High Voltage Pulser Histotripsy Transducer

Completed for:
Dr. Robert Adamson,

Group 7
Liam Kidson, Mohamed Alyousuf,
Isaac Wright and Nikan Fakhari

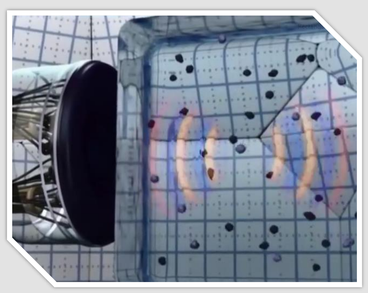
Dalhousie University
Department of Electrical and
Computer Engineering

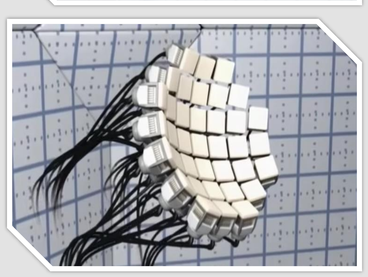
Abstract

- To cavitate tissue non-invasively a powerful ultrasonic wave is required
- Minimum of 660V is necessary for suitable result for testing
- Currently, this implementation can be very large in size and expensive
- To solve this problem a small affordable circuit must be created to provide the transducer with these high voltage pulses
- This circuit must output high intensity (5kV+) periodic pulses (5MHz) with short duration (100ns)
- The device created should be modular in design so that the output voltage is variable

Introduction

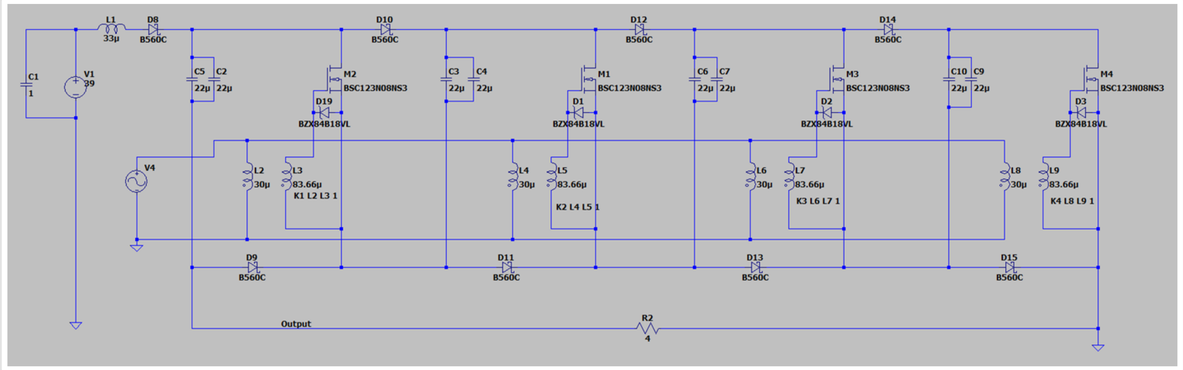
- Histotripsy uses high intensity ultrasound waves to break down unwanted tissues, such as cancer cells
- It is used in non-invasive, non-thermal applications
- High intensity voltage pulses can be created using a Marx generator circuit.
- This allows the use of a low voltage supply to power the high voltage transducer.
- The histotripsy transducer uses these pulses to create high intensity ultrasonic pulses.





