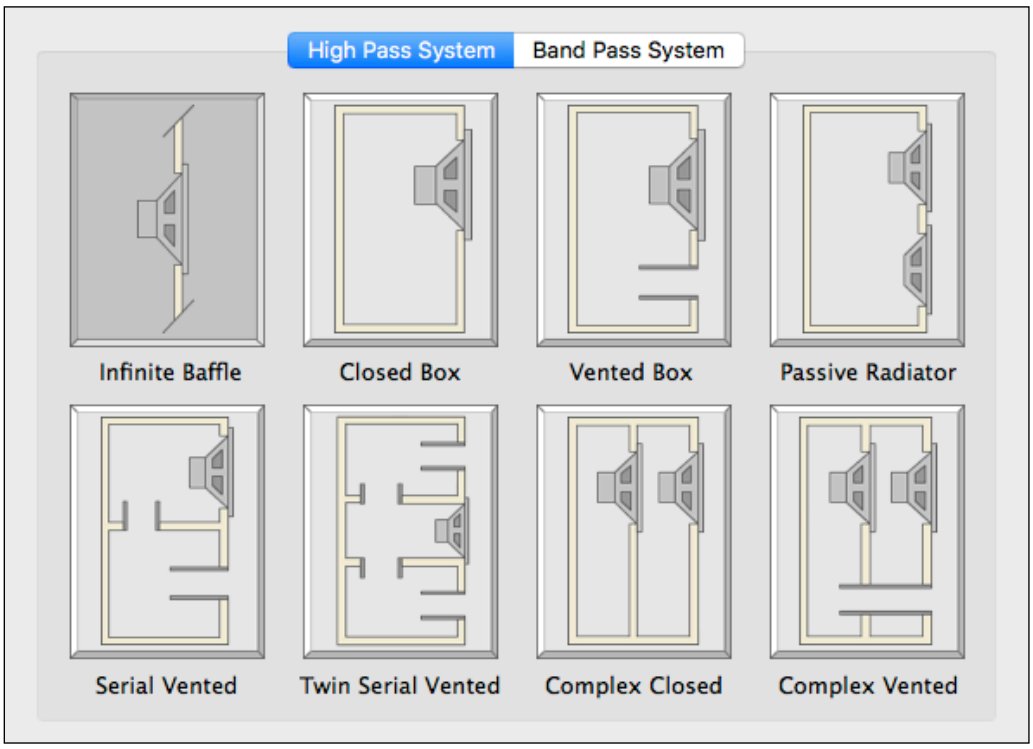
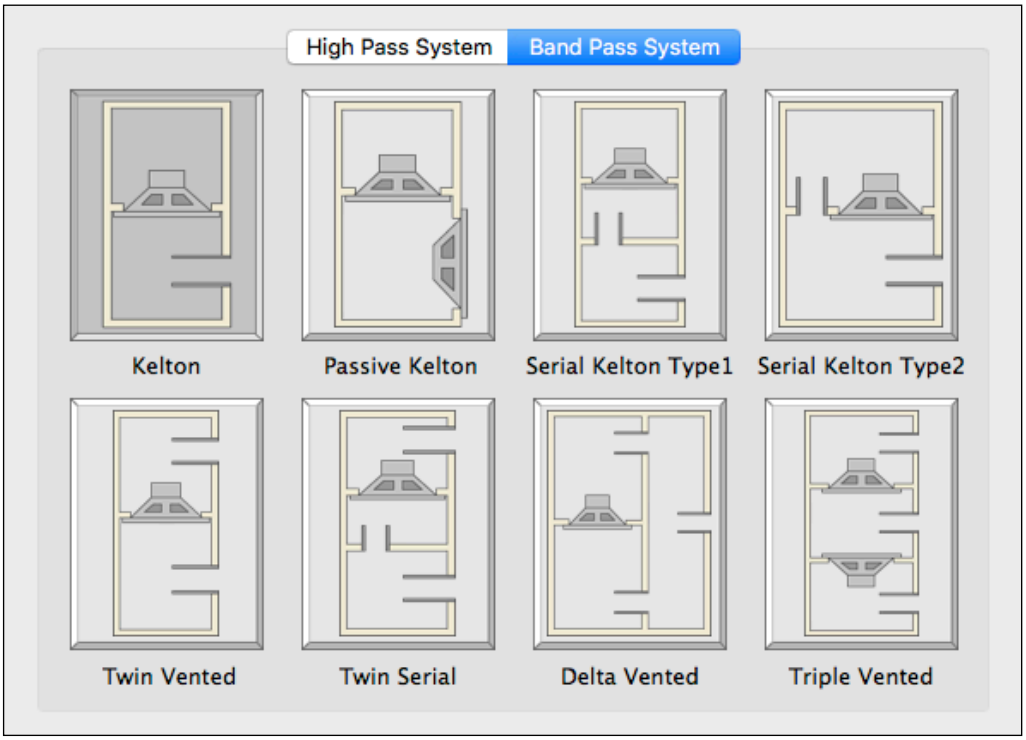
BoxDesigner Explanation of Speaker System

