전자기기계시스템진동 및 음향설계실험실

Acoustic and Vibration Design of Electromagnetic-Mechanical System Lab

목표 : Multiphysics 전문가 양성

부산대학교 기계공학부
PUSAN NATIONAL UNIVERSITY
SCHOOL OF MECHANICAL ENGINEERING

1 Lab introduction– Lab members

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(Sang Moon Hwang)

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학력 및 약력

- Univ. of California at Berkeley 박사학위 취득(1994년)
- 부산대학교 기계공학부 교수 (1996년 ~ 현재)
- ㈜ EM-TECH 창립 및 대표이사 (2001년~2012년)

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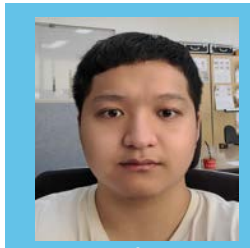
PUSAN NATIONAL UNIVERSITY
SCHOOL OF MECHANICAL ENGINEERING

Undergraduate research student



박 * 탁
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TAK
PARK

Master's course student

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정 * 훈
***
HOON
JEONG

Undergraduate research student

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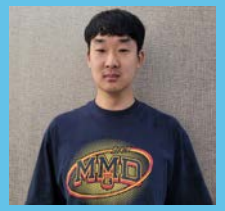

오 * 인
***
INN
OH

Undergraduate research student

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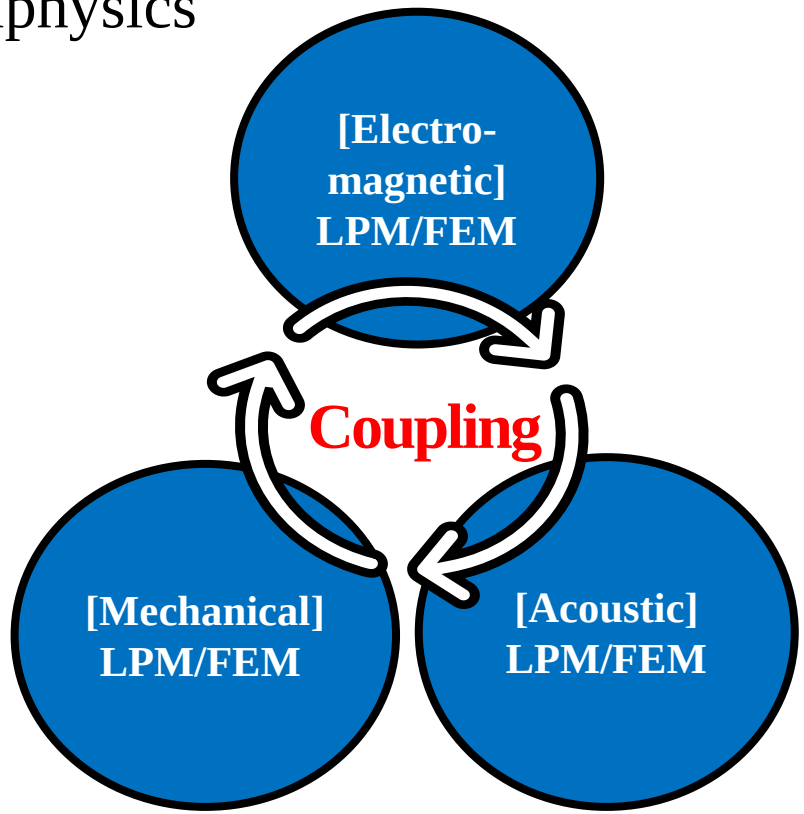
1 Lab introduction– Lab research projects

Research method

Multiphysics



- Electromagnetic-mechanical-acoustic coupling analysis
- Structure design of multimedia device

LPM : Lumped Parameter Method FEM : Finite Element Method

Research project

▪ **Actuator system**

- **Linear vibrator**
- **Vibration motor**
- **SoD (Sound on Display)**

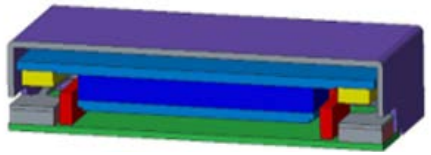
▪ **Speaker system**

- **Neck band passive speaker**
- **Microspeaker**

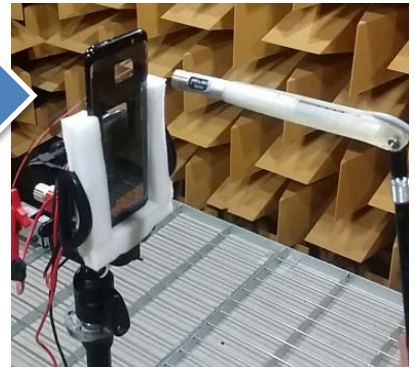
▪ **Earphone system**

- **BA driver**
- **Dynamic receiver**
- **Hybrid earphone**
- **2-way earphone**

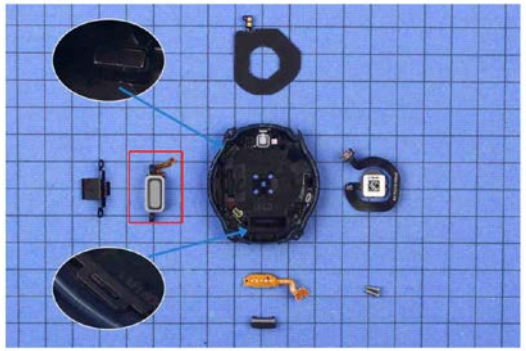
리시버와 진동모터의 역할을 동시에 수행할 수 있는 복합 부품의 개발
(2018~2019)



