

Rotary Speaker Technology White Paper

When we decided to create a studio-class pedal that faithfully recreates the classic, unmistakable sound of the most sought-after rotating speaker system, we prepared to study every nuance.

Our sound design labs have been filled with those signature, swirling, three-dimensional sounds, as we painstakingly analyzed and recreated the physics and mechanics behind these systems.

The result is our rotating speaker technology found in Lex Rotary. Pete Celi, our Lead DSP Engineer and Sound Designer illustrates the research and sound design process in the White Paper below. Check it out!

Strymon Rotary Speaker Technology

Rotary Speaker Overview

Classic rotary speaker systems consist of a spinning horn for the high frequencies, and a rotating drum fed by a separate driver for the low frequencies. There are typically two motor speeds, slow and fast, which are also referred to as chorale and tremolo. These systems were originally designed for use with electric organs, but guitar players soon wanted in on the fun.



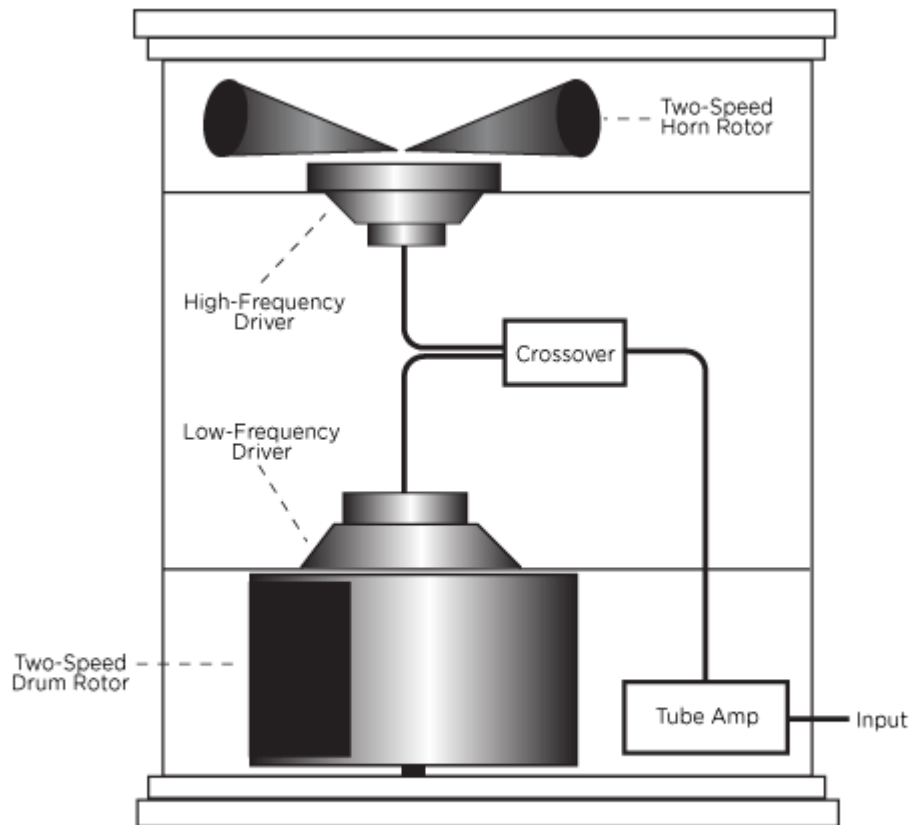


FIG 1. SCHEMATIC DIAGRAM OF LESLIE® TWIN-ROTOR SPEAKER SYSTEM

Rotary speaker systems create dimension and depth when rotating slowly, while generating controlled chaos when spinning at fast speeds. While simple vibrato or chorus effects can create a “poor man’s rotary” sound, a dedicated DSP implementation is required for an accurate reproduction of the many varied aspects responsible for this classic sound. Successful DSP implementation requires a comprehensive study of the physical acoustic phenomena that occur in these rotary speaker systems. Some of the key processes are discussed below.

Horn

The most identifiable effect that a rotary speaker system imparts is the pitch fluctuations known as the Doppler effect. This is a result of the horn’s movement relative to the listener, in the same way a siren appears to change pitch when a fire engine passes by.

