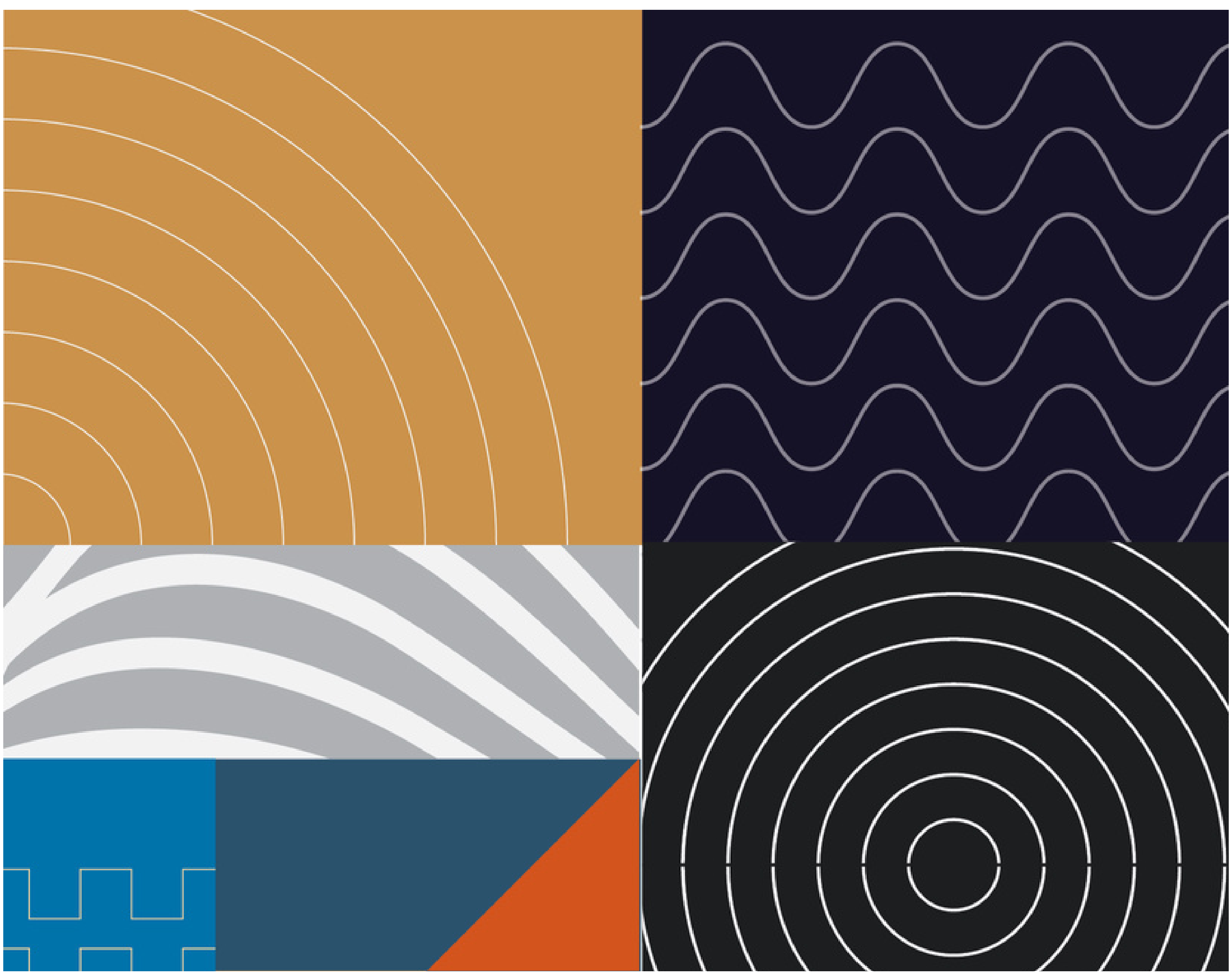
Haptic Application Guide, Intro to Actuators / Actuator Selection



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Introduction

The human body's five senses are the pathways through which we experience the world around us. It is exceedingly rare that any of these senses are experienced in isolation; often, two or more of our senses receive information simultaneously. Think of ordering your favorite food at dinner, for instance. Upon taking the first bite, multiple senses immediately receive information about the meal- the texture of the food, the sight, the taste, and the smell. The brain uses this feedback to quickly determine a response to your first bite- is it good?

