Multiple Chamber Aligned in Parallel Cavity Resonator (MCAP-CR)

Basic Concepts

Advanced Loudspeaker Enclosure

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Revised in November 8,2008*

*** MCAPSS was renamed as MCAP-CR**

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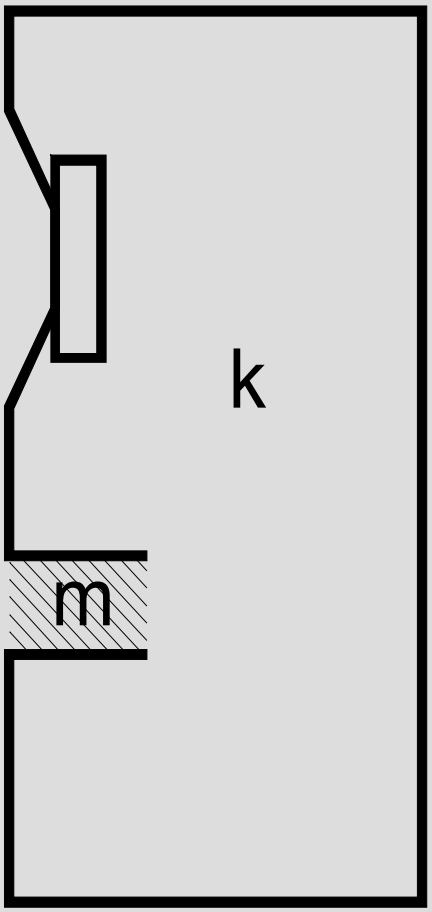
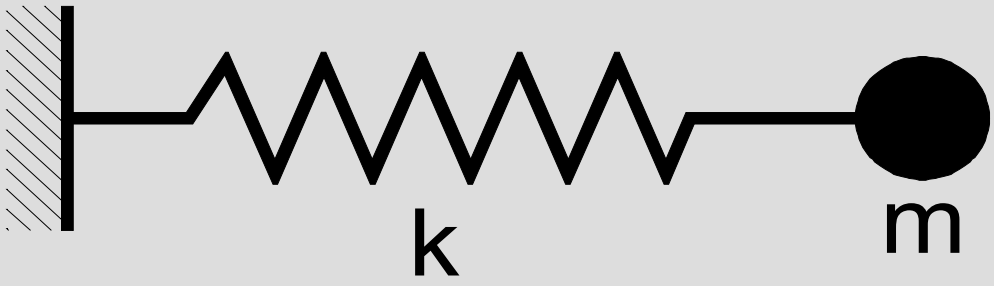
Traditional Approaches Bass-Reflex Architecture



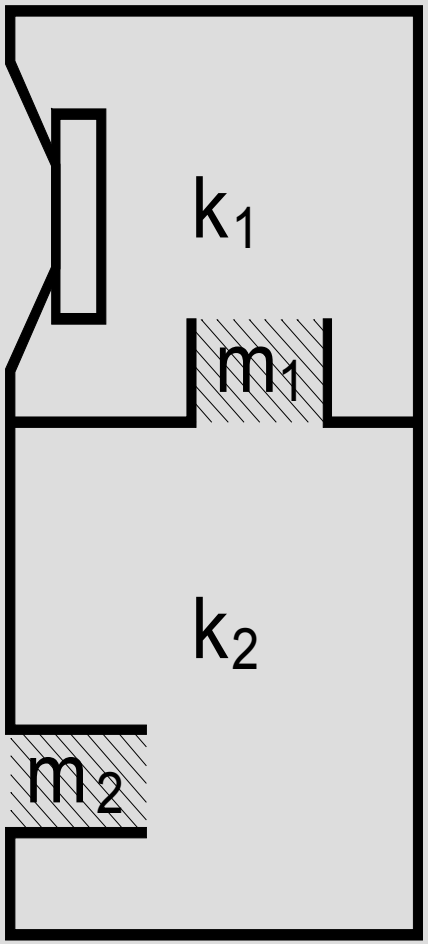


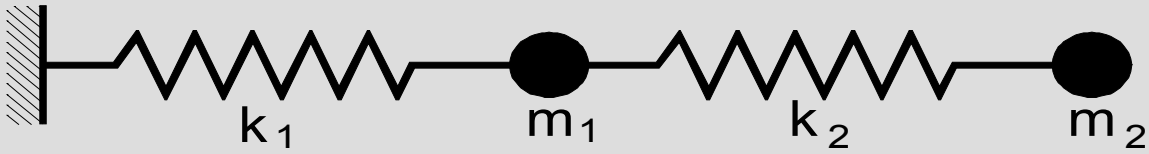
Single Bass Reflex system has just ONE Characteristic Frequency

