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Monopolar Multi Frequency Electrosurgery Unit Design

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Abstract: Electrosurgery Unit (ESU) is a medical surgical device that uses high frequency and high voltage with the aim that the patient does not experience excessive bleeding during the operation process. The development of electrosurgery unit technology evolves over time from monopolar to bipolar. However, in the development of the use of the tool, monopolar technology is always the most widely used in tissue surgery techniques. For this reason, this research was determined to use only the Monopolar principle. In Electrosurgery, the actual unit only uses one frequency selection, by changing (increasing or decreasing) the power value. With cases like this sometimes the user or equipment users will always change the power value during operation to determine the right power value. In this case, the author tries to make a prototype of an electrosurgery device with a frequency that can be selected (300, 350, 400, 450, 500, 550, 600 and 650 KHz) with a fixed power. By examining the results of the effectiveness of cutting (CUT) on tissue samples. It is hoped that it will be known which one is faster and more effective which can be used in cutting techniques (CUT) in surgery.

Keywords: Electrosurgery; Monopolar; Frekuensi; CUT

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Introduction

Electrosurgery Unit is an electrosurgery device that uses high frequency for surgical cutting (CUT) or surgery to clot bleeding (COAG) in tissue. All electrosurgery procedures use high frequency and alternating current at various voltages which can produce a heat effect when passing through the tissue (Eginli et al., 2021).

The basic principle of electrosurgery is an alternating current above >10 kHz that can pass through the human body, and will not cause stimulation or depolarization. This will allow the use of high frequencies (approximately 500 KHz) to achieve a heating effect on the active electrode tip for surgical bypass (CUT) or haemostatic coagulation (COAG) surgery without electrocuting the patient.

A standard electric current that alternates at a frequency of 60 cycles per second is called (Hz). The electrosurgery system can function at this frequency, but because the current will be transmitted or flowed through the body's tissues at 60 cycles per second, it causes excessive stimulation of the neuromuscular nerves and an electric shock may occur (Benias & Carr-Locke, 2019).

Since nerve and muscle stimulation stops at 100,000 cycles/second (100 KHz), electrosurgery can be safely performed at "radio" frequencies above 100 KHz. An electrosurgery device requires 60 current cycles and increases the frequency to over 200,000 cycles/sec. At this frequency, electrosurgical energy can pass through the patient with minimal neuromuscular stimulation and there is no risk of electric shock (Benias & Carr-Locke, 2019). Electrosurgery frequency limit is 300 KHz – 5 MHz (Knopf et al., 2013),(Dafinescu et al., 2012),(Karaki et al., 2017). As seen in Figure 1.

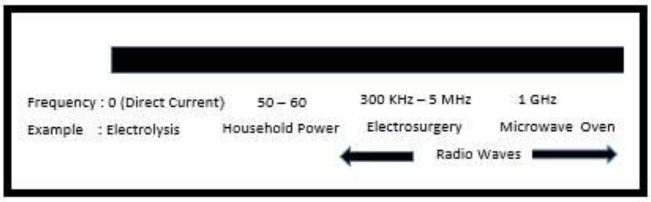

Figure 1. Electromagnetic Spectrum. Electrosurgical units are in the frequency range of 300KHz– 5MHz (Taheri et al., 2014)

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A.*Monopolar*

Monopolar devices consist of a pair of electrodes, namely an active electrode with a small surface area and a dispersive (passive) electrode with a larger surface area (Dodde et al., 2012). Monopolar mode, as shown in figure 2, is a mode that is often used in the surgical process, especially in major surgery, usually used for cutting (CUT) and coagulation (COAG) processes.

By using 2 electrodes, namely the active electrode and the passive/neutral plate (ground). The high-frequency electric current will flow from the active electrode through the network and towards the neutral/passive electrode (plate/ground) and to the device (Salley et al., 2022), (Gallagher et al., 2011). The current focused on the tip of the active electrode will cause the concentration of electric current at one point so that the network will be cut (CUT) or experience freezing (COAG).

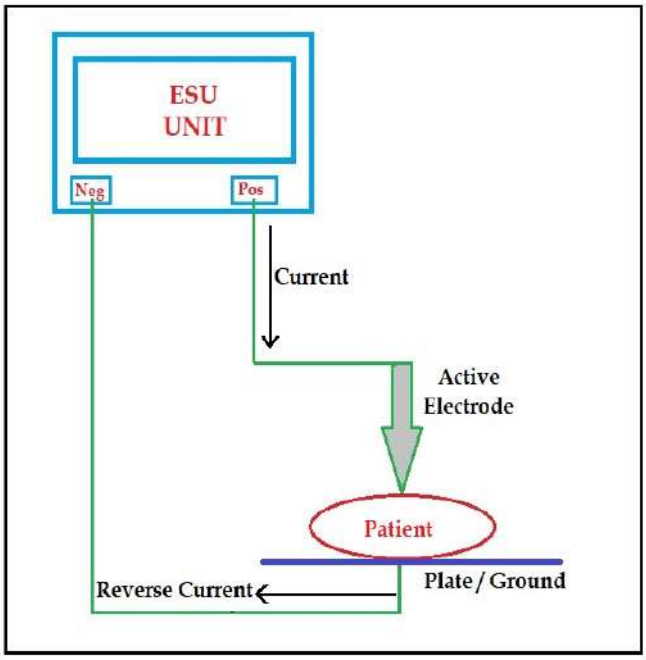

Figure 2. The basis of monopolar electricity

An understanding of the basic theory of electrical physics, which underlies the safe and effective application of electrosurgery, should also be known by surgeons (Messenger et al., 2020). The flow of electrons over a certain period of time is called electric current which is measured in amperes (I) in a circuit. Resistance or resistance (R) and impedance represent resistance for direct current (DC) and alternating current (AC), and are measured in Ohms. Voltage (V) is the force that pushes current through a resistance and is measured in volts.

A larger voltage is required to maintain a constant current, which flows through a circuit if the resistance (R) in a circuit increases, as is the case when a drained grid (Coag) current is being applied. This relationship is described in Ohm's law ($V = I \times R$). Power (P), measured in Watts, is equal to current multiplied by voltage ($P = V \times I$). And shows the amount of energy that flows at one time, The change in temperature or heat (Q) generated when the current flow is applied, based on Joule's law theory, namely ($Q = I^2 \times R \times t$), where Q is the heat generated by the current with an intensity constant (I) through a conductor with electrical resistance (R) for a certain period of time (Tokar et al., 2013). In this study, the focus is on the cutting process (CUT) only on meat tissue samples. Where in the design of the prototype electrosugery unit, the author uses the selection of high frequency values for comparison, namely 300, 350, 400, 450, 500, 550, 600 and 650 KHz.

This combination of electric current and voltage, combined with a high-frequency oscillator circuit, produces a voltage amplitude that can produce a heat effect on the tissue so as to create a cutting effect (CUT), if applied or fed to a tissue sample (beef). With this in mind, the author tries to examine, from various frequency selections that can be applied, what kind of effect will be produced when the active electrode tip is attached to a tissue sample (beef). Will the frequency value be stable, when the knife electrode has not been attached to the network (without the meat load) and when the knife electrode is attached to the meat sample. And which frequency scale will be effective in cutting (CUT) meat samples.