Traditionally, many products use two of the five senses to deliver information to a user- sight and hearing. These two senses are highly complementary and may reinforce whatever information is being provided- for example, providing an audible and visual notification when a process is successful. If the user is in an environment where their sense of hearing is impaired, providing visual reinforcement ensures that the information from the product can still reach the user and vice versa.

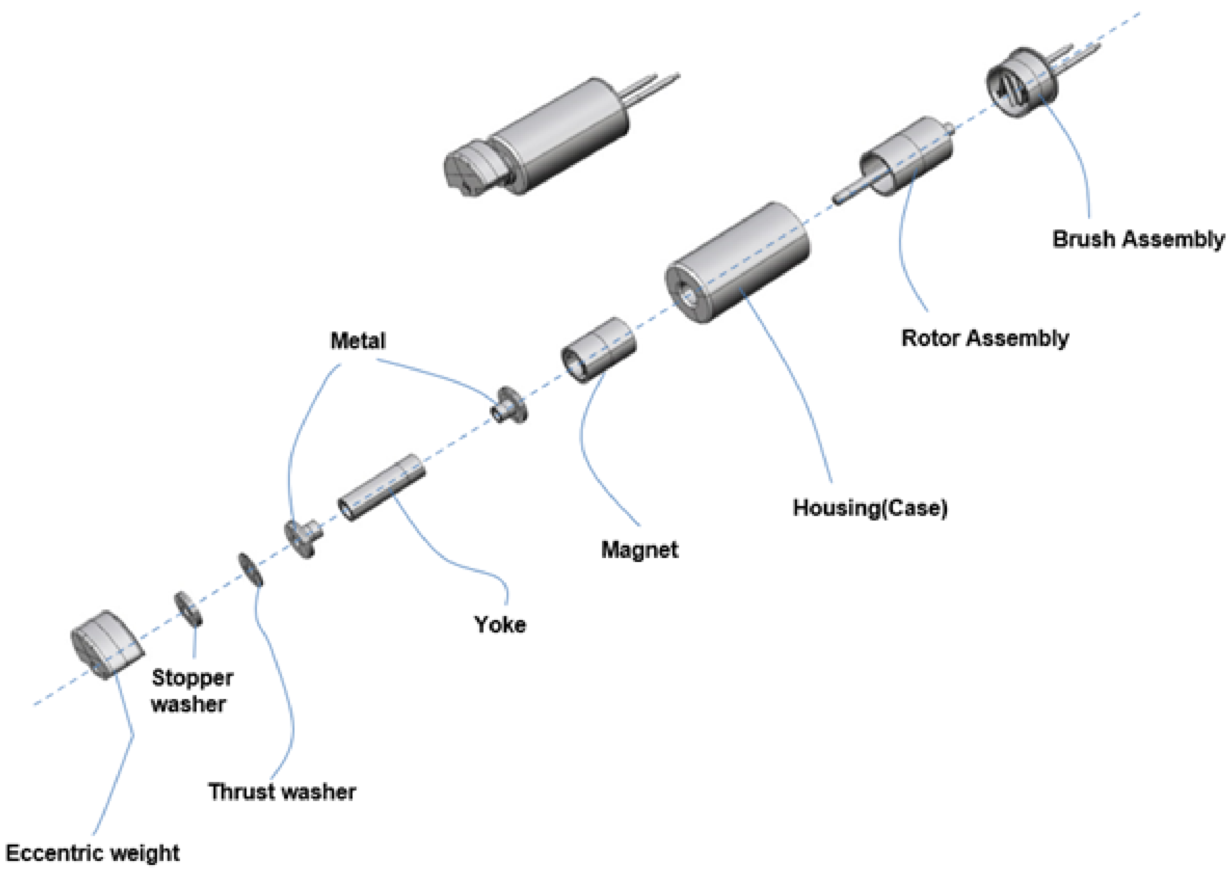
A third dimension of transmitting information has recently grown in popularity, utilizing the sense of touch. This concept, known as Haptics, has spurred development in various industries- consumer products, virtual/augmented reality, IoT, automotive, and medical, among many others. Products capable of providing real-time tactile feedback through vibration have given engineers and product designers more control than ever before and the opportunity to create a perfect user interface for their products. Understanding the differences between available technologies and their design requirements is the first necessary step in adding haptic actuators to an application.

Many different technologies can deliver a haptic response- the most common being electromechanical. This actuation method stimulates the mechanoreceptors in the human body that are the most sensitive to vibrations. While other haptic technologies may stimulate the body's mechanoreceptors for friction, deformation, and force, those technologies are less developed and beyond the scope of this guide. Electromagnetic haptic actuators are commonly grouped into three main categories: Eccentric Rotating Mass (ERM), Linear Resonant Actuators (LRA), and Voice Coils (VCA/VCM).

