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The Effect of Period of Time (T) from 900Hz – 1820Hz of Transcutaneous Electrical Nerve Stimulator for Biomedical Application

(Pengaruh Tempoh Masa (T) dari 900Hz - 1820Hz Stimulator Saraf Elektrik Transkutan untuk Aplikasi Bioperubatan)

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ABSTRACT

Transcutaneous Electrical Nerve Stimulator (TENS) is a device that can stimulate the nerves by using electric current. The main role of TENS is as a pain relief to users by replacing the usage of analgesic or drug. 2-Channel Defence Transcutaneous Electrical Stem Stimulator (2-Channel DTES) device and 5-Channel Defence Transcutaneous Electrical Stem Stimulator (5-Channel DTES) has been developed to improve the previous TENS devices but there were some shortcomings of the devices such as incoming noise in circuit as well as different measurement results if compared to simulation and experimental test. These problems may be solved by designing an alternative circuit of TENS to overcome the noise issue appearing during testing in which this study has tested and analyzed the basic circuit of TENS unit. Even though an issue of incoming small amount of generated electric current, apparently it would not affect the patient by using TENS. The capability of TENS as pain relief has been demonstrated to be comfortable, user friendly, and highly efficient to the user. From the experimental, it has been observed that the percentage measured for period of time, T from 900 Hz to 1820 Hz output measurement using implementation without electrode pads and with electrode pads of Transcutaneous Electrical Nerve Stimulator for biomedical application is around ± 5%.

Keywords: Bio-composite; SolidWork; Wood composite; Impact test

ABSTRAK

Transkutan Electrical Nerve Stimulator (TENS) adalah alat yang dapat merangsang saraf dengan menggunakan arus elektrik. Peranan utama TENS adalah sebagai penahan sakit kepada pengguna dengan menggantikan penggunaan analgesik atau ubat. Peranti Stimulator Elektrik Transkutan 2-Saluran Pertahanan (DTES 2-Saluran) dan Perangsang Batang Elektrik Transkutan Transkutan 2-Saluran (5-Saluran DTES) telah dikembangkan untuk memperbaiki peranti TENS sebelumnya tetapi terdapat beberapa kekurangan peranti seperti kebisingan dalam litar serta hasil pengukuran yang berbeza jika dibandingkan dengan ujian simulasi dan eksperimen. Masalah-masalah ini dapat diselesaikan dengan merancang rangkaian alternatif TENS untuk mengatasi masalah kebisingan yang muncul semasa ujian di mana kajian ini telah menguji dan menganalisis litar asas unit TENS. Walaupun terdapat masalah arus elektrik yang dihasilkan dalam jumlah kecil, nampaknya ia tidak akan mempengaruhi pesakit dengan menggunakan TENS. Keupayaan TENS sebagai penghilang rasa sakit telah terbukti selesa, mesra pengguna, dan kecekapan tinggi kepada pengguna. Dari eksperimen, telah diperhatikan bahawa peratusan yang diukur untuk jangka waktu, T dari 900 Hz hingga 1820 Hz pengukuran output menggunakan implementasi tanpa bantalan elektrod dan dengan pad elektrod Transkutan Elektrik Stimulator Saraf untuk aplikasi bioperubatan adalah sekitar ± 5%.

Kata kunci: Bio-komposit; SolidWork; Komposit kayu; Ujian Impak

INTRODUCTION

By definition, any stimulating device that delivers electrical current across the intact surface of the human skin is known as transcutaneous electrical nerve stimulator (TENS) (Gomez-Tames et al. 2012; Kuhn et al. 2010; Forrestor & Potrofsky 2004; Poletto & Doren 1999; Hsiao et al. 2017). From the previous study, 2-Channel Defence Transcutaneous Electrical Stem Stimulator (2-Channel DTES) device has been created to replace analgesics as pain relief (Miskon et al. 2014). The motive of this device is created because of analgesics have many side effects to the users such as constipation and nausea (Orsini 2017; Santana et al. 2015). The previous 2-Channel DTES does not have variable output to suit with patient's pain level. As every patient have different pain level, adjusting the output needed for each patient found to be crucial in order to increase the effectiveness to DTES.

