January 2020

Graduation Hat Microphone for Waterproof Top Port Microphones

Yuyan Hua
Amazon Service LLC

Carl Philip Taussig
Amazon Service LLC

Shu-Yu Chou
Amazon Service LLC

Doug Kenneth Hogue
Amazon Service LLC

Oct 10th 2019

Graduation Hat Microphone for Waterproof Top Port Microphones

Yuyan Hua

Carl Taussig

Shu-Yu Chou

Doug Hogue

ABSTRACT

Small form factor consumer electronic (CE) devices such Echo Buds and Echo Loop with microphone functions are often required to be waterproof. Integrating waterproof feature at the microphone component level enables consistent audio performance and simplified product design. However, integrating the membrane on the small footprint of the microphone while maintaining the desired audio and water resistance performance has been a big challenge. This paper describes a "Graduation Hat" microphone lid technology to integrate a reactive waterproof acoustic membrane with less than 4dB additional acoustic attenuation compared to the same microphone without the membrane while providing 5atm waterproofing. Thereby enabling a more sleek design, consistent audio performance and simplified device level microphone integration.

BACKGROUND

Small form factor consumer electronic devices with technologies which sense daily activities have become a trend in the market. With emerging use cases for small portable CE devices in the shower or swimming pool, a lot of these devices are required to be 5atm waterproof. A method to waterproof microphones at the component level will simplify the design process and reduce the product envelope thereby enhancing aesthetics and comfort. Waterproofing audio components challenging for product design. Audio components like MEMS microphones must have an acoustic sound port for sound to pass through. However, capacitive MEMS is very sensitive to dust and liquid contamination. Liquid and dust ingress between the diaphragm and backplate will change the gap distance (and capacitance) between the diaphragm and backplate, thus cause permanent function failure [1]. The current approach for waterproofing microphones is to integrate an acoustic membrane inside the device between the housing and the microphone component. However, these membranes' acoustic performance and acoustic recovery rate after deep water immersion are very sensitive to product design and variability in the assembly process. It usually requires complicated product design and well controlled tolerances to keep the membrane under the proper tension. Design and tolerances of the membrane assembly are specific to each microphone and device. Improper design and assembly can lead to poor acoustic performance, prolonged acoustic recovery rate, and inconsistency in waterproofing.

Enabling waterproofing at the microphone component level by embedding the membrane inside the microphone addresses the concerns listed in the preceding paragraph. Integration of the acoustic membrane at microphone component level enables better and more consistent acoustic performance, simplifies the product design process, and validation of waterproofing capability of the device. The biggest challenge of membrane integration at the component level is to fit the membrane inside the small form factor of the microphone. Conventional microphone lids are fabricated from a stamping process and have a large rounded radii (usually >0.25mm) on the four edges of the lid which limits useable flat area on the lid surface to be 2.1*1.5mm for membrane integration. With conventional microphone lid designs, membrane size is limited to 2.1*1.5mm (including both membrane and PSA) which is much smaller than the membranes used for device level waterproofing. This results in acoustic attenuation over 10dB and high risk of water ingress. In order to achieve both 5atm waterproofing and good microphone SNR (signal to noise ratio), relatively large, usually 3.2mm*2.6mm (including both membrane and PSA), reactive membrane [2] will need to be integrated. A solution enabling 3.2mm*2.6mm membrane integration at microphone level without impact the footprint is needed. Because the acoustic port of conventional microphone is not centered in the microphone lid, the available surface for acoustic seal is even smaller (<0.4mm) which creates a risk of sound and water leakage.

