Research Article

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Integrate Bioelectricity Impedance Analysis, Micro-particle Spray, Phototherapy and APP Recording and Analysis Circuits are Controlled in the Same Machine

Vicky Yi-Tzu Chang[1], Melody Yung-Ying Chen[1], Arvin Huang-Te Li[1] and Pei-Fen Tsai[2]*

[1]*ARVIN Bio-Medical Devices Co., Ltd, Taiwan.*

[2]*Financial and Economic Law Department of Asia University, Taiwan.*

***Correspondence:**
Prof. Pei-Fen Tsai, Financial and Economic Law Department of Asia University, Taiwan.

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ABSTRACT

Currently, most portable cosmetics devices are single assistant skincare function products, which lack long-term using motivation because of unable to inspect using history and limit to use a single function. Nowadays people chase scientific evidence to inspect self-related products and customizer their demand. In the project, we provide a portable multifunction device combined detection sensor with two physiotherapy functions. We developed the algorithm and digital filter for the MCU and smart devices to algorithm the data through detecting currents by four probes completely contact on the skin. Otherwise, we integrated immediately replenish micro-particle water function using aerosol variable-frequency transport technology and three wavelengths LED phototherapy to provide all domains of skin conditioning. All the detection data, environmental information and using history will record by the developed APP.

Keywords

Portable multifunction device, Aerosol, MCU, Algorithm, APP.

Introduction

Consumer interest in personalized health is increasing. The largest organ of the body is skin, which protects people against environmental damage like UV light, changed temperature and humid, but most people treat it as casual. When it pops some problems, we finally aware that may reflect some problems inside bodies. Considering people have different habits, it needs to record the quantitative status of skin and environmental data to analyze personal skincare project. Therefore, we developed the algorithms of estimating skin status by using active and passive components to quantitative epidermal hydration, cell health grading, surface pH value, trans-epidermal water loss, surface sebum [1,2]. We know monitoring skin status is important but people lack long-term using motivation because of unable to inspect using history and limit to use a single function. So, in this project, we integrated detection sensor with replenish micro-particle water function and three different wavelengths LED phototherapy function, it could provide an information loop to people from increase the awareness of personal health, taking immediately treatment to observation after treatment. This information loop could provide recommendation and try to improve the skin treatment journey. Convenience is another factor let people lack long-term using motivation, so in this project, we do not only integrate sensor technologies but also design as replaceable functions and whirling storage to reduce the volume and weight and then increase the convenience and usage rate. All of the data are consented by the users before testing to be pursuant of regulation to protect their privacy.

There are four key points in this project we focus on developing. 1. Nowadays on the market there are differently single function skin inspection devices, from professional multi-detection equipment to portable devices. To widespread collect skin data, we focus on portable device such as camera recognition analysis or current receive detection. Each of these portable devices has limits like different light sources will affect interpretation result or single

current only through shallow epidermis will not present full view of skin status. With respect to convenience of skin monitoring, we selected using effective, sensitive and rapid sensor-multi-frequency bioelectricity impedance analysis (MF-BIA) [3-5]. By measuring tiny currents with specific frequencies which divided to other physiological currents, and specific frequency could calculate different resistances and estimate the proportion of body composition. Using the algorithm, we developed we can quantitate the skin status. 2. In this integrated device, the highest usage frequency and the attrition rate is the function of generating micro-particle spray. There are two common problems of commercially available micro-particle: noisy and high attrition rate of piezoelectric ceramics. So, we use waterless detection technology to decrease the attrition rate of piezoelectric ceramics and using sweep control technology to increase and stable the total amount of atomizing water. 3. Mostly LED photo-therapy equipment are large-scale and fixed, which usually used on full face, but considering the main skin problems skin wrinkle, melanin precipitation and acne people will not happen on full face (if it happened, people should seek for medical assistant). So, we designed portable and three different LED wavelengths which proved by animal test to solve these common problems which happened in part of face. 4. This project will be developed as an Internet of things device, because it will effectively motivating adhering to monitoring skin status, personal habit and environment affected. History records of skin status and personal habit could help people awareness personal health and receive precision recommend.

