Unit 2: Waves

Part III

Acoustic: Interference and Beats

- In acoustics, a **beat** is an interference pattern between two sounds of slightly different frequencies, *perceived* as a periodic variation in volume whose rate is the difference of the two frequencies.
- Mathematical representation of two sine waves of unit amplitude:

$$\cos(2\pi f_1 t) + \cos(2\pi f_2 t) = 2\cos\left(2\pi \frac{f_1 + f_2}{2} t\right)\cos\left(2\pi \frac{f_1 - f_2}{2} t\right)$$

where $f_{\text{beat}} = f_1 - f_2$ is the beat frequency

Reference: https://www.youtube.com/watch?v=4M72kQulGKk

Example 1

Two sound waves have frequencies 250Hz and 280Hz but with same amplitudes. What is the beat frequency produced by their superposition?

Solution

$$f_{beat} = abs(f_1 - f_2) = \text{abs}(250 - 280) = 30 \text{ Hz}$$

Psychological effect: binaural beat

- If the two tones are played through headphones (one frequency in the left ear, another in the right ear) each ear receives a pure tone and no physical interference can occur.
- Amazingly, the majority of people will still perceive a beating sound which is a purely psychological effect and is known as a "binaural beat".
- Binaural beats have shown that they can reduce levels of anxiety. However, binaural beats are the auditory equivalent of strobe lights and for certain beat frequencies they may affect the behaviour of brainwaves - a process called "entrainment".

