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A Modified Electrosurgery Unit Based on High Frequency Design with Monopolar and Bipolar Method

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ABSTRACT Loss of a lot of blood during surgery when using a conventional scalpel is something that is highly avoided because it will cause contraindications to lack of blood which will be very dangerous for the patient. The purpose of this study is to design a tool that is used to replace a conventional scalpel with a tool that utilizes high frequency in order to eliminate faradic effects on body tissues where the high frequency will be adjusted to the duty cycle which aims to obtain various types of surgery required by doctor. That makes the Electrosurgery Unit is important to build because it can cause loss of a lot of blood during surgery less than using a conventional scalpel. Electrosurgery Unit can also be used for coagulation which means some surgery doesn't just need dissection but also seal some tissue to reduce or cut loss of some diseases at the patient. The result of the high frequency which is regulated by the duty cycle, will then be centered at one point on an object. In this study, the researchers took advantage of the type of heat effect produced by high frequencies, which were concentrated at one point so that it could be used to carry out the process of surgery (cutting) and coagulation (coagulation) on body tissues so as to minimize the occurrence of large blood loss. The researcher took advantage of the high frequency of 400 kHz generated by the oscillator circuit and then set it with a duty cycle program on the Arduino of 6% on 94% off for coagulation and 100% on for cutting. The module design consists of a 400 kHz frequency generator, a pulse control circuit to adjust the duty cycle, a power control circuit as a power setting, a driver circuit to combine the frequency with the set power so that different outputs are obtained according to the settings, an inverter circuit to increase the voltage. and an interlock circuit as a bipolar and monopolar output separator.

INDEX TERMS Electrosurgery, Frequency, Power, Microcontroller

I. INTRODUCTION

The use of electrosurgery requires an understanding of human body tissues and appropriate power and mode settings to avoid the effects of damage to body tissues[1]. According to research, the most basic things that make electrosurgery dangerous is one of them due to lack of understanding of the technology because the monopolar current generated is greater and will spread more widely throughout the body than by bipolar therefore, the correct power and mode settings are needed for reducing the risk of injury [2][3][4][5]. The heat generated by electrosurgery can also have an impact on the network if the tissue implant is very sensitive to heat because even a little current and voltage passing through the network can damage the network. Therefore power management is needed. Understanding how the electric current through the body can help doctors prevent unexpected medical accidents because each part of the body has a different resistance [2][6], but with the power regulation and cutting mode, each cutting can be done by calculating the resistance of each tissue without damaging another network. An electric scalpel uses the principle of electric charge jumps in tissue surgery, or electrode contact with tissue is not required. With the effect of stepping electrons that burn tissue, the results of surgery will be more sterile [7][8]. Through understanding the output characteristics of electrosurgery will enable surgeons to more effectively vary the power output on the device so that power selection settings will not have an impact or negatively affect tissue effects [9][10]. An electrosurgery is a tool used by surgeons to cut tissue and coagulate or to block blood flow and benefits that are not available with standard cold steel scalpels [11][12][13][14]. The lack of mode is also a factor that is less than the surgical process. Therefore variations in modes other than cutting and coagulation are very necessary to match the surgical process to be performed and also with good power management. In line with technological advances making Electrosurgical is required to be used during the surgical process [4][15]. The frequency range commonly used ranges from 300 kHz to 2.5 MHz [5][16]. ESU operation is divided into 2 (two) modes, namely bipolar and monopolar. Bipolar mode is commonly used in minor surgery for coagulation (freezing) processes[17][18]. A tweezers-shaped electrode is used to clamp unwanted tissue, then a high-frequency electric current flows from the tip of the electrode across the network and then to the other end of the electrode [19][20]. The use of a continuous waveform causes evaporation or cutting of tissue. The continuous waveform causes very rapid heating. By using an intermittent waveform (cut into pieces), more heat will be generated. On the other hand there are also the effects caused including unwanted heating effects that occur around the tissue that is dissected [21][22]. Using a constant waveform, such as "cutting", the surgeon is able to vaporize or cut tissue when the resulting voltage is high enough [23]. In monopolar ESU there are two basic wave forms that form two effects on very different tissues, namely pure cut and coagulation, both of which work in the same frequency and power, thus maintaining constant cutting and freezing [8]. This electrosurgery unit was made in 2000 by Albert where it only uses a frequency generator and pulse control system[24], and in 2009 Ronald made an electrosurgery unit which only observed the impedance caused by the surgical process in a network[25]. Based on the literature study description above, there are several things that need to be developed, namely the mode used, the researcher will design the cutting mod, and coagulation because with the addition of modes can also minimize unwanted tissue damage during the surgical process , here researchers also use the selection of low, medium, and high power, this is also very important in the surgical process because it can help doctors to minimize the effects.

