Study of Piezoelectric Devices for Conversion of Sound to Electricity

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Background: Thermoacoustic Engines

- Source of heat
- Acoustic resonator
- Stack of plates
- Heat exchanger at end of each stack
- Working gas: air
Theory: Piezoelectric Devices

- Pressure-Sensitive Crystals or Ceramics
  - Shape is distorted, it gives off charge which creates voltage
- Can work two ways: loudspeaker or microphone
- Wide Range of Applications
- Why use sound?

Piezoelectric sidewalk used to power streetlights in France
Investigation: Voltage Output and Frequency

- Two types of crystals:
  - Commercially Available and Inexpensive Ceramics vs. Inexpensive specially-manufactured single-crystals
- Which devices give the best voltage output?
- Which devices have resonant frequencies which will fit best with our heat engines?
Diagram of Experimental Setup
Signal Generator

- Input to Loudspeaker
- Sweep signal 20 Hz to 20 kHz audio range
- Results in pressure response of piezo, shows resonant peaks
Loudspeaker

• Outputs sound to be received by piezo
• Broad, even output; does not have resonance
• Sound level measured with decibel meter to make sure sound is at the same level for all piezos
Oscilloscope

- Measures frequency response
- Gives AC-voltage output of piezoelectric device (RMS)
- Used to find the peak of the resonant frequency
Resonance

- Sweep over all frequencies to find the one which gives the highest voltage output
- Sharp Q = Extremely narrow frequency band (~ 5 Hz)
- Output is generally about 10 times larger than off resonance

Frequency (20 Hz to 10 kHz)
Real-Life Setup

Characterizing Piezoelectric Devices
Voltage Response

Mounted Piezoelectric Device Voltage Measurements (RMS)

- 1 7/16' Brass PZT (Commercial): 166 ± 5
- 15 B (Single-Crystal): 140 ± 4
- 1' Brass PZT (Commercial): 71.1 ± 2.1
- 15 A (Single-Crystal): 53.4 ± 1.6
- 18 B (Single-Crystal): 36.5 ± 1.1
- 17 A (Single-Crystal): 34.6 ± 1.0
- 17 B (Single-Crystal): 26.4 ± 0.8

Device Name
Resonant Frequencies

Mounted Piezoelectric Device Measurements
Resonant Frequencies (kHz)

Device Name

- 1 7/16' Brass PZT (Commercial)
- 15 B (Single-Crystal)
- 1' Brass PZT (Commercial)
- 15 A (Single-Crystal)
- 18 B (Single-Crystal)
- 17 A (Single-Crystal)
- 17 B (Single-Crystal)

Frequencies:

- 3.067 +/- 0.092
- 2.907 +/- 0.087
- 4.902 +/- 0.147
- 2.336 +/- 0.070
- 2.874 +/- 0.086
- 2.381 +/- 0.071
- 3.086 +/- 0.093
Interpretation of Results

• The commercially-available piezoelectric devices seem to give better voltage output
• Surprisingly wide variation in the performance of single-crystal piezos
• Nearly all of the devices operate between 2 and 3 kHz
• Best devices to couple with 3-kHz thermoacoustic engine are the commercial 7/16” brass PZT and single-crystal 15B

Using sound to light up LED’s