# The Physics of Electromechanical Keyboard Instruments

Edward Daw

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**Abstract**

In the history of western music, the birth of new musical styles has almost always been precipitated by the invention of new instruments. For example, the invention of the piano played an important part in the transition from baroque music to the classical style of Beethoven and Mozart. In the 20th century, jazz, blues, rock, gospel and many other new music forms changed our culture and our society. In this lecture I will discuss the Hammond organ and the Rhodes piano. I will discuss how these instruments work, and some of the beautiful music they were 'instrumental' in producing.

# A Crude Classification Scheme for Keyboard Instruments

- PIANOS
  - key stroke applies a sharp impulse
  - subsequent tone decays naturally
  - key velocity controls intensity, tone
  - one oscillator per key
  - tonal quality may vary throughout note

- ORGANS
  - continuous excitation of oscillator
  - note continues while key depressed
  - no effect of key velocity on sound
  - one key can control many oscillators
  - each oscillator produces a fairly 'flat' tone

# Waves

Figure 1: LIGO experiment site, Livingston, Louisiana

A typical piano or organ oscillator consists of a vibrating string, pipe, or other metal object. How do you translate vibrations of metal objects in to electrical signals?

# Helmholz's Synthesizer

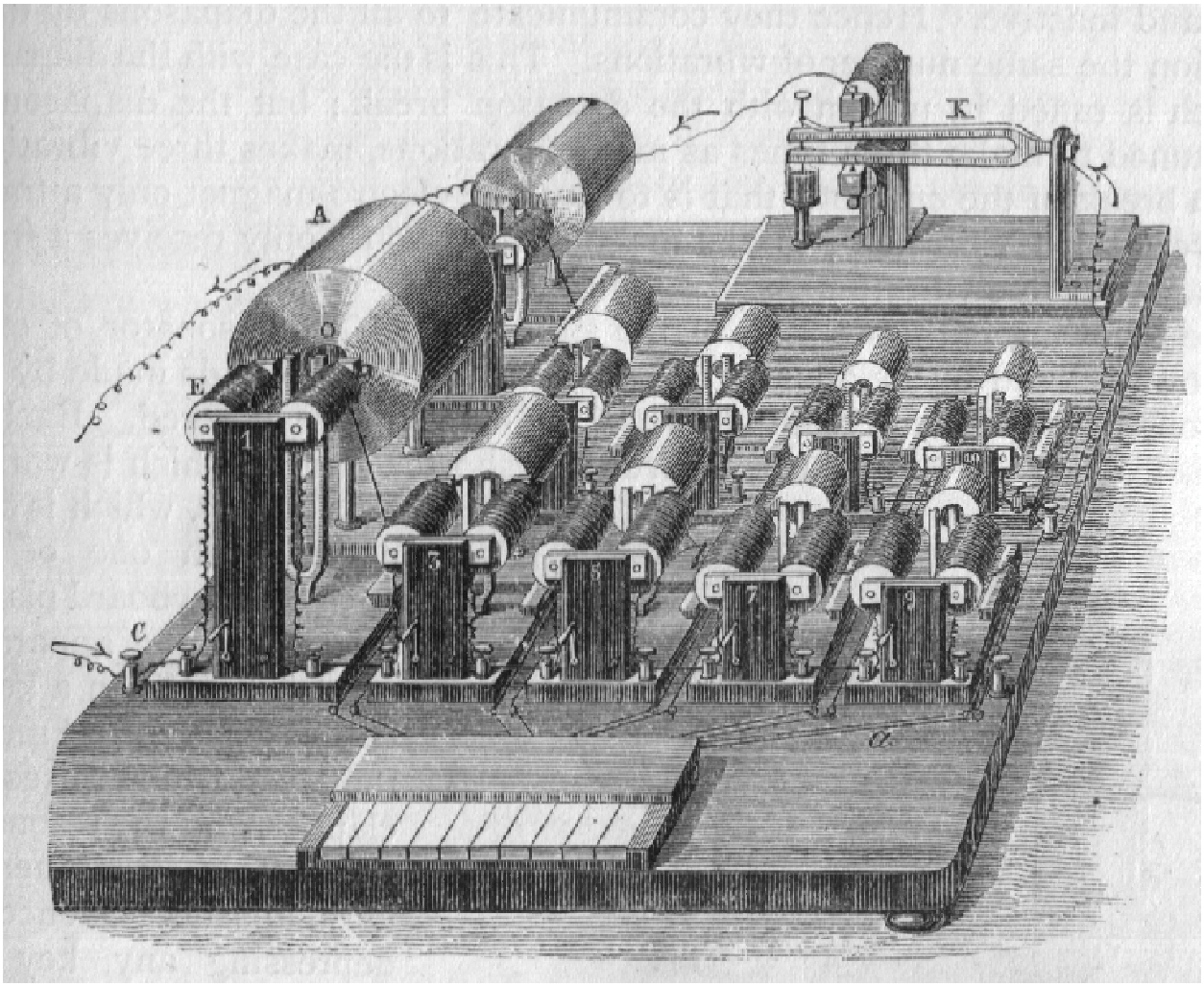


Figure 2: Helmholz's experimental apparatus for the synthesis of tones

# Pickups

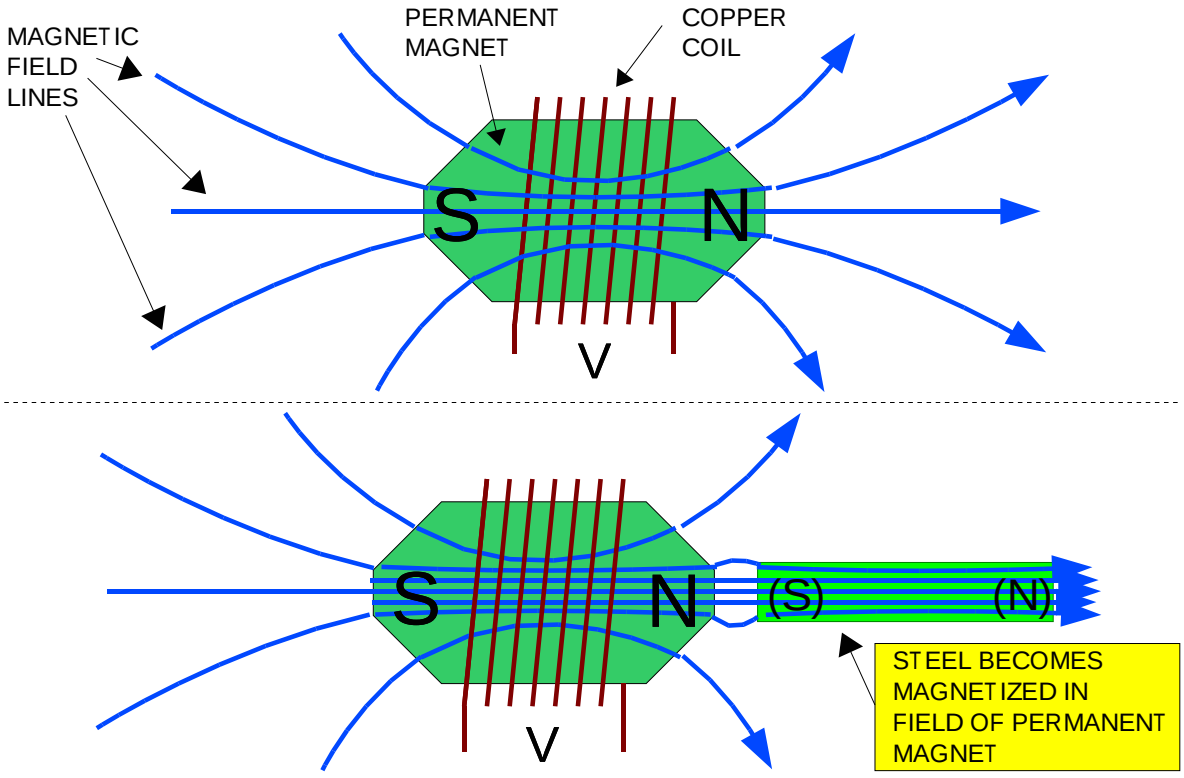


Figure 3: Magnetic fields in a pickup

# Faraday's Law - For More than Just Generators

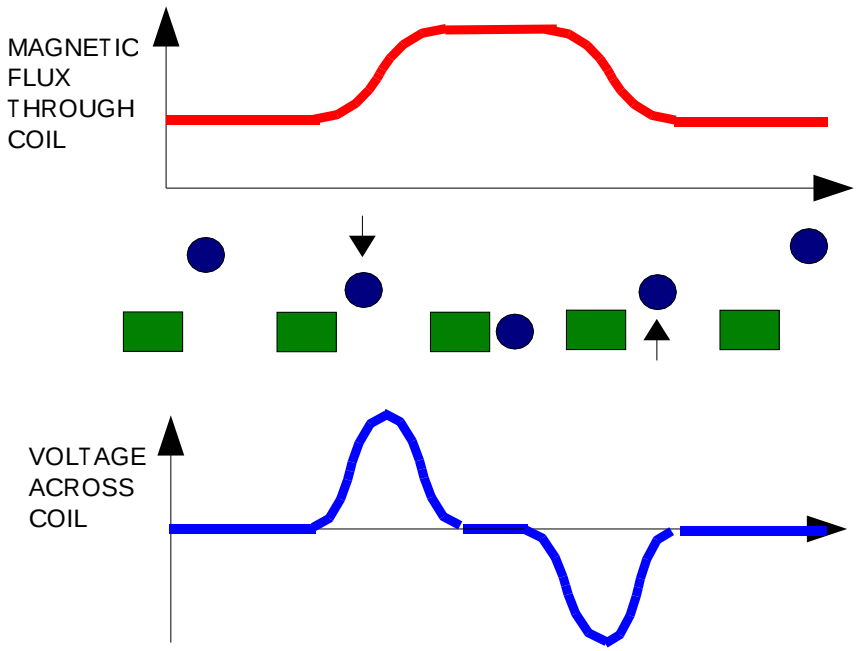


Figure 4: Faradays law of induction as a metal object is bought close to the pickup

# Bring On the Music

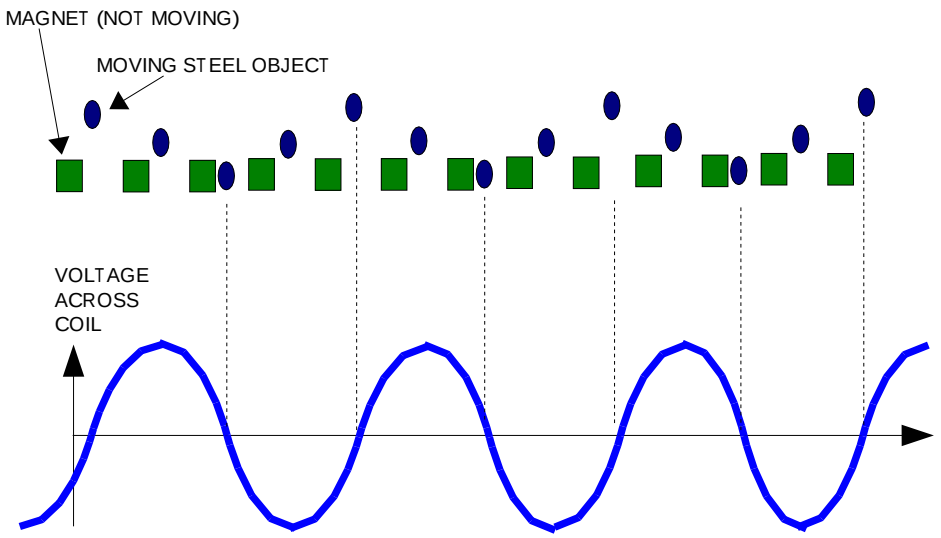


Figure 5: Multiple cycles of motion of the string or bar result in oscillations in the voltage across the pickup coil.