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

In this study, there are two modes; the first is cutting using 100% on duty cycle and Coagulation using 6% on 94% off duty cycle. These three modes use low, medium, and high power settings and use the output of a frequency generator of 400Khz.

1) MATERIALS AND TOOL

This study uses CMOS ICs (CD4069B, Texas Instrument, America) as high-frequency generators, MOC (4N35, Agilent Technologies, America), regulator circuits or MOSFET drivers (740B, Fairchild Semiconductor, America) as A and B type current amplifiers, ferrite type transformers: 42-M58802P01 as a voltage amplifier before entering the electrode. Microcontrollers (Uno, Arduino, Italy) are used as microcontrollers to regulate PWM output and power selection. IC frequency to voltage (LM2907, Texas Instrument, USA) to convert the frequency to voltage. Using a Digital Oscilloscope (Textronic, DPO2012, Taiwan) is used to measure and regulate the output of a frequency generator.

2) EXPERIMENT

After all, circuits are done, the next step is to function test circuits using Digital Oscilloscope for the measurements. The next step after function test circuits is done function test machine using meal and soap as a media.

B. THE DIAGRAM BLOCK

When the switch is on, then the input voltage from the PLN to the switch activates the DC power supply, then the whole series will get a voltage from the DC supply. The input comes from the footswitch / active electrode, which functions as a switch to perform surgery with cutting and coagulation modes with the buzzer indicator sounding, and the button is used to adjust the duty cycle, which connects with the Arduino UNO. Next, the cutting and coagulation button functions as a mode regulator on ESU. The power selection button is used to adjust power via the microcontroller as we wish, and then it will be displayed on the character LCD display for cutting mode power selection.

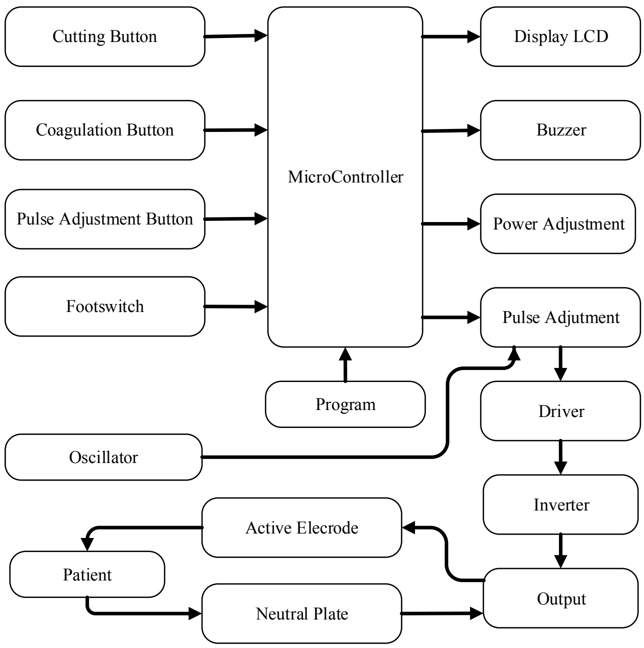

FIGURE 1. The diagram block of the electrosurgery unit

Because the surgery process uses a high frequency and has been determined, there is a clock generator circuit that produces a high frequency, the Oscillator. The oscillator block is then entered in the pulse regulator block and will be processed in the driver block that has been done before the power settings. Then after processing through the driver block will then enter the ferrite transformer circuit. Ferrite transformer in the above series of blocks functions as an increase in the output voltage of the driver. Then the output of the ferrite transformer will enter the passive electrode and can be used for the surgical process. (FIGURE. 1).