$$f_D = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Bass-reflex architecture is an application of Helmholtz's cavity resonator

Traditional Approaches
Double-Bass-Reflex Architecture





Double Bass Reflex system has TWO Characteristic Frequencies.

$$f_D = \frac{1}{2\pi}\sqrt{\frac{k_{11}m_2 + k_{22}m_1 \pm \sqrt{(k_{11}m_2 + k_{22}m_1)^2 - 4\,m_1 m_2 (k_{11}k_{22} - k_{12}k_{21})}}{2\,m_1 m_2}}$$

See Appendix-A of "Equations to calculate characteristic frequencies of Multiple Chamber Aligned Cavity Resonator (MCAP-CR)" by Shigeru Suzuki.

Document Number : MCAP002E

Technical Target of MCAP-CR

- Improve frequency response over low range (below f_0 of speaker unit)
- Let this architecture suitable not only for woofer drivers but also for full-range speaker drivers.
- Make Speaker Enclosure size smaller as much as possible compared with existing equivalent systems.
- Develop calculation method so that everyone could design one's own.

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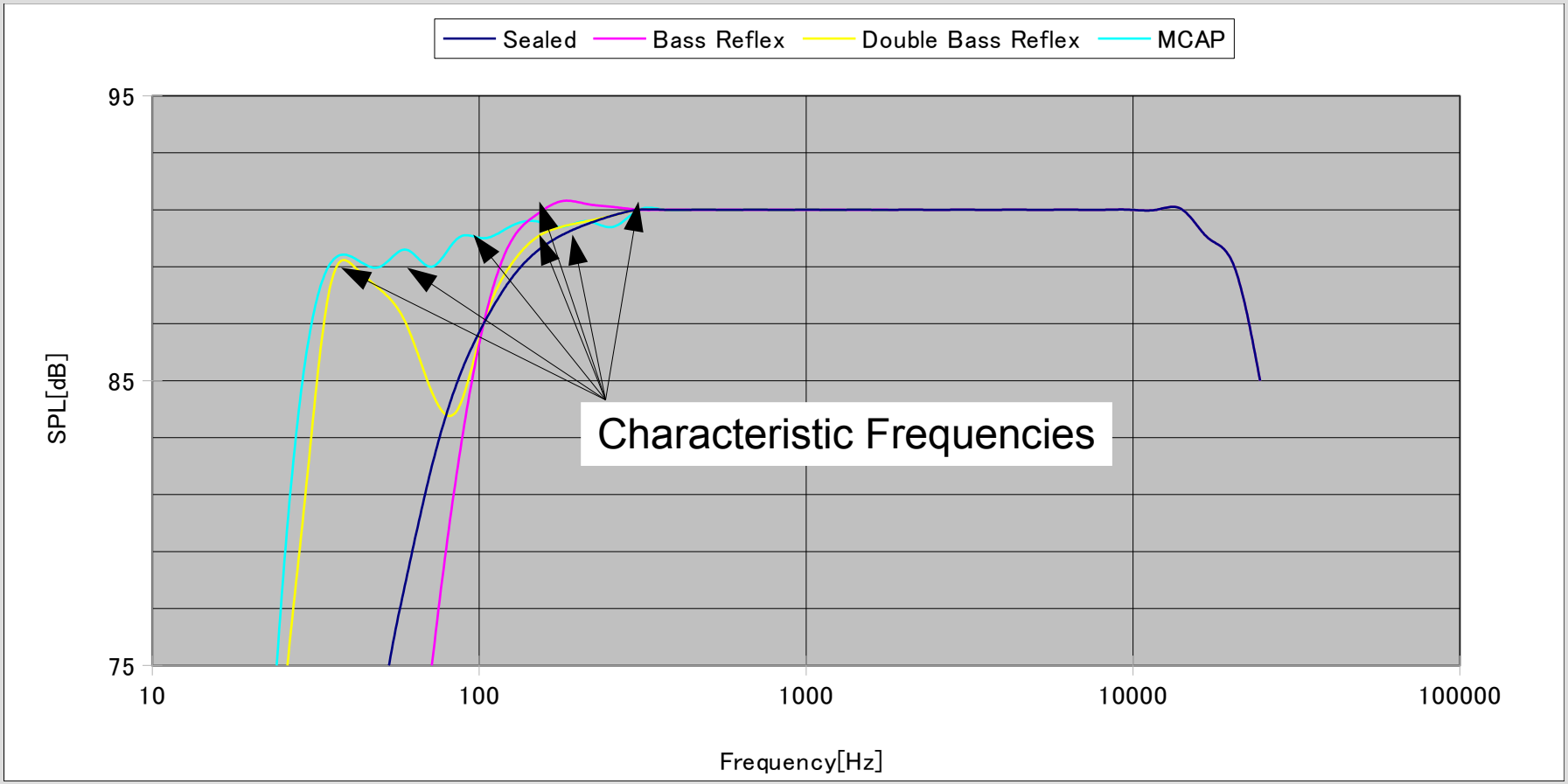
Advantages of MCAP-CR

