THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF ELECTRICAL ENGINEERING

DESIGN OF WEARABLE ELECTRO-MECHANICAL VIBRATION DEVICE

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A thesis
submitted in partial fulfillment
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in Electrical Engineering
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Reviewed and approved* by the following:

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ABSTRACT

After a whole day’s work, or even during the work, people always suffer from the ache from their arms, legs, backs, and especially their necks. Many people have the cervical spondylitis. They may stay sitting for a long time, looking at the computer or bending over their desks writing. My project is to design such a device that can release people’s pains. It can be put and buckled on user’s stressed body and simulate the real kneading to relax the muscle.

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ACKNOWLEDGEMENTS

I would first thank my thesis supervisor, Shizhuo Yin, who did his best to help me accomplish the machine, which is part of my childhood dream. I also offer thanks to my roommate Yuhan Luo. She is really good at circuit design and helped me with the circuit control. Without their help, I cannot make it .

Thank to the Engineering department and Schreyer Honors College for this great opportunity. It’s a perfect closing point of my four-year electrical engineering studying.

Chapter 1

Introduction

The whole device contains four parts. The first part is the core that simulates the hand, which consists of a coil and a cylindrical metal. The second part is the current generation part, the magnitude and the frequency of the current flowing throw the coil can be adjusted in order to have different strength and frequency of the pulse. The third part is the user control panel. There are four pressed buttons on the chip. One is for turning on or off. Two of them are for increasing the strength and decreasing the strength. Last one is for changing the frequencies. The final part is the clothes for the whole device.

The main target customer is the people who spend lots of time sitting in the office with lots of pain on the shoulders, backs and arms. It will also be a perfect gift for elders, or students. The most advantage of the massager is that it is much smaller than usual massage machine, and it’s easier to be carried.

Chapter 2

Rational

One of the basic principles is the axial force generated by the coil and cylindrical metal. The solenoid consists of many turns of wire, when there is a current flowing through there will be an interaction force between the thick coil and the metal stick (permanent magnet). [1]

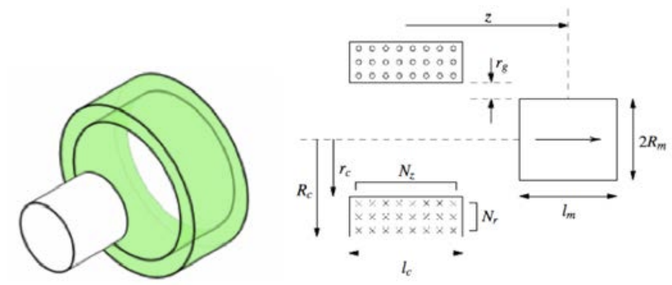

Figure 1. Model of Thick Coil and Permanent Magnet

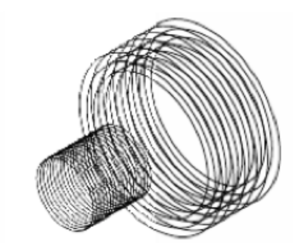

Figure 2. The Filament Method

By using the filament method, we can model the coil and the magnet as single turns (Figure 2), and the total interaction forces can be summed using superposition of each element. The force between two circular coaxial loops is given in below:

$$F_f(r_1, r_2, z) = \mu_0 I_1 I_2 z \sqrt{\frac{m}{4r_1 r_2}} \left[K(m) - \frac{m/2-1}{m-1} E(m)\right]$$

$$m = \frac{4r_1 r_2}{[r_1 + r_2]^2 + z^2}$$

I_1 and I_2 are the currents in each loop; r_1 and r_2 are the coil radii and z is the axial distance between them; Functions K(m) and F(m) are the complete first and second elliptic integrals respectively with parameter m. Then, by using superposition, the total force is given below:

$$F_{z1} = \sum_{n_m=1}^{N_m} \sum_{n_r=1}^{N_r} \sum_{n_z=1}^{N_z} F_f(r(n_r), R_m, z + L(n_m, n_z)) ,$$

$$r(n_r) = R_c + \frac{n_r - 1}{N_r - 1} [R_c - r_c] ,$$

$$L(n_m, n_z) = -\frac{1}{2} [l_m + l_c] + \frac{n_z - 1}{N_z - 1} l_c + \frac{n_m - 1}{N_m - 1} l_m ,$$

R_m is the magnet radius; r_c and R_c are the inner and outer coil radii; l_m and l_c are the magnet and coil lengths; z is the axial distance between their centers, N_r and N_z are the number of turns.

Another way to look at how the force can be generated is the integral method. We assume that the solenoid can be modeled as a volume current density and the magnet can be modeled as a surface current density around its circumference. The force will be the derivative of work to z. Therefore, if the magnet is at the middle of the coil, there is no force. When it has some deviation from the central point, because of the asymmetry, there will be a force.

