on this method. Thomasett and his coworkers used this method first to determine total body water. But recently tetra polar bioelectrical impedance plethysmography method is used to determine total body water^[1]. Body composition is an important procedure used

in nutritional assessment. A various techniques have been used which are used to accurately measure the total body water (TBW), the fat free mass (FFM) and the fat mass (FM). Initially isotope dilution techniques used to measure the FFM and FM depends on the density of two compartments. But these methods are expensive, more expertise and time is required. To determine total body water is most important to diagnosis renal diseases. Body impedance analysis is safe, noninvasive, and portable, it requires minimal operator training and easy to perform etc^[2]. Recently peoples want to know their health status like information about total body water, fat free mass and fat mass etc. Personal Digital Assistance (PDA) is a portable wireless device and it become widely popular. There are various methods used to

determine body fat such as a Ultra sound, Hydro densitomeny, a Calipers and total body electrical conductivity. But these methods are difficult to use and restricted to the space and time and expensive device. PDA based body impedance analysis method is based on the different conductive and electrical properties of biological tissues present in human body^[3]. Bioimpedance technique is used to determine the passive electrical properties of biological tissues. But in new applications there is need of embedded impedance measurement system which is small in size, transportable, wearable and comfortable to use. AD5933 is an embedded impedance measurement system which is used for body composition analysis^[4]. Air-displacement plethysmography method is used to measure human body composition, but it was not developed for routine use until the mid-1990s. There is only single commercially available method for air-displacement plethysmography which is known as BOD POD. There are various advantages by using this method like quick, comfortable, automated, noninvasive, safe measurement process and accommodation of various subject types. This BOD POD method is validated in December 1995 and in august 2001 this method is compared with reference method i.e. hydrostatic weighing, dual-energy X-ray absorptiometry, and multicompartiment (3C) and 4-compartment (4C)) models^[5]. Impedance based devices are used for various applications such as body composition analysis purpose and electrical impedance cardiography etc. But we need device which has high performance and minimum size. This becomes possible with the help of AFE4300 impedance spectrometer developed by Texas Instruments. AFE4300 is a four electrode impedance measurements device, which allows both single and multifrequency measurement through internal multiplexer. If user wants performs single frequency measurements then it employs in FWR demodulator mode, if user want perform multifrequency then it is possible with the help of I/Q demodulator mode^[6].

METHODS

In this section we see the various methodologies which are used for body impedance measurement like AD5933, PDA based body fat measurement module, Whole body air displacement plethysmography and AFE4300 etc.

- **AD5933**

AD5933 is a fully integrated impedance

measurement chip used for body impedance analysis. The block diagram of AD5933 is shown in fig.1 It includes voltage excitation stage which generates sinusoidal signal; frequency of sinusoidal signal is varied between 1 kHz to 100 kHz and minimum amplitude of signal is about 198 mVpp, it contain current measurement stage which is based on transimpedance amplifier also it include discrete Fourier transform that is used to determine spectral power of measured current. In AD5933 four electrodes are used in that two electrodes are used for current injection and remaining two for voltage measurements^[4].

- **PDA based Fat measurements** PDA (Personal Digital Assistance) based body fat measurement system is used for BIA, PDA is portable wireless device. There are various methods are used to determine body fat like hydro densitometry, a caliper, a ultra sound and total body electrical connectivity but these methods requires more space, time and expensive so that BIA method is used for body composition analysis. In that sixty three weight stable subjects include 53 men and 10 women between aged 20-32 yr are participated. Body fat rate measurement is done through PDA system and HTM100 plus whose correlation coefficient is about 0.928. Fig.2 shows the module which is used for body fat measurement purpose. Current is injected at 300uA and 50 kHz frequency^[3]

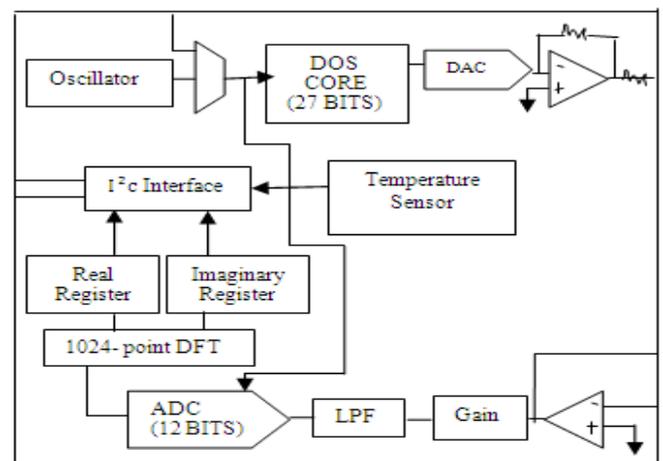


Fig. 1: AD5933 measurement system^[4]

In table I (A) is result of HTM1000plus and (B) is the result of PDA module. Here HTM100 plus is used as reference method for comparison purpose.