# The Rhodes Piano

Figure 6: Harold Rhodes (1910 - 2000)


Figure 7: Rhodes Stage 2a

# Tuning Forks

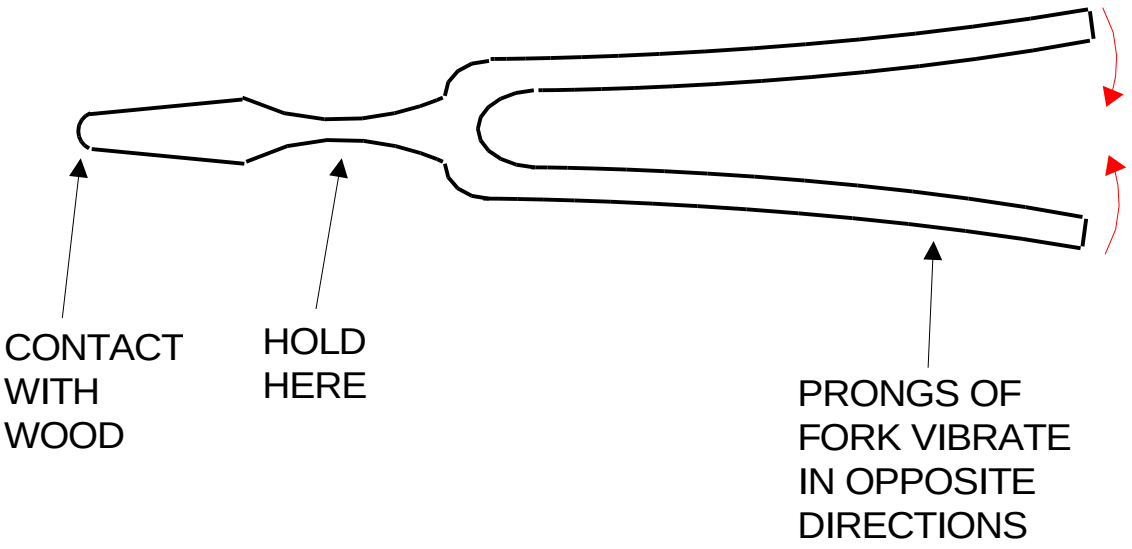


Figure 8: Vibrations in a tuning fork

# A Piece of the Action...

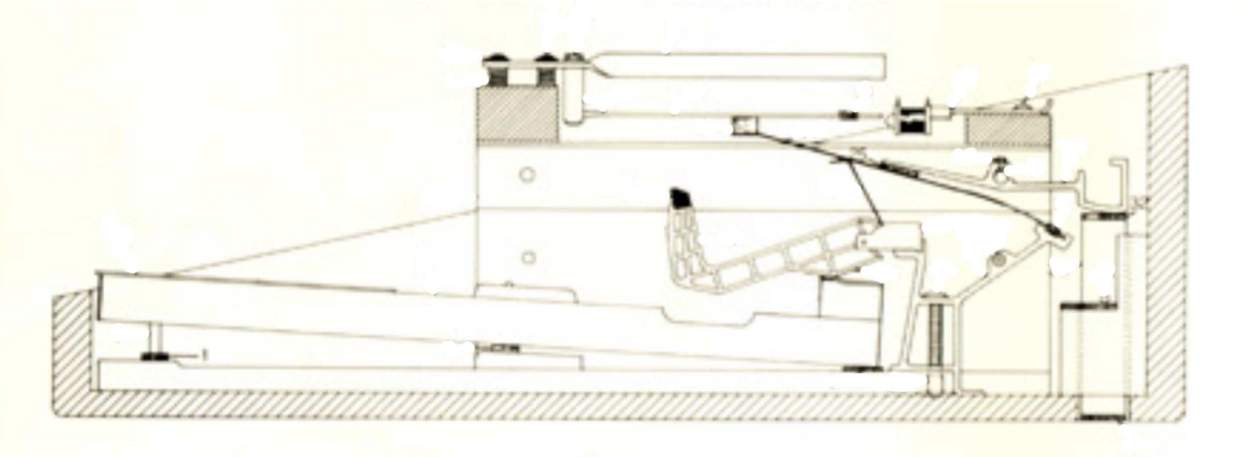

Figure 9: Rhodes Stage 2 action

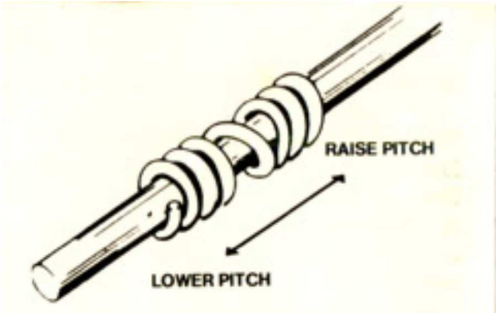


