RESEARCH ARTICLE

A Coagulation Mode on Bipolar Electrosurgery Unit Using 350 kHz Frequency and Power Selection

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ABSTRACT Losing a lot of blood during surgery using a conventional scalpel is something that is highly avoided. The purpose of this study is to replace the conventional scalpel with a tool that utilizes a high frequency whose duty cycle is regulated and then centered at one point. Researchers take advantage of the effect of heat generated by high frequencies, which are centered at one point so that it can be used for the process of surgery and coagulation in body tissues so as to minimize the occurrence of a lot of blood loss. Researchers use a high frequency of 350 kHz, which is set with a duty cycle of 6% on 94% off and is equipped with three levels of power selection and uses forceps as a medium to concentrate high frequencies at one point. The module design consists of a 350 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, and an inverter circuit to increase the voltage. In this study, after measuring using an oscilloscope in the driver circuit, the average output amplitude at each low, medium, and the high setting was 27.25 Vpp, 28 Vpp, and 28.625 Vpp. However, the frequency generator and power selection need to be improved. The results showed that the bipolar electrosurgery unit (coagulation) module as a whole could replace conventional scalpels so that it can minimize the occurrence of a lot of blood loss during surgery.

INDEX TERMS Electrosurgery, Bipolar, Coagulation, Frequency, Power.

I. INTRODUCTION

Things that must be avoided in surgery on patients are large blood loss and infection [1]. An electrosurgery unit (ESU) is a device used to perform surgical procedures using a high-frequency electric current [2]. ESU can injure the patient as well as the operator if not used and maintained properly [3]. The influencing factors are current density, time, electrode size, network conductivity, and signal waveform [4]. Blood plays an important role in tissue conductivity [5]. The difference in the signal waveform is a major factor in the surgical process [6]. ESU has two modes, namely monopolar and bipolar. Monopolar mode is a surgical procedure that uses current flowing from an active electrode through the patient's body tissue and back to the device through a passive electrode [8]. The bipolar model uses a medium called forceps which is shaped like tweezers; the current flows from one side of the forceps through the tissue and back to the tool via the other side of the forceps. In bipolar mode, the electric current only passes through the tissue between the two sides of the forceps, so the risk of burns to the other tissue is significantly reduced [8]. In this study, researchers plan to use signal waves 6% on and 94% off to get the process of thickening the network [7]. ESU has a power selection setting feature that is directly proportional to the penetration of network damage [9]
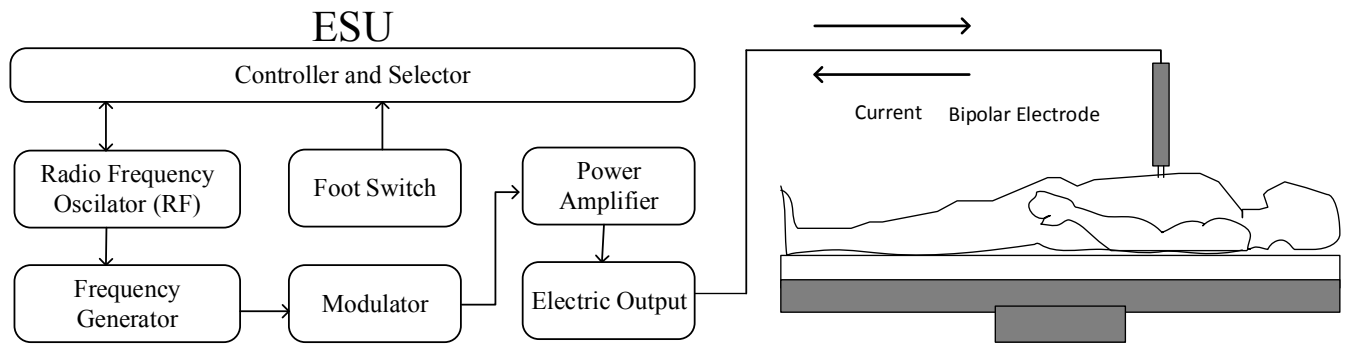
FIGURE 1. Basic operation of electro surgery unit (ESU)