C. THE FLOWCHART

The flow chart proposed method in FIGURE. 2 When the switch is on, the character LCD screen will start to be initialized. On the LCD screen, the characters will display the power selection parameters in the cutting and coagulation mode. There are buttons that are low, medium, and high that function to choose the power regulator, which will then be displayed on the LCD character screen for cutting mode. When the footswitch is pressed, the tool will work with the appearance of power on the LCD character screen complete.

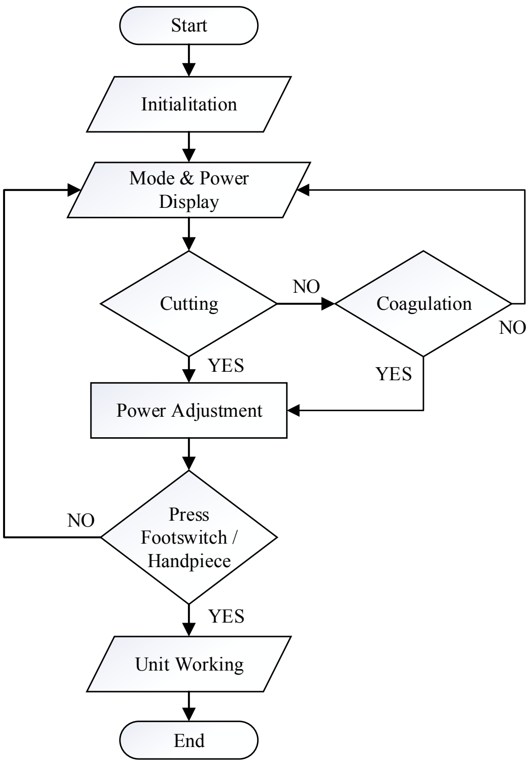

FIGURE 2. The ESU flowchart

III. RESULT

1) DEFIBRILLATOR DESIGN

There is an image look outside FIGURE 3 which visible handpiece and footswitch as a switch to activate the existing mode. There is also a ground plate that functions as a media attached to the patient. FIGURE 4 shows several circuits, including a microcontroller, oscillator circuit, power regulator, pulse circuit control, driver, power management, and inverter circuit.

FIGURE 3 The ESU

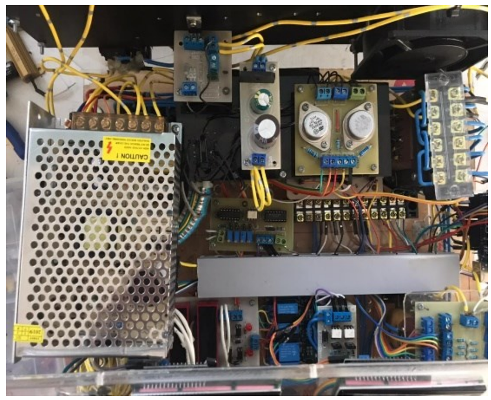

FIGURE 4 The circuit

2) THE LISTING PROGRAM FOR CHARGE PROGRAM

In this study using two control systems namely handpiece and footswitch.

Listing Program Power Adjustment

```
void toneftvmono()
{ if (dayamono == 1) {frekuensimono = 300;}
  if (dayamono == 2) {frekuensimono = 400;}
  if (dayamono == 3) {frekuensimono = 700;}
  if (dayamono == 4) {frekuensimono = 0;}
}
```

Listing Program Pulse Adjutsment

```
void dtcmono()
{ if (modemono == 1)
  {dcmono = 0;
   relaycut = 9;
   relayhvmono = 11;}
  if (modemono == 2)
  {dcmono = 240;
   relaycoag = 10;
   relayhvmono = 11;}
  if (modemono == 3)
  {dcmono = 255;}
}
```

3) Measurement results using digital Oscilloscope

FIGURE. 5 and Table 1 is the measurement result of the oscillator output, which is 400 kHz for frequency and 12V amplitude with a mean of 400,4 kHz. Then FIGURE. 6 and is the measurement results of the pulse circuit which is 100% used for cutting mode, and FIGURE. 7 is the measurement results of the pulse circuit which is 96% off and 6% on used for coagulation mode. The voltage of the pulse circuit is using 12V.