Figure 10: Tuning a rhodes tine

# Pickup Location and Tonal Quality

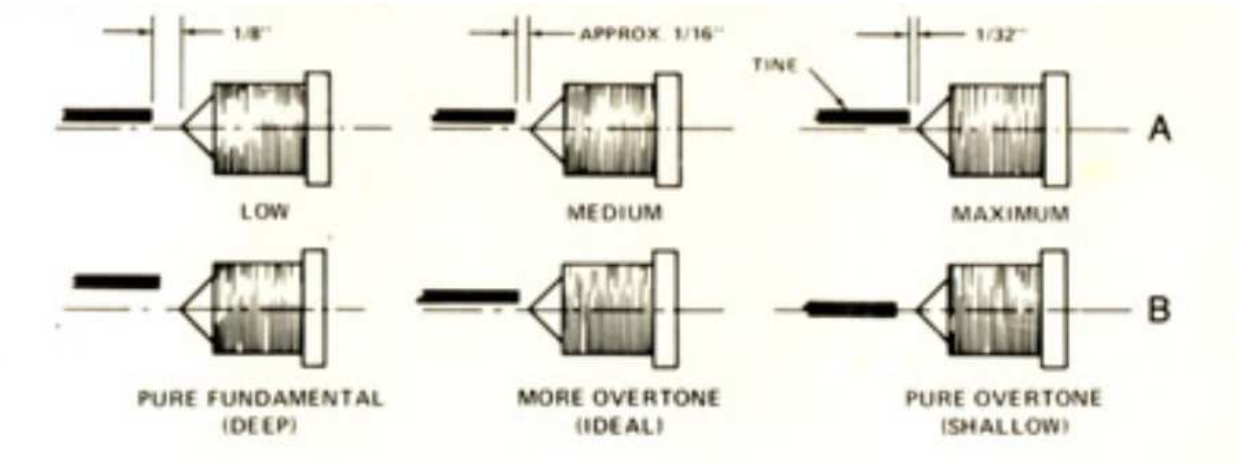


Figure 11: Pickup location instructions from manual

# Hammond Organs

Figure 12: Laurens Hammond ( 1895 - 1973 ). The first hammond was designed and built by Laurens in 1935.