As follow we will introduce our system configuration and the main technologies in section 2. Methods and Materials and then present the prototype design in section3. Discussion and results, and then focus on this project will provide more value-added service in section4.

Materials and Methods

System configuration

Overview of this system design and application, it provides a series of skincare tools to increase the awareness of personal health, so it is important to decrease the complex instruction and present necessary functions to guide user naturally use a series tools and indirect receive the feedback records to quantified self and, in the future, accumulate enough data to become important and effective feedback opinion.

For clarity the system we divided it as hardware and software design. In hardware design we integrated three functions – skin detection, micro-particle spray and LED phototherapy [6,7], and these three functions are sequential and different control methods. Each function has its limitation: (1) Skin detection function needs a flat surface to ensure each probe connected to the test area. (2) Micro-particle spray needs a space to refill liquid and prevent liquid leaking to short the circuit. (3) LED lights are unable to be blocked. Considering the order of use, the appearance arrangement will be from left to right or top-down design, and the operate control must arrange in the middle of the design. And the hardware block diagram of overall system shown in Figure 1.

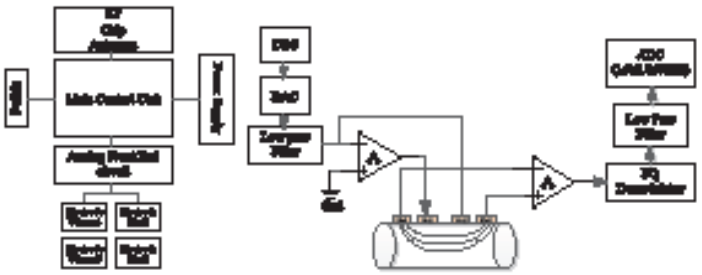

Figure 1: The hardware block diagram of overall system.

Under the consent of the user, skin detection data are transferred to a smartphone for analysis and display on it, and we guide the user naturally use the series of skincare tools by the interface design. The comprehensive skin status data and environment situation will be recorded to assist analyzing user feature to optimization consumer experience. The overall process flow is as shown in Figure 2.

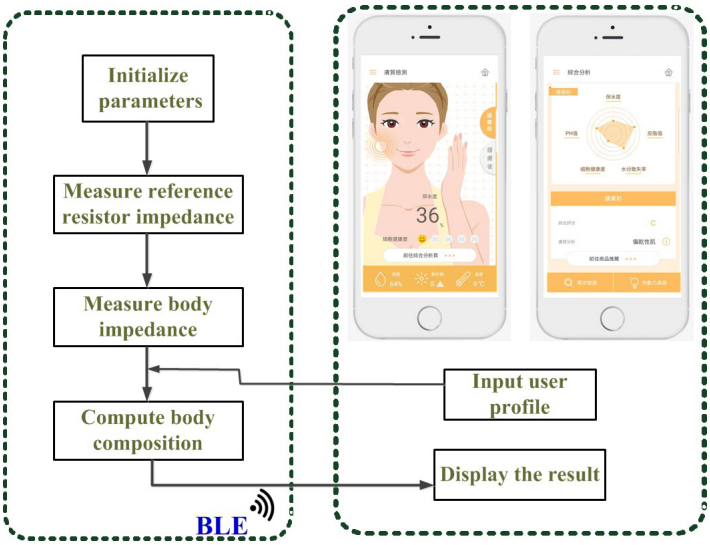

Figure 2: The overall process flows.