- MCAP-CR architecture has multiple characteristic frequency. The number of characteristic frequencies is theoretically unlimited.
- MCAP-CR architecture generates lower frequency than f_o at considerably high sound pressure level.
- MCAP-CR architecture requires smaller enclosure than existing equivalent systems.
- MCAP-CR is not only suitable for woofer drivers but also full-range drivers . Full-range drivers are free from electrical network circuits so that they are advantageous.

Frequency Response
MCAP-CR vs. Traditional Approaches

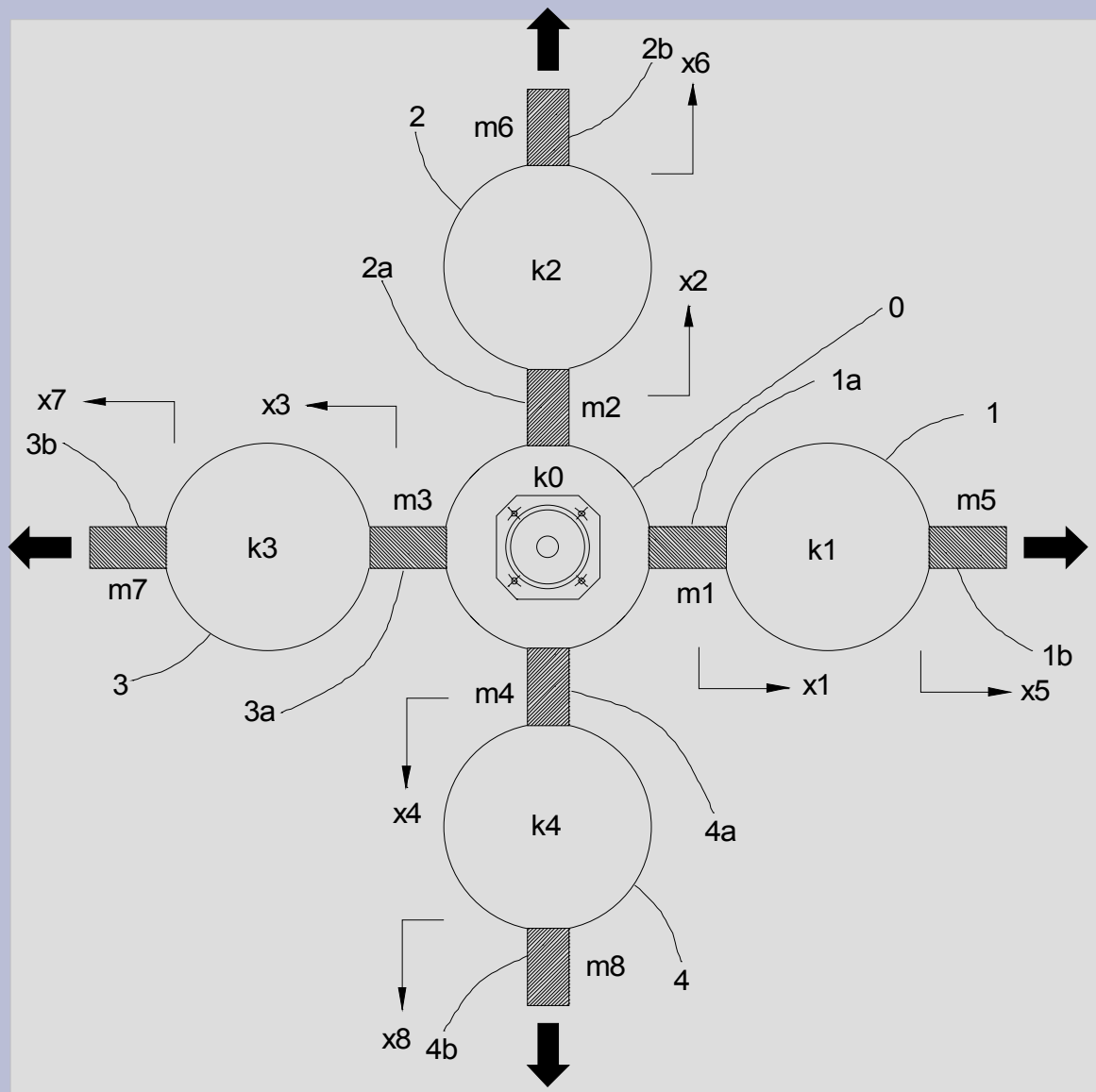


MCAP-CR has 4 or more characteristic frequencies (depends on number of chambers and ducts), while double-bass-reflex has 2 and single-bass-reflex has one.
Multiple characteristic frequency realizes improved response in low frequently region.
Note: This is just conceptual figure to explain difference among different systems.

Technical Feature of MCAP-CR

- MCAP-CR stands for *Multiple-Chamber Aligned in Parallel Cavity Resonator*.
- MCAP-CR is designed to boost multiple-characteristic frequency.
- MCAP-CR consists of main chamber where speaker driver is installed, sub-chambers, and ducts.
- Each sub-chamber is connected to main chamber through inter-chamber duct.