Human tissue will receive faradic effects in the form of muscle and nerve stimulation if surgery is performed using frequencies below 100 kHz [10]. In 2018, Ali et al. conducted a study to build high-frequency bipolar by simulating a frequency generator of 1 MHz using MATLAB. The research is limited to simulation and does not carry out tool design. [11]. In 2019, Dhany et al. conducted a study by producing a monopolar energy ESU with a frequency of 300 kHz and equipped with three levels of power selection [12]

Based on the description of the literature study above, there are several problems that need to be solved, 1) The frequency used is still below 100 kHz, 2) The power selection has not varied, 3) The energy used is only Monopolar, 4) There is no coagulation mode on the bipolar ESU. Therefore, the purpose of this research is to design a Coagulation mode at Bipolar Electrosurgery Unit, and the module will be designed with a high frequency of 350 kHz equipped with three levels of power selection.

II. MATERIAL AND METHODS

A. EXPERIMENTAL SETUP

This research produces a bipolar energy electrosurgery unit with coagulation mode which has a fixed frequency specification of 350 kHz, using a coagulation mode with a duty cycle of 6% on and 94% off and three settings for selecting low, medium, and high power. The results are applied to the object's intestines or soap.

B. MATERIALS AND TOOLS

In this study, the resulting tool uses forceps-shaped electrodes to carry out the coagulation process on objects. Footswitch as control. Power display set on the 20x4 character LCD display. IC CD4069 as a frequency generator, IC LM2907 to convert frequency into voltage. Arduino module as a high-frequency duty cycle regulator and as a power selection control controller. Step up ferrite transformer as a high voltage booster. A multimeter (HELES, UX 78 TR) is used to measure voltage. A digital oscilloscope (GW INSTEK, GDS-3152) was used to measure the frequency.

C. EXPERIMENT

In this study, the results of the design were carried out by measuring the voltage at each setting in the power control circuit using a multimeter and measuring the frequency and amplitude at each power selection setting in the driver circuit using a digital oscilloscope.

D. BLOCK DIAGRAM

Figure 1 is a block diagram of a bipolar electrosurgery unit (coagulation). The way the block diagram works is when the power on button is pressed, the voltage from PLN provides power to the DC power supply. The output of the DC power supply will be distributed voltage throughout the circuit. The Footswitch functions as a switch that provides input to the Arduino module to carry out the coagulation mode surgery process with an indicator in the form of a buzzer sound.
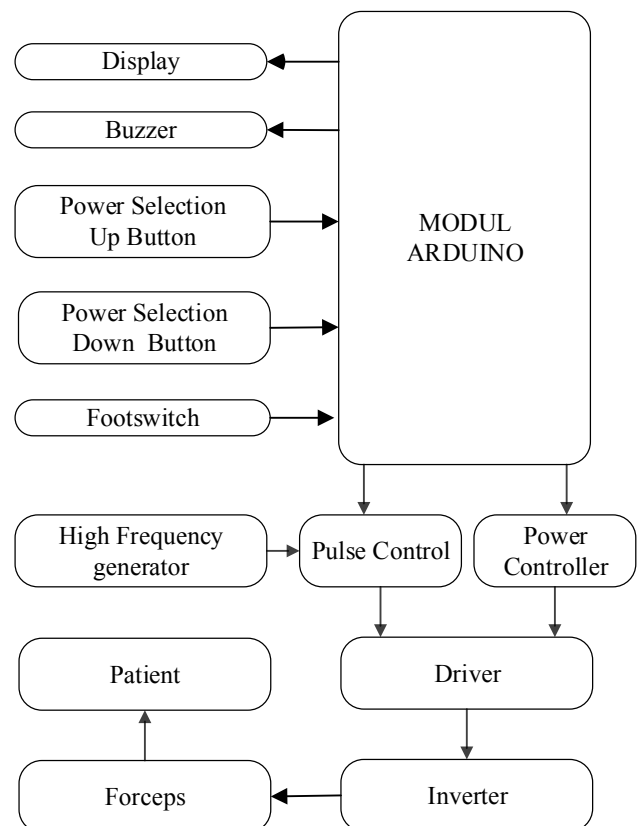

FIGURE 2. Block diagram

The up and down power selection buttons function as input power settings. The high-frequency generator functions as a 350 kHz frequency generator. The Arduino module functions to control the input power regulator settings that will be displayed on the character LCD display and to set the duty cycle 6% on and 94% off on the pulse control block. The input frequency from the high-frequency generator block with a duty cycle of 100% will be converted into a frequency with a duty cycle of 6% on and 94% off in the pulse control block and then processed in the driver block that has been set to power regulator. Furthermore, after processing through the driver block, then enter the inverter circuit. In the inverter circuit, there is a ferrite transformer that functions to increase the voltage. The output of the ferrite transformer will flow an electric current to the forceps, which is used as a medium for the coagulation surgery process.