Besides that, 5-Channel Defence Transcutaneous Electrical Stem Stimulator, also known as 5-Channel DTES device, has been developed for improvement from the previous 2-Channel DTES by adding the number of electrodes from 2 to 5 (Miskon et al. 2016). However, the percentage error of frequency and pulse period were large. The noise interference may be affected an effectiveness of the TENS system which may disrupt the production of the real value of the electrical stimulation appropriate to the patient's pain level.

There are various methods to overcome this problem. One of the methods is by designing a new alternative circuit which is more effective in capacity than the previous circuit design using a Proteus software. Furthermore, by making suitable arrangements to components in the circuit, the noise can be reduced gradually, to obtain accurate data reading. Therefore, the objectives in this project are to provide a new TENS device which consists less noise from previous design and to verify the frequency of TENS.

METHODOLOGY

The conceptual framework of this study has been simplified as shown in Figure 1. The project was carried out by performing studies on TENS related works focusing on the characteristics of electrical stimulation, characteristics of the human body system for electric current application to transmit signal, and the advantages as well as comparison of TENS with itself or with any other methods for pain inhibitor for designing the appropriate circuit. Next, familiarization in using software such as Proteus ISIS software and MicroStudio software is very crucial in the designing steps. These are useful in designing the circuit and simulating the coding for the microcontroller to execute during the circuit operation.

However, if the outcome is not as desired, the design circuit and simulation coding are redone until the desired outcomes are obtained. Once the designed circuit produces the desired outcome, then the hardware design for TENS takes place. The components have been selected based on their function, specification, characteristic, and limitation. In the final process, the hardware then tested for the variable output and the efficiency of the TENS as a pain inhibitor.

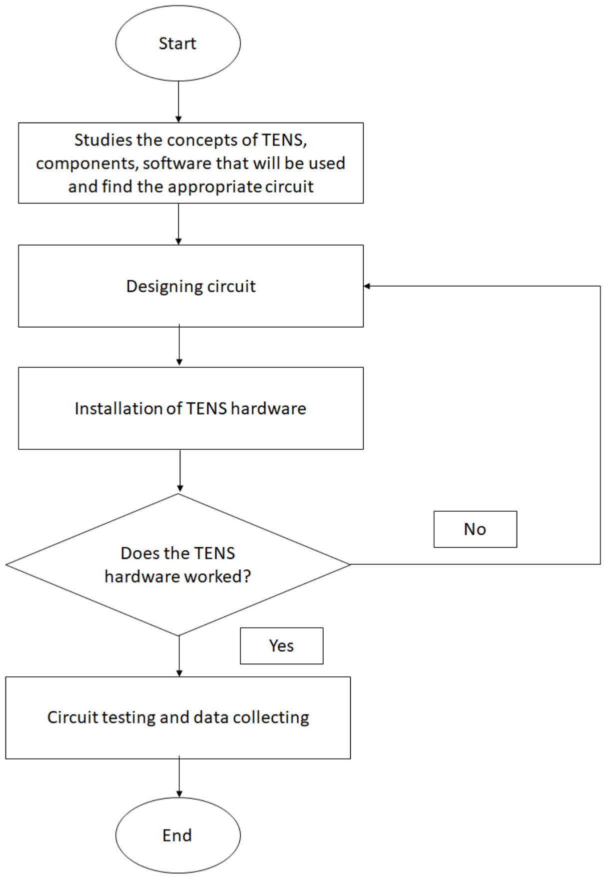

FIGURE 1. Project flow chart

Based on the project's objective of developing new TENSs with various frequencies, the experiments that have been developed were only focusing on outputs produced by TENS according to the frequency. There are only two methods implemented to get the TENS output for this study. First, by using the electrode pads and second is without using the electrode pads (detached).

MEASUREMENT OF OUTPUT FREQUENCY WITHOUT ELECTRODE PAD

There are several steps to get the frequency reading using oscilloscope and the steps are stated as follows. Before a test on TENS was performed, the oscilloscope equipment was prepared and installed. Red crocodile clip was connected to positive output and black crocodile clip was connected to negative output of TENS. Voltage supply for TENS device was connected to 12 Volt input and a reference frequency was set to 900 Hz. During measurement, results appear on the oscilloscope screen consisting frequency and pulse waveform were captured by 'Run / Stop' button. The results were saved permanently by using a 'Save / Recall' button. For data collection session, the frequency was adjusted at varies value.