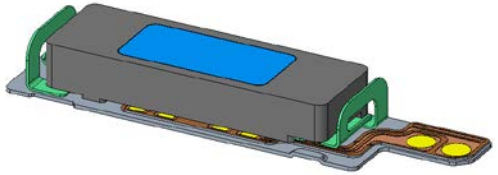
Full-Wide Screen LCD의 실현을 위한 스마트폰용 복합 부품의 개발
(2019~2020)



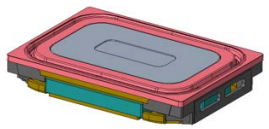
폭 슬림 이중 사출 LSR 웨어러블 마이크로 스피커 개발
(2020~2021)

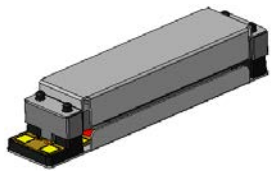


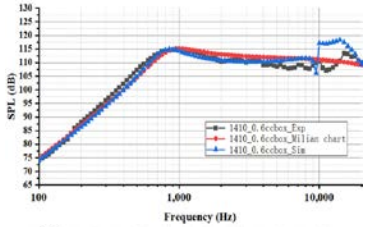
스마트폰 용 수평 진동 haptic 모터 개발
(2021~2022)

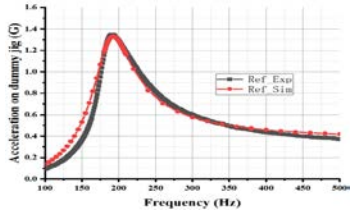


마이크로 스피커 및 모터 해석 모델 개선
(2022~2023)

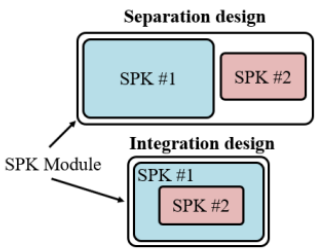


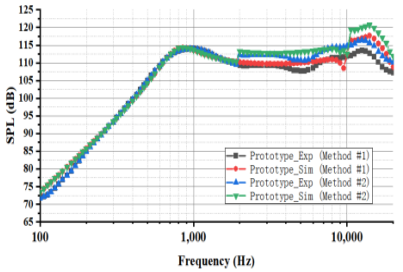






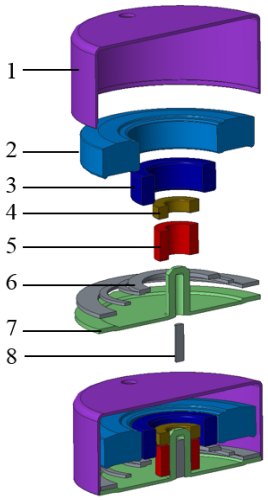
2-way 마이크로스피커의 해석방법 개발
(2023~2024)



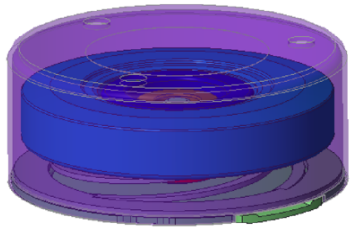


SPK #1: Full-range SPK (100 Hz ~ 20 kHz)
SPK #2: Mid-frequency range SPK (2 kHz ~ 20 kHz)

Vibration motor (Vertical)



(a) Exploded view of Motor

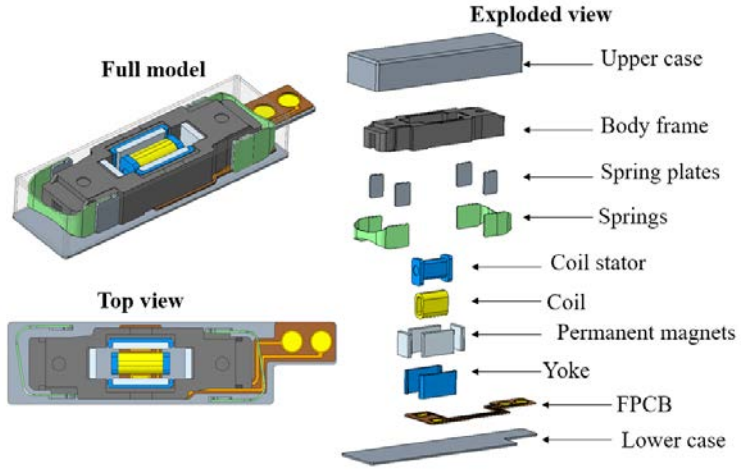


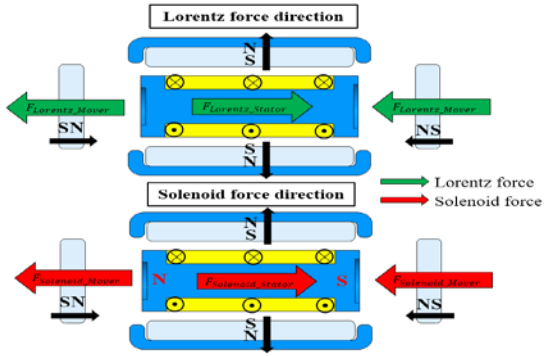
(b) Projection view of Motor

1. Upper Cover
2. Mass
3. Magnet
4. Pole Cover
5. Coil
6. Spring
7. Lower Cover
8. Shaft

►Point
- One set of coil and magnet
- Simple structure

Vibration motor (Horizontal)