E. FLOWCHART

FIGURE 3 is a flow diagram of the bipolar electrosurgery unit (coagulation) process. The way the flowchart works is that when the power button is pressed, the device will start system initialization, then the power display will appear on the coagulation character LCD. When the power selection button is pressed either up or down, it will change the power settings that will be used in the coagulation surgery process and the power selection display on the coagulation character LCD.
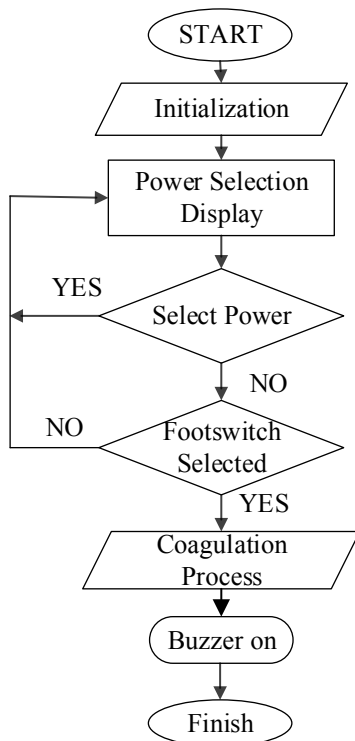

FIGURE 3. Process flowchart

When the footswitch is pressed, there will be a coagulation surgery process on the object with the power that has been set and is displayed on the LCD with the coagulation character accompanied by a buzzer sound.

FIGURE 4 is a flow diagram of a bipolar electrosurgery unit (coagulation) program. The way it works is when the tool is turned on, the program will initialize the program. The power selection control program functions to regulate the amount of output power that will be used in the coagulation surgery process and will be displayed on the character LCD. When there is input data from the hardware, the power selection control program will change the amount of power that will be used in the coagulation surgery process according to the input data and will be displayed on the character LCD. The footswitch control program functions to regulate the pulse regulation process that will be used in the coagulation surgery process. When getting input from the hardware, the footswitch control program will output a coagulation pulse.
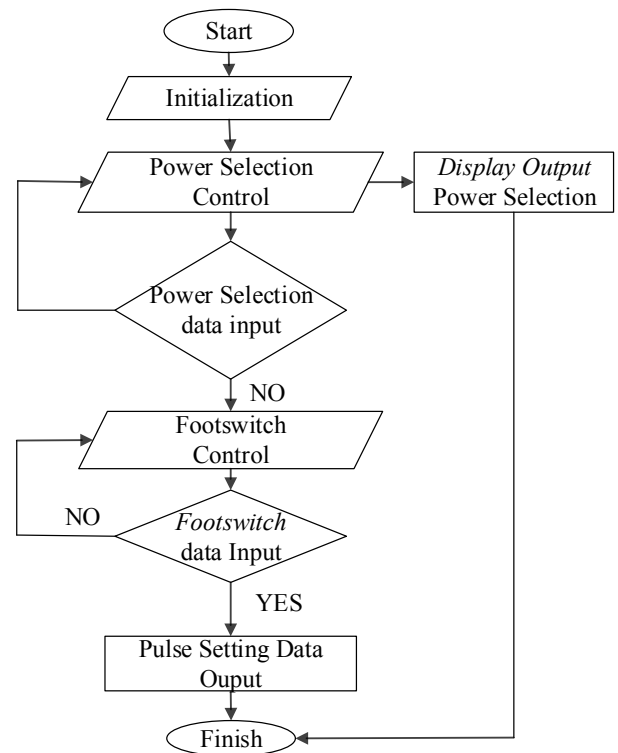

FIGURE 4. Software flowchart

F. ELECTRONIC CIRCUITS

1. FREQUENCY GENERATOR CIRCUITS

The frequency generator circuit is a pulse generator circuit that works continuously. In this study, researchers used IC CD4069 as a high-frequency generator of 350 kHz. The frequency generator circuit with a NOT gate is also called a Schmitt trigger. The output is a square pulse by utilizing the NOT gate to form a high-frequency signal (FIGURE 5).