# A Nice Example of a Hammond B3

Figure 13: A Hammond B3

# Tonewheels

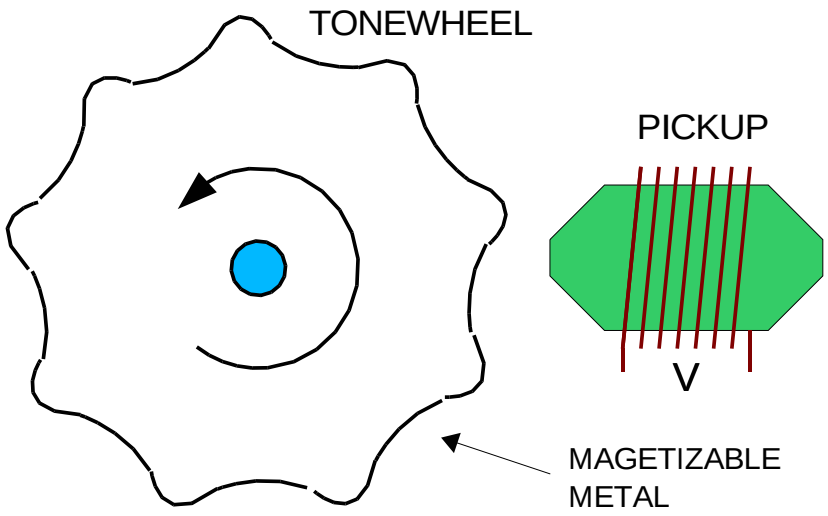


Figure 14: Tonewheel driving a pickup

# Actual Hammond Tonewheels

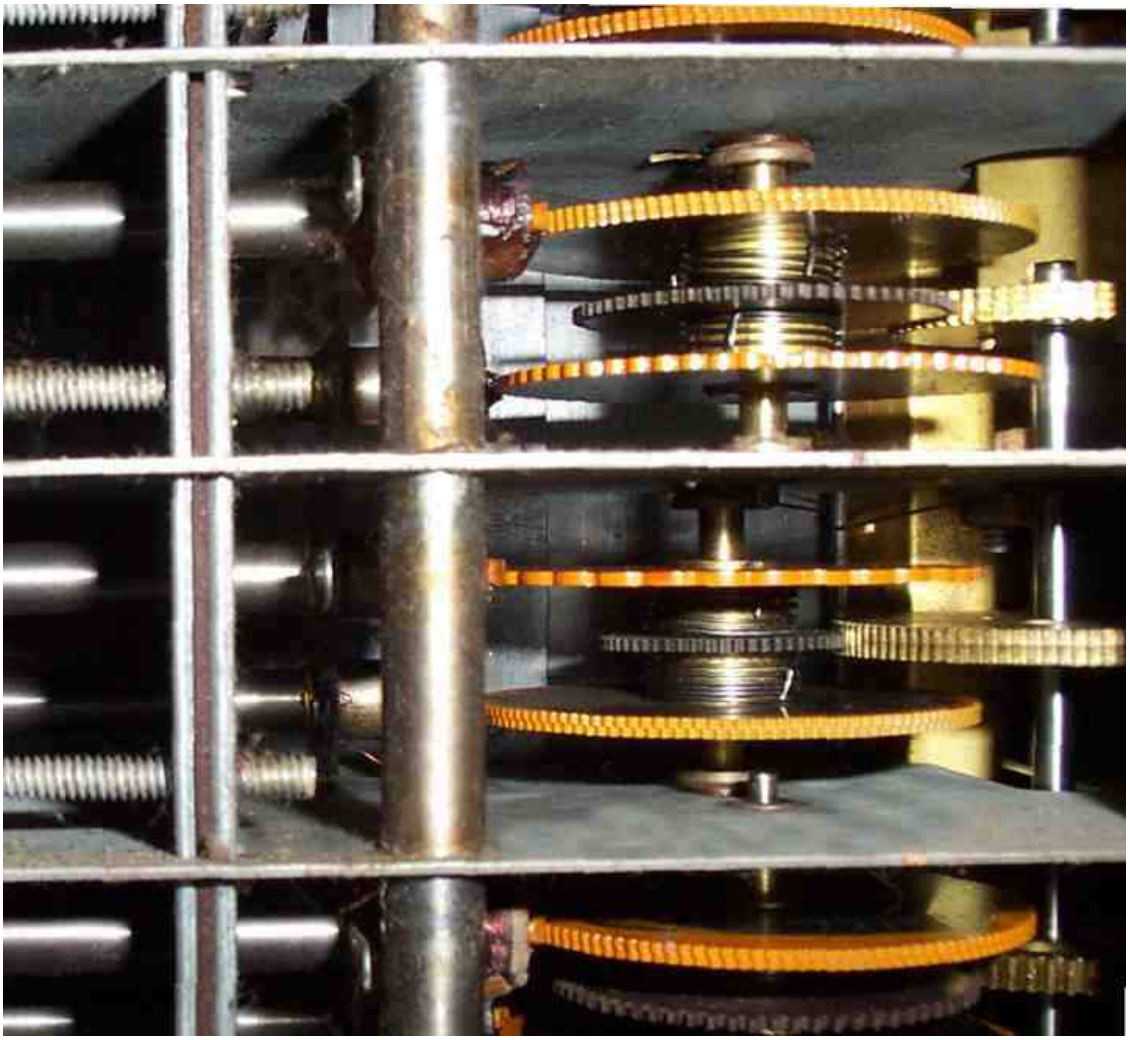

Figure 15: Actual tonewheels and pickups
http://theatreorgans.com/hammond/keng
/kenhtml/HammondEricb.htm

# Drawbars

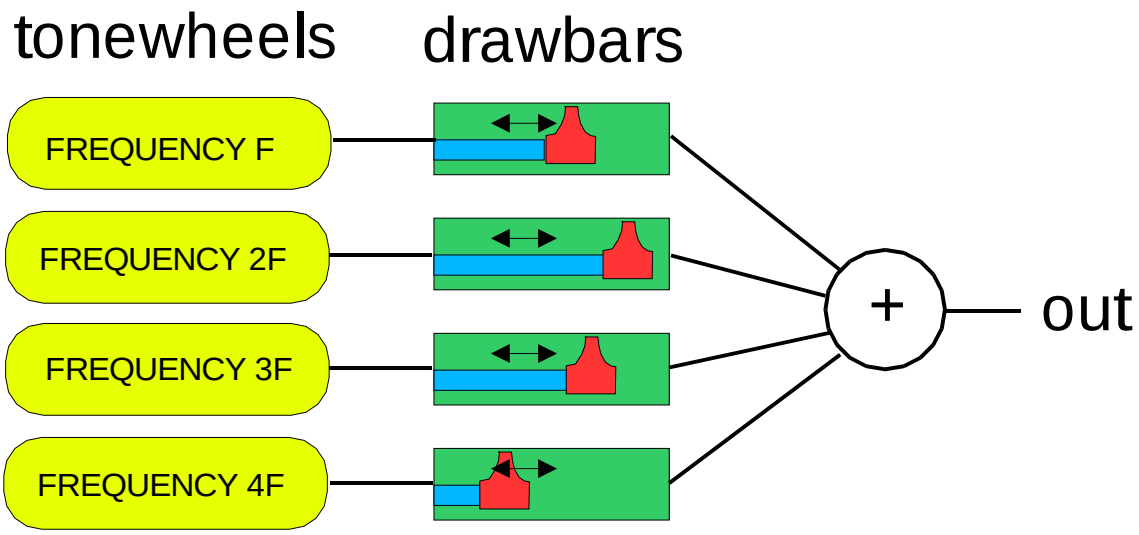


Figure 16: Drawbars combine oscillators at different $harmonics$ of the fundamental frequency to generate the overall sound

# Leslie Cabinets

Invented by Don Leslie

Figure 17: Inside a Leslie speaker cabinet

# Conclusions

- Electromechanical keyboards are fabulously ingenious applications of classical physics to our art and culture

- Their continued popularity alongside more modern alternatives such as waveform and digital synthesizers is a fitting testament to the ingenuity and skill of their inventors.

- I wish I had longer to play the music. Thank you for coming !

- I will round off this talk with a tune called 'Yaba Funk', courtesy of Captain Yabaa