Method

Block Diagram

Making the prototype design for this electrosurgery device, includes several circuit blocks. Overall it can be seen in the block circuit diagram in Figure 3.

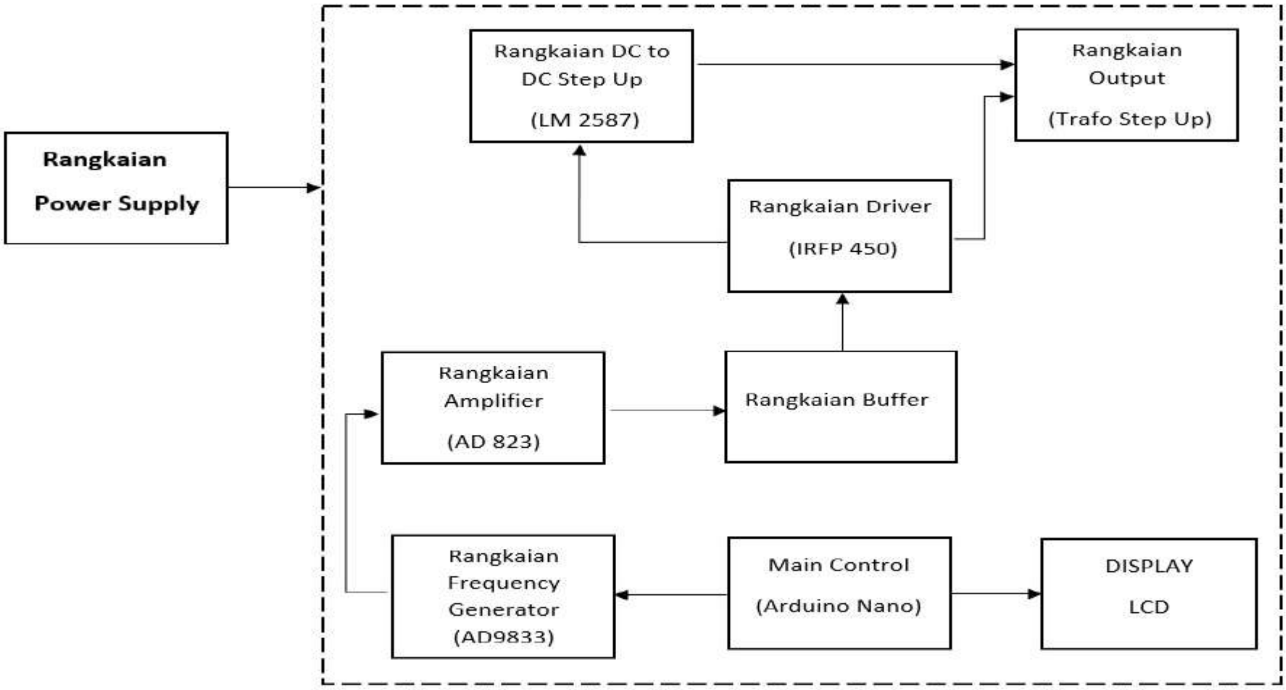

Figure 3. Block Diagram of Electrosurgery

I. *Power Supply Circuit*

Using a DC voltage power supply as a power supply for all components incorporated in the circuit block diagram. With a voltage of 12 and 5 V.

II. *Main Control Arduino Nano*

Using the Arduino Nano Microcontroller as a program controller to determine the frequency value used. And as the control of the work order of the electrosurgery unit.

III. LCD Display

This circuit as a display of mode and frequency information used.

IV. *Generator Frequency Circuit*

This circuit serves to generate a sinusoidal frequency signal that has been set by the Arduino nano microcontroller.

V. *Amplifier Circuit*

This circuit serves as a frequency signal amplifier generated by the frequency generator.

VI. *Buffer Circuit*

This circuit acts as a filter and buffer that converts the resulting sinusoidal frequency signal into a square frequency signal.

VII. *Driver Circuit*

This circuit functions as a driver or tiger to command the mosfet work signal as a step up dc to dc circuit driver.

VIII. *DC to DC step up circuit*

This circuit serves to increase the output voltage of 30V DC as the input voltage of the ferrite transformer in the output circuit.

IX. *Output Circuit*

This circuit is the output voltage of the ferrite transformer which flows the voltage on the blade electrode.

Flowchart

In the work on the design of this electrosurgery prototype, it requires a work order design on the Arduino nano microcontroller which regulates the setting of the selected frequency value and orders the tool to work, and the work order will display the results on the LCD display. In general, it can be seen in Figure 4.

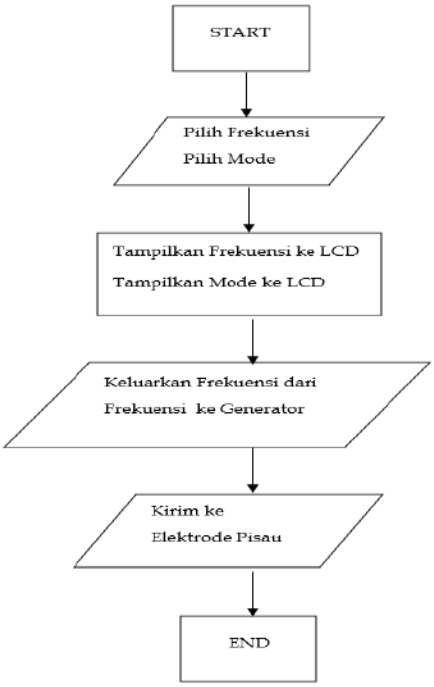

Figure 4. Electrosurgery Flowchart

Electrosurgery Electronic Circuit

I. *Main Control Arduino Nano and Display*

In the design of this electrosurgery tool, as a control work circuit using an Arduino nano microcontroller to determine the frequency values used, namely 300, 350, 400, 450, 500, 550, 600 and 650 KHz. And as control of the work order this electrosurgery tool uses the Start/Stop button which will be displayed on the LCD Display series. This circuit requires a power supply of 12 V input voltage, and produces an output voltage of 5 V which is used to input the power supply voltage on the AD9833 frequency generator circuit. In general, the main control unit and display circuit can be seen in Figure 5.

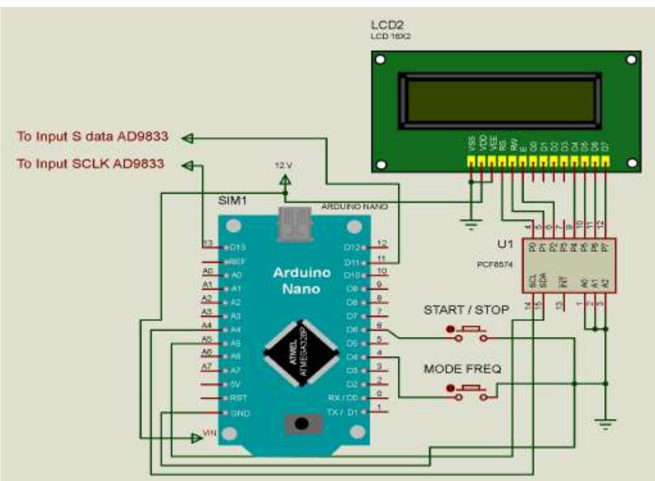

Figure 5. Arduino Nano Circuit and Display

II. *Generator and Amplifier Frequency Circuit*

In this generator frequency circuit, it will generate a frequency signal that has been set by the Arduino nano microcontroller, so that the output voltage becomes a sinusoidal wave. AD9833 frequency generator circuit uses 5V voltage power supply, which comes from arduino nano, the output frequency will be generated by this circuit, according to the selected frequency. (Examples of the selected frequencies are 300, 350, 400, 450, 500, 550, 600, and 650 KHz).