2. POWER CONTROL CIRCUIT

The power control circuit serves to adjust the amplitude of the driver circuit output. In this module, the researcher uses the LM2907 IC as a frequency to voltage converter. The frequency of the Arduino module in the form of square pulses is used as input for the LM358N comparator IC to change the voltage. The voltage from the Arduino module output, high 5V and low 0V, is changed to high 5V and low -5V. The

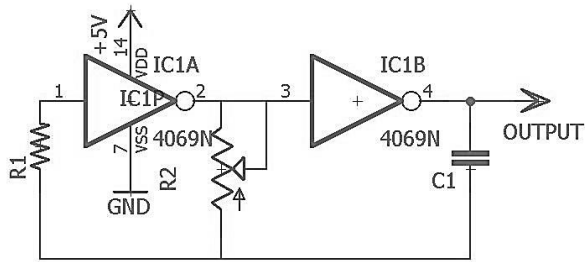output of the LM358N IC is forwarded to the TIP3055 base to amplify the current (FIGURE 6).
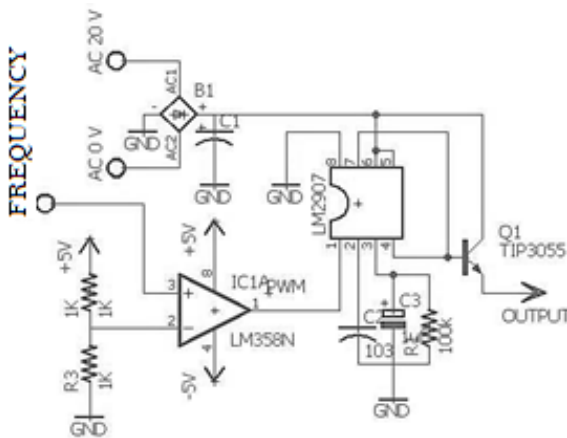

. **FIGURE 5. Frequency generator circuits**

FIGURE 6. Power control

3.   PULSE CONTROL

The pulse control circuit functions to regulate the shape of the main pulse generated by the 350 kHz frequency generator, whose continuous form becomes discontinuous. It is cut by a pulse with a duty cycle of 94% off and 6% on (FIGURE 7).
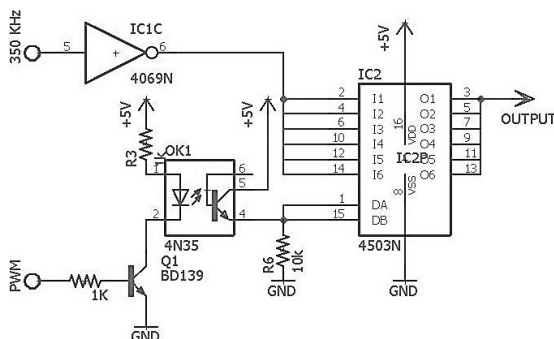

FIGURE 7. Pulse control

4.   DRIVER CIRCUITS

The driver circuit is a circuit that functions to combine the frequency of the coagulation signal with the output voltage of the power regulator circuit and then forward it to the transformer, which will be used to trigger the MOSFET gate in the inverter circuit (FIGURE 8).
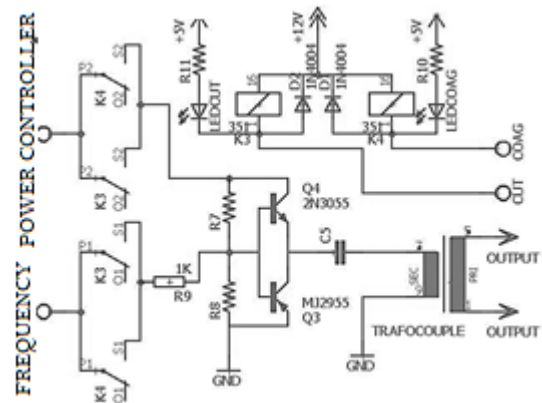