System Architecture

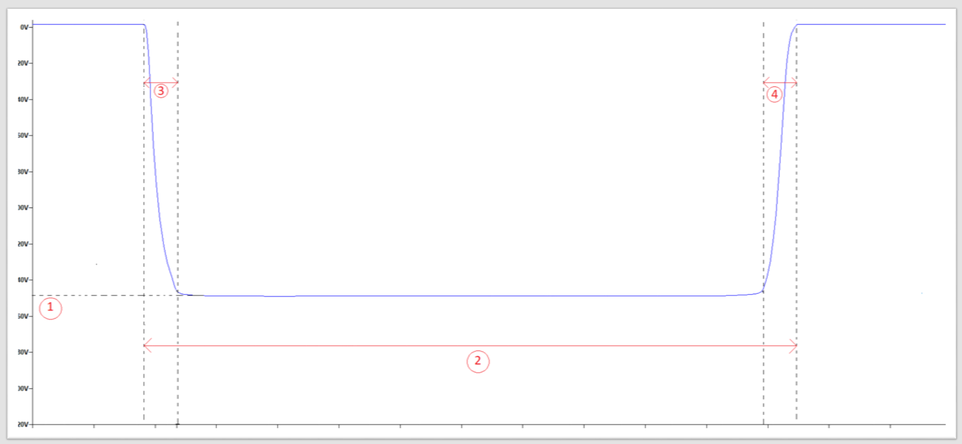
Below is the topology of the circuit we have designed.



- Our design choices are dependent on two different time constants (charging and discharging states)
- It takes approximately 5 time constants for the capacitors to fully charge and discharge
- This can be controlled by the ON-OFF time of the function generator and help us to calculate the equivalent capacitance of each stage
- This relationship will allow us to achieve a pulse duration of 100 ns
- The transformers are used to isolate the ground of each Marx stage from the previous

Results

Below is the output pulse from the LTSpice simulation, along with the key performance data. This circuit represents 4 Marx Stages at an input voltage of 39V. The Function Generator is set to 8Vpp, 100kHz at 1% Duty Cycle.



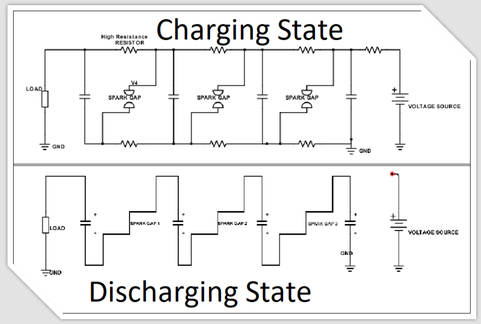
Peak Voltage:	-156V (1)
Pulse Width:	106ns (2)
Rise Time:	5.78ns (3)
Fall Time	5.94ns (4)

- The results we saw in LTSpice simulations showed that we would be able to meet the design requirements for the Transducer's centre frequency of 5Mhz, or 100ns pulse width.
- When testing the voltage in LTSpice we see the voltage is the theoretical output of -156V (39*4).
- Using 4 or more of these PCBs in series would be sufficient to achieve our goal of 600V+ which is an intense enough wave to cavitate water using the transducer
- Currently the lab results do not match the simulation results from LTSpice. We believe this is due to loading issues from the function generator as well as working on the RF protoboard rather than a custom PCB.

Marx Generator Circuit

The Marx Generator Circuit works by doing the following:

- Charges all capacitors in parallel
- Using a switching method, changes the capacitors to series configuration
- Discharges all the capacitors in series configurations, multiplying the input voltage by the number of capacitors.

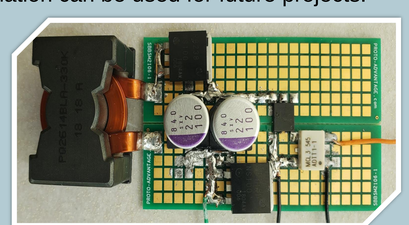


Conclusion

Throughout the year, while working on this circuit we have arrived at the following conclusions.

- The Marx Generator Circuit is a viable method to power a histotripsy transducer.
- We were able to show this circuit is capable of producing a 156V pulse at an operating frequency of 5MHz and a pulse repetition rate 100kHz through LTSpice simulation
- From these results we were able to select components to build a circuit in the lab
- The initial circuit testing was not able to provide results that matched the LTSpice simulations.
- More time is needed to investigate the source of the discrepancies.

Overall, we were able to learn more about the operation of the Marx Generator circuit and this information can be used for future projects.



References and Acknowledgment

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T. E. D. Talks, "Using sound waves to destroy cancer | Christine Gibbons | TEDxDetroit," YouTube, 27-Feb-2017. [Online]. Available: https://www.youtube.com/watch?v=GKh2XFmsUx4&t=298s.