The AD823 amplifier circuit will receive input from the AD9833 generator frequency circuit output, the output voltage output signal will be amplified and will enter the 4503 buffer circuit input. as shown in Figure 6.

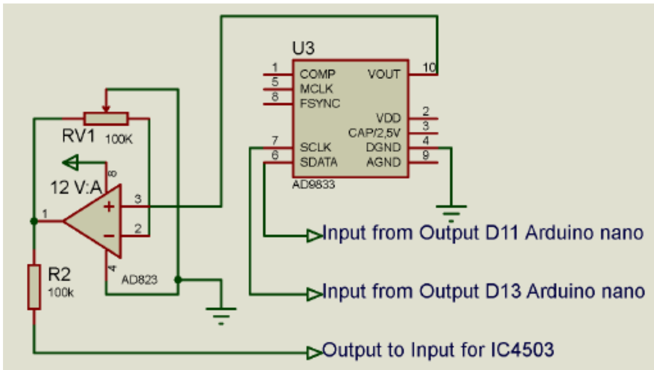

Figure 6. Generator and Amplifier Frequency Circuit

III. *Buffer Circuit and Mosfet Driver*

The 4503 buffer circuit as shown in Figure 7 is designed to convert a sinusoidal voltage frequency signal into a high frequency square wave voltage coming from the output of the AD823 amplifier circuit. It is expected that the resulting voltage and frequency will be stable, because this circuit also functions as a filter.

The IRFP450 mosfet driver circuit will receive a trigger command at gate 2 which comes from the output buffer voltage 4503, and will drive the LM2587 dc to dc stepup IC circuit, so that there is a current and voltage that passes through the IRFP450 mosfet to ground.

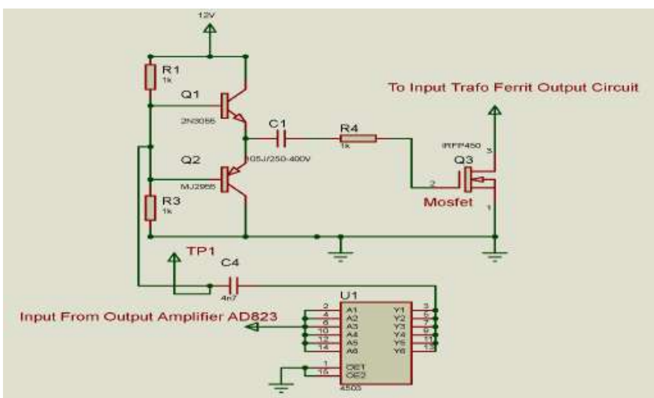

Figure 7. Buffer Circuit and Mosfet Driver

IV. *DC to DC Step Up Circuit and Output Circuit*

In this dc to dc stepup circuit, the design uses the IC LM2587 module, which requires a 12V input voltage supply and ground. Designed to increase the output voltage to 30V, which is used as the input voltage of the ferrite transformer. And this circuit will work if the IRFP450 mosfet driver gets a voltage trigger from the driver circuit.

In the design of this output circuit, the output transformer uses a ferrite (6/200) transformer. Measurement of the frequency signal using a digital storage oscilloscope model DS8202 Batronix, with a gain on the oscilloscope probe voltage x 10, getting a high enough voltage gain because there is a voltage gain in the DC to DC step up circuit so that the output voltage on the ferrit transformer output circuit (6/200) becomes high. As can be seen in Figures 18 to 25.

The work of this circuit gets a voltage input from the dc to dc stepup IC LM2587 module, which is controlled from the work of the IRFP450 mosfet. The output of the ferrite transformer is used for input voltage from the knife electrode, and current will flow through the knife electrode that is touched to the tissue sample (meat), through the neutral plate pcb, and the current returns to the ferrite transformer. So it will produce a cutting effect (CUT) on the tissue sample (meat). Overall this circuit can be seen in Figure 8.

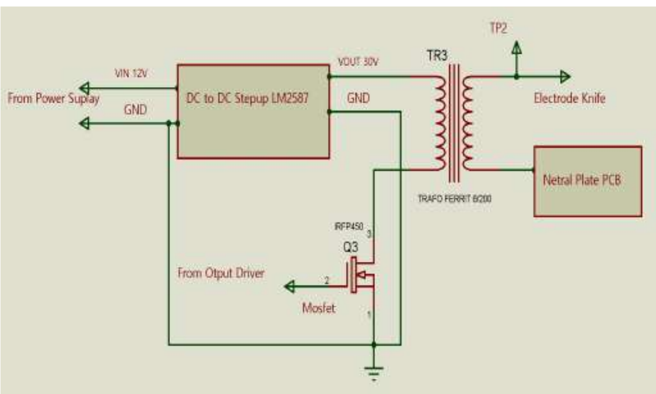

Figure 8. DC to DC step up circuit and Output Circuit

Results and Discussion

The test results include measurement of the output on the selected frequency circuit, which can determine the performance of the frequency generator circuit system to the buffer and driver circuits. This measurement is located at the output of the IC4503 frequency buffer circuit (TP1). It is expected that the measured frequency will be in accordance with the selected frequency, and the test results can be seen directly using a sample of beef tissue to analyze the results of the cuts (CUT) on the meat sample. as seen in the measurements in the ferrite transformer output circuit (TP2).

Measurement of the voltage frequency signal on TP1 using a digital storage oscilloscope model DS8202 Batronix, with amplification of the voltage probe x 10, gets a voltage result, as shown in Figure 9 to 16, where the average voltage measured is 1.50V x 10 = 15V , with the results of frequency measurements in accordance with the settings (300 – 650 KHz). While the measurements in the ferrite transformer output circuit on TP2 at the end of the active electrode (knife electrode), which uses beef samples, show the results of frequency measurements that are in accordance with the settings (300-550 KHz) with a very high voltage ranging between 460-552V, as shown in Figure 18 to 23. The measurement results on both TP1 and TP2 produce a continuous waveform, pure sinusoid (square).

In accordance with the theory that, monopolar (CUT), requires a well-concentrated current at the tip of the active electrode (knife electrode) with a typical continuous wave current (continuous), pure sinusoidal (pure sine) or rod wave current (square) (Livaditis, 2001).),(Vilos & Rajakumar, 2013),(MacG Palmer, 2019).

The results of the 4503 buffer IC frequency measurement when without beef tissue samples

When the program command is made in the Arduino nano microcontroller module circuit, the frequencies that can be selected are 300, 350, 400, 450, 500, 550, 600, and 650 KHz. By measuring the output (TP1) of the 4503 buffer IC circuit. At no load the beef tissue sample, with the measurement results as follow.