On-line generator: https://onlinetonegenerator.com/binauralbeats.html

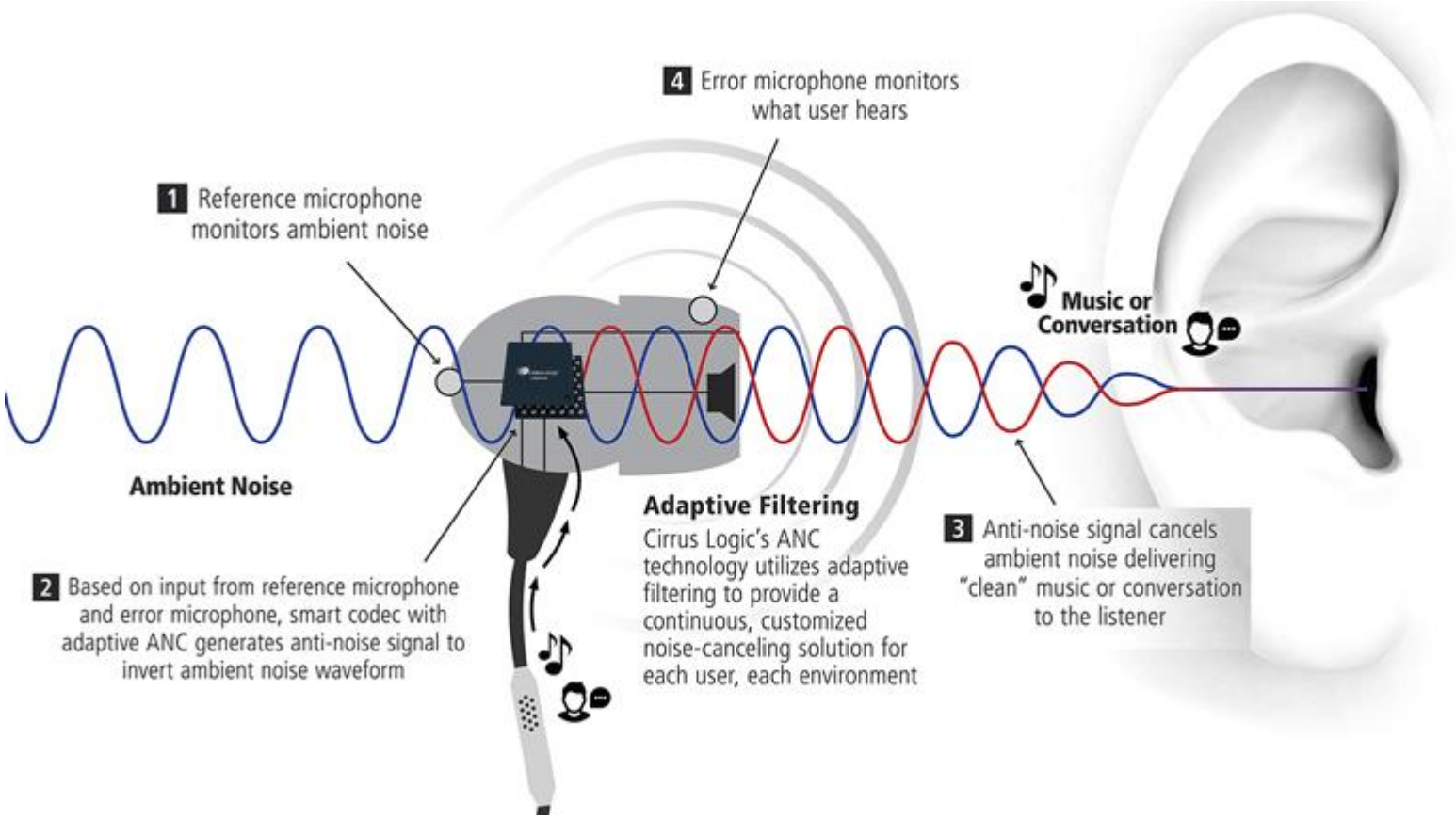
Noise-cancelling headphones

- **Noise-cancelling headphones** are headphones that reduce unwanted ambient sounds using active noise control. This is distinct from passive headphones which, if they reduce ambient sounds at all, use techniques such as soundproofing.
- Noise cancellation makes it possible to listen to audio content without raising the volume excessively. It can also help a passenger sleep in a noisy vehicle such as an airliner.

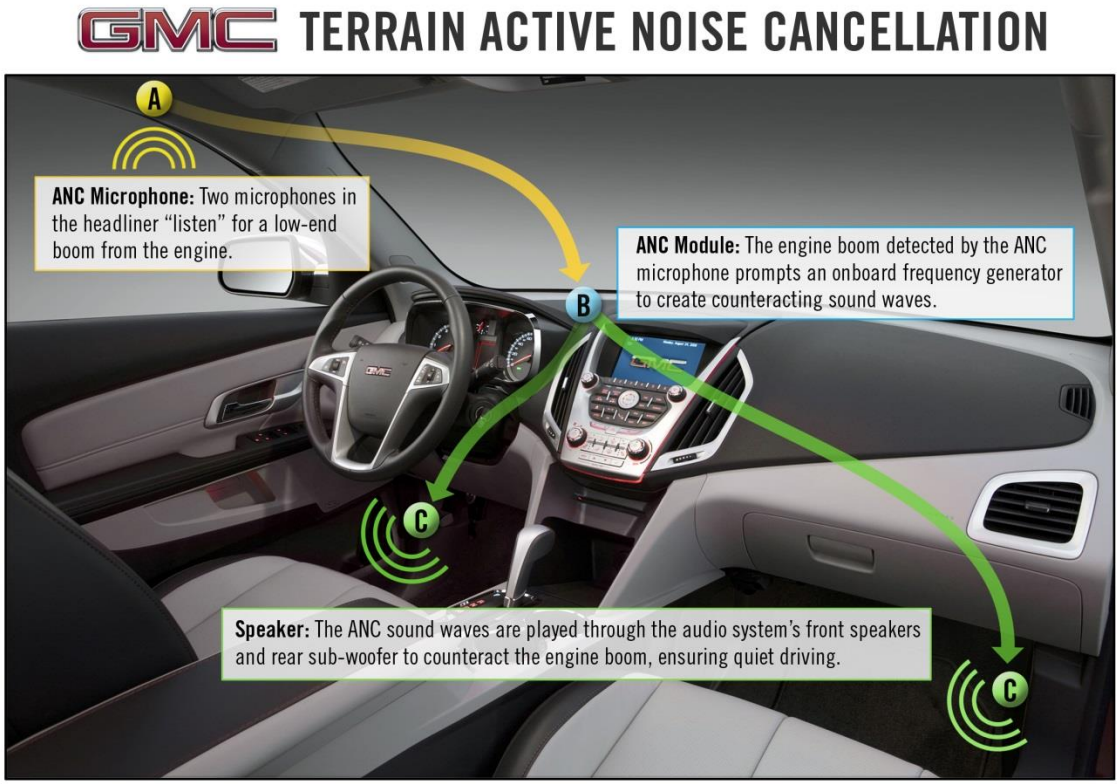
Ref: https://en.wikipedia.org/wiki/Noise-cancelling_headphones