FIGURE 8. Driver circuits

5.   INVERTER

The inverter circuit is a circuit used to convert a 94-volt DC voltage into a high voltage AC. In the circuit, there is an IRF740 MOSFET which is used for high voltage drivers, and a ferrite transformer to increase the voltage (FIGURE 9).
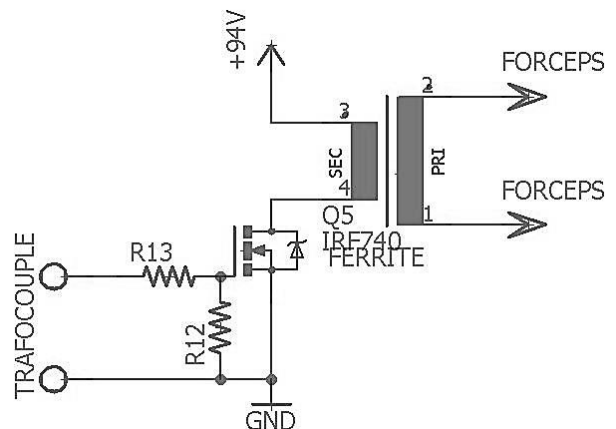

FIGURE 9. Inverter

6.   ARDUINO

The Arduino module functions as an input control to perform power selection by issuing a frequency to be converted into a voltage by a power regulator circuit. Set the 20x4 character LCD display. Issues PWM output to set the duty cycle 6% on 94% off in the pulse control circuit and is used as a footswitch control for the coagulation relay switch in the driver circuit and sounds the buzzer.

III. RESULT

In this study, the bipolar electrosurgery unit (coagulation) module has experimented with surgery with coagulation mode on intestinal media and soap. The external image of the module in standby can be seen in FIGURE 10. There is a probe in the form of a forceps which is used as a scalpel, and a footswitch as a switch. FIGURE 11 and FIGURE 12 are the results of the coagulation process on the intestine and soap object with different power settings. The overall circuit picture of the module can be seen in FIGURE 13. There is an Arduino module, a frequency generator circuit and a pulse controller, a power control circuit, a driver circuit, and an

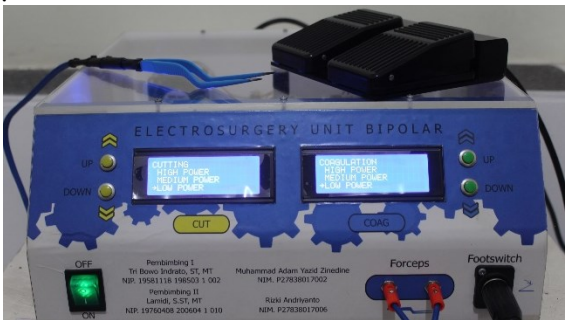inverter circuit. Measurement Results on Frequency Generator Circuit
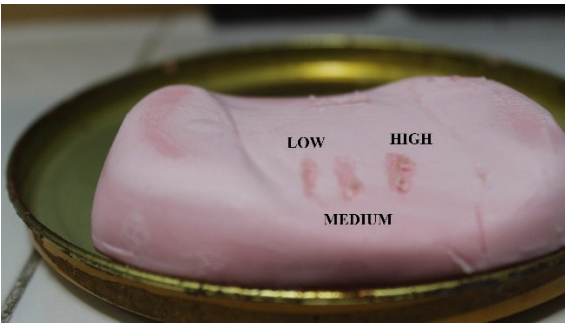

