Tactile Stimulator

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ABSTRACT

It is important to understand stochastic resonance on the hands in order to prove how it effectively enhances vibrosensory perception. To do this, an MR-compatible tactor is needed to provide a vibration stimulus to the hand during an MRI of the brain. The key design requirements of the device are that it must run at a frequency range of 30-300 Hz, and be small enough to fit on the subject's finger while maintaining a 1 mm thickness. In order to achieve these requirements, three design options were evaluated: solenoid, piezoelectric, and pneumatic. Of these three options, the piezoelectric device was determined to be the best suited design. Optimal materials for the tactor were determined, as well as the required circuitry needed to drive the system.

PROBLEM STATEMENT

Motivation

According to the U.S. Bureau of Labor Statistics, the leading cause of disabling injuries and second leading cause of fatalities in the workplace is falling from a ladder or scaffold. In order to reduce these injuries, a device must be developed to improve the worker's response time by stimulating their sense of touch through a vibration to stimulate the nerves in their hands. The average response time to a vibration stimulus to the hand is 100 milliseconds, including a 60 ms delay period for the stimulus to reach the nerves through the skin. Using stochastic resonance, it is possible to reduce this 60 ms delay time, allowing a person to sense vibrations earlier and prevent a fall from a ladder or scaffold.

Stochastic Resonance

Stochastic resonance is the phenomenon that occurs when a sub-threshold signal is enhanced by the presence of noise. For this application, the noise from a vibrotactile stimulator will add to a vibration stimulus, making it easier to reach the nerve threshold and allow a person to sense vibrations that would otherwise go unnoticed.

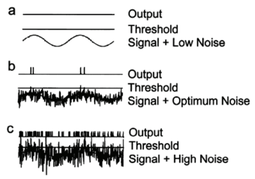


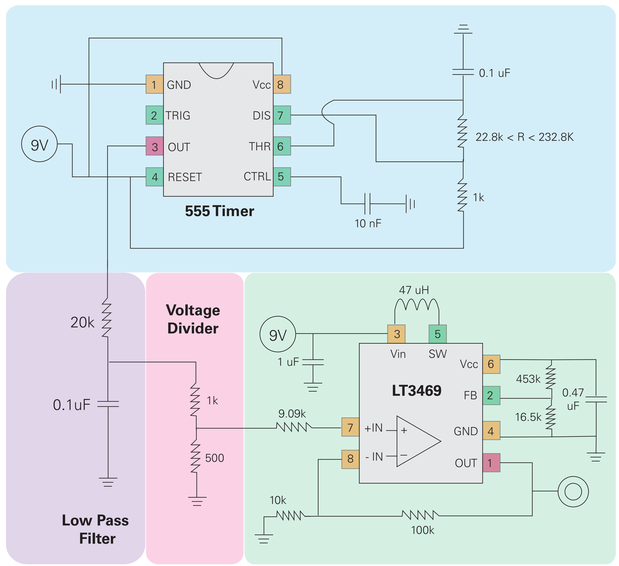
Figure 1. Stochastic resonance waveforms

It is important to develop a device to allow researchers to observe stochastic resonance in order to determine its applicability in industry to reduce the number of workplace injuries. Magnetic resonance imaging (MRI) is the most effective method for viewing the brain activity due to vibration stimuli; thus, an MR-compatible stimulation device must be created.