At Sonic Design Labo, we carefully selected and installed as many self-made enclosures as possible, as well as methods that are relatively easy to design and manufacture. We provide the enclosure design application "BoxDesigner".
It is the following 8 types of High Pass System Band Pass System A total of 16 types of speaker systems including 8 types can be designed.
This booklet describes the characteristics and design points of each method.



High Pass System



Band Pass System

"BoxDesigner" adopts a design method that is not too difficult but that allows trial and error to be fun.
Also, in the method with a vent (bass reflex duct) first determine the frequency characteristics and then we take steps to design each vent.
In this booklet what is generally called a bass reflex system is called a vented system and a bass reflex duct is called a vent. This is to respect the naming in Thiele and Small's paper but for the sake of convenience both names are used so please interpret them appropriately in each case.

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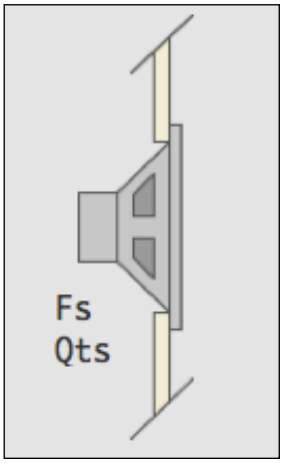
1. High Pass System

The high-pass system is a method in which the cone of a general speaker unit (SP) can be seen from the outside and the high-frequency characteristics of the SP appear on the high-frequency side. In the Thiele and Small theory which is based on the filter theory of electronic circuits it is called that because it has characteristics equal to the high-pass filter of electronic circuits.

1－1. Infinite Baffle System



Although the infinite baffle is not a very realistic method, we have adopted it because we believe that it is very meaningful to know the inherent characteristics of the SP. You can see the characteristics of the T･S parameters Fs and Qts themselves. Also, since the volume is equivalent to infinity, Vas is irrelevant.

Each method has a comparison mode with an infinite baffle.

(View Menu → Comparison IB)

In a closed box, when the volume is more than 5 times the Vas of SP, it becomes a nearly infinite baffle characteristic.

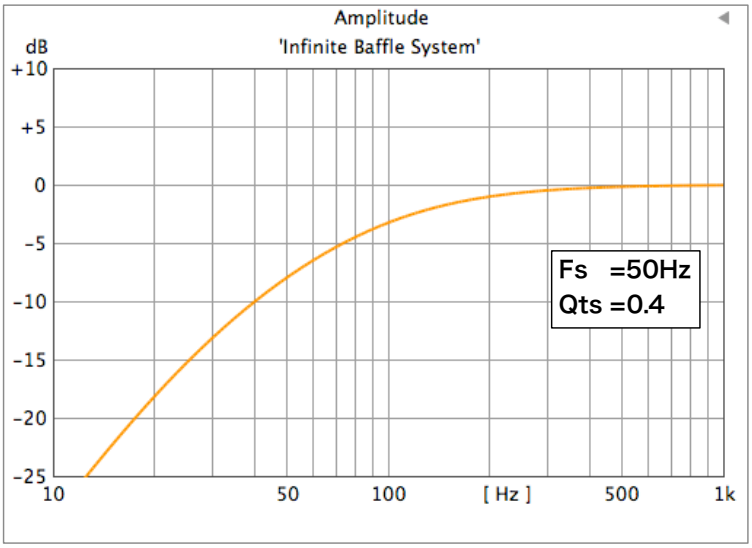


Fig1 Infinite Baffle Characteristic example

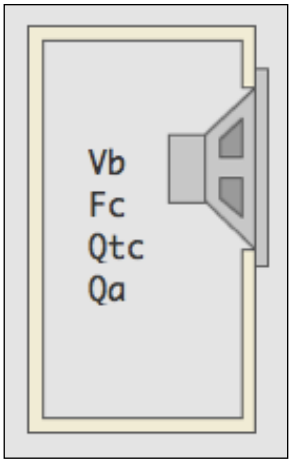
However if Vas = 50 liters in a 20 cm unit, a volume of 250 liters is a rather unrealistic value.

Many overseas unit manufacturers seem to often measure the frequency characteristics listed on the spec sheet by attaching them to a very large baffle (partition of a partitioned room).