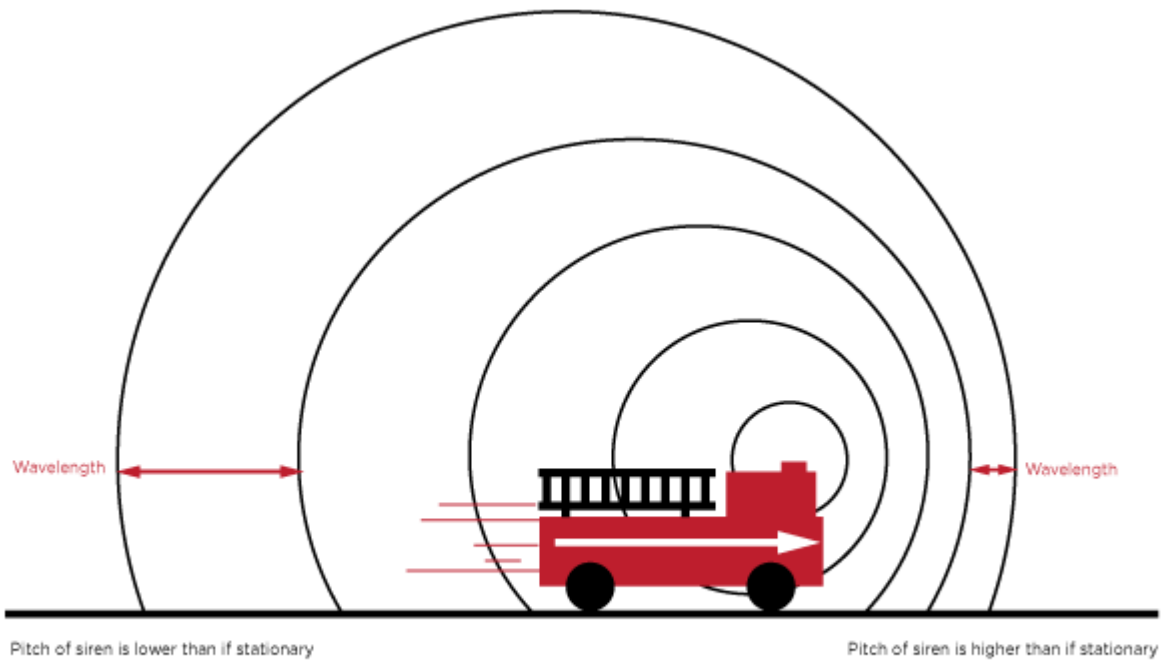


FIG 2. THE DOPPLER EFFECT FOR A MOVING SOUND SOURCE

Since the speaker makes the same movement cyclically, the pitch fluctuations occur cyclically also. This is why a traditional vibrato or chorus is sometimes substituted for a rotary effect.