ERM

ERM actuators deliver vibrations by utilizing an off-axis rotating mass attached to a DC motor. When voltages are applied to the motor, the actuator vibrates at a frequency corresponding to the frequency at which the mass completes a full rotation- resulting in a vibration strength that is directly correlated with the driving voltage of the device. These actuators excite a device with lower frequency, “rumble” sensations. However, due to the nature of using a rotating motor as the actuator, a short time is required to reach the desired rotation speed when voltage is applied, as well as slowing the motor to a stop. As a result, ERM actuators are a good option when precise vibration patterns are not strictly necessary, but a noticeable vibration effect is still required.

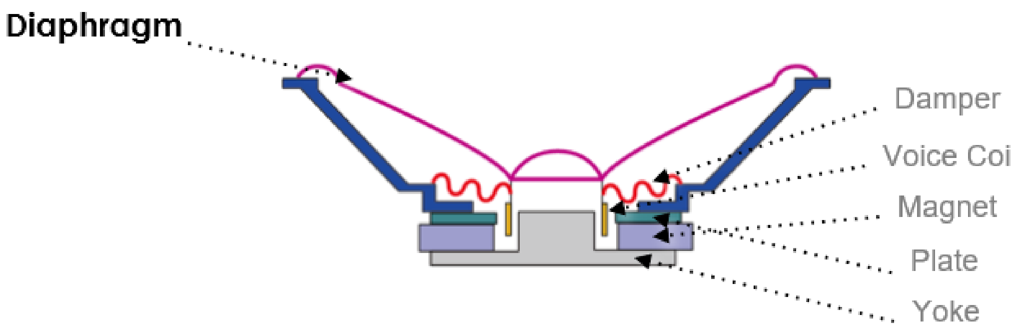
ERM Exploded View



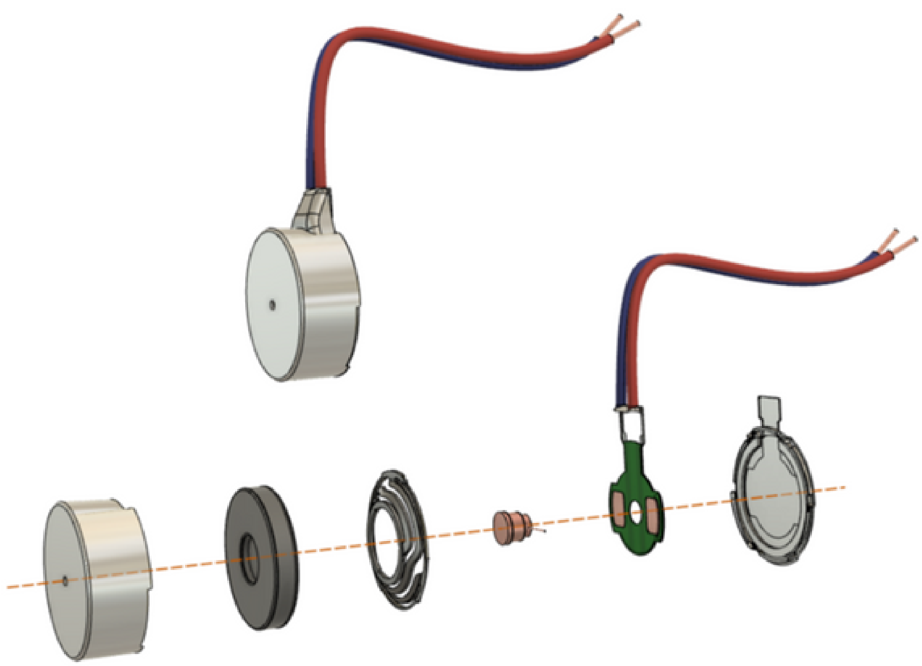
LRA

LRAs use a different method to deliver vibrations, closely related to the technology found in traditional speakers. In a speaker, a diaphragm is attached to a coil and electromagnet; when the coil is excited with a waveform, it causes the magnet and diaphragm to move, creating sound waves that eventually reach a person's ears.

Speaker Technology



In an LRA, instead of a diaphragm, there is only a mass attached to a coil. Instead of creating sound waves through the air when the diaphragm moves, the LRA creates vibrations by moving the mass in a linear direction when the coil is excited. The mass moves corresponding to the frequency and voltage of the signal applied to the device-giving independent control over both vibration strength and frequency.