FFM (B) was derived from equation $FFM = 0.0005 \text{ Height} - 0.0160 * \text{Impedance} + 0.3920 * \text{Weight} - 0.0684 \text{ Age} - 5.8141 * \text{Sex} + 25.984$.

Table I : Measured values of 63 subjects

	Male		Female	
	Mean ± SD	Range	Mean ± SD	Range
Z(ohm)	707.1 ± 93.2	1016.0-518.8	910.4 ± 79.6	1073.6-827.6
FFM(A)	57.4±5.8	75.1-42.9	37.4 ± 2.3	41.5-34.3
FFM(B)	57.3 ± 5.5	72.4-43.1	36.7 ± 2.4	40.5-33.0
PF(A)	21.6 ± 3.8	29.1-11.6	26.8 ± 2.0	31.1-24.6
PF(B)	21.4 ± 4.6	30.9-9.1	28.1 ± 2.3	32.8-25.1

• **Air-displacement plethysmography**

The word plethysmography is used to measure size, usually volume. In air-displacement method volume of subject is measured indirectly by measuring the volume of it displaces inside an enclosed chamber. I.e. human body volume measurement is done when subjects sits inside the chamber. In that body volume is calculated by subtracting the volume of air when chamber is empty and volume of air when subject sit inside the chamber. Air inside the chamber is measured by using physical gas laws, Boyle’s law states that constant pressure, volume and temperature are inversely proportional as, $P1/P2=V2/V1$.when constant temperature is maintained Boyle’s law is applied. But early plethysmography requires temperature-controlled Surroundings and isothermal conditions within the test chamber. Due to rapid fluctuation in temperature, humidity and pressure generated by human inside the closed chamber, measurements become difficult. Infant plethysmograph developed by Friis-Hansen requires 1-2 h calibration process before each measurements, addition test procedure is about 2-3 h. Later Petty used the motor driven pump and oscillating piston in order to create pressure change within their system. After that infant plethysmograph developed by Taylor uses two chambers, dynamic, pressure-differential system, it contains test chamber and a reference chamber [5].

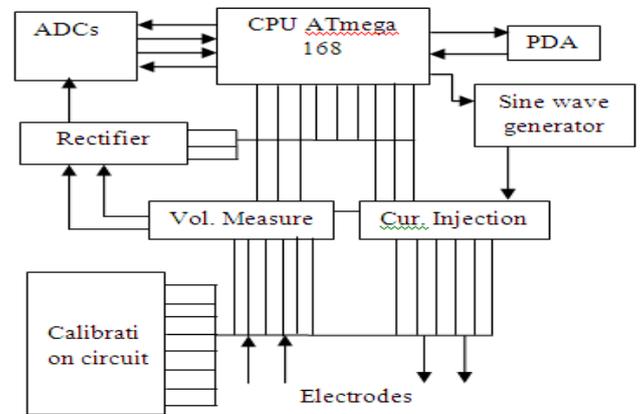


Fig. 2 Block diagram of body fat module [3]

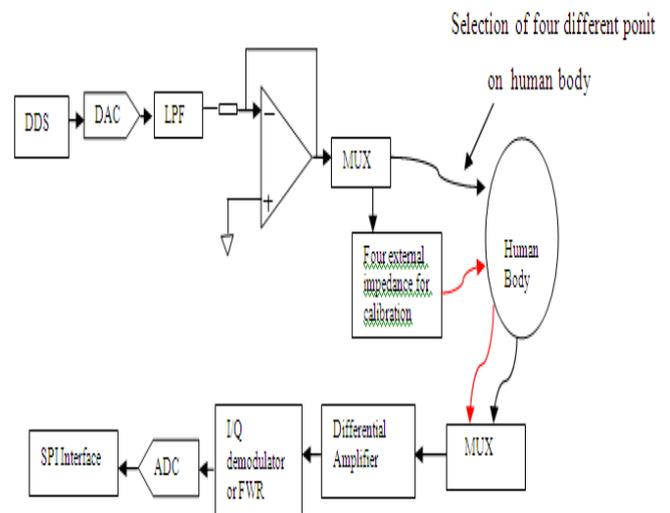


Fig. 3 AFE4300 functional block diagram [6]