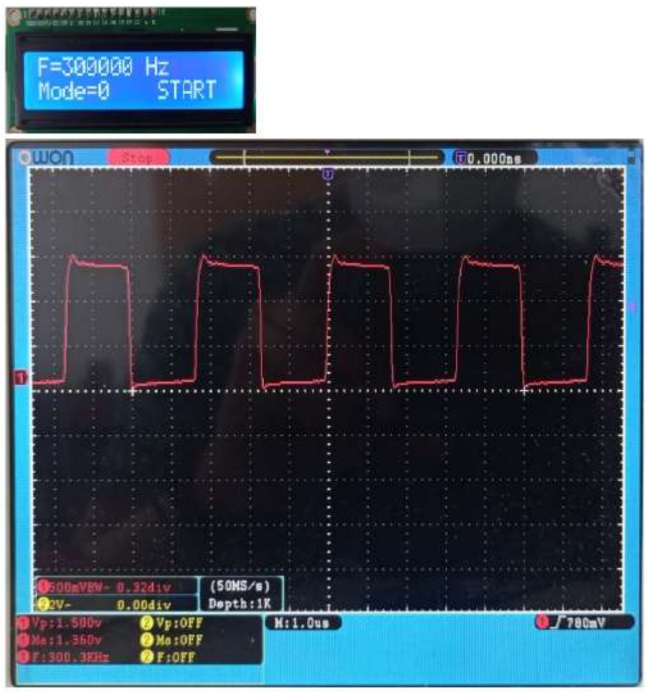

Figure 9. Measurement of TP1 Signal Frequency 300 KHz

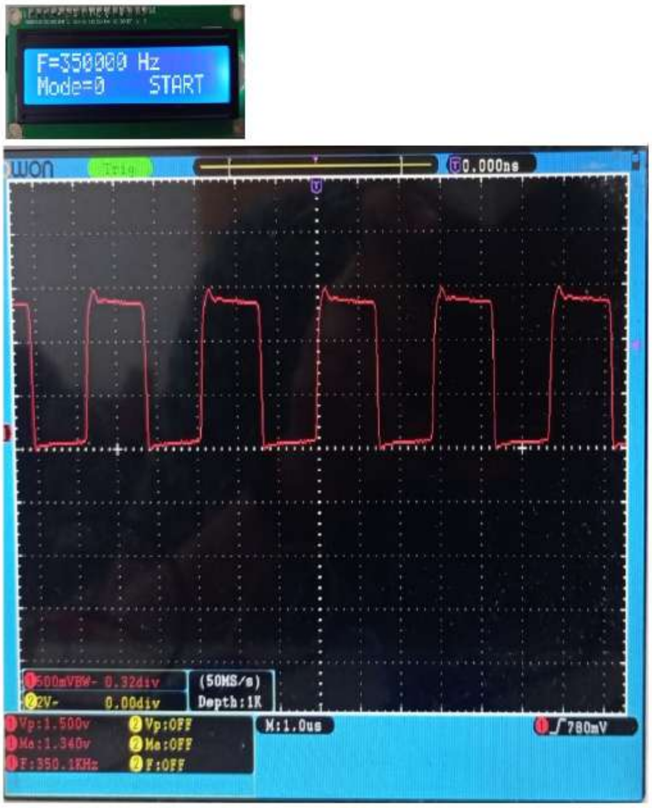

Figure 10. Measurement of TP1 Signal Frequency 350 KHz

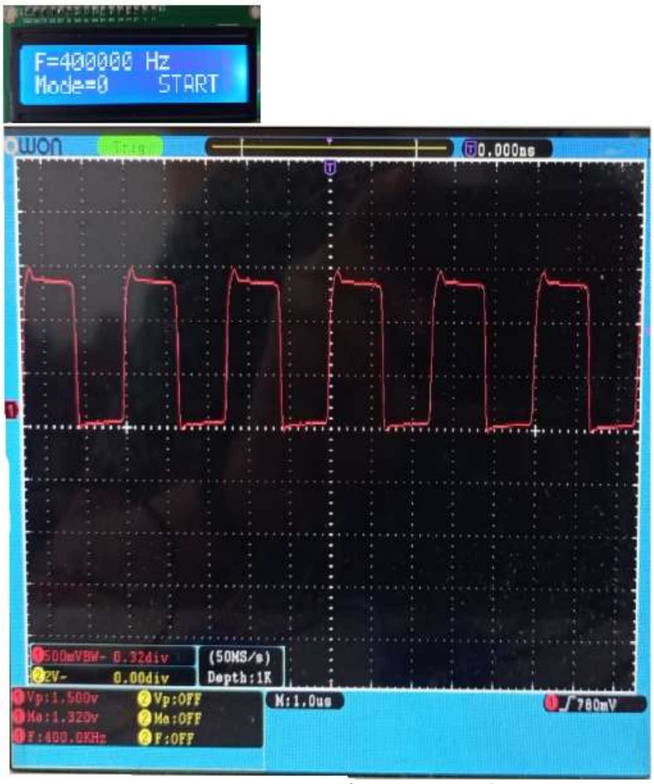

Figure 11. Measurement of TP1 Signal Frequency 400 KHz

Figure 12. Measurement of TP1 Signal Frequency 450 KHz

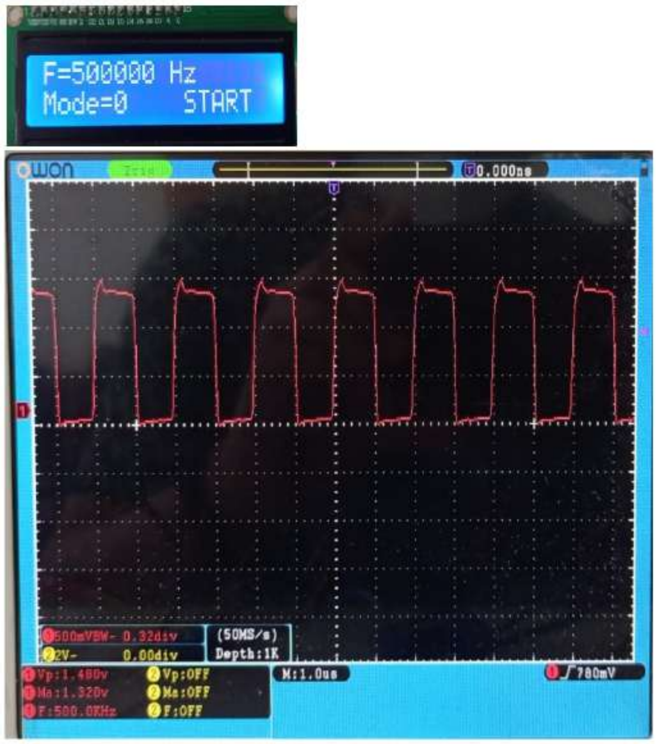

Figure 13. Measurement of TP1 Signal Frequency 500 KHz

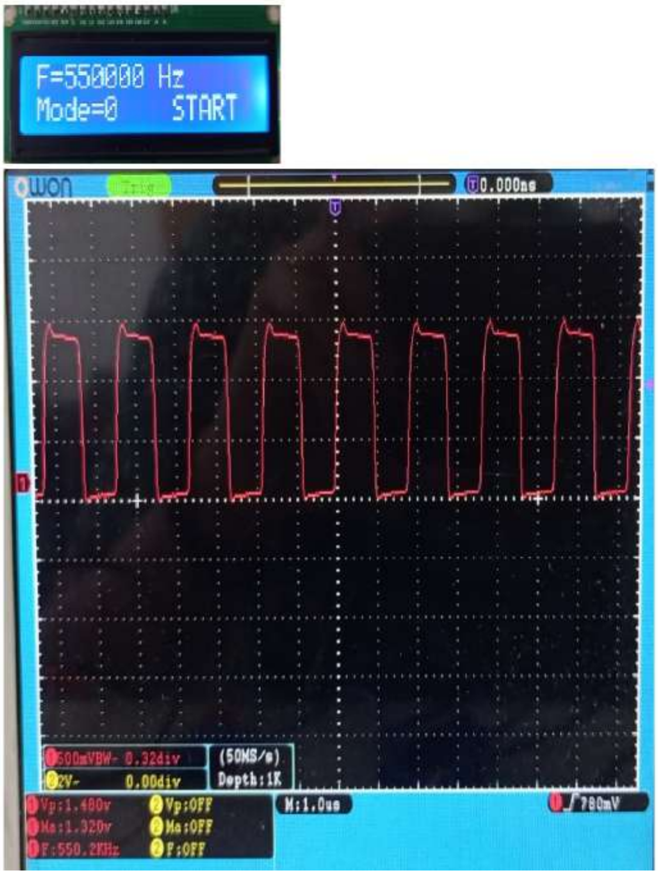

Figure 14. Measurement of TP1 Signal Frequency 550 KHz

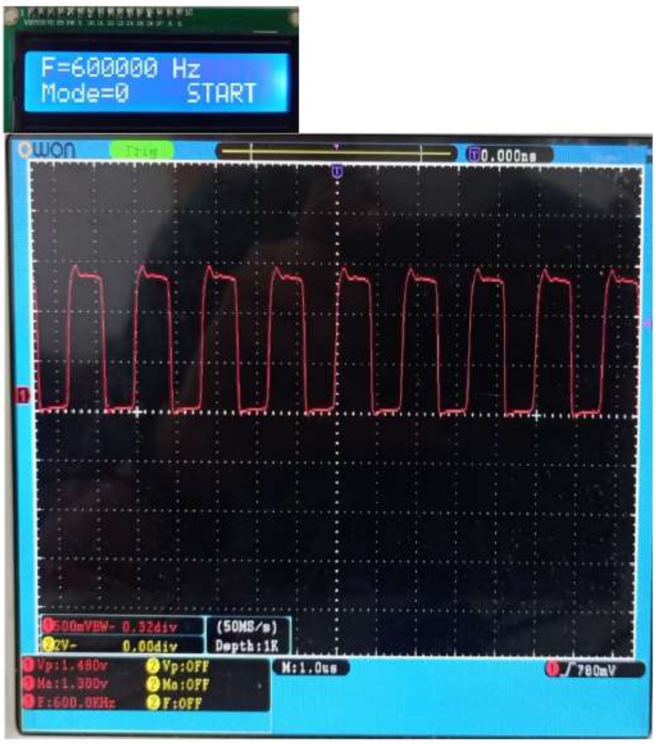

Figure 15. Measurement of TP1 Signal Frequency 600 KHz

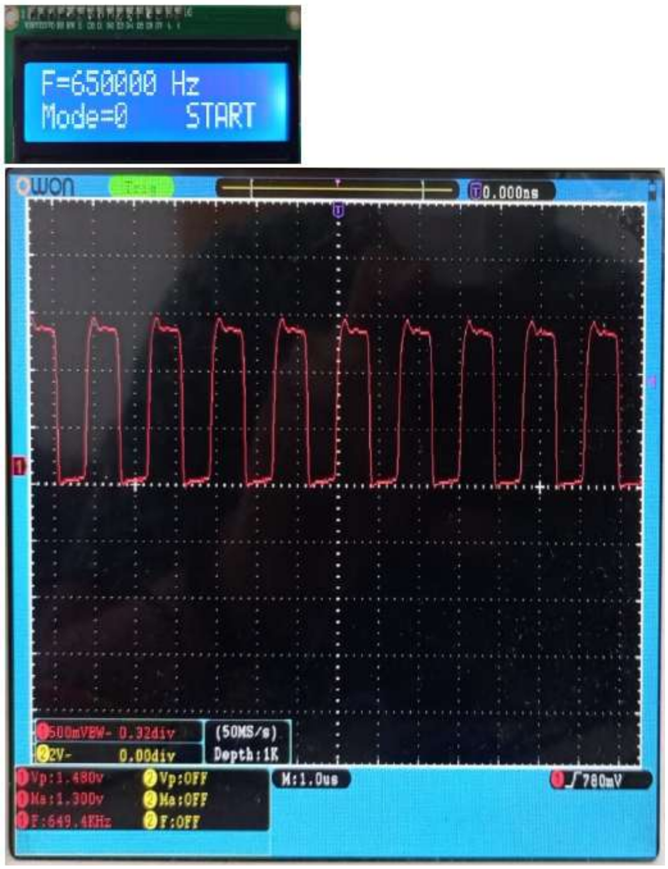

Figure 16. Measurement of TP1 Signal Frequency 650 KHz