BRIEF DESCRIPTION OF THE DESIGN

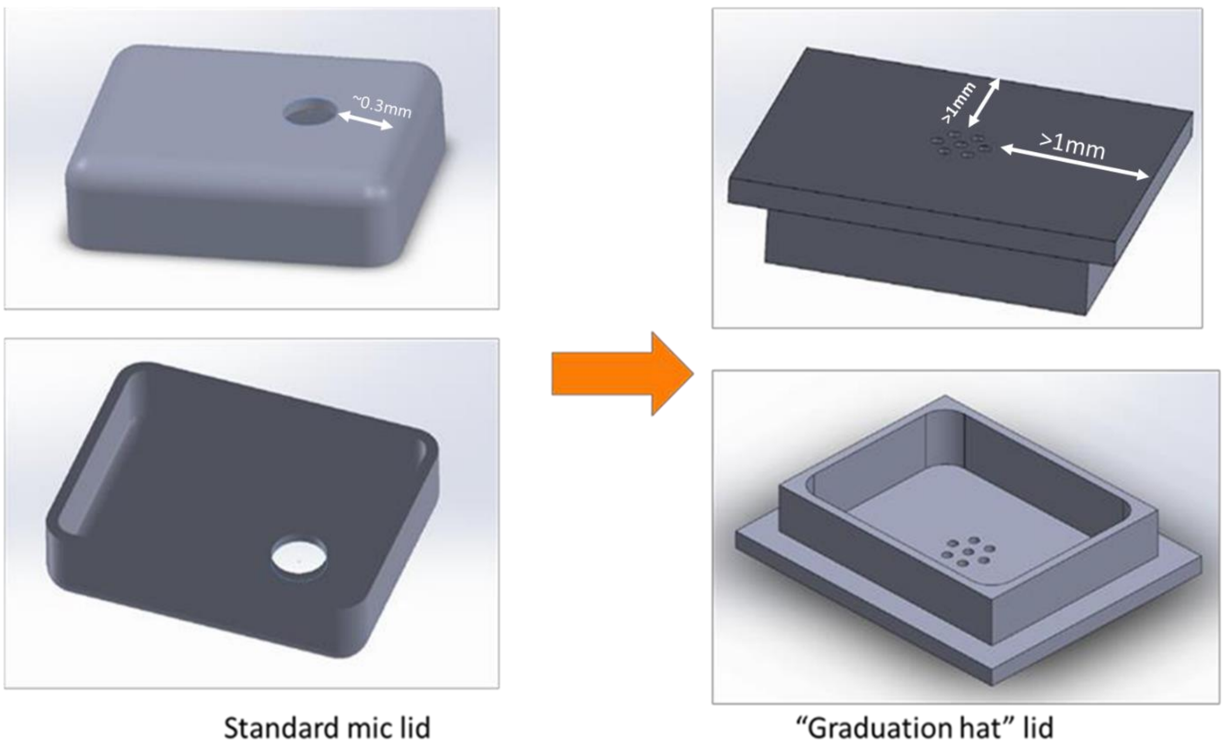

Figure1: Example of Graduation Hat design drawings

The “Graduation Hat” microphone lid has been developed to extend flat area on the metal lid to accommodate larger acoustic membranes and provide a larger flat acoustic/water seal area. Compared to conventional microphone lids. The Graduation Hat lid design removes the rounded curvature (usually 0.25mm radius) on the four edges and extends beyond the microphone lid top surface by another 0.35mm. This provides 0.6mm extension on all the four edges enables larger and flatter surface for membrane integration, without impacting the footprint of the microphone on the FPC. With the Graduation Hat design, the membrane with PSA dimension can be extended from 2.1*1.5mm to 3.2*2.6mm. The “Graduation Hat” design significantly increases the flat area of the lid which enables integration of a larger membrane and easier acoustic seal.

GRADUATION HAT DESIGN BENEFITS

1. **Better acoustic performance and acoustic recovery rate than system level integrated membrane:**

Figure 2 illustrates the structure of graduation lid design on microphones with membrane/mesh integration. The Graduation Hat microphone lid design enables larger membrane integration, which is critical for microphone acoustic performance. With a conventional microphone lid, the maximum 5atm. membrane size that can be integrated will have 10-15dB acoustic attenuation, which is more than most designs can tolerate. With the Graduation Hat design, larger reactive membrane can be integrated and the acoustic attenuation can be limited to 2.5dB.
On the top surface of the Graduation Hat lid, the single through-hole acoustic port can be replaced with an array of small holes. The Graduation Hat top surface can also serve as a mechanical backer for the membrane during deep water immersion. The reactive waterproof membrane deformation during deep immersion can be controlled by the gap between the membrane and lid to prevent membrane over-stretch, which can cause slow acoustic recovery rate or permanent yield of the membrane [3].