• **AFE4300**

AFE4300 is a low cost impedance spectrometer, which is used for both weight scale measurement and body impedance measurement. In that only one condition is in working at a time i.e. AFE4300 impedance spectrometer is used either weight scale measurement or body impedance measurements. It doesn't need external analog front end for weight scale measurement. It is portable, low cost and easy to handle that's why we go for AFE4300 impedance spectrometer. AFE4300 is a fully integrated electrical impedance spectrometer used for body impedance measurements purpose. In that peak to peak to value of sinusoidal signal is controlled with the help of external resistor, sinusoidal signal is generated internally through direct digital synthesizer. The difference, however, lies in how the measured voltage across the impedance is processed to obtain the final result. The main function of the DDS is to generate sinusoidal signal in digital form

.Then generated sinusoidal signal is given to DAC. DAC converts all incoming digital signal into analog one. Here second order low pass filter is used to filter signal at output of DAC which remove all image components. Current is flowing into human body through multiplexer. It allows selection of six different points on human body also four points for external Impedance calibration purpose. Second mux provide feedback path to human body that connect to the differential amplifier. By putting I/Q mode enable bit as a one we perform multifrequency measurements. We can use this device for both single frequency and multiple frequency measurements^[6].

DISCUSSION

Results from table 1 indicates PDA based system is safe to measure body fat. In order to check the performance of PDA based body fat measurement module, here HTM 1000 plus data as reference method is used .Performance of PDA based module is higher as compare to other method, but it is used only for body fat measurements purpose [3]. AD5933 is one type of impedance spectrometer which is used for body composition measurement .It contain four electrodes, measurement of body composition is done through two steps in AD5933.First step is measure the current flowing through the samples after that measure the voltage across each electrodes for each frequency.AD5933 is evaluated for different test and it gives good accuracy, when circuit correctly calibrated. It has ability to operate at microelectrodes [4]. BOD POD is reliable valid technique used to measure body composition in various range subjects including those who are difficult to measure such as elderly, children and obese individual. Most study uses multicompartement models reference method to validate performance of BOD POD [5]. AFE4300 has ability to acquire both stationary and no stationary behavior of bioimpedance.AD5933 require external front end to measure four

electrode bioimpedance, AFE4300 doesn't require such external front end. With the help of AFE4300 impedance spectrometer it is possible to perform both single and multifrequency measurement. It is portable, easy to handle and no expertise is requires to handle AFE43000 impedance spectrometer^[6].

REFERENCES

1. H. C. Lukaski and W. W. Bolonchuck, "Estimation of body fluid volumes using tetrapolar bioelectrical impedance measurements," *Aviat Space and environmental*, vol. 59, no. 12, pp. 1163-1169, December 1988.
2. Saxena and R. Sharma, "Role of Bioelectrical Impedance Analysis (BIA) in Renal Diseases," Department of Nephrology SGPGIMS, January 2005 Lucknow.
3. S.M. Lee, S.Y. Kwon, B.H. Cho, I.Y. Kim, S.I. Kim , "A new PDA based body fat measurement system," in *Annual International conference of the IEEE Engineering in medicine and Biology Society*, Korea, 2003, pp. 44-45.
4. C. Margo, J. Katrib and M. Nadi, "Four electrode embedded bioimpedance measurement system," in *Annual International conference of the IEEE Conference in Faible Tension Faible Consommation*, Paris, 2013.
5. D. A. Fields, M. I. Goran, and M. A. McCrory, "Body-composition assessment via air-displacement plethysmography in adults and children: a review," *The American journal of clinical nutrition*, vol.75, no.3, pp. 453-467, March 2002.
6. B. Sanchez, A. Praveen, E. Bartolome, K. Soundarapandian and R. Bragos, "Minimal implementation of an AFE4300-based spectrometer for electrical impedance spectroscopy measurements," *Journal of Physics*, vol. 434, no.1, pp. 1742-6596, April 2013.