Frequency signal measurement using digital storage oscilloscope model DS8202 Batronix. From the measurement results obtained, it can be analyzed through Figures 9 to 16. The percentage accuracy value of the set frequency and compared to the frequency value seen on the oscilloscope can be seen in Table 1.

Table 1. Comparison of Frequency Accuracy on TP1

Frequency (KHz)	TP1 (KHz)	Accuracy (%)
300	300.30	99.90
350	350.10	99.97
400	400.00	100.00
450	449.80	100.04
500	500.00	100.00
550	500.20	99.96
600	600.00	100.00
650	649.40	100.09

Measurement results on the output circuit with a load of meat tissue samples

Measurements were made on the transformer output circuit, TP2 when testing cutting, the oscilloscope probe at the tip of the knife electrode, when attached to a sample of beef tissue.

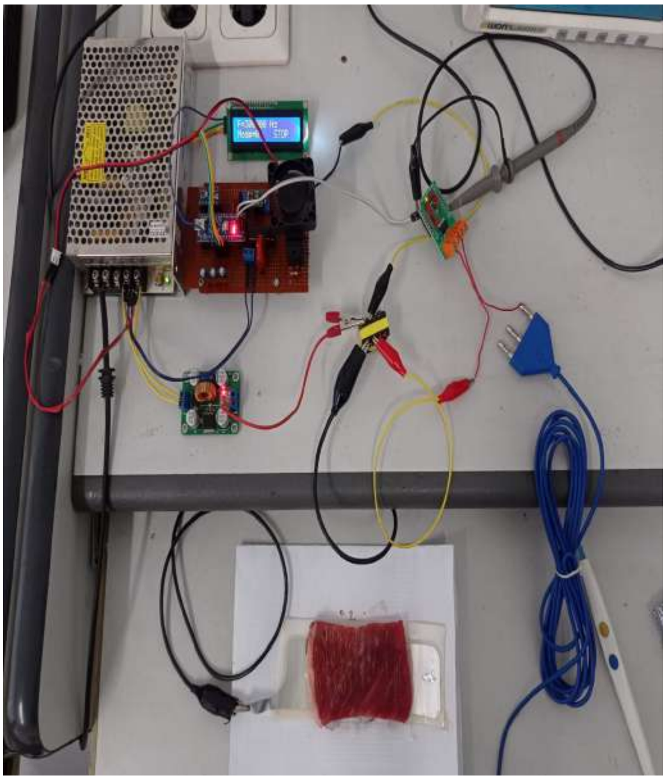

Figure 17. Electrosurgery Unit Prototype Design

The measurement results obtained for each frequency selection are as follows.

