

"I think you've carried the successive refinement of that module far enough."

Recap

Design a DAC

Experimental method

Output a sine wave

Overview

Use DAC to create sounds

What are the fundamental limitations?

Precision,

Sampling rate,

Memory size,

Processor calculations

Testing

Need software to create sounds. Frequency is the pitch

Amplitude is the loudness. Shape is the voice.

- Humans can hear from about 25 to 20,000 Hz.
- Middle A is 440 Hz
- Other notes on a keyboard are determined
 - $440 * 2^{N/12}$
 - "N" is number of notes up or down from middle A.
- Middle C is 261.6 Hz.
- music contains multiple harmonics

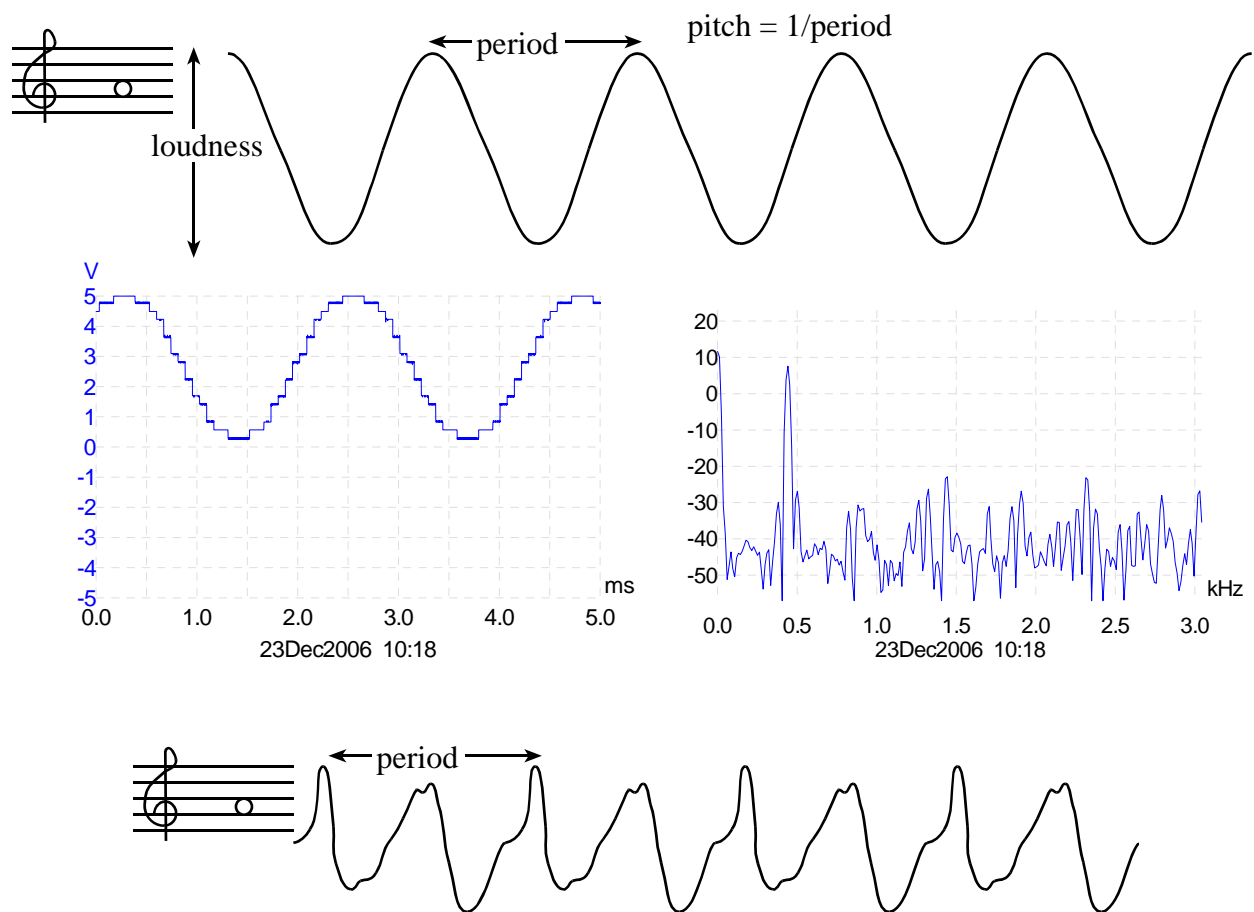


Figure 7.3. A waveform shape that generates a trumpet sound.