- Some of (typically, all) sub-chambers have open-air duct.

How MCAP-CR works
Schematic: Number of Sub chambers=4



0: Main chamber
1-4 : Sub-chamber

m1 - m8: mass of air that is involved in each duct
k0 : reference spring constant for speaker cone
k1 -k4 : equivalent spring constant for each duct
x1 - x8 : displacement of mass of air

Note: Number of sub-chambers is theoretically unlimited.
If number of sub-chambers is one, it is identical to traditional double-bass-reflex architecture.

Document Number : MCAP002E

Equations of Motion of MCAP-CR

Equations of Motion : Free Vibration

$$m_j \ddot{x}_j + k_0 r_j \sum_{i=1}^{N} r_i x_i + k_j r_j \left(r_j x_j - r_{j+N} x_{j+N} \right) = 0$$

$$m_{j+N} \ddot{x}_{j+N} + k_j r_j \left(r_{j+N} x_{j+N} - r_j x_j \right) = 0$$

m_j: mass of air involved in each duct
N: number of sub-chambers
k_0: reference spring constant of base chamber
k_1-k_N : spring constant of each sub chamber for reference cross-sectional area
r_j : ratio of cross sectional area divided by reference area
x_j : displacement of air mass in each duct

Document Number : MCAP002E

Equation of Motion: Matrix Form

Equation of motion of free vibration can be expressed in matrix form.