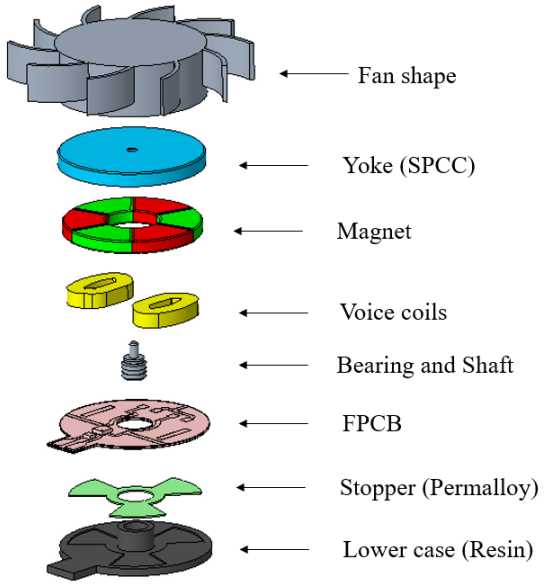


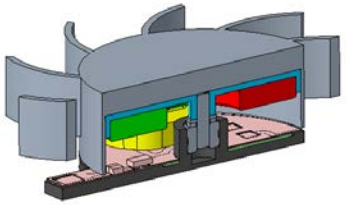


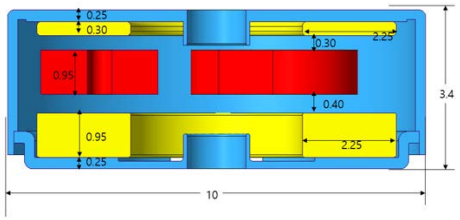
►Point
- Horizontal vibration
- 4 mangets
- Designed for smartphone

1 Lab introduction– Lab research projects

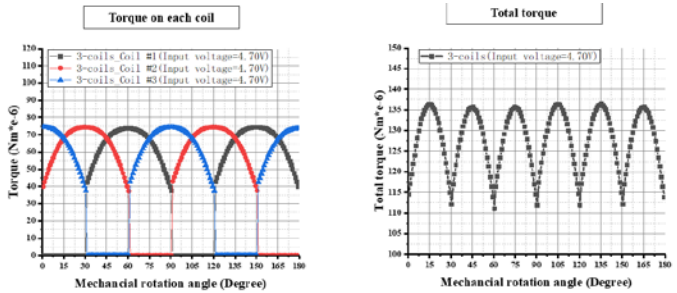
BLDC motor







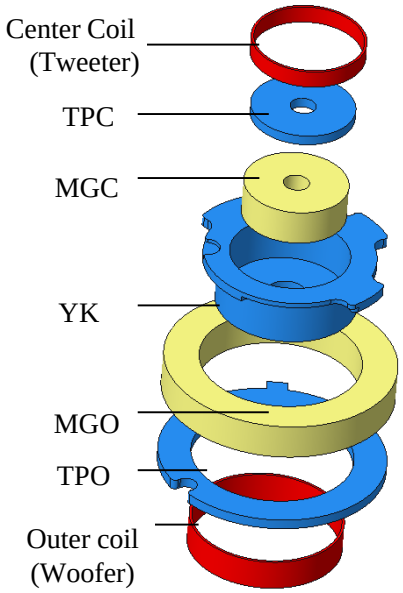
3-coils Brushed motor

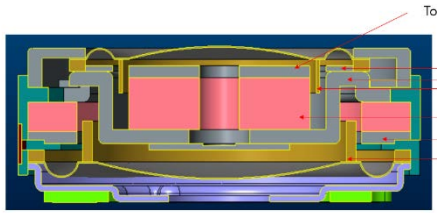


►Point

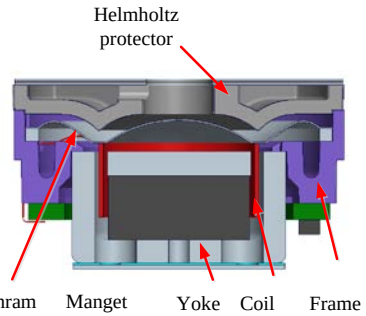
- Force distribution in each rotation angle in BLDC motor
- Increasing the current force for each point and easy control