2. **More compact device design:**
   Graduation Hat microphone lid enables the same microphone footprint on the FPC with membrane integration. This eliminates the system level membrane and related features (rubber boot, flat plastic or metal strap to enable a flat surface for membrane bonding) to accommodate the membrane integration. The mechanical seal between the microphone and device housing is still needed. This can be achieved by using pressure sensitive adhesives (PSA) or liquid glue etc.

3. **More consistent device to device performance than system level membrane integration:**

   Graduation Hat design enables membrane integration at the component level. Reactive membranes' acoustic performance is very sensitive to the membrane tension. The membrane tension is very sensitive to the system level design, tolerance, and the assembly process. Component level integration isolates the sensitive acoustic membrane from rest of the system level design. The membrane's tension is controlled at microphone level which is not dependent on entire device design. The Graduation Hat design enables automated reactive membrane assembly process at the component level which improves membrane assembly precision and device to device performance consistency compared to a manual assembly process for integrating the membrane at device level.

4. **Simplified device level design and assembly:**
   With the Graduation Hat lid and protective membrane integrated at microphone component level, microphone acoustic port can be repositioned to the center of the Graduation Hat. For a conventional microphone without mesh/membrane integration, the acoustic port is facing to the ASIC side of the microphones and offset from the MEMS component to avoid any dust ingress or sudden pressure change which could damage the MEMS. With microphone level membrane integration, the acoustic port can be moved to the center of the lid since the membrane protects the MEMS from dust and pressure damage. With the extension of the four edges and the reposition of the acoustic port, the distance between the acoustic ports to the edge of the microphone lid will be extended from 0.3mm to >1mm. This extended flat surface enables much easier acoustic seal and water seal.

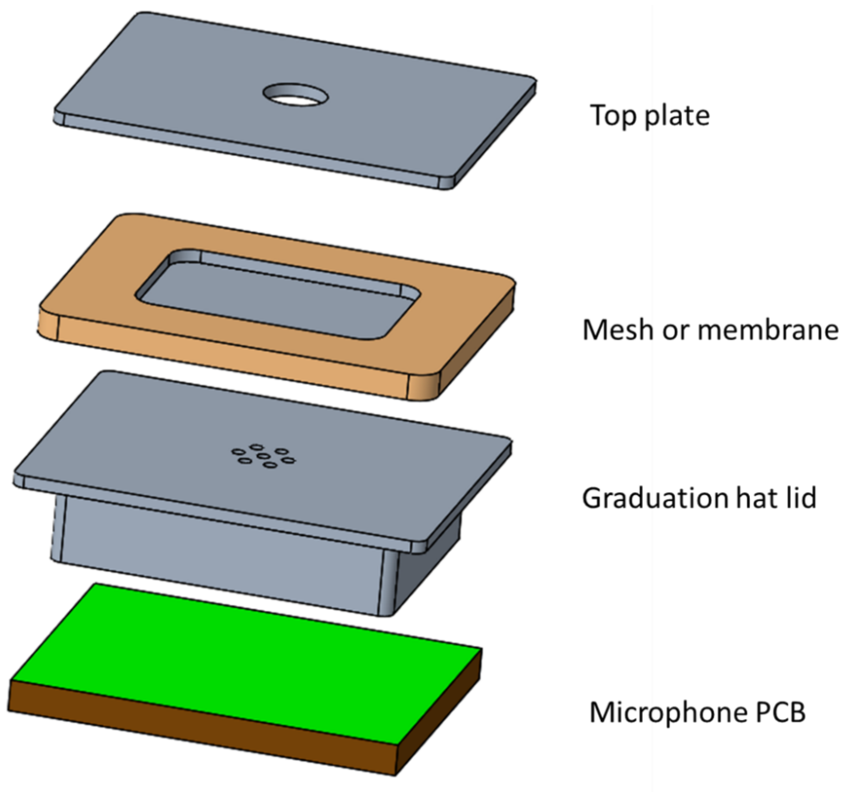

Figure2: Example of Graduation Hat design on microphones

RESULTS:

Acoustic performance and waterproof performance with grad hat design

Figure 3 showed the acoustic performance comparison of a conventional non-waterproof microphone to the same microphone fitted with Graduation Hat components. There is 2.5DB sensitivity attenuation from the membrane.