Active Noise Cancellation Explained

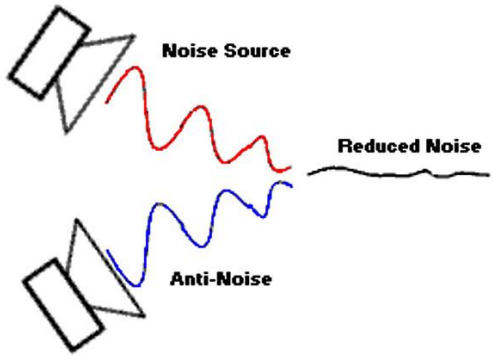
Electronic design of Active Noise Reduction for Apple Airpod Pro



Application – Active Noise Cancellation



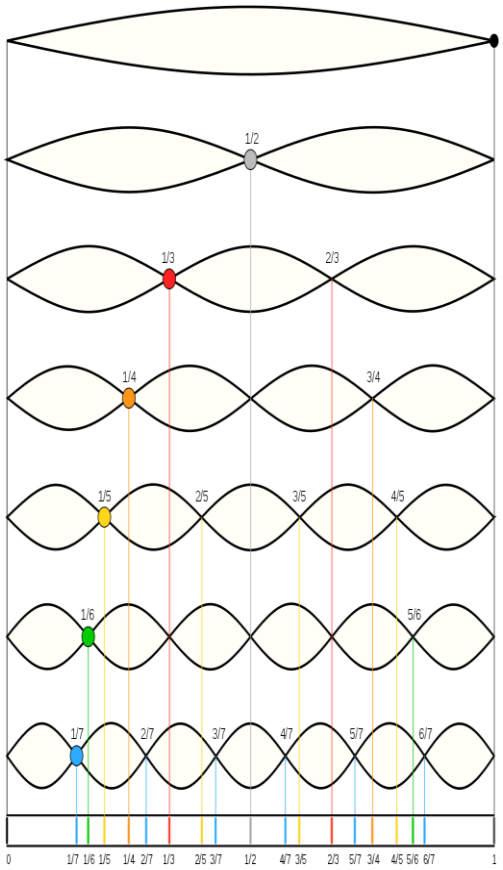
One of General Motors' first applications of Active Noise Cancellation (ANC) technology is used on the 2.4L-equipped 2011 GMC Terrain to enable segment-leading highway fuel economy by allowing lower engine RPMs and helps deliver one of the quietest interiors in the crossover segment.



Active Noise Reduction

Fundamental Frequency and Harmonics

- A **harmonic** is any member of the harmonic series. The term is employed in various disciplines, including music, physics, acoustics, electronic power transmission, radio technology, and other fields.
- It is typically applied to repeating signals, such as sinusoidal waves.
- A harmonic of such a wave is a wave with a frequency that is a positive integer multiple of the frequency of the original wave, known a
- For example, if the fundamental frequency is 50 Hz, the frequencies of the first three higher harmonics are 100 Hz (2nd harmonic), 150 Hz (3rd harmonic), 200 Hz (4th harmonic).



The nodes of a vibrating string are harmonics.