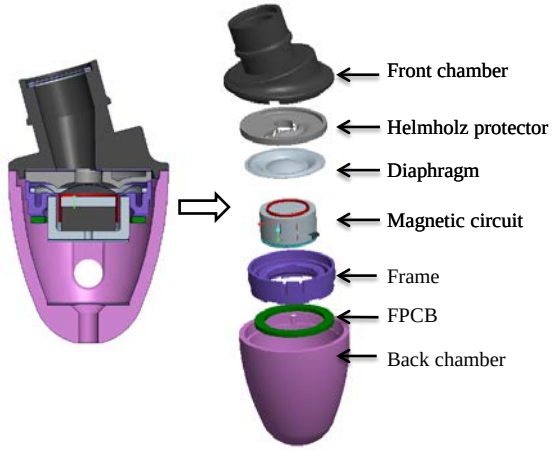
Dynamic, 2-way Earphone





2-way earphone



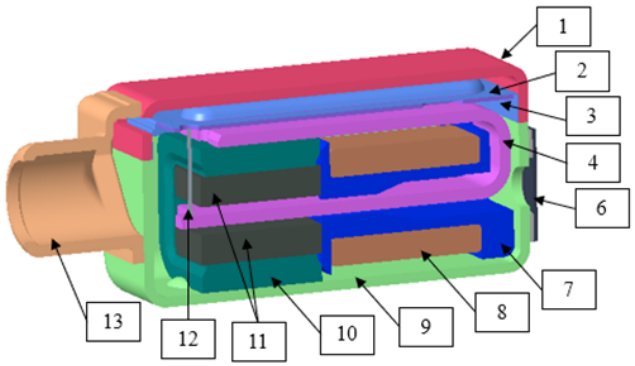


Dynamic earphone

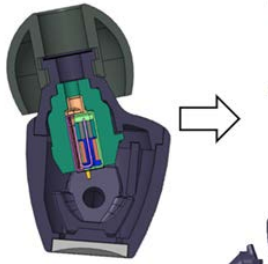
►Point

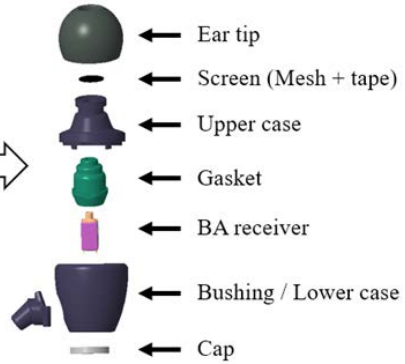
- Coil and diaphragm vibration due to Lorenz force
- 2 way microspeaker for performance enhancement

Balanced Armature (BA) driver



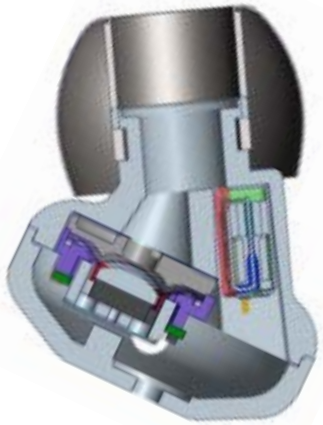
1. Front cover
2. Side diaphragm (SDP)
3. Center diaphragm (CDP)
4. Armature
5. PCB
6. Screen
7. Bobbin
8. Voice coil
9. Back cover
10. Magnet housing
11. Permanent magnet (PM)
12. Pin
13. Spout

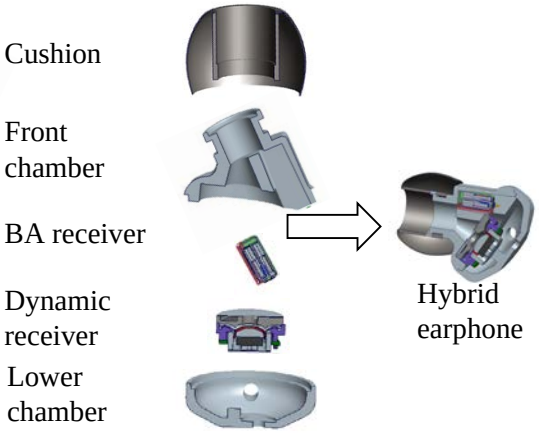




►Point
- Armature and diaphragm vibrate due to magnetic force
- Fast response: Rapid vibration due to small current
- Excellent high frequency response

Hybrid earphone

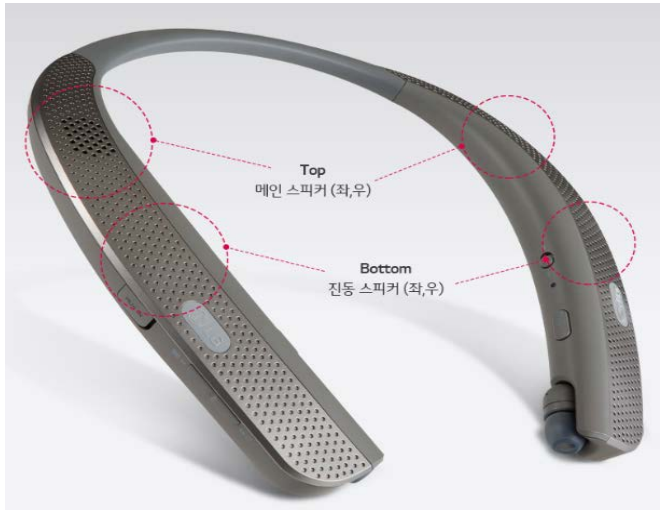




►Point
- BA receiver focus on high frequency
- Dynamic receiver: :Focus on low frequency
- Hybrid: Combine the advantage, better performance

1 Lab introduction– Lab research projects

Neck band speaker with passive vibrator



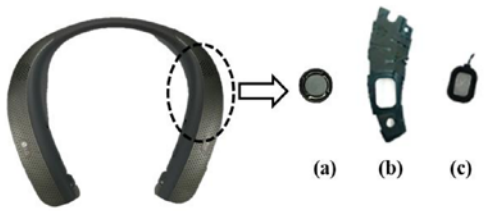
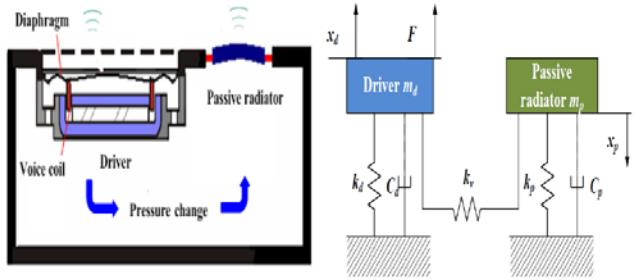
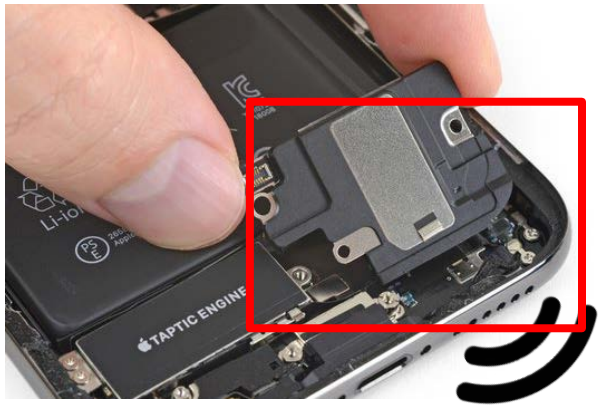