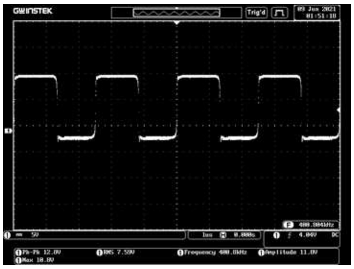

FIGURE 5 **Output Oscillator**

TABLE 1
Measurement the oscillator frequency

No.	frequency (Khz)	Mean	SD.	Error (%)
1.	400,4			
2.	400,5			
3.	400,4	400,4	0.07	0.03
4.	400,4			
5.	400,3			

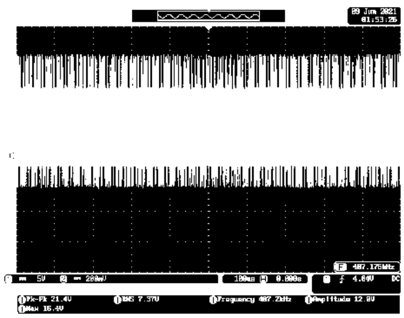

FIGURE 6. **Measurement Pulse Cutting**

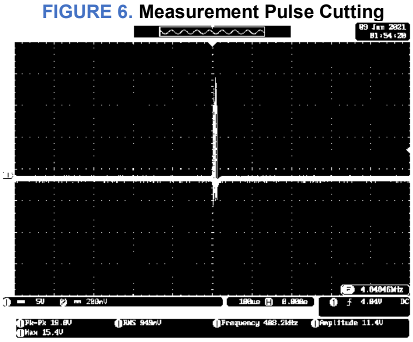

FIGURE 7 **Measurement Pulse Coagulation**

4) Measurement results of final output using ESU Analyzer

The final output Electrosurgery is at Power Inverter circuit, and the measurement used ESU Analyzer with setting impedance at 300-ohm, 400 ohms, and 500 ohms and the results used HIGH, MEDIUM and LOW setting power with two pulse mode cutting and coagulation.

TABEL 2.
Measurement Results at Power Inverter Circuit

Cutting Mode with impedance (ohm)	Power output (W)		
	Low	Medium	High
300	30,3	44,3	43
400	38,3	53	58,3
500	44,3	60	65,3

TABEL 3.
Measurement Results at Power Inverter Circuit

Coagulation Mode with impedance (ohm)	Power output (W)		
	Low	Medium	High
300	3	3	3
400	3	3	3
500	3	3	3

IV. DISCUSSION

The results of electrosurgery research with an Oscillator can be seen in FIGURE. 5 with an Error of less than 1%, and the final power results of the Electrosurgery Unit with cutting and coagulation modes can be seen in Table 2 and Table 3. The results of the Oscillator mean that the use of power settings and modes used are running well, in this study using a frequency to voltage converter circuit, a pulse regulator circuit, a power regulator circuit, and also a frequency generator that produces an output of 400Khz, which is the frequency forgotten the faradic effect. The different thing with past research is in this research that we combine the monopolar method and bipolar method to be one model. Also, we enhance the frequency and the power until 400KHz and the power up to 68W.

In practice, the use of power settings and correct selection of modes can minimize unwanted tissue damage during surgery, and this study only has two modes cutting and coagulation. That is still not using power settings with predetermined values, and the power is less than enough for macro surgery. With all the weaknesses in this research, I hope in the next research can be enhanced high frequency or the other option can be increasing the amplifier/upgrade with other circuits which is optimal.

V. CONCLUSION

This study aims to make power settings and also several modes to minimize tissue damage during surgery, the power settings applied in this study are good enough. This study can also make a simple oscillator circuit that can produce high frequencies with an average of 400,4Hz. This study illustrates the difference in the signal produced in each mode due to the use of different duty cycles in each mode and also the effect on power settings. The results showed in cutting mode is 30,3W – 43W at 300Ohm, 38,3W – 58,3W at 400 Ohm, 44,3W – 65,3W at 500Ohm, and coagulation mode is 3W in every impedance. The next development that can be done in subsequent studies is the addition of more modes and also the power that can be determined with the appropriate value.

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ATTACHMENT

https://drive.google.com/drive/folders/1XaM5IuAgHsXh1_tlnfQALsOQGbKsRsqw?usp=sharing