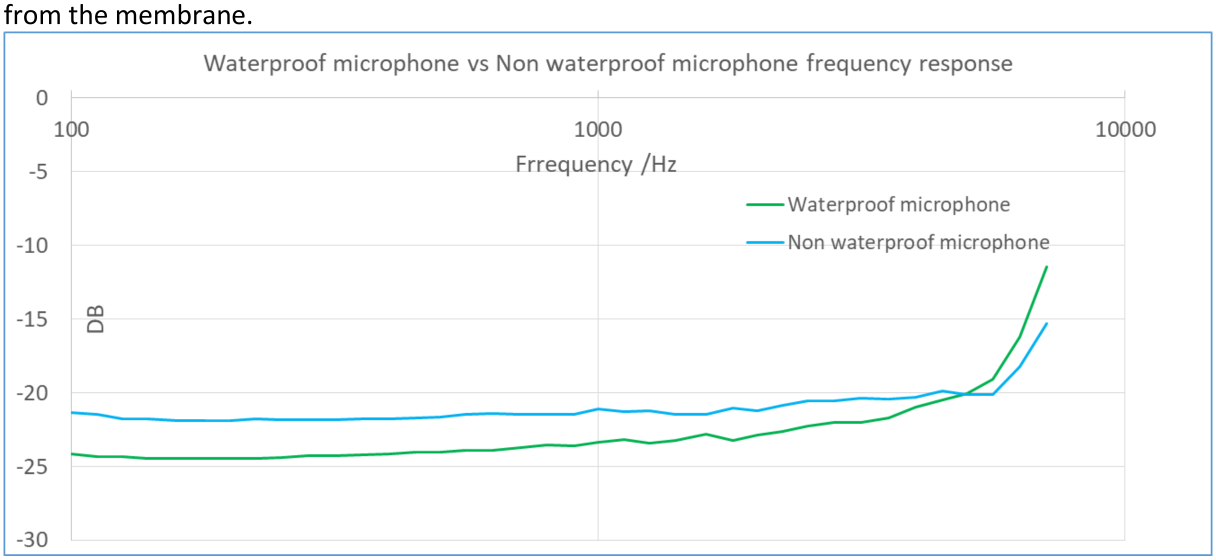

Figure 3: Frequency response comparison between Graduation Hat waterproof and non-waterproof microphones.

Figure 4 shows the microphone frequency response comparison between a 2.1mm*1.5mm membrane integrated on a conventional microphone lid and a larger 3.2mm*2.6mm membrane on a Graduation Hat lid. There is ~10DB sensistiivty increase for the Graduation Hat microphone while still maintaining the same footprint of 3.1mm*2.5mm on the PCB.