PARAMETERS IN MEASURING WOOD MEASUREMENT OF OUTPUT FREQUENCY WITH ELECTRODE PAD

The steps in measurement of output frequency without electrode pad were repeated for the measurement of output frequency with electrode pad.

RESULTS AND DISCUSSION

FREQUENCY OUTPUT WITHOUT ELECTRODE PADS

In order to observe the differentiation output frequency, data measurement comes with different method which measures frequency output without electrode pad as well as measuring frequency output with electrode pad. Both data are shown below.

Output of frequency, f = 900 Hz

Equation 1 was used to calculate the output of frequency which the value of frequency is 900 Hz or 900 cycle of sinusoidal wave. Figure 2 shows the output waveform for 900 Hz.

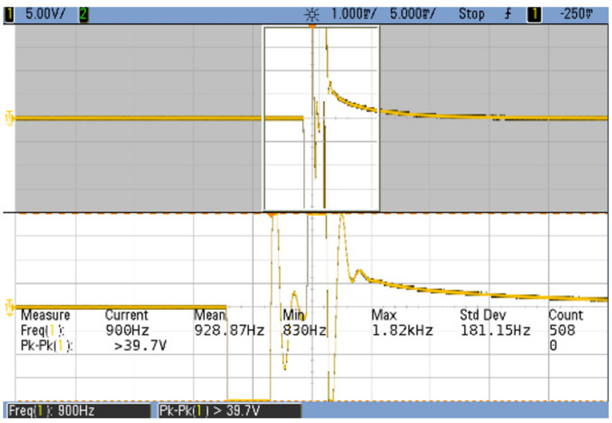

FIGURE 2. Waveform of 900 Hz

$$f = \frac{1}{T} \quad (1)$$

$$T = \frac{1}{900} = 1.111 \text{ ms}$$

From the calculation, 900 cycles of sinusoidal wave produce 1.111 milliseconds of time period. Next, is to determine the frequency for one cycle sinusoidal wave.

TABLE 1. Sinusoidal wave for 900 Hz

Frequency	Period of Time (T)
900 cycles	1.111 milliseconds
1 cycle	$T = \frac{1.1111 \text{ ms}}{900 \text{ Hz}} = 1.234\ \mu s$

Frequency of T=1.234 µs;

$$f = \frac{1}{1.234\ \mu s}$$

= 0.81 MHz

Output of frequency, f = 1.41 kHz

Equation 1 was used to calculate the output of frequency which the value of frequency is 1.41 kHz or 1 410 cycle of sinusoidal wave. Figure 3 shows the output waveform for 1.41 kHz.

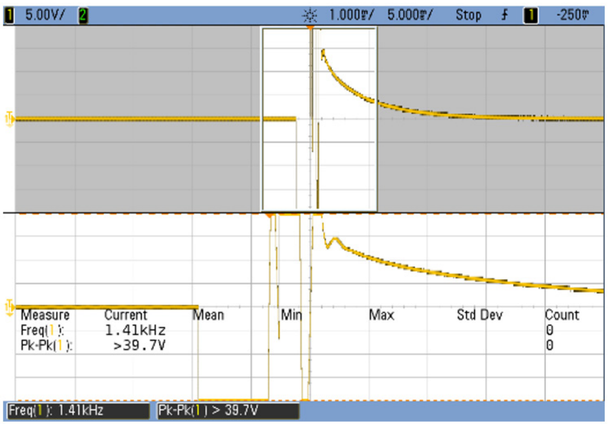

FIGURE 3. Waveform of 1.41 kHz

$$T = \frac{1}{1410} = 0.709 \text{ ms}$$

From the calculation, 1 410 cycles of sinusoidal wave produce 0.709 milliseconds of time period. Next is to determine the frequency for one cycle sinusoidal wave.

