Project Proposal
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Introduction: Ultrasound imaging is a vital medical technology, as it allows professionals to get a closer look at the inside of what they are studying without actually having to open the person or object they are attempting to observe. While this variety allows people the ability to choose exactly what they want in a machine, many industry machines are designed with a great deal of adjustable features, and therefore cost a great deal of money. The primary goal of this project is to design a low-cost pulser/receiver. Some additional functionality is desired, and will be designed into the project, but the current plan is to have the main phase of the design completed by the end of fall term. The first half of winter term will entail adding optional features to the device, and the second half ensuring that the overall device is functional and presentable.

Proposed project: As mentioned above, this project involves creating a low-cost alternative to the over a thousand dollar machine Professor Buma has (and uses). The low cost aspect also means that should Professor Buma need more than one pulser, he does not have to purchase another expensive machine, rather; he can use another, simpler device. Designing this device will also allow me to work with a topic not covered in depth through any course here at Union. The majority of the project time will be spent working with the individual circuit elements, trying to build a functional prototype, but the desired finished project should be constructed on a Printed Circuit Board (PCB) and mounted in a metal enclosure, with appropriate BNC connectors to allow the device to be connected to coaxial cables and used just like the more expensive machine it is based on. An image of the original machine is shown below for reference, but my device will likely not look identical. Additionally, a rough sketch of the device in use is shown.

Figure 1: Image of Professor Buma's device

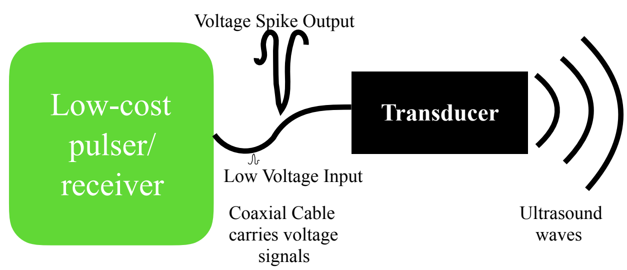

Figure 2: Sketch of key device stages

Design Requirements:
<u>Output Requirements:</u> The pulser shall produce a negative voltage spike around 180 volts (V) or greater, for 20 nanoseconds or less. A greater voltage spike, around 350 V, is more desirable, but 180 volts is a starting baseline. The repetition rate shall begin at 1 kilohertz (kHz), but can (and should) eventually be adjusted to go as high as 20 kHz. 5-10 kHz would be considered a more typical goal. The unit should also have two different trigger options; an internal trigger (that would keep time and self-trigger) and an external trigger (that would operate on a 0-5 volt logic scale and trigger due to an input signal to the device). Adjustability with regards to both the repetition rate and the triggers are longer term goals, but is desired.

Input Requirements: For initial testing, the load will be assumed to be 50 ohms. The receiver should be capable of measuring the pulse echo. One cable will be used both to transmit and receive, and as such, needs to be able to route a very high voltage signal and a very low voltage signal with no data loss at either extreme. The receiver circuitry would also need to be protected against the very high voltage pulse by using a duplexer and limiting diodes.

Cost Requirements: As the project is meant to be a cheaper alternative to Professor Buma's approximately $2,000 machine, the economic cost of this project is definitely a constraint. The design proposed in Brown and Lockwood's paper costs around $50, so the final circuit design, which would have more functionality than their proposed design, and include additional elements, would ideally be under $100, discounting the costs of the high voltage supply, the PCB, and the mounting hardware. More discussion of cost will be featured in the Budget section.

Electrical/Safety Requirements: The pulser/receiver shall run off the 120 volt wall line, and will be designed with those limitations in mind. It likely will not be used to take measurements on living beings, but it should be safe enough for such an eventuality. Because of the very high voltage, the system shall be designed with careful attention paid to the current running through components and the amount of power dissipated.

Size Requirements: The original machine is approximately 7 inches wide, 3.5 inches tall, and 9.1 inches deep, so my device should be no larger than those dimensions. Since this device will be a low-cost version, it should be even smaller than the more expensive machine. I do not yet have exact dimensions, as they will depend on the final circuit design and the size of the PCB and other components.

Design Approach: Much of the aesthetic elements of the project will be implemented during the winter term, after various sub-functions are confirmed to be working as expected. The goal for the end of the term is to have the pulser and receiver elements of the device functioning, and a preliminary design for the final device housing should be implemented. A high level block diagram of the key stages is shown below.