MF-BIA with skin status

Bioelectrical Impedance Analysis is known as a simple operation, rapid, non-invasive, inexpensive method to evaluate the composition of whole body. There are five combinations on the basis of body composition elements, which as the whole body, 2-compartment model: fat mass and fat free mass, 3-compartment model: fat mass, lean mass, skeleton, 4-compartment model: fat mass, protein, total body water (TBW), skeleton, the cellular model-fat mass, extracellular solid, extracellular water (ECW), cell mass [8]. According to this project, we focus on detecting the skin status, so we take cellular model of body composition as our principle. Various body compositions have large differences in conductivity when current is passed through. It can be used for the determination of body composition by using the differences in bio-resistance of various tissues [9,10]. The current frequency through the cell is 0, it only penetrates the ECW but not through the cell membrane. The measured resistance R0 at this time can

represent the resistance of ECW. Further the measured resistance R_∞ could represent the resistance of ECW and intracellular water (ICW), because unlimited current frequency could penetrate the cell membrane, ECW and ICW. Research from Fricke's circuit, the resistance of ICW (RICW) and the resistance of ECW (RECW) are connected in parallel with each other and separated by the capacitive reactance of cell membrane XC.

The relation between the reactance and the resistance will change by some factor affected the nutritional status or moisture status. Reference the relation chart of Cole-Cole plot [11], it describes the relation between the reactance and resistance, and present phase angle ψ as relation parameter [12]. According to the research of Patel et al, Multi-frequency Bioelectrical Impedance Analysis (MF-BIA) is more accurate than Single-frequency Bioelectrical Impedance Analysis (SF-BIA). Therefore, we take MF-BIA to measure the resistance and reactance.

As shown in Figure 3, it presents the design of our MF-BIA front end circuit block [13]. At first, through the Direct Digital synthesizer (DDS), 6 bit Digital to analog converter (DAC) and Low-pass filter to transform the MCU clock square wave to currents with specific frequency [14]. We designed it to generate four specific frequency currents in turns, and through the human resistance we can receive the corresponding voltages by the system circuit of differential amplifier. After differential amplifier synchronous rectify the analog voltages signals, and through16 bit ADC capturing to digital signals.

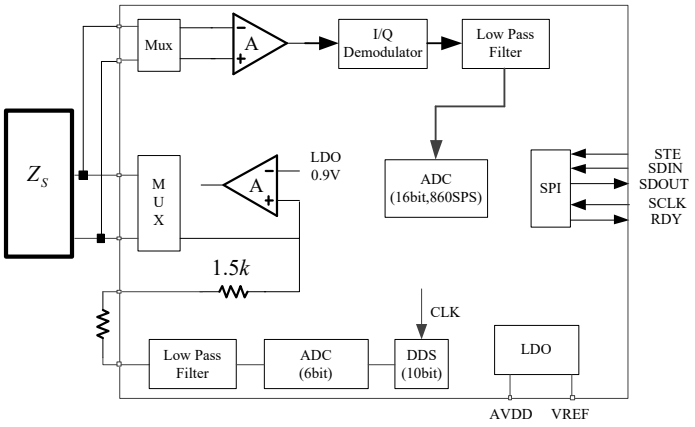

Figure 3: MF-BIA front end circuit block.

When we switch on the MF-BIA system, we will set up initialize in progress. We calibration with the reference resistances, which using 100~750Ω precision resistor to calculate the slope by the designed four specific frequency currents (8 kHz, 16kHz, 32 kHz, 64 kHz) [15] and calculate the offset by the corresponding voltages measured on the I/Q mode. As shown in the Chart. Thereby we could get the Equation (1) from practical testing reference resistance (R). The phase angle (ψ) is equal to arctan-1Q/I, calculated slope is equal to 0.077, and the offset is equal to -0.026.

$$R=(\sqrt{I^2+Q^2}*Slope)+Offset$$
$$Slope=0.077\ ,\ Offset=-0.026 \quad (1)$$
$$\text{Dphase}=\arctan^{-1}\frac{Q}{I}$$

After calibrating, the resistance (R) and the phase angle (ψ) analytical comparison with animal experiment data, we can get equations which are water retention (WR), pH value, sebum, (DH), total water loss (WL), (CL) as follow equation (2) ~ (6).

$$WR=(196.67-(R*0.6667)); \quad (2)$$
$$PH=Z*0.0361-(R^2*0.0006)+2.896 \quad (3)$$
$$DH=\left(\left(R^2*-0.0833\right)+\left(R*7.41\right)-77.22\right) \quad (4)$$
$$WL=\left(\left(R^3*0.0014\right)-\left(R^2*0.1862\right)+\left(R*7.66\right)-82.67\right) \quad (5)$$
$$CP=\text{Dphase}*0.04+2.6818; \quad (6)$$

Waterless detection and sweep control technologies

Micro-particle spray generally exists two main problems on the market- the high attrition rate of piezoelectric ceramics and unstable amount of spray. Therefore, we generate waterless detection and sweep control technologies to optimization the micro-particle spray performance called Aerosol Variable-frequency Transport Technology (AVTT).