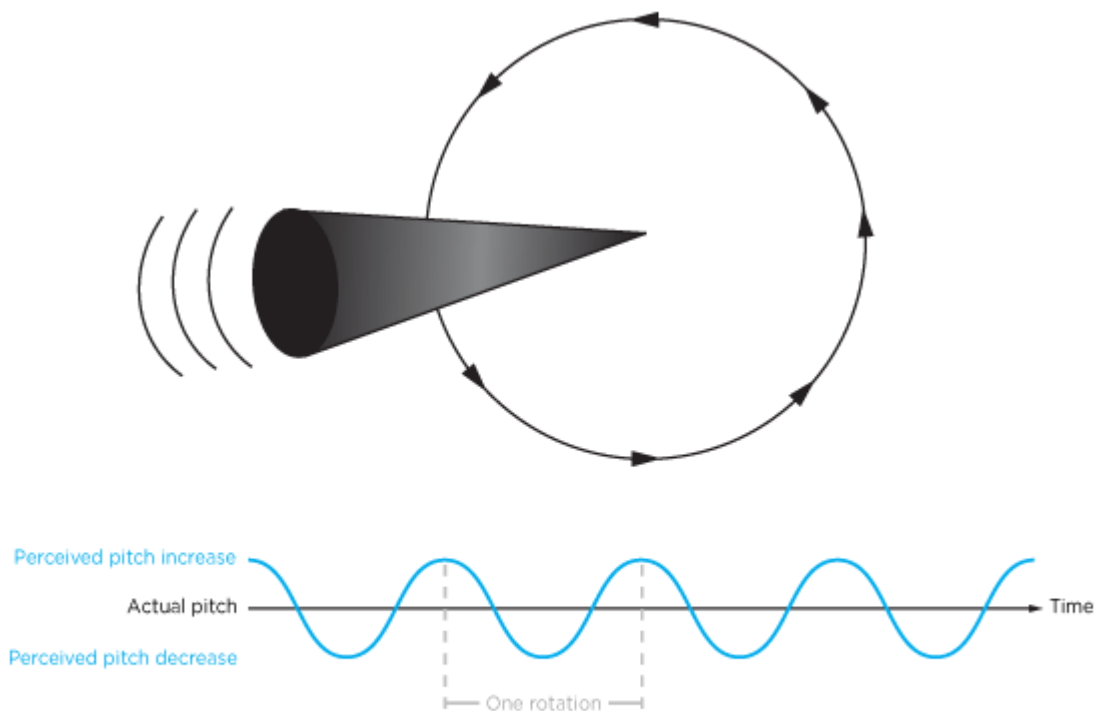


FIG 3. DOPPLER EFFECT OF ROTATING HORN SPEAKER

However, the Doppler effect as produced by a horn spinning inside a cabinet is much more complicated than what is produced by a simple chorus or vibrato effect. As the horn spins, the sound waves from the horn reflect

off the interior surfaces of the speaker cabinet, with each of these surfaces experiencing its own Doppler effect before creating secondary reflections on to other surfaces. The sound that emanates from the cabinet to the listener (or microphone) is a complex combination of the horn's direct sound and the many reflections.