In the device, once there is a current, the magnetic force will let the metal move back and force, which will create a feeling of peening.

Another important part is the signal control. In order to control the strength and the frequency of the vibration, we need a circuit that can be used to generate variable frequency sin wave. As in the figure showed below, by changing the resistance, the output frequency can be adjusted. [2]

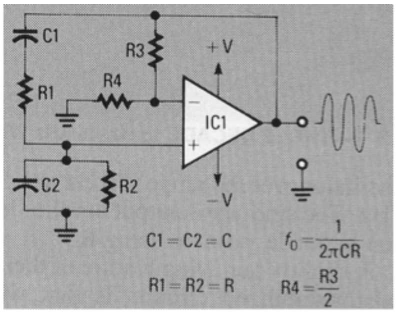

Figure 3. Basic Wein-Bridge Sine Wave

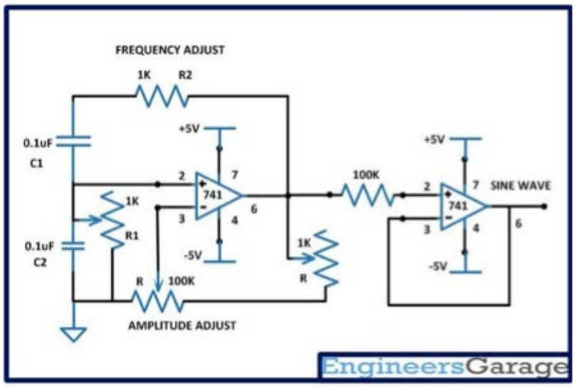

Figure 4. Variable Frequency Sine Wave Generator

The simplified circuit that I used is in figure 4. The frequency’s expression in figure 4:

$$\mathbf{F} = \frac{1}{2\pi\sqrt{R1R2C1C2}}$$

The circuit that I used is the simple massage circuit.

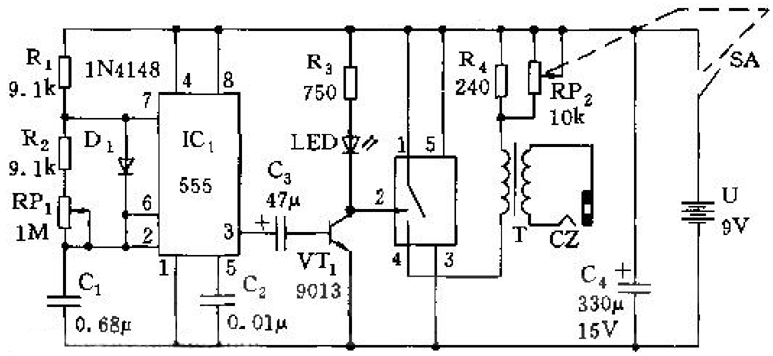

Figure 5. Massage Circuit

In this circuit, frequency can be adjusted by adjusting RP1, which is

$$f = \frac{1.44}{(R1 + R2 + RP1)C1}$$

$$f = \frac{1.44}{(R1+R2+RP1)C1}$$

The frequency is between 2 to 106 Hz. RP2 is used to adjust strength. 555 timer IC is a really useful chip that acts like an oscillator, and as a flip-flop element.

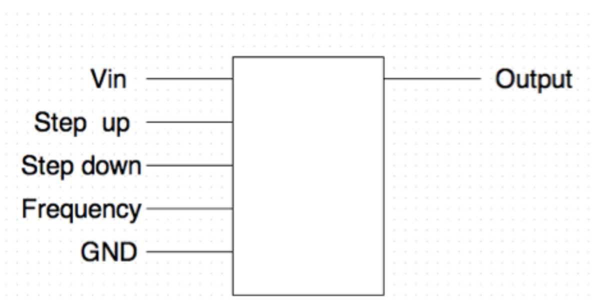

Figure 6. User Control Panel

Moreover, a control panel is needed for user to adjust the strength. It can be done by using switch circuits. There are four switches. One is used for turning on or off. Two of them are for controlling strength by changing the resistance using potentiometer. One is used for controlling the frequency also by changing the capacitance.

Chapter 3

Implementation

Blow is the block diagram showing the implementation step.

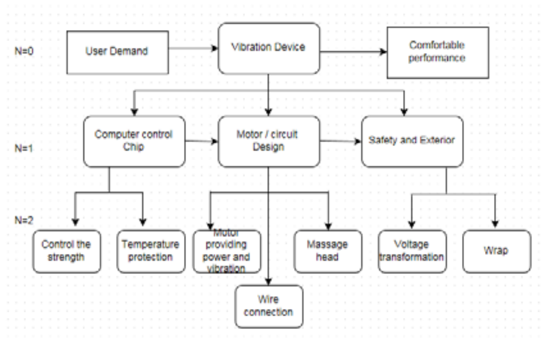

Figure 7. Block Diagram

The first step is to build the physical structure of the coil and metal in figure8. There is also a temperature protection in serious with the wire in the case that the temperature is too high.