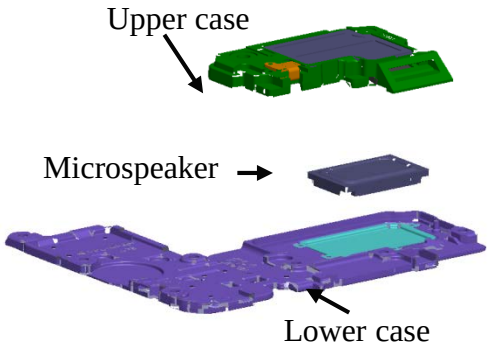
FIGURE 1. A typical neckband speaker (a) Linear vibrator, (b) speaker box, and (c) microspeaker driver.

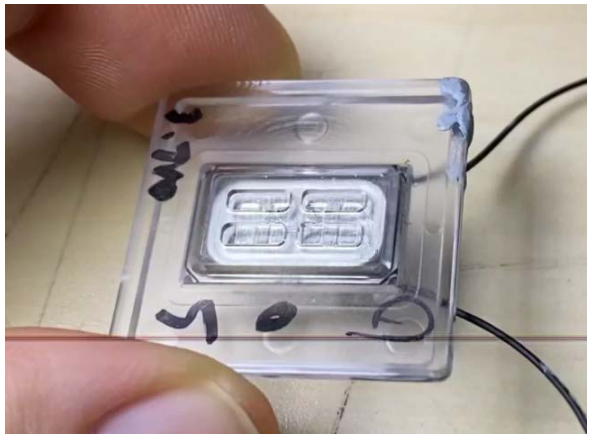


►Point
- Passive vibration due to the air pressure force in speaker box
- Speaker –Sound radiation
- Passive Vibrator- Generate vibration

Smartphone side firing speaker module



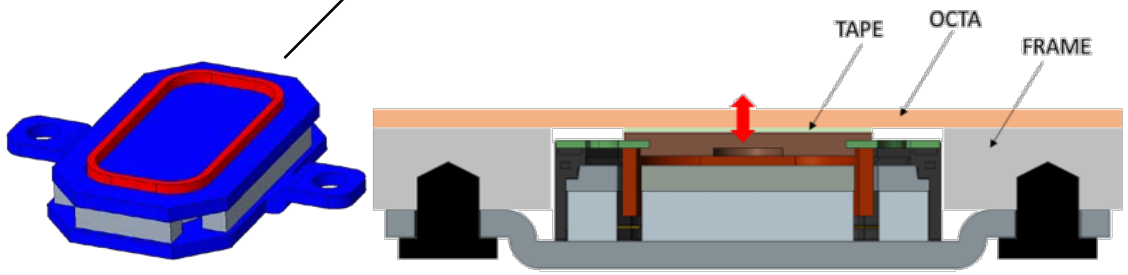




►Point
- Thickness limitation due to smartphone thickness
- Side firing speaker adopted.

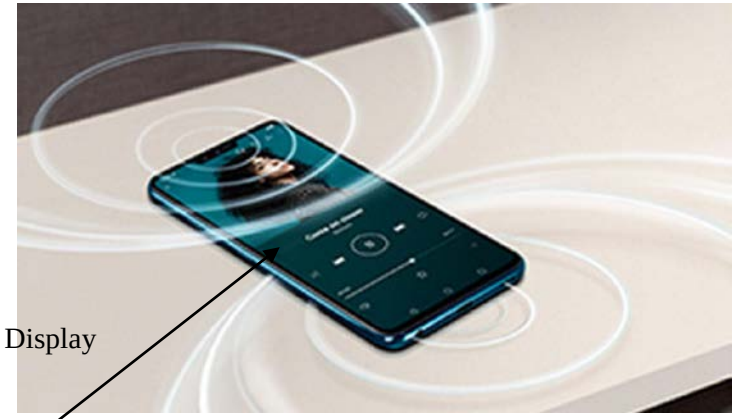
Sound on display: Actuator

Actuator in Display

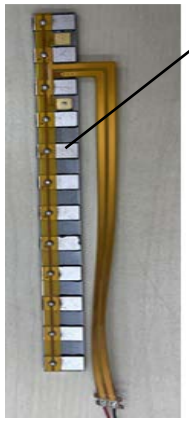


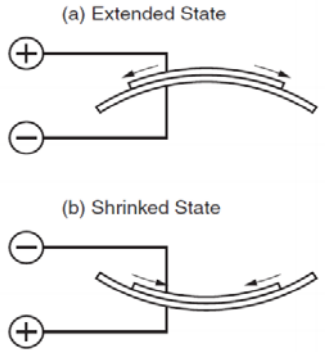
►Point
- Full-Wide Bezel-Less Display
- Dynamic receiver removed
- Screen vibration cause by actuator