$$M\ \ddot{x} + K\ x = 0$$

M: Mass Matrix
K: Stiffness Matrix
X: Displacement Vector

Eigen Value Problem

$$\left| K - \lambda\ M \right| = 0$$

λ : Eigen Value

Solving Equations of MCAP-CR

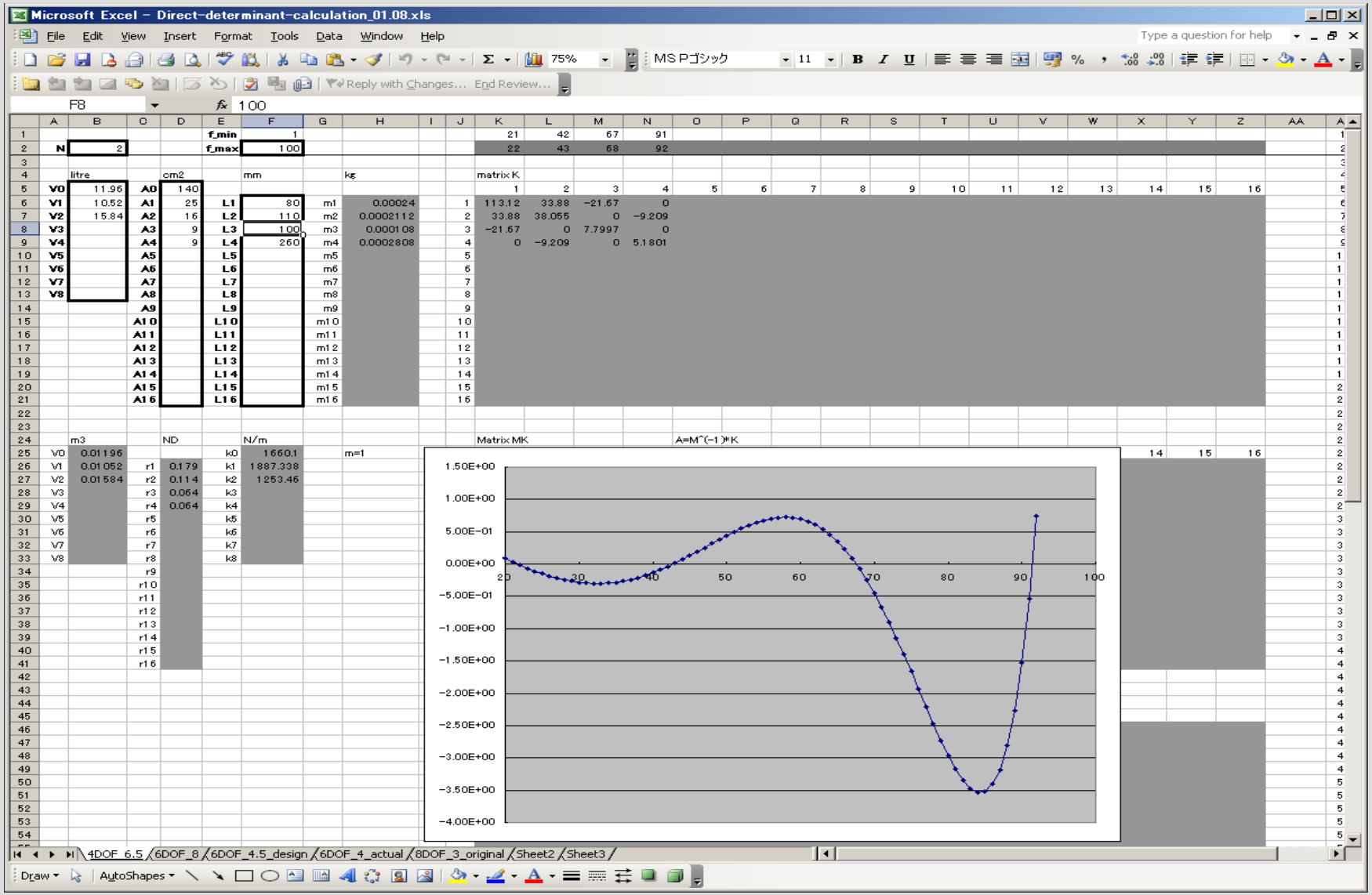
Refer to another document

1. Determine number of sub-chambers
2. Determine principal dimensions (size of chambers, ducts)
3. Develop equations of motion of your model
4. Calculate mass-matrix and stiffness-matrix
5. Solve Eigen Value Problem using a computer program (described in another document).

