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High Frequency Circuit Design using Feedback Control on Localized Obesity Relief Therapy with Body-Load Variation

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Abstract

An attempt of sequence selection is made for multiple alignments of transmembrane proteins in order to detect the structural similarity in the protein families. A high frequency therapy device increases metabolism by flowing alternating currents of frequencies above 100 KHz to human tissue and increasing tissue temperature and blood flow due to the fat dissolving mechanism. However, intermittent sparks between ceramic parts that apply high-frequency power to the subject's metal plate during contact with the patient during treatment with a high frequency therapy device cause adverse effects such as skin burns or experienced therapists. This causes not only physical damage but also the patient's refusal to treat the high-frequency therapy device. The purpose of this study is to develop a high-frequency system for the treatment of obesity that does not cause sparks even if it is not a skilled therapist. It is also desirable to control the output by feeding back the load fluctuation of other therapists to secure the safety.

Keywords: High Frequency, Obesity treatment, Feedback Control, and Load variations

INTRODUCTION

Obesity is simply a state of excess body fat accumulation in the body rather than just a lot of weight. In other words, when the amount of muscle is large and the body fat is not increased, it cannot be said to be obesity even when the body weight is large. It is now known that abdominal obesity is more important than systemic body fat accumulation. Recently, the accumulation of visceral fat in the abdomen is more important than subcutaneous fat. Since 1996, the World Health Organization has identified obesity as a disease that requires long-term treatment, and is now recognized as one of the major diseases that humankind needs to overcome. Non-surgical treatments are of great interest because of their simple treatment methods, their low side effects and their short recovery time. Non-surgical therapies include middle and low frequency, high frequency, ultrasound, and cooling decomposition therapy. Among these treatments, this paper focuses on efficiency improvement and safety in high frequency treatment of obesity. Currently, high-frequency stimulators are classified into medical low-frequency (less than 200Khz), mid-frequency, and high-frequency (200Khz or more) depending on various constitutions and skin conditions. In addition, therapies that can maximize efficiency in a short period of time by appropriately applying cold / hot stimulation along with high frequency have been developed. If a current of more than 10,000 [Hz] is energized in the human body, muscle contraction is not induced but the temperature rises. Depending on the frequency of the high frequency current, the temperature rise range and the penetration depth change [3].

MATERIALS AND METHODS

Heating of output electrode

The feedback signal is detected with respect to the load variation occurring when the human body touches, and the output is controlled constantly. In this case, the load impedance detection method detects the output current, converts it to voltage, sends the converted voltage to the MCU ADC, and the MCU calculates it and sends it to the DAC to control the output with constant current. At this time, when the contact impedance becomes large, To achieve a certain therapeutic effect and to ensure safety. Conventional high-frequency stimulator is to generate heat by contact resistance in the ceramic part that touches the skin when the heat is generated in the human body, and it burns the part of the ceramic other than discharge (spark). It uses the thermoelectric element to heat the skin. It is necessary to continuously cool the heat generated from the opposite side of the thermocouple surface where the thermoelectric element is placed and the ceramic is cooled by using the following structure in the existing ceramic part, which uses the water jacket as the coolant as the water.

Interpretation of the water jacket model

The model was analyzed by using COMSOL Multiphysics 5.2 (COMSOL Inc.)[1], coupling the electric field, fluid flow, Peltier effect, and heat transfer, and setting the time to 0 ~ 1200 seconds. The Reynolds Average Navie-Stokes equation and the k-ε model were used as the governing equations for the flow of refrigerant [2].

$$\nabla \cdot (\rho U) = 0$$

$$\rho(U \cdot \nabla U) = -\nabla p + \nabla \cdot [(\mu + \mu_T) + (\nabla U + \nabla U^T)]$$

$$u(x,t) = U(x,t) + u'(x,t)$$

$$u = \rho c k \cdot \frac{k^2}{\epsilon}$$

$$\rho^u \cdot \nabla k = \nabla \cdot ((u + \frac{uT}{\sigma k})\nabla k) + P_k - \rho\epsilon$$

$$\rho u \cdot \nabla \epsilon = \nabla \cdot ((u + \frac{uT}{\sigma k})\nabla \epsilon) + C_{\epsilon_1}\frac{\epsilon}{k}p_k - C_{\epsilon 2}\rho\frac{\epsilon^2}{k}$$

$$P = \mu(\nabla u : (\nabla u + \nabla u^T) - \frac{2}{3}(\nabla \cdot u)^2) - \frac{2}{3}\rho k \nabla \cdot u$$

Property by element

In order to analyze the defined problem, the physical properties corresponding to each governing equations are required, and the physical properties for each element are shown in Table 1. Other materials are water, cooler is copper, thermoelectric element is Bismuth Telluride (Bi2Te3), and material property is COMSOL Material Library.