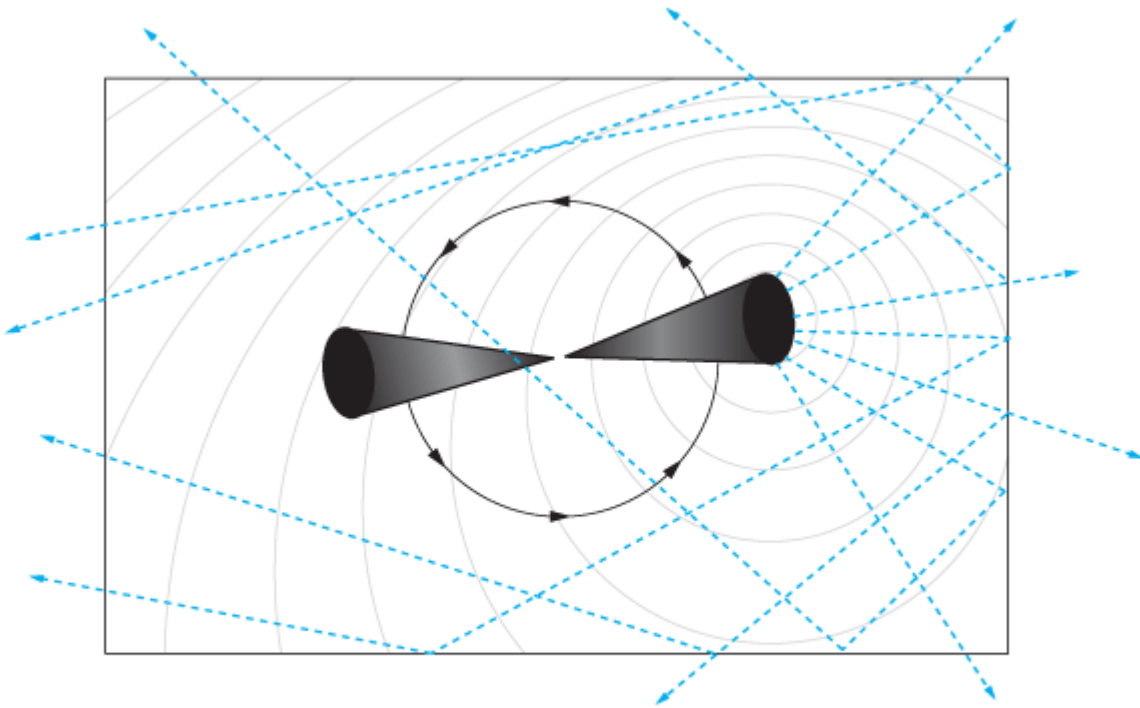


FIG 4. DOPPLER EFFECT AND MULTIPLE REFLECTIONS INSIDE ROTARY SPEAKER CABINET

The spinning horn also produces amplitude and frequency response variations throughout its rotation. As expected, the horn's direct signal is loudest and brightest when facing the listener, and softer and duller when facing away. These aspects also come into play in determining the nature of the many reflection signals.

Drum

The typical drum configuration is a downward-firing speaker projecting into a rotating cylinder that has a rectangular cutout. An electronic crossover circuit limits the bandwidth of the speaker such that only low frequencies are projected into the drum. As the cylinder spins and the cutout revolves, a pulsing amplitude modulation (tremolo) effect is produced for the lower frequencies. The phase of the amplitude-modulated signal also changes as the cutout moves across and to the rear of the cabinet. The resultant sound produced by the drum is hypnotic and has a "breathing" quality to it.

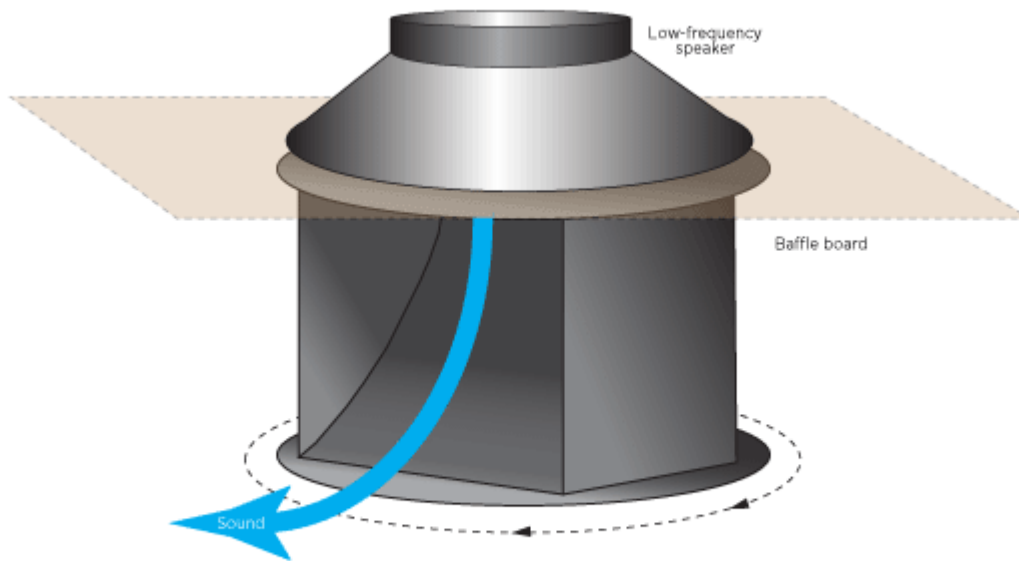


FIG 5. THE LOW-FREQUENCY BASS ROTOR

Miking

The classic approach to capturing the movement of sound involves a pair of mics at the top of the cabinet at the horn and a single mic at the bottom to pick up the drum. As the mics are moved closer to the cabinet, the amplitude fluctuations caused by the inverse square law effect become more pronounced and the horn signal gets a recognizable “choppy” quality at high speeds. Another result of close miking is an enhanced stereo effect that is very noticeable at slow speeds as the horn passes by one mic and then the next. As the mics are moved back, the fluctuations even out, eventually creating the sound that would be heard naturally in the room at a distance from the cabinet.