TABLE 2. Sinusoidal wave for 1.41 kHz

Frequency	Period of Time (T)
1410 cycles	0.709 milliseconds
1 cycle	$T = \frac{0.709 \text{ ms}}{1410 \text{ Hz}} = 0.503\ \mu s$

Frequency of T=0.503 µs;

$$f = \frac{1}{0.503 \ \mu s}$$

=1.99 MHz

Output of frequency, f = 1.82 kHz

Equation 1 was used to calculate the output of frequency which the value of frequency is 1.82 kHz or 1 820 cycle of sinusoidal wave. Figure 3 shows the output waveform for 1.82 kHz.

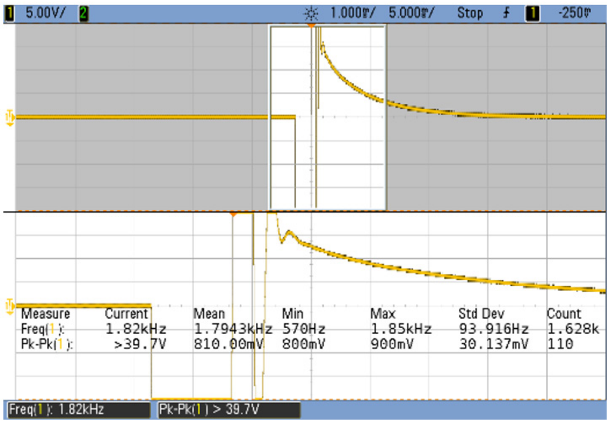

FIGURE 4. Waveform of 1.82 kHz

$$T = \frac{1}{1820} = 0.549 \text{ ms}$$

From the calculation, 1 820 cycles of sinusoidal wave produce 0.549 milliseconds of time period. Next is to determine the frequency for one cycle sinusoidal wave.

TABLE 3. Sinusoidal wave for 1.82 kHz

Frequency	Period of Time (T)
1820 cycles	0.549 milliseconds
1 cycle	$T = \frac{0.549 \text{ ms}}{1820 \text{ Hz}}$ = 0.302 µs

Frequency of T=0.302 µs;

$$f = \frac{1}{0.302 \ \mu s}$$

=3.31 MHz

FREQUENCY OUTPUT WITH ELECTRODE PADS

Output of frequency, f = 900 Hz

Equation 1 is used to calculate the output of frequency with electrode pads which the value of frequency is 880 Hz or 880 cycle of sinusoidal wave.

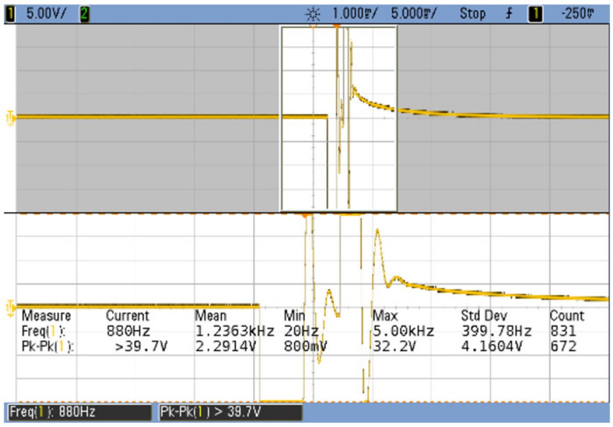

FIGURE 5. Waveform of 900 Hz

$$T = \frac{1}{880} = 1.136 \text{ ms}$$

From the calculation, 880 cycles of sinusoidal wave produce 1.136 milliseconds of time period. Next is to determine the frequency for one cycle sinusoidal wave.

TABLE 4. Sinusoidal wave for 900 Hz

Frequency	Period of Time (T)
900 cycles	1.111 milliseconds
1 cycle	$T = \frac{1.1111 \text{ ms}}{880 \text{ Hz}}$ = 1.291 µs

Frequency of T=1.291 µs;

$$f = \frac{1}{1.291 \ \mu s}$$

=0.77 MHz

Output of frequency, f = 1.41 kHz

Equation 1 is used to calculate the output of frequency with electrode pads which the value of frequency is 1390 Hz or 1 390 cycle of sinusoidal wave.