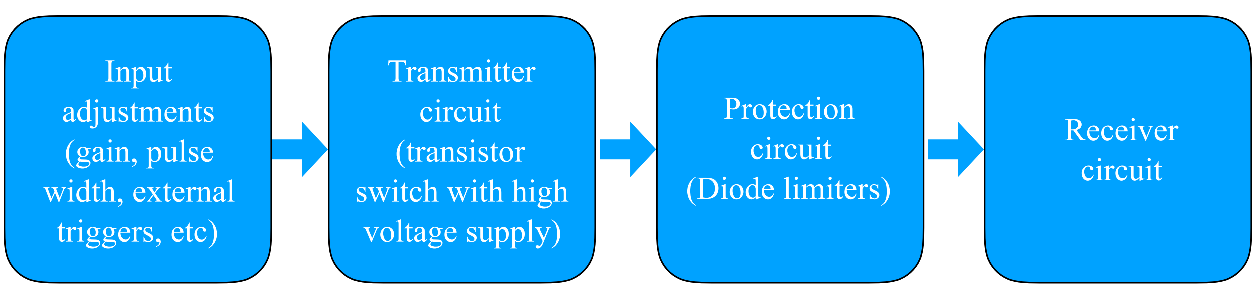

Figure 3: Overall Model of the Pulser/Receiver

The pulser will initially be tested alone. In order to do this, an oscilloscope probe can be used to measure the system output and display it on the oscilloscope. The output will be measured with and without a 50 Ω load. The voltage amplitude, duration of the pulse, and any pulse ringing will be the main aspects of the signal to observe.

The receiver will also be tested by itself before it is implemented with the pulser. A function generator will be used to model the input signal. Again, a scope probe will be used to measure the output of the receiver. In this case, the amplifier gain, frequency response, and noise will be the observed parts of the signal.

When both the pulser and receiver are tested together, the output (of the pulser)/input (of the receiver) cable will be connected to an ultrasound transducer. The transducer will then be placed in front of an acoustically reflective device, and a pulse will be sent. The final output of the receiver will be measured using an oscilloscope. Here, it is the peak frequency and bandwidth of the received pulse that will be measured.

These methods can be used to test each step of the device individually, but will also be used in the future to test the device when additional features are added. Assuming that a successful pulser/receiver is designed, the final result of those tests will be used as a benchmark for the device's future functionality, with appropriate scaling.

Anticipated Outcomes: The final device should behave comparably to the one Professor Buma is currently using. It should, at minimum, be able to send a very high voltage pulse (on the order of a hundred volts) to the ultrasound transducer and receive the very low voltage pulse (on the order of millivolts) sent back through the transducer. Additionally, some front-end adjustments will be implemented. These requirements include, but are not limited to, adjustable gain, adjustable pulse width, and adjustable gain, all of which should be able to be implemented with fairly simple circuit components. These components include variable resistors or capacitors, as well as regular resistors, capacitors, inductors, and other simple circuit components. Though the device may not be as finely tuned or accurate as the one Professor Buma currently uses, it should be able to be used for a rough estimation of the imaging work he is trying to accomplish.

Reason(s) Funding is Necessary: Funding is necessary for this project because I will need to be able to purchase key components, such as a high voltage supply, PCB materials, and mounting materials in order to successfully create and test the ultrasound pulser/receiver.

References:
[1] J. A. Brown and G. R. Lockwood, *A Low-Cost, High-Performance Pulse Generator for Ultrasound Imaging,* IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control., vol. 49, no. 6, June 2002.

[2] Olympus, "Manually Controlled Pulser- Receivers," 5072PR datasheet, 2009.

[3] J. K. Poulsen, *Low Loss Wideband Protection Circuit for High Frequency Ultrasound,* IEEE Ultrasonics Symposium, 1999.

Budget Breakdown: The components necessary to complete the device are broken down in the table below. The total amount requested is $399, with $362 going toward component purchase and $37 for shipping costs. The most expensive component is the high voltage supply, which is also the most necessary, due to the fact that the project features high voltage spikes. Many standard electrical components, such as resistors, transistors, and op-amps, can be found in the ECBE department, and so their cost is not included in the budget breakdown.

Table 1: Detailed Budget Breakdown

Item	Justification	Cost
Acopian Power Supply Model U400Y20	This high-voltage power supply can produce up to 400 volts. 400 volts is necessary to create a buffer for the maximum 350 volts Brown and Lockwood's circuit was designed for, though most of the testing will be conducted at a lower voltage. When using high voltage, care will be taken to ensure user safety.	$250
THS3001 Operational Amplifier	420 MHz current-feedback amplifier, used as a high input impedance line driver	*
3 VN2106 MOSFETs and 3 VP1304 MOSFETs	These MOSFETs are paired together (1 P-Type and 1 n-Type) to act as a push-pull switch.	*
501N04 Fast Power MOSFET	Used as a high power switch to turn the circuit on or off.	$27
2 50 Ω Resistors	Component in pulser circuit	*
150 Ω Resistor	Component in pulser circuit	*
1k Ω Resistor	Component in pulser circuit	*
25 Ω Resistor	Component in pulser circuit	*
100k Ω Resistor	Component in pulser circuit	*
620 Ω Resistor	Component in pulser circuit	*
2 1.0 μF Capacitor	Component in pulser circuit	*
0.01 μF Capacitor	Component in pulser circuit	*
2 BNC Connectors	Necessary to input/output voltage pulse and resultant signal, and to input external trigger	$11
Custom PCB Fabrication	Necessary for the final device to be neatly organized	$32
Mounting Hardware	Includes mounting enclosure, small metal sheets, screws, spacers, and washers	$42
Shipping Costs	Must pay for shipping for some specialty websites/companies	$37

* These components will be paid for by/are freely available in the ECBE department.