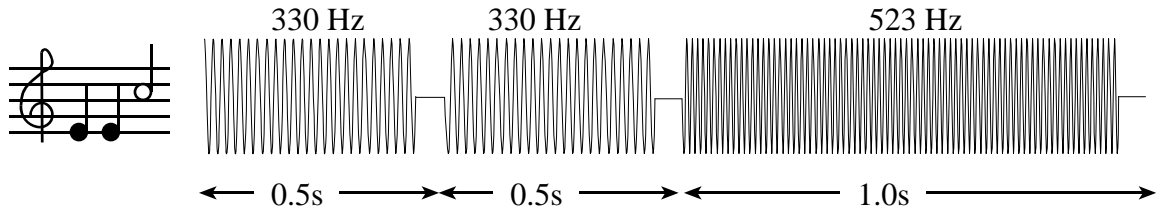


Figure 7.4. You can control the amplitude, frequency and duration of each note (not drawn to scale).

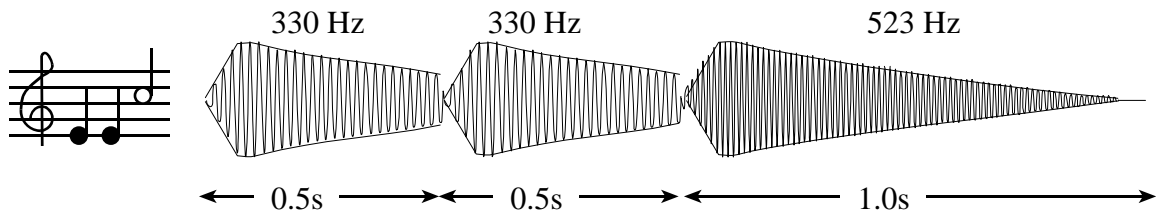


Figure 7.5. The amplitude of a plucked string drops exponentially in time.

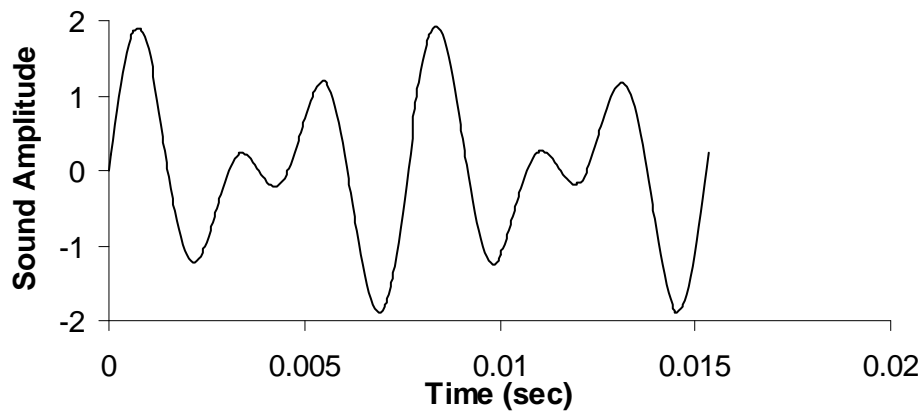


Figure 7.6. A simple chord mixing the notes C and G.

How much memory does it take to store a song

3 minutes

Stereo channels

44 kHz

12-bit per channel

How many bus cycles does it take to output one value?

Fetch data from memory

Decompress

Filter/amplify/mix/envelop

DAC speed

How do we test Lab 7?

Static testing

Complete coverage 0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15

Corner testing 0,1,2 13,14,15

Interval 0 4 8 12

Voltmeter in AC mode is measure of noise

$$\text{RMS} = \sqrt{\frac{1}{n} \sum_i (V_i - \bar{V})^2}$$

Dynamic testing

Oscilloscope (voltage versus time)

Spectrum analyzer (voltage versus frequency)

The bottom line

DAC and OC interrupts create waveforms

DAC and ADC have the same two fundamental limits

Sampling rate: signal has 0 to 1/2 fs

Number of bits: Resolution = Range/Precision

Static testing versus dynamic testing