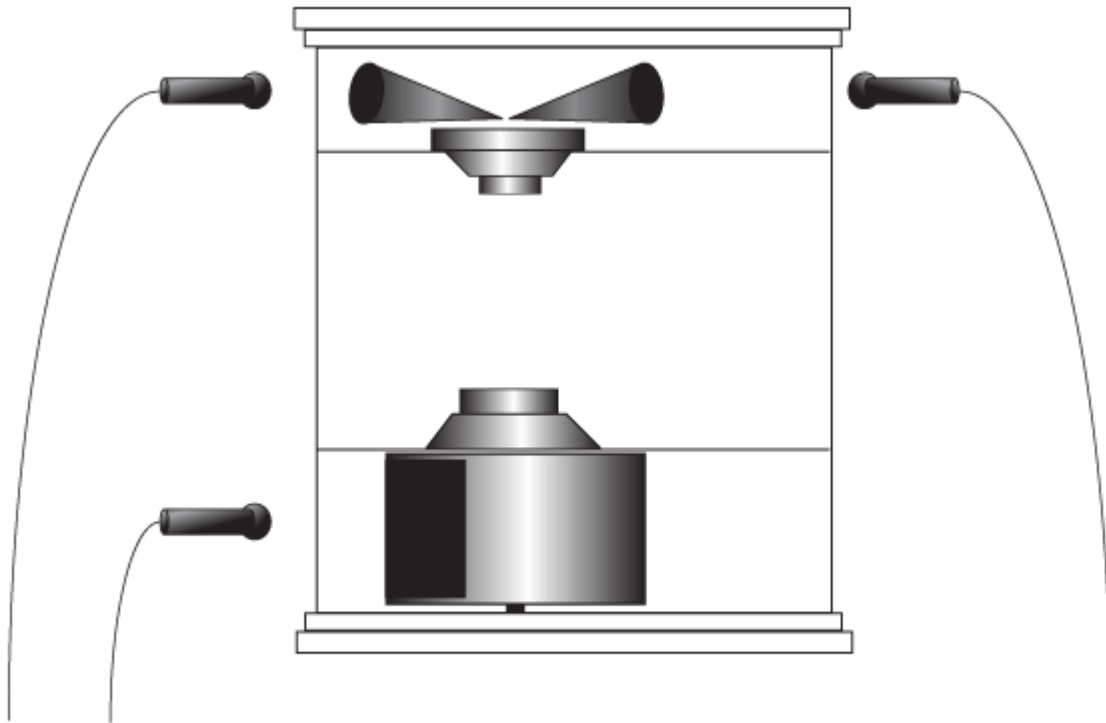


FIG 6. CLASSIC APPROACH TO LESLIE® CABINET MIKING

Motor speeds, ramping, and braking

In both the tremolo and chorale speeds, the horn spins slightly faster than the drum, so that the resultant sound is much more complex and evolving than if the two were spinning at identical speeds. Additionally, the inertia of the low-frequency drum is much greater than that of the horn, making it more resistant to changes in speed. Thus, while the horn speeds up and slows down rather quickly, the drum takes much longer to reach its speed. Changing speeds is where the “magic” of these systems is most apparent.

Some rotary systems allow for “braking”, which is when the speed of the horn and drum is reduced to zero so there is no more rotation. With the brake applied, the system is just a two-way stationary speaker system. When the brake is released and the systems starts spinning again, the full impact of the complexity of the system unfolds.

Amplifier

The original rotary systems had a tube amplifier built in to drive the speakers. Overdriving the amp creates harmonics that add a new dimension once they are set into motion through the rotating system. This sound is often referred to as the “growl” of a rotary speaker system, and it has become a signature trademark of these systems.

Strymon Rotary Algorithms

In developing the algorithms that produce these unmistakable sounds, we painstakingly analyzed and recreated the physics, mechanics, and intricate processes discussed above.

The horn signal exhibits all the chaotic yet periodic fluctuations inherent in rotary speaker cabinets. The drum signal pulses and breathes. A two-speed motor engine with braking capability controls the independent Horn

and Drum processes. The speed ramp-times reflect the drum's resistance to change and the horn's light weight. Fast and slow speeds are independently adjustable, and trimming of the acceleration times is allowed for. Additionally, a variable mic-distance control allows a wide range of sounds, from dramatic close up sweeping and swirling, to more mellow and calming undulations. A tube preamp drive control allows for overdriving the system to create rich harmonic content, with additional control of the Horn level to match your amp's voicing. All of this without the need to lug around a behemoth cabinet, setting up microphones, worrying about proper microphone placement, and performing costly motor maintenance and cleaning.

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