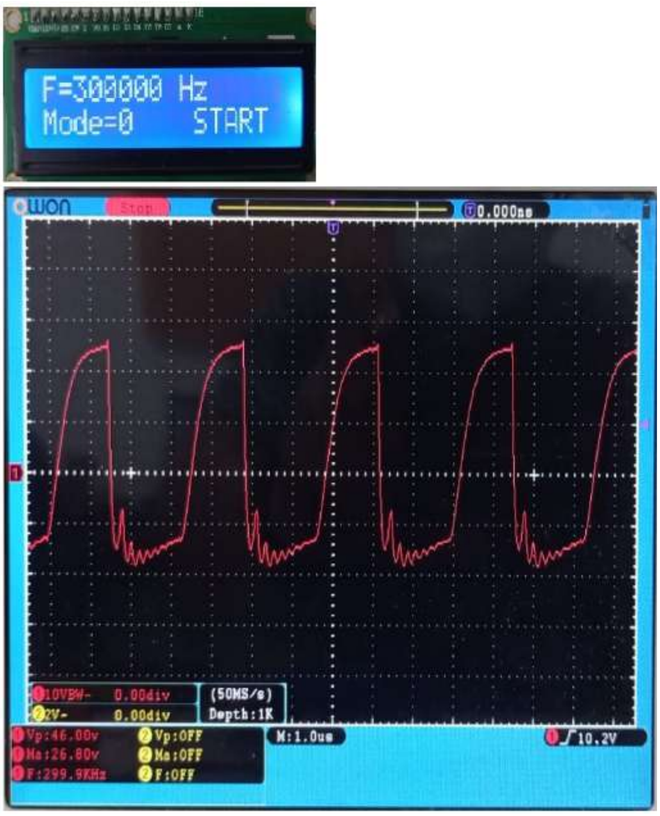

Figure 18. Measurement of TP2 Signal Frequency 300 KHz with beef load

Figure 19. Measurement of TP2 Signal Frequency 350 KHz with beef load

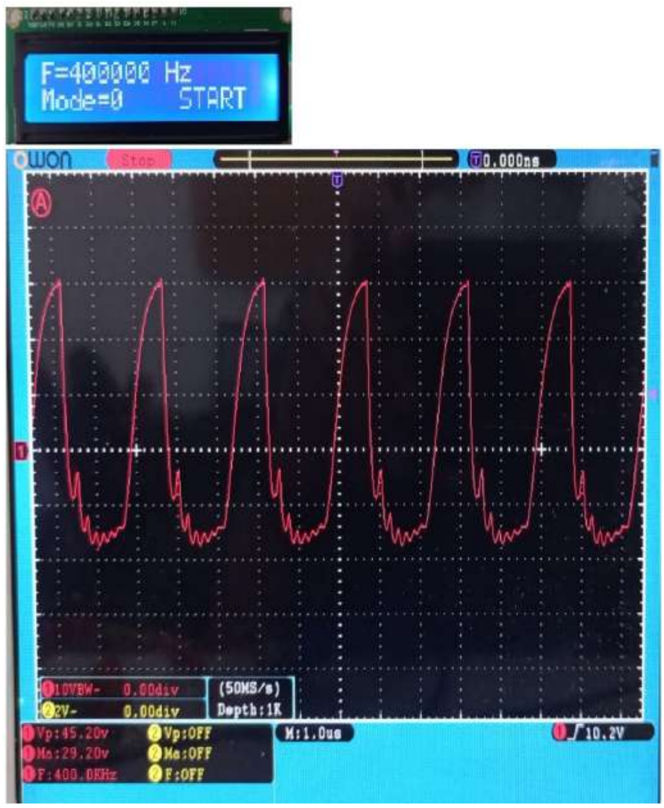

Figure 20. Measurement of TP2 Signal Frequency 400 KHz with beef load

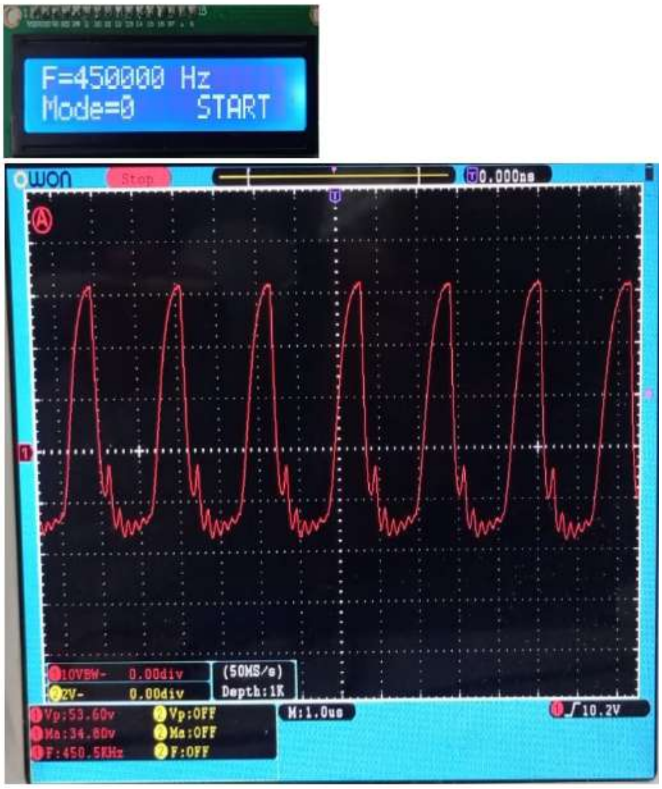

Figure 21. Measurement of TP2 Signal Frequency 450 KHz with beef load

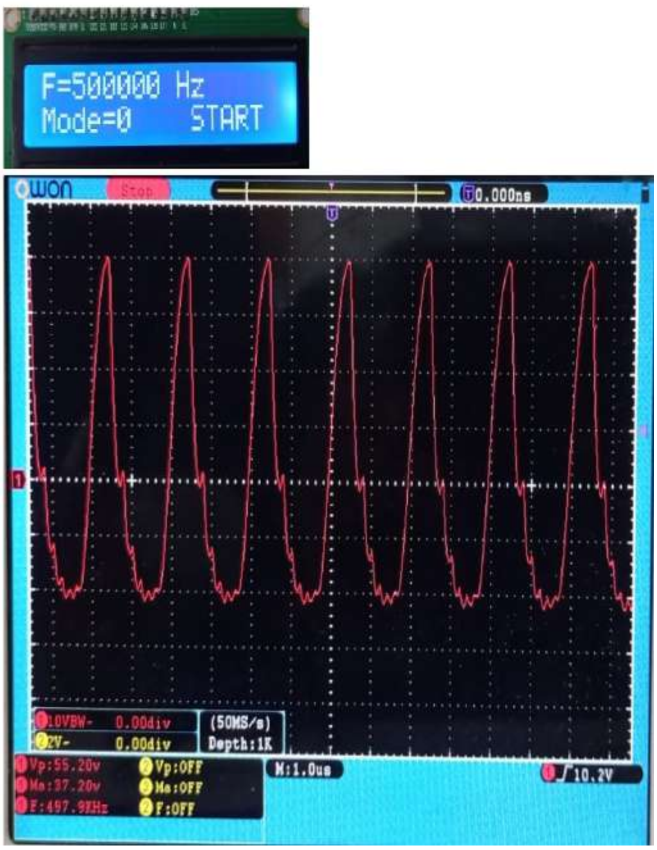

Figure 22. Measurement of TP2 Signal Frequency 500 KHz with beef load

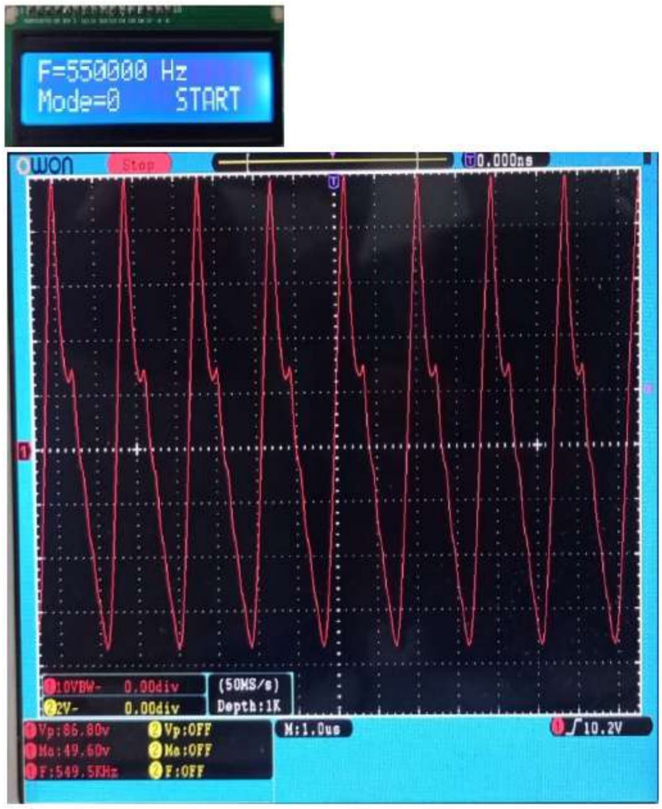