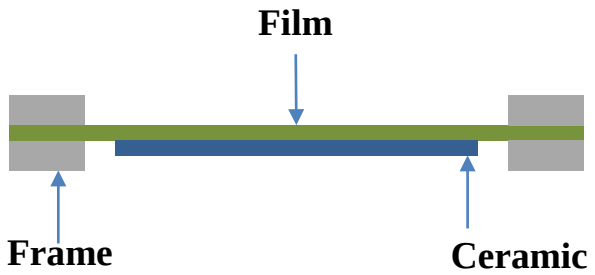
Sound on display: Piezo



Piezo Actuator in Display

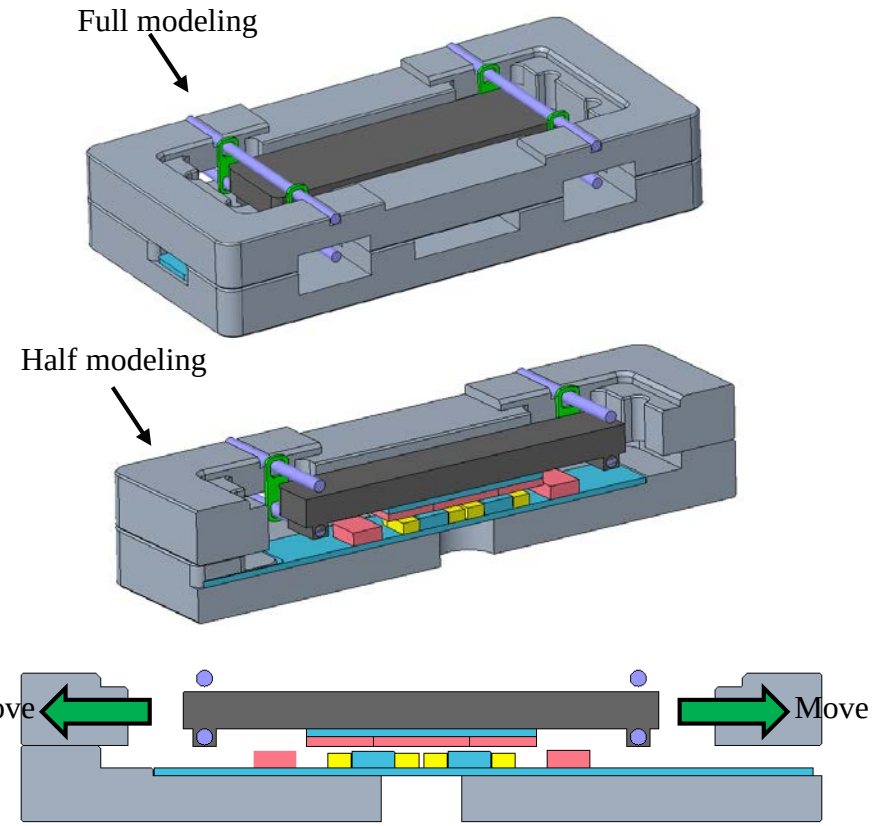






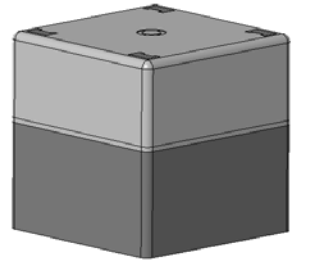
►Point
- Full-Wide Bezel-Less Display
- Dynamic receiver removed
- Screen vibration cause by piezo actuator

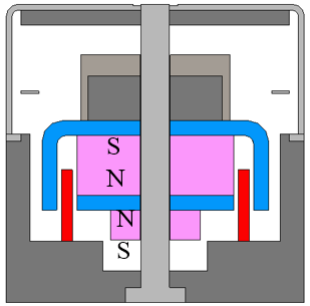
Pure magnetic spring motor



►Point
- Horizontal vibration motor
- Replace mechanical spring to magnetic spring
- Designed for smartphone

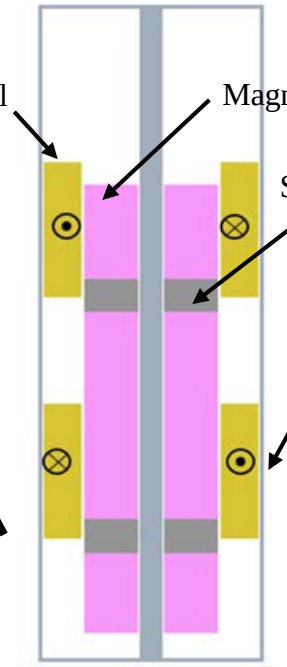
Actuators





Vibration actuator

Actuators in game pad



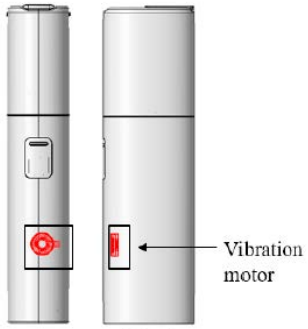
Impact actuator

►Point
- Focus on one big impact and vibration
- Higher force in limited space

2 Applications (EM-Tech)

E-cigarette

Linear vibration motor



Front view Side view

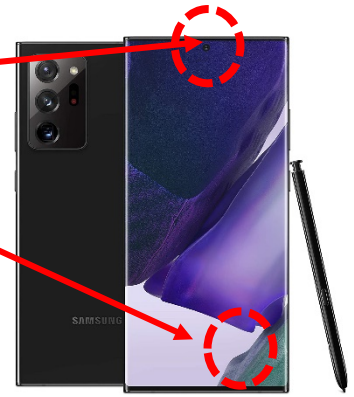
Smartwatch

Smartwatch speaker (5 atm)

