Beeps in Everyday life

- All the *Beeepps* around you come from microcontrollers
  - Your phone
  - The microwave
  - Your PDA
  - …
- Your kit has an inexpensive piezoelectric (crystal) speaker

The Piezoelectric Speaker

- Low current audio device
  - Best at "high" frequency > 2k Hz
- Lots of sizes and shapes
- Ceramic crystals deflect with charge
  \[ \varepsilon = f(q) \]
  \( \varepsilon \) = mechanical strain, \( q \) = electrical charge

The Piezoelectric Speaker

- How does it work???
  - Let’s look at the system
- Electrical Power is Potential*Current
- What’s the Speaker input?
- What’s the Speaker output?

\[ P = vi \]
The Piezoelectric Speaker

- Electrical Power is Potential*Current
- What’s the Speaker input? “v”
- What’s the Speaker output? “i”

$$P = vi$$

![Piezoelectric Speaker Diagram]

The Room Acoustics

- Acoustic Power is Pressure*Flowrate
- What’s the Speaker input?
- What’s the Speaker output?

$$P = pQ$$

![Room Acoustics Diagram]

The Room Acoustics

- Acoustic Power is Pressure*Flowrate
- What’s the Speaker input?
- What’s the Speaker output?

$$P = pQ$$

![Room Acoustics Diagram]

The Room Acoustics

- Acoustic Power is Pressure*Flowrate
- Why is the small hole there?
  - An acoustic resonator amplifies “Q” response

$$P = pQ$$

![Room Acoustics Diagram]

Piezoelectric Speaker Geometry

- Structural Bi-morph
  - piezoelectric ceramic layer
  - metallic plate
- Electric Charge => Plate Bending

![Piezoelectric Speaker Diagram]

Piezoelectric deflection

- Piezoelectric strain deforms metallic plate
- Deflection "pumps" air => flowrate, Q into room
  - Room acoustics respond with Pressure p output "Sound"
The speaker

Acoustics of enclosure can be predicted
“Helmholtz Resonator”

Audio Response

- Small devices are not loud
- SPL varies with frequency
- They are efficient (small power required)

Programming Tones

FREQOUT Pin, Duration, Freq1 {, Freq2}

Generates a high speed PWM “sinewave”
on I/O Pin for
period Duration at
Frequency Freq1 (Hz)
Simultaneous second tone at {, Freq2}

More than a Square Wave

- PWM used to form “analog” signal level

Actual BS2 Output

Freqout 9, 10000, 1000 = 10 second, 1 Khz tone, to pin 9

10 x 50µsec = 0.5 msec
~ ½ cycle for 1 kHz tone
~ 25 PWM cycles