Considering the production process of piezoelectric ceramics exist the tolerance 110 ± 5kHz of resonance frequency, so output in constant frequency will not optimize drive each piezoelectric ceramic. The circuit design of sweep control is shown in Figure 4.

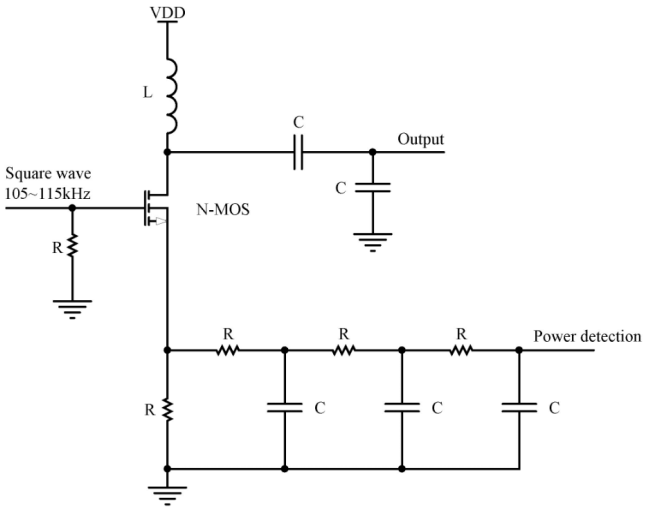

Figure 4: Sweep control circuit.

Through adjustment the frequency of square wave (f_{sw}) which calculating by the Equation (7) ' drive the circuit receiving the maximum Vp corresponding f_{sw} to obtain the optimization resonance frequency of piezoelectric ceramics. Therefore, we could ensure driving each piezoelectric ceramics to stable maximum amount of spray.

$$f_{sw}=16\text{MHz}/\text{Number of counts}/2 \quad (7)$$

Otherwise, the best way to solve the high attrition rate of piezoelectric ceramics is avoid no load. In the Figure 5, we setting up sweep frequency and AVTT within the resonance frequency tolerance range could show the difference between water and waterless.

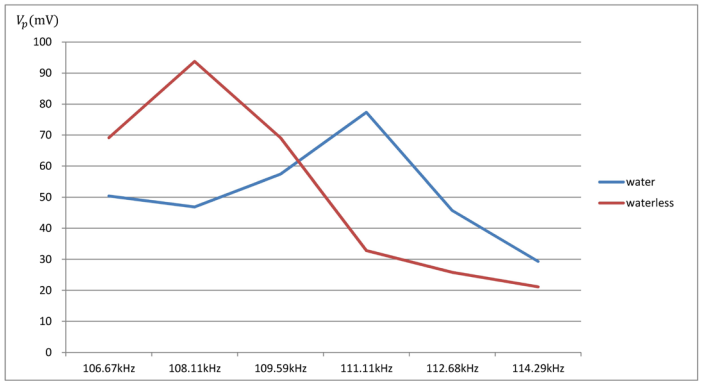

Figure 5: Sweep frequency within the resonance frequency tolerance range.

Using MCU take the number of counts and calculating 6 frequencies (114.29 kHz, 112.68 kHz, 111.11 kHz, 109.59 kHz, 108.11 kHz, 106.67 kHz), it presents different voltage curves between water and waterless. According to this feature, we assumed there is water in the container at first. We drive the circuit continuous working in the highest fre ncy (114.29 kHz) for 100ms, and then capture the first voltage (V_p). The first voltage needs more time to capture because piezoelectric ceramics takes some time to stable working condition, and the other remaining five voltages are captured by the frequencies working for 25ms. In this case we shown in the Figure 8, compared these 6 voltages, MCU will drive piezoelectric ceramics working in111.11 kHz as optimization resonance frequency. When the voltage drops under 40 mV, MCU will stop piezoelectric ceramics working as waterless in the container.