LRA

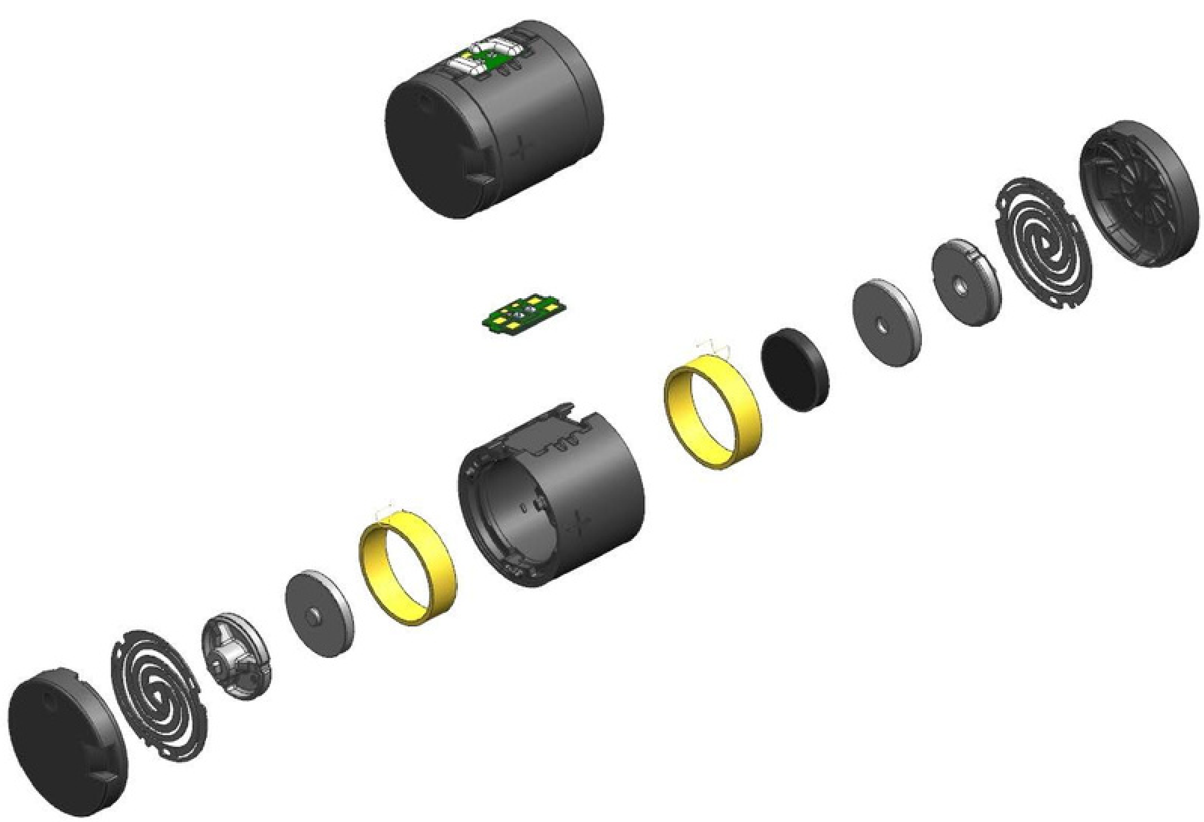
A key benefit of using an LRA is the linear response- there is no ramping time for the device to reach a threshold for proper actuation like an ERM. The user will feel a vibration as soon as the coil is excited and the mass moves up or down. LRA devices fit into some of the smallest form factors available for haptic actuators. They are incredibly power efficient, making them the most popular choice in products such as wearables and smartphones.

Designers using LRA devices in their products can take advantage of high-resolution, responsive vibration patterns to deliver information to the user. These vibrations are often supplementary to another stimulus, like audio effects or information on the devices' screen, but also may be used as an independent source of information for a user. The rapid linear response of LRA devices allows product designers to design custom vibration patterns to fit the needs of any situation.

VCA

VCM/VCAs take this technology further than the LRA, increasing the actuator's physical size and vibration strength. VCA devices use the same voice coil technology (adapted for vibration) as LRAs but have been modified further to "blur" the lines between a speaker and a vibration actuator. Like in an LRA, a mass moves linearly in response to an input signal's voltage and frequency. However, due to the increased size and mass, the resulting vibration effect is significantly more substantial and more realistic than what could be replicated with an LRA. Of course, these benefits do not come freely, as the VCA has a higher power draw than an LRA.