Document Number : MCAP002E

Solving Equations of MCAP-CR

Calculation Window (Example)



Expected Q & A (1) General

QUESTIONS	ANSWERS
• Do I like MCAP-CR sound?	• *It is recommended for those who like full-range system's sounds, but not recommended for those who prefer multiple-way systems rather than full-range systems.*
• Is designing MCAP-CR difficult for me?	• *It may be difficult if you are not good at mathematics. Knowledge level of MS in Engineering may be required.*
• Do you have examples of MCAP-CR?	• *Yes. I have already made six models. Some of them will be uploaded to this web page.*
• Is MCAP-CR good for high fidelity system?	• *I believe YES. One advantage of MCAP-CR is it is good for full-range drivers.*
• Is it difficult to assemble MCAP-CR?	• *It may be difficult for beginners.*

Expected Q & A (2) General

QUESTIONS	ANSWERS
• I have difficulty to calculate and design MCAP-CR. May I ask you for more details?	• *Yes, I would try to help you as much as possible. Please do not hesitate to contact me.*
• Where can I buy MCAP-CR?	• *Any MCAP-CR is not sold right now. There is no manufacturer. I wish I could, but I have no fund to found a company.*
• Where can I hear sound of MCAP-CR?	• *There is nowhere you can hear sound of MCAP-CR except my home. You may write to me if you really want to hear them. My home is located in Tokyo, Japan.*
• Do I need to pay for the patent.	• *Patent application was submitted in 2007, but it has not yet become a right. Even though patented, it does not affect non-commercial personal use.*

Expected Q & A (3) Technical

QUESTIONS	ANSWERS
• What is the recommended number of sub-chambers?	• *It must be at least 2. N=2, 3, or 4 will be suitable for practical reasons.*
• What characteristic frequency should be targeted?	• *From my experience, lowest characteristic frequency should be 50Hz for 3" drivers, 40Hz for 4" drivers, and 20Hz – 30Hz for 6.5" and bigger drivers. Highest characteristic frequency may be determined based on driver's response curve.*
• How can I determine size of ducts and volume of each chamber?	• *You may begin with defining volume of chambers. Chamber's size depends on practical constraint. I suggest that summation of cross sectional area of each inter-chamber duct does not exceed ½ of driver's effective area (a_0). Cross sectional area of open-air duct should be equal or even smaller than of inter-chamber duct. Then calculate characteristic frequencies. Parameter should be lengths of ducts.*

Expected Q & A (4) Technical

QUESTIONS	ANSWERS
• Response in low frequency region seems not enough. What can I do?	• *MCAP-CR generates lowest characteristic frequency, so you may boost low frequency using tone control. Bass-reflex system cannot boost lower than f_D; it is true to MCASPS, but MCAP-CR has lower f_D, thus using tone control is very effective.*
• Which drivers should be suitable for MCAP-CR?	• *Considerably powerful full-range drives are recommended. I suggest 3" drivers of Tangband: W3-316 is most recommended. If you like Fostex, I suggest FE126E, FE166E, FE206E, FF125K, FF165K, and FF225K; however, any driver can be used as you prefer.*

Expected Q & A (5) Technical

QUESTIONS	***ANSWERS***
• May I think that MCAP-CR is compete technology?	• *MCAP-CR is proven technology, yet it is not complete. Any technology is NOT perfect. We have to improve applications everyday.*
• How can you complete MCAP-CR technology?	• *I will try to design, assemble and test as many models as possible, but cannot make enough. I would be the most happy, if you want to work with me to help developing MCAP-CR. One purpose of publishing this document is to find a partner. My contact email address is shown in the web page.*

Summary

- *MCAP-CR is an application of cavity resonator Cavity Resonator with multiple characteristic frequency.*
- *Equations and solution were proposed.*
- *MCAP-CR is suitable not only for woofer drivers but also full-range drivers.*
- *I would be the most happy if you become interested in MCAP-CR. - Thank you.*