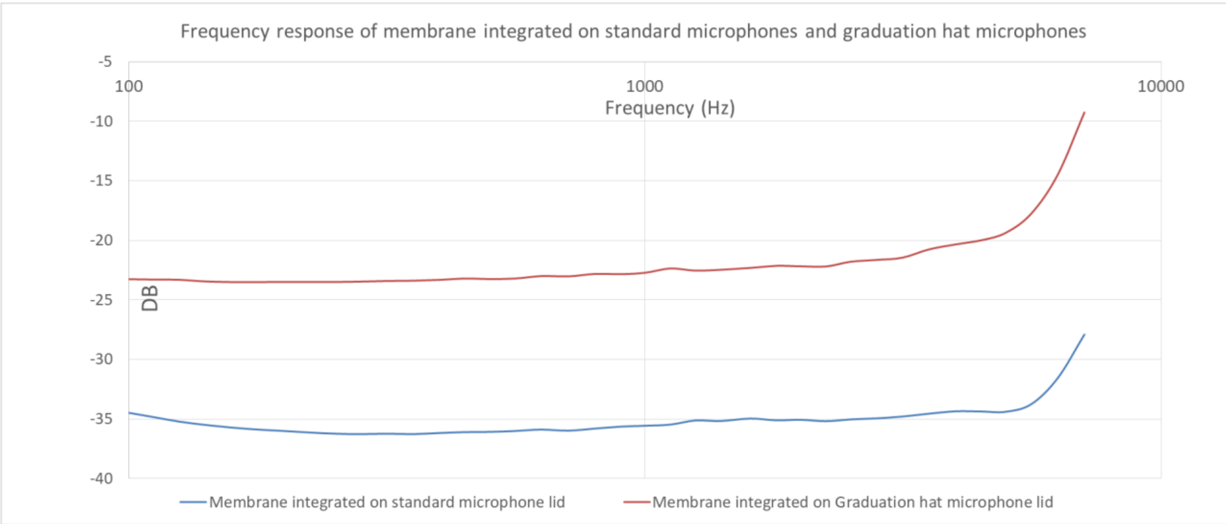

Figure 4: Frequency response comparison between membrane integration on standard microphone lid and Graduation Hat lid.

Waterproof performance with Graduation Hat microphone design

Figure 5 illustrates the acoustic recovery behavior of the microphones. The data showed acoustic performance completely recovers after exposure to 3atm and 5atm pressure water test (ISO22810).

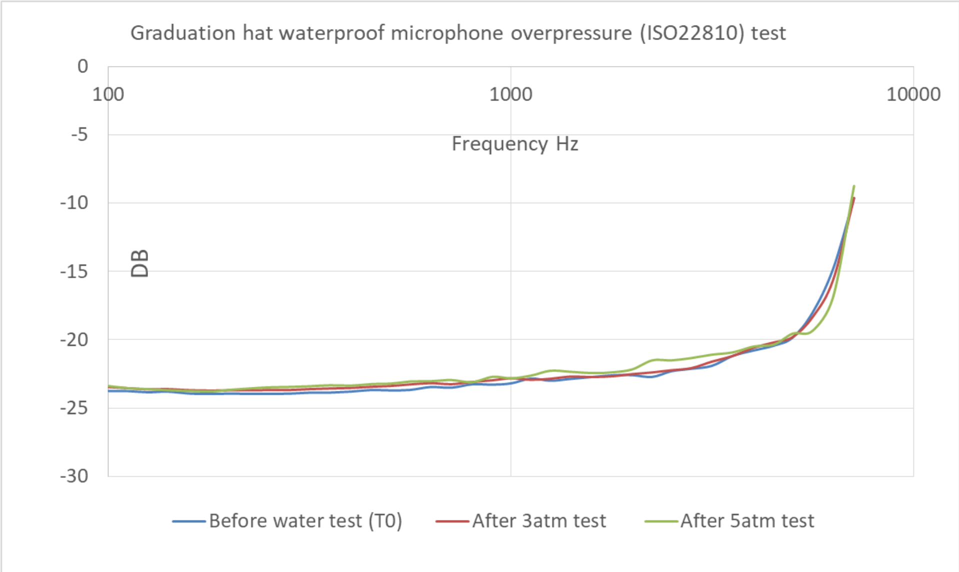

Figure 5: 3/5atm waterproof performance of Graduation Hat microphones

CONCLUSION

This paper describes techniques of using the Graduation Hat microphone lid design to integrate acoustic membrane for desired acoustic performance. It enables good acoustic and water resistance performance, and simplified product design.

REFERENCES

[1] Handbook of Silicon Based MEMS Materials and Technologies (Second Edition), Micro and Nano Technologies, 2015, Pages 744-763, Chapter 41 - MEMS Reliability

[2] Expanded PTFE Applications Handbook, Technology, Manufacturing and Applications, Plastics Design Library, 2017, Pages 163-170, Chapter 7 - Properties, Characteristics, and Applications of Expanded PTFE (ePTFE) Products

[3] Alireza Sadeghi Alavijeh, Ramin M. H. Khorasany, Aronne Habisch, G. Gary Wang, Erik Kjeang,

Creep properties of catalyst coated membranes for polymer electrolyte fuel cells, Journal of Power Sources, Volume 285, 1 July 2015, Pages 16-28