Figure 23. Measurement of TP2 Signal Frequency 550 KHz with beef load

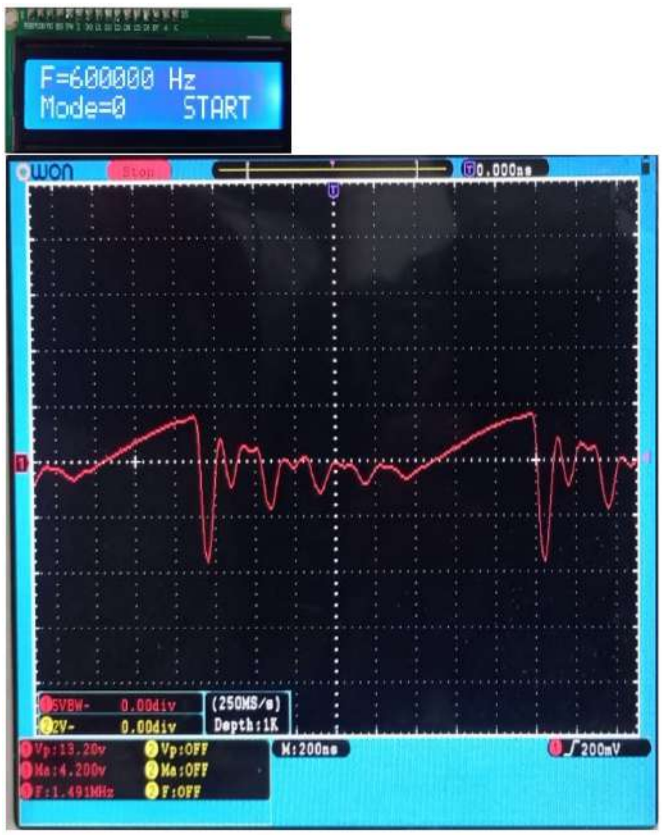

Figure 24. Measurement of TP2 Signal Frequency 600 KHz with beef load

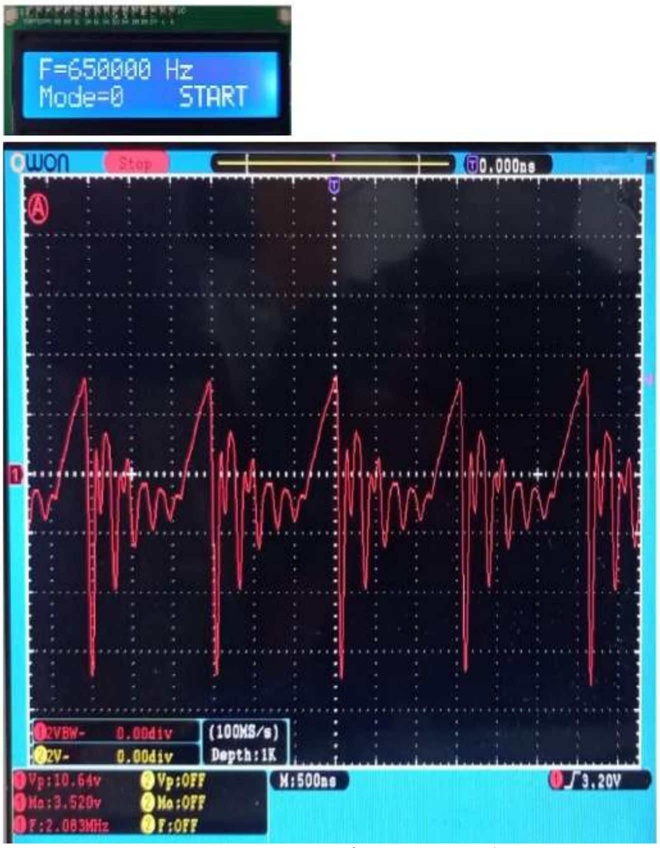

Figure 25. Measurement of TP2 Signal Frequency 650 KHz with beef load

The percentage accuracy value of the frequency that is set on the main control arduino nano when the tool START command and the Cut effect is performed on the beef tissue sample, based on Figure 18 – Figure 25, can be compared with the frequency value seen on the oscilloscope, as shown in Table 2.