Three different LED wavelengths with skin indications

According to the data from animal test, LED wavelength could penetrate deep into the skin to trigger natural intracellular reactions. Depending on the light, your skin is going to response differently [16]. Considering the main skin problems, we designed 3 wavelengths to correspond indication (Table1). The wavelength of Red is 660nm, your skin responds by building, strengthening and maximizing cellular structure [17]. It also believed to target oil glands to reduce cytokines, which cause inflammation and play a role in chronic acne. In the case of blue light, it stimulates production of oxygen radicals that kill acnes bacteria without damaging skin. Green light brings balance and calm to the skin and organs. So, it has anti-inflammatory properties and can even help reduce hyper-pigmentation [18].

Table 1: The project takes 3 different wavelengths LED.

Item	Wavelength	Voltage	Current
Red LED	660 ± 10nm	1.83	350mA
Green LED	520 ± 10nm	1.83	350mA
Blue LED	410 ± 10nm	3	350mA

Results and Discussion

The limitation of MF-BIA and the benefit to record skin status

Currently, skin condition could be distinguished into three types by skin surface sebum: oily, dry, neutral. According to the different sections, there are different definition value ranges. There is an experiment shown it is inconsistency results from subjective and objective quantification measured by Sebumeter (SM 810). In other words, the adscription of skin types is various from personal cognition to the result of Sebumeter (SM 810). And no matter what skin type, there is high sebum secretion amount on the T-part section. Also, skin surface sebum is various from intra-individual to inter-individual. Oily or dry skin state is not absolute, it could simultaneously exist.

There is just one factor to the skin status, but in this project, we could measure and calculate the other four factors: WR, pH value, DH, WL, and CP. Each factor exists different reference of skincare principle. But considering measure these factors are limited by time, place, temperature, age and personal habits, it will be hard to receive massive collection data. Through the MF-BIA detection technology we developed to skin status, we precise calibrating the resistance and introduce the phase application, it could easier widespread collect data. Further, we designed it as an IOT device, we simultaneously record the environmental data such as temperature, humid, UV light, and menstrual cycle and so on. In the future, cross-comparison these data will effectively present skin status personally.

The prototype designs

In hardware design we integrated three functions – skin detection, micro-particle spray and LED phototherapy. Although these three functions are sequential, users will not follow entire process. Preventing using arrange in pairs as casual, skin detection we will fix the probes on the bottom of device, the other functions-micro-particle spray and LED phototherapy we take it replaceable design by magnetic. Using priority data selector to drive packet engine with different input signals, successfully simplify complex multifunction skincare tools.

In the software design, we need to guide users pay attention to their own skin status with environmental factors, and compare before and after data by radar chart, through overlapping the diagraph to

imply skin problems. And record the trend in a week or in a month, we could cross comparison by seasonal alternation or menstrual cycle in the future.

Conclusions

When we use multi-functions skincare tools with detection device to deal with skin problems, we can get better results and less chemical harmful than just using traditional application methods (usually put some cream or ointment on the problem skin regions). Skin detection data with environmental factors could present overall skin status, users could through these value range to choose active ingredients to the relatively indication. And according to the feature of piezoelectric ceramics, the active ingredients will reduce additives. Led phototherapy in this project enhances the completion of skincare process. Thus, the device will become the pioneer tools to aware personal skin health.

By the APP recording, we will be able to accumulate a lot of data. In the future these data compare to the biological experimental data and developing with AI to cosmetic AIoT. For further explanatory of the regulation and qualitative analysis about medical equipment will be discussed and presented in the other article for the limit of the number of words. Of course, those data are collected and saved under the free will to consent of all users, and the users have the choice to reject.

Acknowledgments

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