Example 2

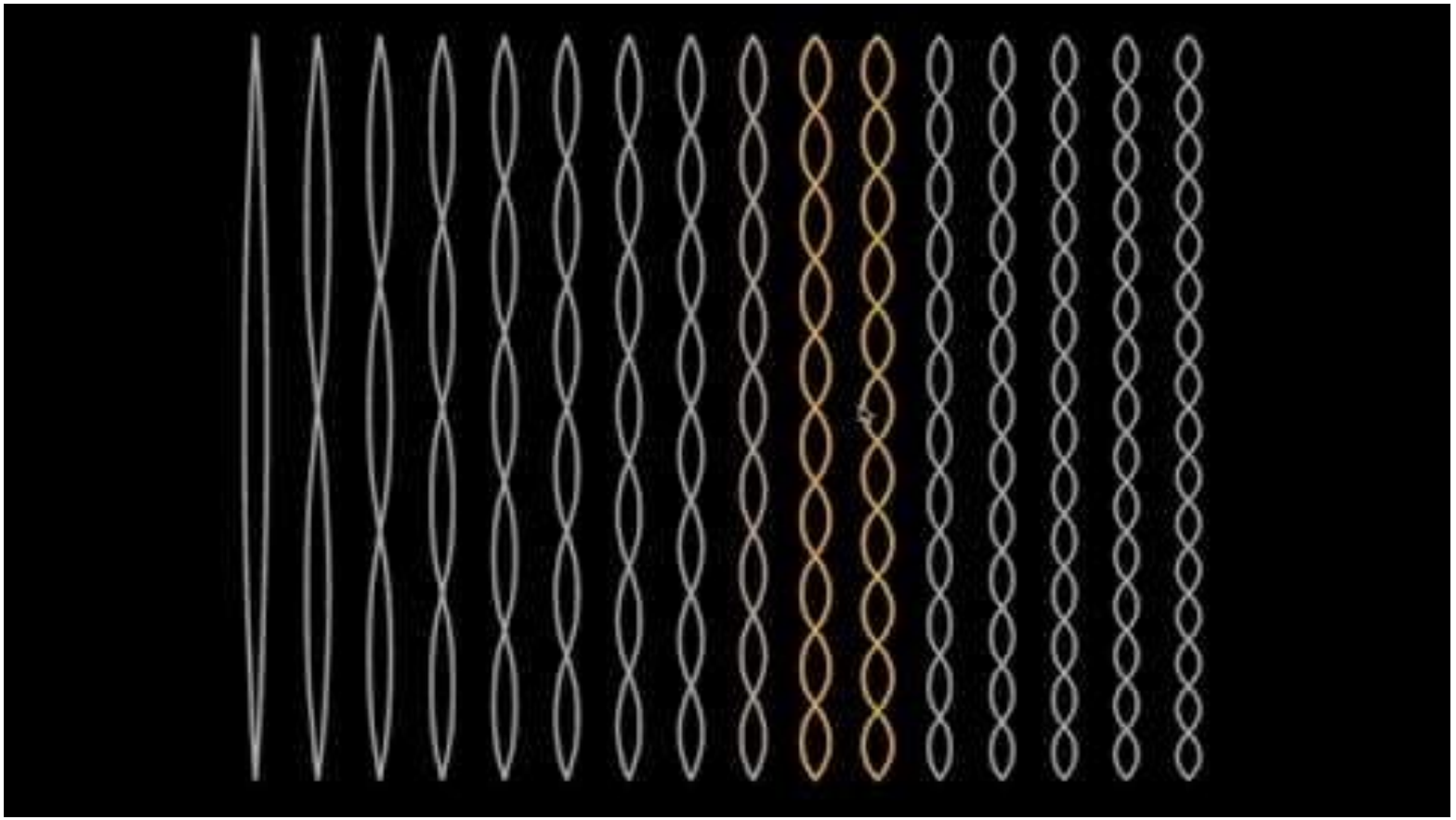
What is the first harmonic of the musical note A?

Solution:

Refer to the p.17 of power point Unit 2 Part II,
The frequency for musical note A is 440Hz

So the first harmonic of the A = 2 x 440Hz = 880Hz
(an octave higher than A)

What does the harmonic series sound like?



What happens when harmonic waves are superposition together?