Table 1. Property according to element

	Property				
	εr	σ [S/m]	k [W/m/K]	cp [J/Kg/K]	cp [J/Kg/K]
Skin	1832.8	0.22	0.53	3800	1200
Fat	27.22	0.025	0.53	2300	850
Muscle	1836.4	0.5	0.53	3800	1270
Electrode & plate	1.0037	1.38×10^6	16.3	50	7900

RESULTS AND DISCUSSION

System

The controller is implemented to control the constant current control circuit using microcontroller as below.

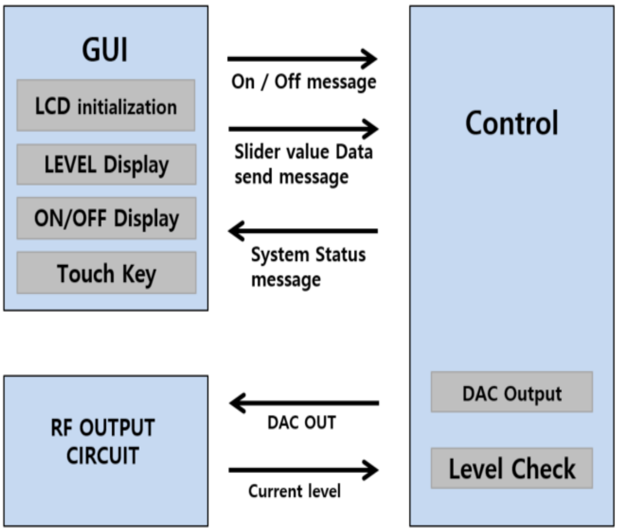

Figure 1. Complete system configuration

The current detection part was detected through A / D port and the DAC output was controlled in the range of ± 5% corresponding to the preset 10-divided output stage.

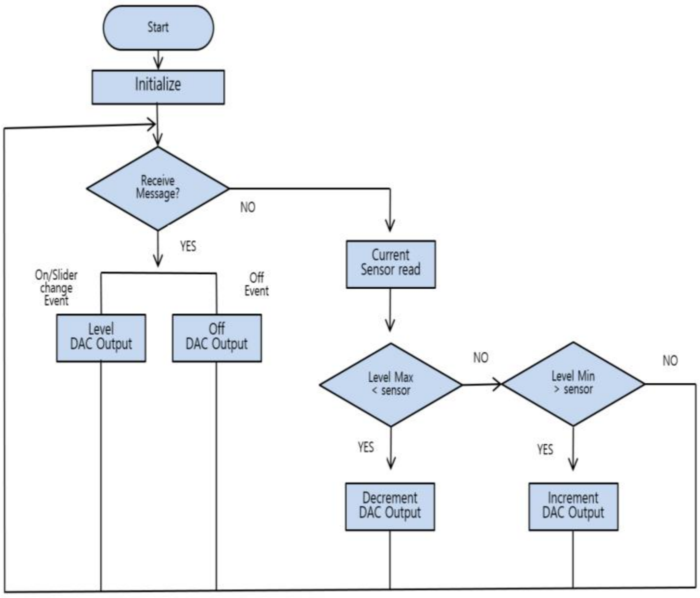

Figure 2. Control part flow chart

To select the most efficient transformer, the coil of transformer (T-1) core (0.0047mH), transformer (T-2) core (1.24mH), transformer (T-3) core (0.038mH) Was prepared. The generated voltage value of the transformer (T-1) is 23.5 V, the generated voltage value of the transformer (T-2) is 620 V, and the transformer (T- T-3) output voltage was 19V. As a result, it was confirmed that the highest voltage of the transformer (T-2) was outputted.

