**Characterization of Acoustic Properties of a Piezoelectric Generator Membrane**

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### Purpose

We propose a micro scale system for power production. As electronic components become smaller and more portable, they are increasingly used in many diverse applications. To power these embedded or remote electronics, novel power sources will be needed. Current electricity supplied through batteries or photovoltaic cells have limitations. Our goal is to use a thermoacoustic engine to capture waste heat and produce acoustic power. That power will then be converted into electricity using a piezoelectric generator membrane. This system has the advantages of no moving parts, inexpensive and easy manufacture, and small size.

The thermoacoustic engine consists of a tube with one closed end, a stack in the middle and an open end. Heat is supplied to the closed end, and the temperature differential across the stack creates a pressure differential which produces a sound wave accompanied by air streaming out the open end. This is analogous to a laser, but emitting sound instead of light. The piezoelectric generator membrane will be placed at the open end of the engine to capture the sound energy and produce power.

### Experimental Procedure

A sound tube was designed and built consisting of an acrylic tube with a speaker on one end and mounts on the other end for the piezoelectric membrane and a pressure transducer. Tests were then conducted driving the speaker at various frequencies and amplitudes. Data was collected from the signal generator, pressure transducer, laser vibrometer and the membrane using an oscilloscope and recorded to computer for analysis.

As seen below, this is the procedure followed to collect and analyze the data. First impedance data is taken using the Agilent Impedance Analyzer. Next this data is run using a MatLab code which constructs a curve fit. From this the parameters are taken which are then used for the mathematical model. This is executed using a new MatLab code which returns the simulation of the generator membrane.

### Experimental Results

After an initial debugging period, the sound tube experiment is beginning to show good results. Some technical difficulties that needed to be overcome were nonlinear behavior in the sound tube, noise introduced into the signal by the amplifier, unaccounted resonances in the sound tube and speaker, and nonlinear behavior of the membrane at lower than expected deflections. The experimental results from the sound tube show encouraging agreement with the numerical model. The pressure deflection curves below are used to calculate stiffness of the membrane. It is interesting to note that stiffness appears to change with a change in frequency. The stiffness calculated from these pressure deflection curves is 418.75N/m². This is consistent with other stiffness measurements made for this range of displacements- 638.9N/m² is a good representation.

As we see in the graph below, the resonant frequency for the device is between 6300 Hz at low pressures and shifts to 6200 Hz at higher pressures. This is consistent with other measurements made for these conditions. The impedance analyzer calculated a resonance of 6250 Hz and the MatLab program predicts a resonance of 6200 Hz.

### Methodology

By first using the equivalent circuit model for the membrane, the parameters of resonant frequency, capacitance, resistance, quality, and coupling coefficient k² are determined. From these parameters, and with measurements of stiffness and area, effective mass, damping coefficient and ψ are calculated. These parameters are then used to numerically model the behavior of the membrane. This is compared to the equivalent circuit analysis to verify the results. A sound tube with variable frequency and amplitude has also been designed and built to gather experimental data to independently verify the modeled results.

This analysis of the sound tube experiment data shows good agreement of resonance and alignment of impedance trends between the numerical and experimental methods of obtaining these parameters.

### Conclusions

We have been successful in the characterization of the electrical, mechanical and acoustic properties of the piezoelectric membrane. We have confidence in our measurements by demonstrating that our procedures and data are repeatable, our experimental and modeled data agree and we have verified our results using independent tests. Our next step is to optimize the generator membrane parameters with the thermoacoustic engine parameters. By impedance matching our engine and its load, we can optimize the system. Once these constraints have been well established, we can design a new generator membrane to optimize the design constraints of the system.