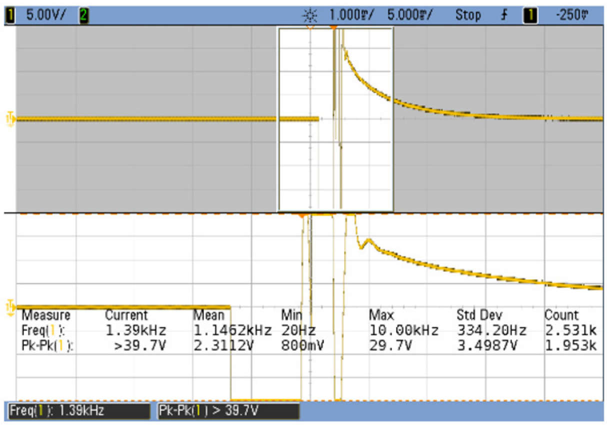

FIGURE 6. Waveform of 1.41 kHz

$$T = \frac{1}{1390} = 0.719 \text{ ms}$$

From the calculation, 1 390 cycles of sinusoidal wave produce 0.719 milliseconds of time period. Next is to determine the frequency for one cycle sinusoidal wave.

TABLE 5. Sinusoidal wave for 1.41 kHz

Frequency	Period of Time (T)
1390 cycles	0.719 milliseconds
1 cycle	$T = \frac{0.719 \text{ ms}}{1390 \text{ Hz}}$ $= 0.517\ \mu s$

Frequency of T=0.517 μs;

$$f = \frac{1}{0.517\ \mu s}$$

=1.93 MHz

Output of frequency, f = 1.82 kHz

Equation 1 is used to calculate the output of frequency with electrode pads which the value of frequency is 1790 Hz or 1 790 cycle of sinusoidal wave.

$$T = \frac{1}{1790} = 0.559 \text{ ms}$$

From the calculation, 1 790 cycles of sinusoidal wave produce 0.559 milliseconds of time period. Next is to determine the frequency for one cycle sinusoidal wave.

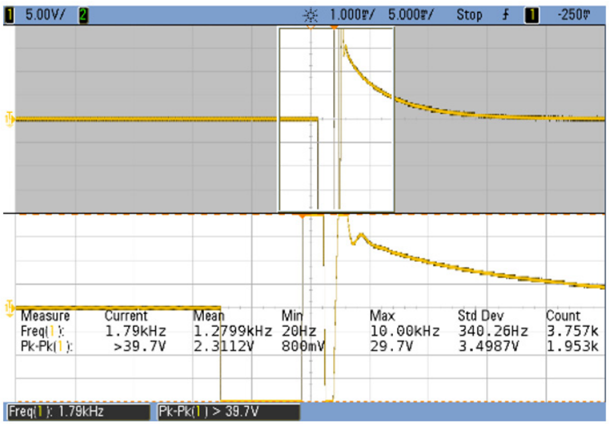

FIGURE 7. Waveform of 1.82 kHz

TABLE 6. Sinusoidal wave for 1.82 kHz

Frequency	Period of Time (T)
1790 cycles	0.559 milliseconds
1 cycle	$T = \frac{0.559 \text{ ms}}{1790 \text{ Hz}}$ $= 0.321\ \mu s$

Frequency of T=0.321 μs;

$$f = \frac{1}{0.321\ \mu s}$$

=3.21 MHz

TABLE 7. Comparison for period of time (t) between output measurement without electrode pads and output measurement with electrode pads

Subject	f (Hz) without Electrode Pads	f (Hz) With Electrode Pads	Diff, T in percentage, (%)
Output of frequency, f = 900 Hz	1.234 μs	1.291 μs	4.6
Output of frequency, f = 1.41 kHz	0.503 μs	0.517 μs	2.8
Output of frequency, f = 1.82 kHz	0.302 μs	0.312 μs	3.3

According to above Table 7, it shows that a percentage measured for period of time, T between output measurement without electrode pads and output measurement with electrode pads is ± 5% for 900Hz – 1820Hz of Transcutaneous Electrical Nerve Stimulator.

CONCLUSION

From the experiments that had been conducted, it was found that, this project achieved its objective in increasing variable output and can be concluded that the multiple output is feasible for DTES system. This is crucial as to strengthen the electrical stimulation method in replacing the function of analgesic as a pain inhibitor in human body with related range for Peripheral Nervous System.

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DECLARATION OF COMPETING INTEREST

None

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