FIGURE 10. Electrosurgery unit bipolar
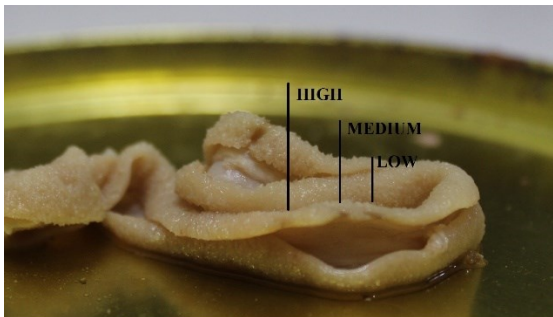

FIGURE 11. Coagulation results in intestinal objects
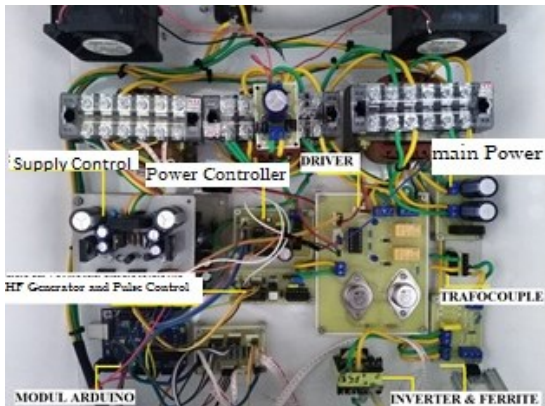

FIGURE 12. Coagulation results on soap objects

FIGURE 13. Overall design

TABLE 1
Frequency measurement

Power Selection		Average (Vpp)	SD	UA	Error
Low	Setting	27	0	0	± 0.9 %
	Module	27,25	0,36	0,25	
Medium	Setting	28	0	0	± 0 %
	Module	28	0	0	
High	Setting	29	0	0	± 1.3 %
	Module	28,625	0,53	0,375	

In TABLE I, the average frequency generator output value is 350,451 kHz with two measurements, there is an error value of ± 0.13%, a standard deviation of 0.46, and UA 0.33. The error value can be caused by unstable capacitor charging and discharging, and the frequency read by the oscillator is too high so that every second there is a change in the reading.
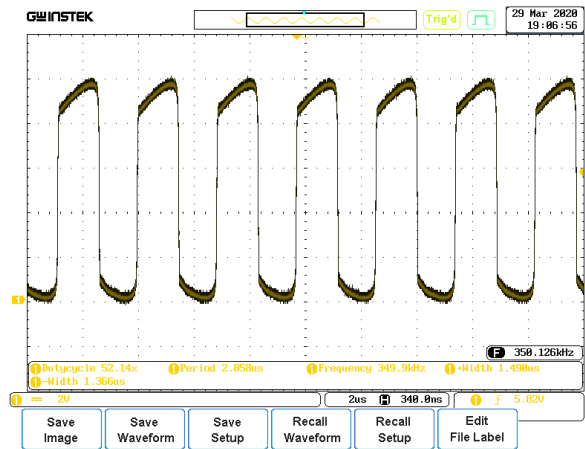

FIGURE 14. Output of frequency generator

. In FIGURE 14, shows the shape of the output signal from the 350 kHz frequency generator circuit which is measured using an oscilloscope.

TABLE 2
Output of power control

Power Selection		Average (V)	SD	UA	Error
Low	Setting	4	0	0	± 5 %
	Module	4,2	0	0	
Medium	Setting	6	0	0	± 5 %
	Module	6,3	0	0	
High	Setting	9	0	0	± 0 %
	Module	9	0	0	

TABLE 3
Output of driver

Measurement	Frequency	
	Setting (kHz)	Module (kHz)
1	350	350,126
2	350	350,776
Average		350,451
STDEV		0,46
Error (%)		± 0,13 %

TABLE 2 shows the results of the average voltage generated by the power regulator circuit. At each power selection setting, measurements are made two times using a multimeter to get the average value. The lowest error result is 0%, and the highest is 5%.

TABLE 3 shows the results of the average output value of the amplitude generated by the driver circuit. At each setting, measurements are taken two times at the driver output using an oscilloscope to get an image and the amplitude of each setting. The lowest error result is 0%, and the highest is 1.3%.
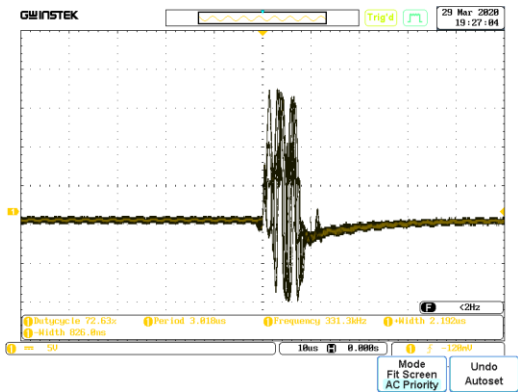