Automobile

Linear vibration motor

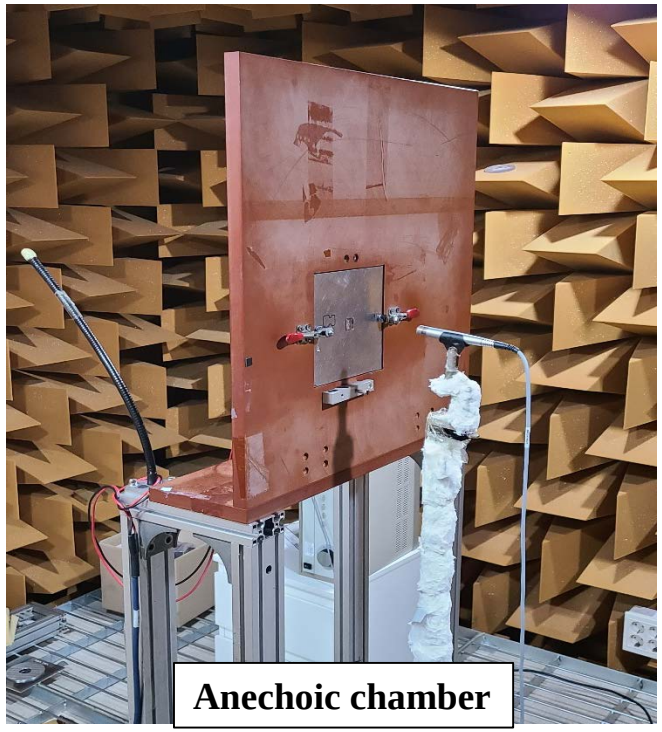
Smartphone



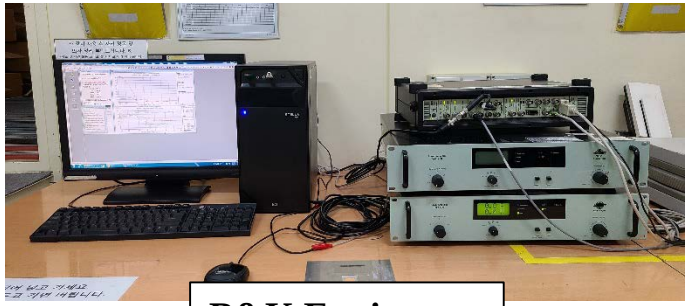
Microspeaker (top, bottom)

3 Experiment setups (EM-Tech)

SPL Measurement



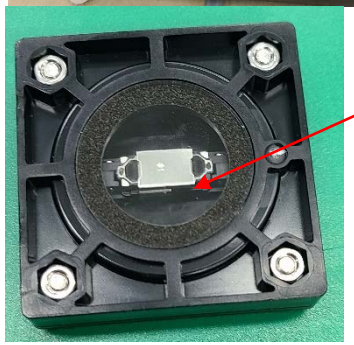
Anechoic chamber



B&K Equipment

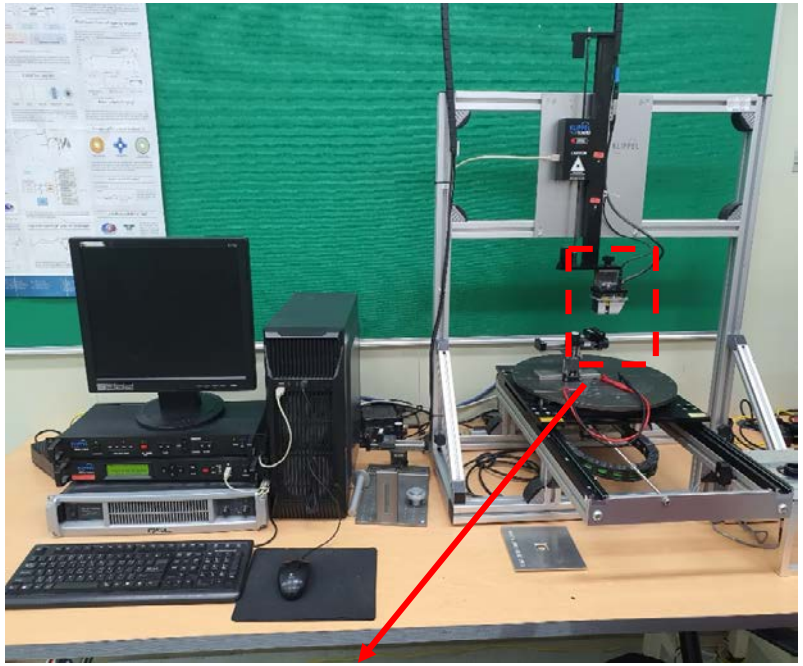
Waterproof test

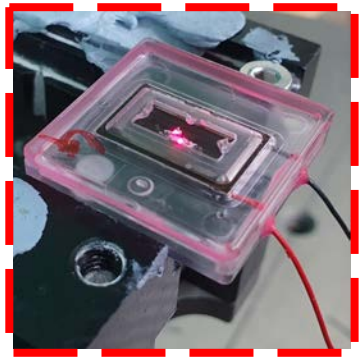
Waterproof test machine



Smartwatch speaker
(5 atm)

Klippel equipment





Laser based device

3 Publications (2019 ~ 2020)

[2019]