Table 2. Comparison of Frequency Accuracy on TP2

Frequency KHz)	TP2 (KHz)	Accuracy (%)
300	299.90	100.03
350	350.30	99.91
400	400.00	100.00
450	450.50	99.89
500	497.90	100.42
550	549.50	100.09
600	1491.00	40.24
650	2083.00	31.20

Results of Cutting on beef tissue samples

From Figure 26 it can be seen the results of the cuts on the beef tissue samples. on any selectable frequency on the arduio nano program from a frequency of 300 KHz – 650 KHz.

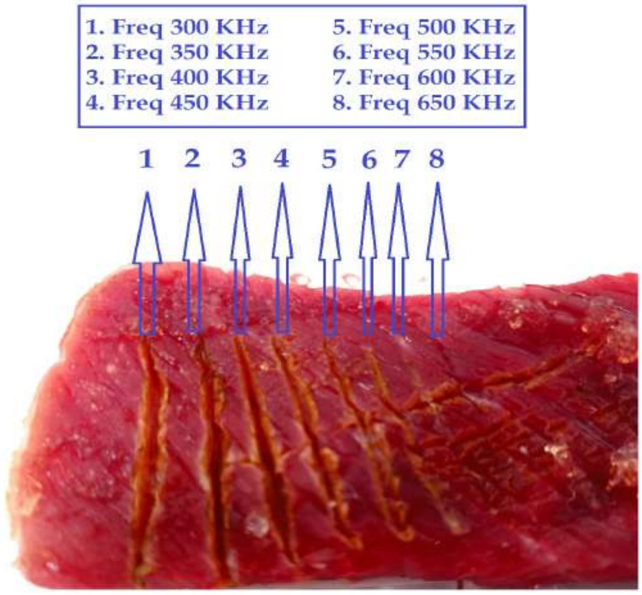

Figure 26. Results of the CUT effect on beef

Table 3. Comparison of Accuracy (Ak) Frequency

Freq (KHz)	TP1(khz) (khz)	Ak%	TP2	Ak%
300	300.30	99.90	299.90	100.03
350	350.10	99.90	350.30	99.91
400	400.00	100.00	400.00	100.00
450	449.80	100.00	450.50	99.89
500	500.00	100.00	497.90	100.42
550	500.20	99.96	549.50	100.09
600	600.00	100.00	1491.00	40.24
650	649.40	100.09	2083.00	31.20

Conclusion

From the results of the frequency design on the electrosurgery prototype design that the author made, it can be seen that, in the measurement of TP1 without meat loads, almost all of the frequency selection shows a good level of accuracy. In the measurement of TP1 there are two most stable frequency ranges, namely the frequency of 400 KHz - 500 KHz. In the measurement of TP2 with meat loads, a stable percentage of frequency accuracy is obtained from the frequency range of 300 KHz - 550 KHz, while at the frequencies of 600 KHz and 650 KHz the measurement results show a poor level of accuracy. From the results of cutting observations (CUT) on beef samples, it can be concluded that the level of effectiveness of the cuts shows that the best cutting rates start from the frequency of 300 KHz - 500 KHz, while in the frequency range of 600 KHz and 650 KHz the results of the cuts are not good.

Referensi

Benias, P. C., & Carr-Locke, D. L. (2019). Principles of Electrosurgery. *Ercp*, 86-92.e1. https://doi.org/10.1016/b978-0-323-48109-0.00011-0

Dafinescu, V., David, V., & Tutuianu, A. (2012). Electromagnetic emissions due to electrosurgery. *EPE 2012 - Proceedings of the 2012 International Conference and Exposition on Electrical and Power Engineering*, *20*(Epe), 525–528. https://doi.org/10.1109/ICEPE.2012.6463880

Dodde, R. E., Gee, J. S., Geiger, J. D., & Shih, A. J. (2012). Monopolar electrosurgical thermal management for minimizing tissue damage. *IEEE Transactions on Biomedical Engineering*, *59*(1), 167–173. https://doi.org/10.1109/TBME.2011.2168956

Eginli, A., Haidari, W., Farhangian, M., & Williford, P. M. (2021). Electrosurgery in dermatology. *Clinics in Dermatology*, *39*(4), 573–579. https://doi.org/10.1016/j.clindermatol.2021.03.004

Gallagher, K., Dhinsa, B., & Miles, J. (2011). Electrosurgery. *Surgery*, *29*(2), 70–72. https://doi.org/10.1016/j.mpsur.2010.11.009

Karaki, W., Akyildiz, A., De, S., & Borca-Tasciuc, D. A. (2017). Energy dissipation in ex vivo porcine liver during electrosurgery. *IEEE Transactions on Biomedical Engineering*, *64*(6), 1211–1217. https://doi.org/10.1109/TBME.2016.2595525

Knopf, C., Klockner, S., Liu, Z., Kanoun, O., & Himmel, J. (2013). Comparison of DAQ-methods to measure the potential distribution in electrosurgery. *2013 10th International Multi-Conference on Systems, Signals and Devices, SSD 2013*, 31–34. https://doi.org/10.1109/SSD.2013.6564157

Livaditis, G. J. (2001). Comparison of monopolar and bipolar electrosurgical modes for restorative dentistry: A review of the literature. *Journal of Prosthetic Dentistry*, *86*(4), 390–399. https://doi.org/10.1067/mpr.2001.118729

MacG Palmer, J. H. (2019). Surgical diathermy and electrical hazards: causes and prevention. *Anaesthesia and Intensive Care Medicine*, *20*(11), 609–614. https://doi.org/10.1016/j.mpaic.2019.09.011

Messenger, D., Carter, F., Noble, E., & Francis, N. (2020). Electrosurgery and energized dissection. *Surgery (United Kingdom)*, *38*(3), 133–138. https://doi.org/10.1016/j.mpsur.2020.01.006

Salley, J. R., Johnson, R., Mitchell, R. B., Shah, G., & Coffey, A. R. (2022). Comparison of outcomes between thermal welding forceps, controlled ablation and monopolar electrosurgery for tonsillectomy in children. *International Journal of Pediatric Otorhinolaryngology*, *152*(October 2021), 110941. https://doi.org/10.1016/j.ijporl.2021.110941

Taheri, A., Mansoori, P., Sandoval, L. F., Feldman, S. R., Pearce, D., & Williford, P. M. (2014). Electrosurgery: Part I. Basics and principles. *Journal of the American Academy of Dermatology*, *70*(4), 591.e1-591.e14. https://doi.org/10.1016/j.jaad.2013.09.056

Tokar, J. L., Barth, B. A., Banerjee, S., Chauhan, S. S., Gottlieb, K. T., Konda, V., Maple, J. T., Murad, F. M., Pfau, P. R., Pleskow, D. K., Siddiqui, U. D., Wang, A., & Rodriguez, S. A. (2013). Electrosurgical generators. *Gastrointestinal Endoscopy*, *78*(2), 197–208. https://doi.org/10.1016/j.gie.2013.04.164

Vilos, G. A., & Rajakumar, C. (2013). Electrosurgical Generators and Monopolar and Bipolar Electrosurgery. *Journal of Minimally Invasive Gynecology*, *20*(3), 279–287. https://doi.org/10.1016/j.jmig.2013.02.013