FIGURE 15. Output signal of driver at low setting

FIGURE 15 shows the shape of the output signal and the amplitude obtained in the driver circuit with a low setting measured using an oscilloscope.
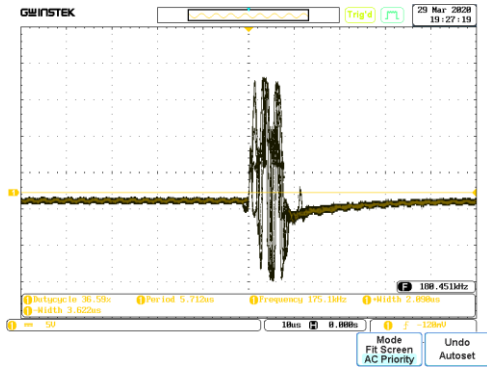

FIGURE 16. Output signal of driver at medium setting

FIGURE 16 shows the shape of the output signal and the amplitude obtained in the driver circuit with a low setting measured using an oscilloscope.
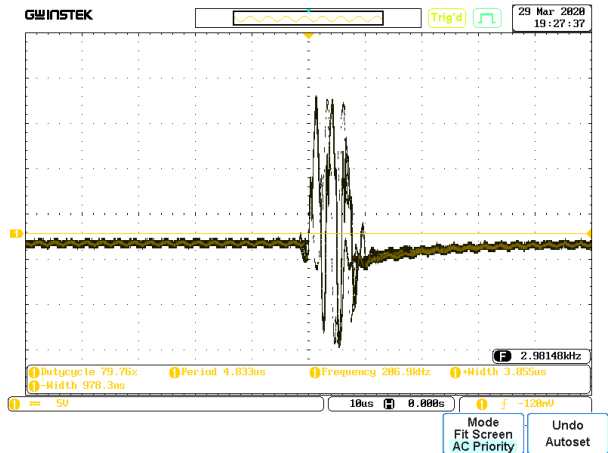

FIGURE 17. Output signal of driver at high setting

FIGURE 17 shows the shape of the output signal and the amplitude obtained at the output of the driver circuit with a high setting which is measured using an oscilloscope.

IV. DISCUSSION

In the study of bipolar electrosurgery unit (coagulation) with a frequency of 350 kHz and power selection, output measurements have been made on the power control circuit, pulse control circuit, and driver circuit, and have been tested on soap objects and intestines using forceps media. In this module, the frequency has been increased from the previous study to 350 kHz, as well as adding a coagulation mode to the module by setting the duty cycle of 6% to 94% off in the pulse control circuit [14][15]. The output obtained in the driver circuit measured using an oscilloscope shows the difference in each selected power setting at the low setting, the average value is 27.25 Vpp, then at the medium setting, the average value is 28 Vpp, and at the high setting, the average value is obtained. Average 28,625 Vpp. This module can display the power that is set on the character LCD and can be controlled using a footswitch to perform the surgical process. In this study, the actual value measurement was not carried out using a tool such as the ESU analyzer. From the results of experiments using soap, it is shown that the output power is small. In ESU tools on the market, the power used is large. The implication of this study can be used as a basis for designing the coagulation mode on the bipolar electrosurgery unit [16][17][18].

V. CONCLUSION

Based on the results obtained, it can be concluded that the aim of this study, to design a coagulation mode on a bipolar electrosurgery unit, was achieved. A bipolar electrosurgery unit has a main frequency of 350 kHz and three power selections. The pulse control circuit can set the duty cycle of 6% to 94% off. The power control circuit can adjust the power at each different setting displayed on the character LCD, then the results of the power difference are shown from the measurement results using an oscilloscope and the output differences generated by the driver circuit at each setting. And

the module can work as its function, which is to carry out the coagulation process on intestinal objects or soap with forceps media and controlled by a footswitch. Of course, the output power is still below 100 watts, so it would be better in future research to make designs that can produce the greater power output.

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