Load impedance feedback control results

The output stage was fixed to step 5, and the load resistance was changed from 200 Ω to 650 Ω in 50 Ω intervals. As a result, the output current difference was 118 mA and the output voltage difference varied greatly to 462 V.

Table 2. Output test according to load variation without feedback control

Load resistance (Ω)	Output current (mA)	Output power (W)	Output voltage (V)
200	455	31	250
250	454	42	337
300	448	50	406
350	430	56	466
400	416	61	520
450	396	63	549
500	382	65	593
550	364	66	623
600	352	68	654
650	337	68	712

In the output current feedback control, the step is fixed to step 5, and the load resistance is changed from 200 Ω to 650 Ω in 50 Ω intervals. As a result of measuring the output, the output current fluctuation is detected from 200 Ω / 15 W to 650 Ω / 9 W, .

Table 3. Output test according to load variation with feedback control

Load resistance (Ω)	Output current (mA)	Output power (W)	Output voltage (V)
200	320	15	182
250	262	14	203
300	227	13	218
350	197	12	227
400	178	11	237
450	168	11	251
500	154	11	256
550	140	10	254
600	134	10	262
650	120	9	254

The output current is 136mA, the output power is 4W, and the output voltage is 106V. The maximum output is 405mA and the output power is 33W. The result of the voltage 319V was obtained and it was found that it steadily increased at an average 3.22W until the 10th step.

Table 4. Output measurement results in feedback control according to step

Step	Output current (mA)	Output power (W)	Output voltage (V)	Load resistance (Ω)
1	136	4	106	200
2	175	6	138	200
3	213	9	169	200
4	248	13	195	200
5	270	15	211	200
6	301	18	233	200
7	329	22	255	200
8	356	26	273	200
9	380	29	290	200
10	405	33	319	200

The portion of the ceramic that is in contact with the skin is maintained at 20 ° C by the thermoelectric element and the fat portion of the human body is increased by about 60 ° C when the temperature is peak-to-peak voltage Vpp = 100V and is increased by about 85.5 ° C when the temperature is 150 ° C .

In order to verify the distribution and temperature of deep heat generation by the high frequency output which is normal (load change feedback application) in the system implemented in this study, the experiment method was set as below and the high frequency output was applied to the pork meat, The temperature was measured by inserting 5 temperature sensors from the epidermis at intervals of 5 mm to the inner 2Cm. At this time, the temperature was measured by applying high frequency to the output level in 10 steps. For accurate deep heat measurement, a 1 mm hole was drilled to a depth of 2 cm and a sunsheet was inserted.

Table 5. Deep heat measurement result (unit: ° C)

sensor position	0Min	1Min	2Min	3Min	4Min	5Min
CH1 (5mm)	24.8	25.3	27.5	30.7	33.4	36.3
CH2 (10mm)	22.5	23.8	24.7	26.4	27.3	29.6
CH3 (15mm)	20.0	20.7	21.5	22.6	23.7	24.5
CH4 (20mm)	17.0	17.6	18.8	19.8	20.6	21.2
CH5 (25mm)	13.7	14.3	16.3	15.8	16.5	18.0

In this study, to secure the safety of the system, the feedback signal according to the load variation was detected and controlled by the microcomputer to prevent sudden change of the instantaneous output. The system is validated through the following experiment.

The control signal measurement was compared and analyzed through an oscilloscope. The feedback current was immediately increased and the voltage dropped when the load (skin) was applied. In order to check whether the high frequency output of the implemented system is normally output, a sample (pork cell section) was purchased and a high frequency output was applied. The high-frequency handle was fixed on the sample for about 20 minutes, and the temperature change trend caused by the high-frequency current was confirmed. It was confirmed that the initial temperature increased to 92 ° C after 20 minutes at 27 ° C, and it was confirmed that normal high-frequency output was possible. The sample test proceeds to a static state of the output section, and it is confirmed that the temperature has risen sharply. Since the actual treatment proceeds with curving, it is judged that the risk of the image due to the temperature rise is reduced. It is considered that it is necessary to reduce the risk of image and the like. Based on the results of this study, if we extend the clinical experiment to various treatment subjects and verify the stability of the load change feedback control system through application to actual patients, we will provide improved high frequency treatment environment than existing high frequency stimulator.

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