Figure 8. Wires with coil

Figure 9. Permanent Magnet

The temperature switch is an inexpensive temperature-sensing mechanism, which is the “bimetallic strip:” a thin strip of two metals, joined back-to-back, each metal having a different rate of thermal expansion. When the strip heats or cools, differing rates of thermal expansion between the two metals causes it to bend. The bending of the strip can then be used to actuate a switch contact mechanism. [4]

The control panel and circuit are in figure 10.

Figure 10. Control Panel and Circuit

Chapter 4

Testing

The testing is very important. My first testing is to test whether the cylindrical metal can generate enough force. I packed the vibration part in a bag to not let the metal fall out. Then I connected voltage across the coil. As I increased the voltage, the strength went up. Since the optimistic setting voltage is 12V when it reaches to the biggest strength, when it reached to 12V, it didn’t have enough strength, so I added more wires on the coil until I found that under 12 V, it had enough energy of pulse.

Here is the test result shown in the table below.

	Voltage/V	Current /A
Test 1	12	5
Test 2	12	6.2
Test 3	12	7.5

Table 1. Test Result

Chapter 5

Conclusion and Future work

Figure 11. Magnet in the coil

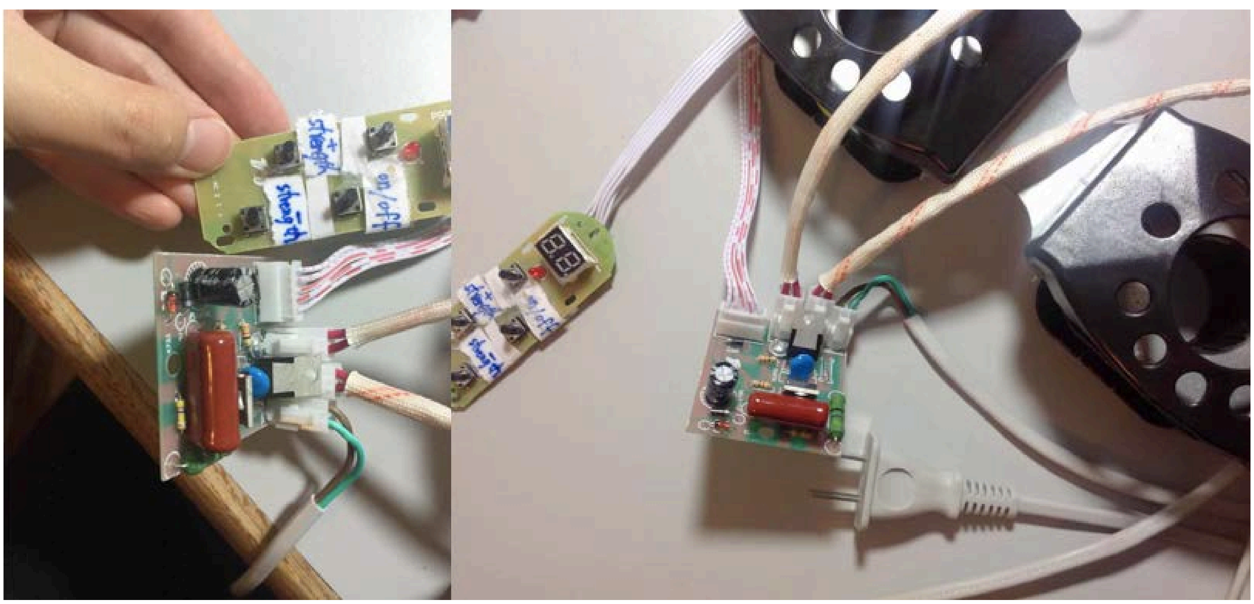

Figure 12. Connecting All the Part Together

Figure 13. With the Final Cloth

Since I don't have any experience of make a real electrical device, it's very hard for me at the beginning. I experienced the real world of electrical engineering. The thing beyond what we have learned from the class or the textbook is much more beneficial as being an engineer. I'm looking forward to improve the device.

First, I want the device to give more massage feeling. There will be another mode that provides more comfort. When the motor is turned on, the transmission shaft will drive the white massage ball to rotate, which will create the massage kneading.

Figure 14. Mode 2

Another important issue is the safety. The rated voltage is 12V. Therefore, there will be a voltage converter that transforms 110V to 12 V to ensure the safety.

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Design of linear analog Mosfet circuit State College, PA Spring 2015
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