1. Jiang, Y.W., Xu, D.P., Jiang, Z.X., Kim, J.H., and Hwang, S.M., **2019**. Comparison Of Multi-Physical Coupling Analysis of A Balanced Armature Receiver Between The Lumped Parameter Method and The Finite Element/Boundary Element Method. *Applied Sciences*, *9*(5), p.839.
2. Jiang, Y.W., Xu, D.P., Jiang, Z.X., Kim, J.H., and Hwang, S.M., **2019**. Analysis and Design of Helmholtz Protector to Improve High-Frequency Response of Insert Earphone. *Applied Sciences*, *9*(12), p.2541.
3. Jiang, Y.W., Xu, D.P., Kwon, J.H., Jiang, Z.X., Kim, J.H., and Hwang, S.M., **2019**. Analysis and Application of Zeolite in Microspeaker Box. *Journal of Mechanical Science and Technology*, *33*, pp.3679-3683.
4. Jiang, Z.X., Kim, J.H., Jiang, Y.W., Xu, D.P., and Hwang, S.M., **2019**. Analysis and Design of a Novel Concept Gasket to Improve the Reliability of the Balanced Armature Receiver Used in Earphones. *Applied Sciences*, *9*(18), p.3661.
5. Jiang, Y.W., Xu, D.P., Jiang, Z.X., Kim, J.H., and Hwang, S.M., **2019**. Analysis and Development of Hybrid Earphone Combining Balanced-Armature and Dynamic Receivers. *Applied Sciences*, *9*(23), p.5047.

[2020]

1. Jiang, Y.W., Xu, D.P., Jiang, Z.X., Kim, J.H., Park, K.H., and Hwang, S.M., **2020**. Analysis and Application of Screens for Acoustic Impedance in A Speaker Box with A Passive Radiator to Decrease Standing-wave Influence. *Applied Sciences*, *10*(3), p.866.
2. Jiang, Z.X., Park, K.H., Kim, J.H., Jiang, Y.W., Xu, D.P., and Hwang, S.M., **2020**. Analysis and Design of A New Linear Vibration Motor Used to Reduce Magnetic Flux Leakage in In-vehicle Infotainment. *Applied Sciences*, *10*(10), p.3370.
3. Park, K.H., Jiang, Z.X., Jiang, Y.W., and Hwang, S.M., **2020**. Development of Direct-vibration Actuator for Bezel-less Display Panels on Mobile Phones. *Applied Sciences*, *10*(14), p.4975.
4. Park, K.H., Jiang, Z.X., and Hwang, S.M., **2020**. Design and Analysis of A Novel Microspeaker with Enhanced Low-Frequency SPL and Size Reduction. *Applied Sciences*, *10*(24), p.8902.
5. Jiang, Z.X., Park, K.H., and Hwang, S.M., **2020**. Design and Analysis of Novel Low-Cost Linear Vibration Motor for an Electronic Cigarette. *Applied Sciences*, *10*(24), p.8915.

3 Publications (2021 ~ 2023)

[2021]

Jiang, Z.X., Park, K.H., and Hwang, S.M., **2021**. Design of a Width Slim Linear Vibration Motor Used for Automotive LCD Panel. *IEEE Transactions on Magnetics*, *58*(2), pp.1-5.

[2022]

1. Jiang, Z.X., Park, K.H., and Hwang, S.M., **2022**. Design and Analysis of Watch Speaker to Enhance Waterproof Performance by Using Liquid Silicone Rubber Side Diaphragm. *Sensors and Actuators A: Physical*, *338*, p.113452.
2. Jiang, Z., Park, K.H., and Hwang, S.M., **2022**, June. Novel Magnetic Circuit Design and Acceleration Calculation of Horizontal Linear Vibration Motor. In *Actuators* (Vol. 11, No. 6, p. 149). MDPI.
3. Jiang, Z.X., Park, J.H., Xu, D.P., and Hwang, S.M., **2022**. A Linear Haptic Motor with Cogging Force Optimization. *Sensors and Actuators A: Physical*, *346*, p.113860.
4. Jiang, Z.X., Park, J.H., and Hwang, S.M., **2022**. Novel Design of Dual-voice-coil Microspeaker for Low-frequencies Sound Pressure Level Improvement. *Sensors and Actuators A: Physical*, *346*, p.113853.

[2023]

1. Jiang, Z.X., Park, J.H., Xu, D.P. and Hwang, S.M., **2023**. Analysis and prediction of mid-high peak frequency for microspeaker with side-firing front chamber. *Applied Sciences*, *13*(2), p.1018.
2. Jiang, Z.X., Park, J.H., Xu, D.P., and Hwang, S. M., **2023**, February. Analysis Method Development of Hybrid Linear Motor Considering Cogging Force Effect. In *Actuators* (Vol. 12, No. 3, p. 99). MDPI.
3. Jiang, Z.X., and Hwang, S.M., **2023**. Design and Analysis of Wide-bandwidth Actuator for Haptic Controller with Novel Magnetic Circuit. *IEEE Transactions on Magnetics*.

3 Publications (2024 ~)

[2024]

1. Jiang, Z.X., Park, K.T., Xu, D.P. and Hwang, S.M., **2024**. Design and Analysis of two-way Microspeaker to Enhance Mid-frequency Sound Pressure Level. *Sensors and Actuators A: Physical*, (Vol. 365, p.114914)
2. Park, K. T., Jiang, Z.X., Oh, Y, I. and Hwang, S.M., **2024**. Novel Microspeaker Design for Smartwatches with Integrated Woofer and Tweeter Units. *IEEE CEFC*
3. Jiang, Z.X., Park, K.T., Xu, D.P. and Hwang, S.M., **2024**. Design and Analysis of Linear Haptic Motor with Pure Magnetic Spring. *IEEE CEFC*

Thank you very much