DESIGN REQUIREMENTS

- Prototype must be MR-compatible
- Frequency: 30-300 Hz (adjustable)
- Displacement: 10-500 μm
- Thickness: under 2 mm
- Diameter: 1 cm
- Accommodate varying hand sensitivities
- Stimulation must be sub-threshold
- The device should fit on the tip of a person's finger

FINAL DESIGN



Circuit Components

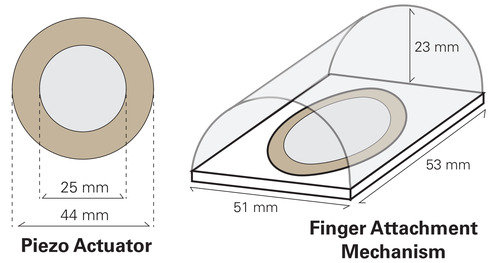
555 Timer
Input DC voltage = 9V
Conversion from DC input to AC output
Provide square wave signal
Provide adjustability of the frequency (30~300Hz)

Low-Pass Filter
Filter undesired frequency
Modify and reshape to sine-like wave signal
Reduces piezo audible noise during vibration
Determine cutoff frequency using a linear equation

Voltage Divider
Modify the voltage input into LT3496 (9V to 3V)

LT3496 Piezo Actuator Driving Circuit
Driving circuit designed for specific piezo
Output voltage varied from 0V to 33V
Provide adjustability of the displacement

Finger Attachment



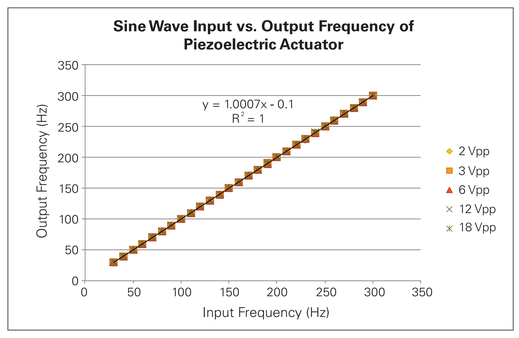
Piezo Actuator

Finger Attachment Mechanism

Cost Analysis

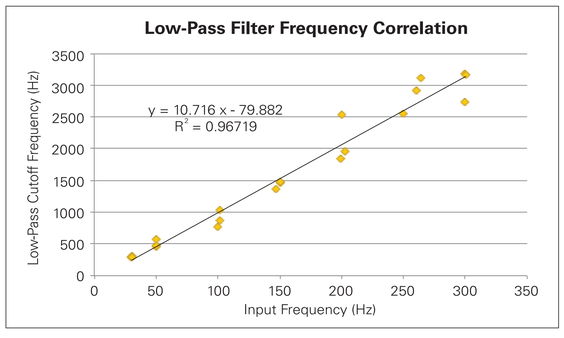
Elements in Prototype	Quantity	Price (USD)
CEB-44D06 Piezoelectric Actuator	1	2.21
LT3469 Transconductance Amplifier	1	2.45
555 Timer Chip	1	0.49
Resistors	8	0.13
Capacitors	5	0.83
Inductor	1	1.44
Finger Attachment Mechanism	1	0
Total Price		$11.78

TESTING



Input-output frequency

- Used 2 piezo buzzers (1 as actuator, 1 as receiver)
- 1:1 correlation with $R^2 = 1$
- Shows piezos do not mutate the frequency



Low-Pass Filter

- Determine relation between input frequency for actuator and desired cut-off frequency for the filter
- Used Oscilloscope to measure output wave
- Found linear relationship (y = 10.716x - 79.882) with an $R^2 = 0.9672$
- Testing was bias on testers idea of a what the desired wave looked like

Laser Vibrometer

- Measures displacement using light scattering
- No voltage-displacement relation on piezo data sheet or from CUI
- Unable to complete test due to equipment availability
- Plan on finding the voltage vs. displacement correlation

FUTURE WORK

Stand-Alone Power Source Eliminate the need for a signal generator, lowering the cost.
MR-compatibility The piezoelectric actuator and the wires that connected to the 555 timer circuit need to be fully MR-compatible before testing in the MRI room.
Frequency Develop a system to determine the output frequency of 555 timer circuit without the help of oscilloscope. The low pass filter also needs to be easily adjustable without constantly measuring the output signal of the circuit, including a display for the user.
Testing Use the device inside an MRI to test stochastic resonance.

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