VCA Exploded View

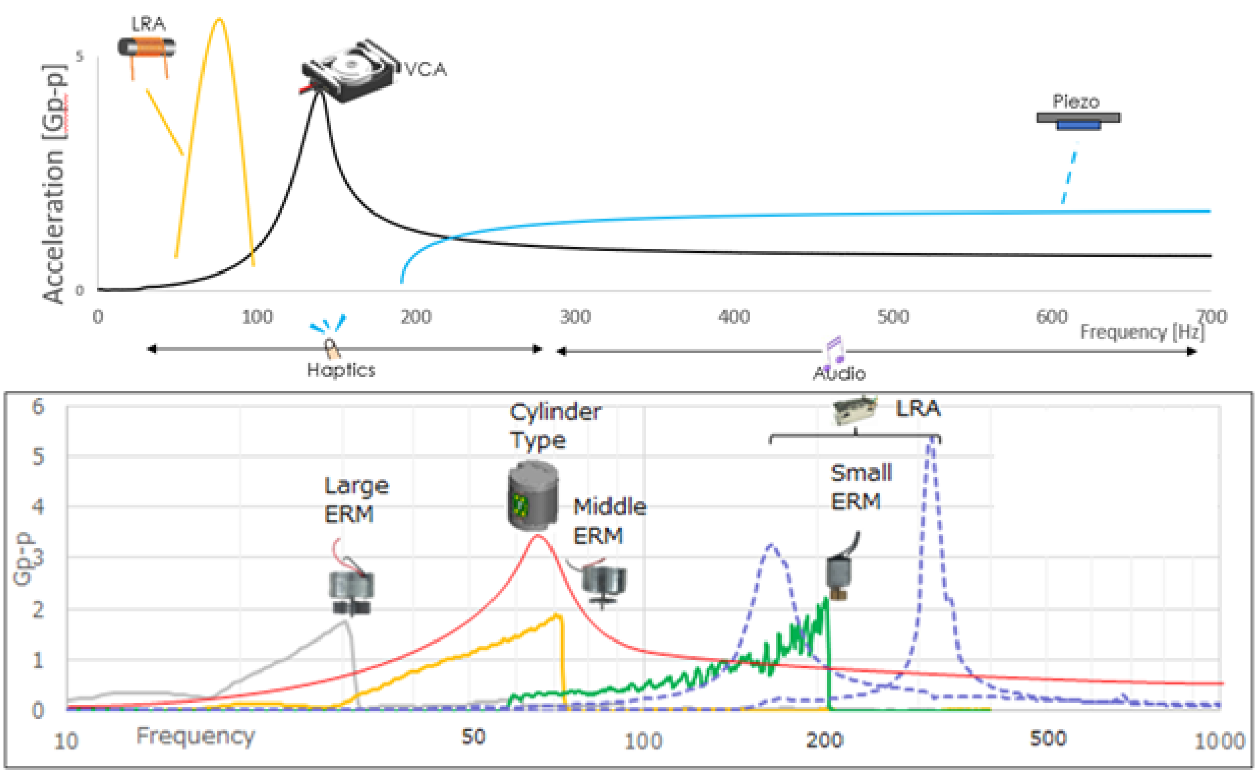


VCA

Depending on the applied signal, VCAs also can replicate auditory effects at the same time as vibrations. The increased size of the moving mass excites the body of the actuator and the surfaces it is mated to, allowing a user to hear the signal applied to the actuator while simultaneously feeling the vibration pattern. This is a similar effect as seen in our PUI Audio Exciter products.

LRA and VCA devices both have a specific frequency that corresponds to the optimal operating conditions of the device and, therefore, the strongest vibration strength. This means that in everyday use, LRA and VCA devices have a narrow band of operation- designers must ensure that the devices stay near their ideal operating point through either hardware or software. ERMs do not face this limitation, as the vibration only varies in response to voltage changes, not frequency- allowing for a wide range of vibration frequencies. Product designers must evaluate what type of vibration is appropriate for their design and consider the benefits and limitations of each actuator.

Comparison



Conclusion

Adding tactile feedback through haptic technology allows product designers to reimagine how information can be communicated with their users. Through integration with other technology in a device or as a standalone communication module, a complete ecosystem of information delivery may be created for the user of a product. Designers must understand the different actuator technologies to select the ideal haptic actuator for their product and provide the most significant benefit to the user.