This is a convenient property for designs based on Thiele and Small theory.

In addition there are IEC and JIS standard boxes that have been used for a long time. Its volume is about 600 liters, and the low-frequency characteristics measured with this box are considered to be close to an infinite baffle if the diameter is small.

1－2．Closed Box System



These days manufacturers and homebrews are simplistic and cannot reproduce low frequencies, so there is little motivation to make them.
It is a method that is being reviewed such as a closed method called "Linkwitz Transform" that boosts the low range with an analog or digital filter and reproduces the low range more than the vented method.
At -12dB/oct the low frequency rolls off with the lowest order for SP and the phase rotation, that is the group delay, in the low frequency range is less than the vented.

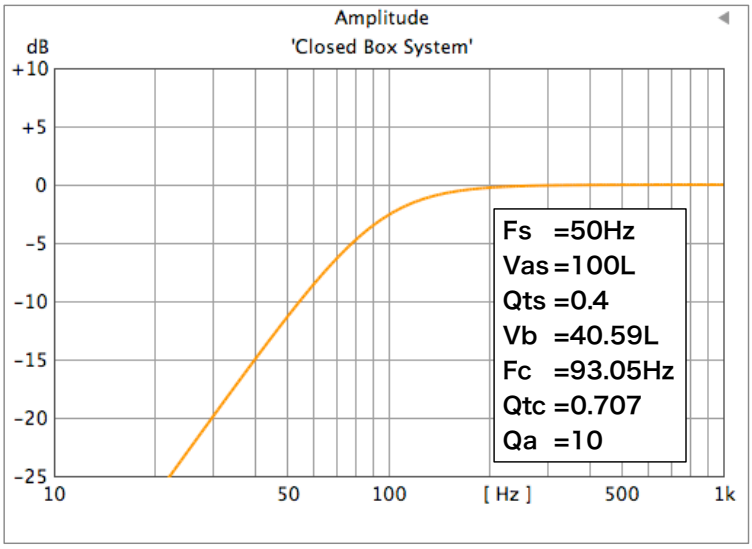


Fig2 Closed Box Characteristic example

In other words, and by using the above together, there is a possibility that the original sound can be reproduced more closely. (The original sound means the waveform contained in the media.) The point of design is how much Qtc (total Q of the closed box) should be set. In filter theory, when Q=0.707=1/√2 it is considered to be the optimum flatness (the flattest characteristic : Butterworth characteristic). Fc (resonant frequency) is also uniquely determined depending on the volume Vb of the box. However when Qts (total Q of the unit) is 0.707 or less,

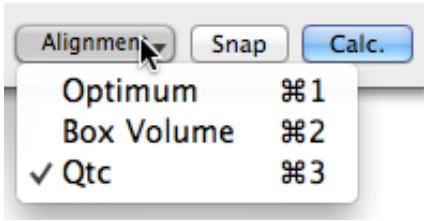


Fig3 Closed Box Alignment

Since the Qtc increases by putting the unit in a box (the smaller the volume the larger the Qtc, for infinite baffle it is Qtc= Qts) the Qtc cannot be less than Qts even if the volume is increased. Since Qtc determines the slope (shoulder characteristics) of the low range it is also possible to increase the volume of the low range by setting Qtc=1 which is an important factor and intentionally increasing the slope.

For Alignment,

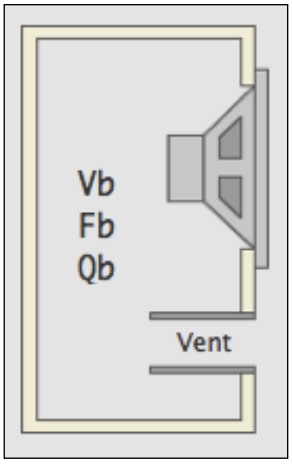
Optimum : Qtc of 0.707 Qts approaches flatness in realistic volume for units above

Box Volume : Specify the box volume (Liter)

Qtc : Specify Qtc

We have established the above three.

1－3．Vented Box System



Although it is late it is a method in which the low frequency region enhanced by the Helmholtz resonance Fb due to the internal volume Vb and the air column of the vent is emitted from the vent and the synthesized sound with the radiation from the cone. This is the most popular method regardless of the manufacturer or the DIY because it is easy to make and if it is designed well the bass can be reproduced well. Since the radiation from the vent operates behind the cone it is in opposite phase, and the composite characteristic is 360° phase rotated (180° for the closed) and rolls off at -24dB/oct which inevitably increases the group delay. Group delay correction using digital FIR filters is also a current trend.

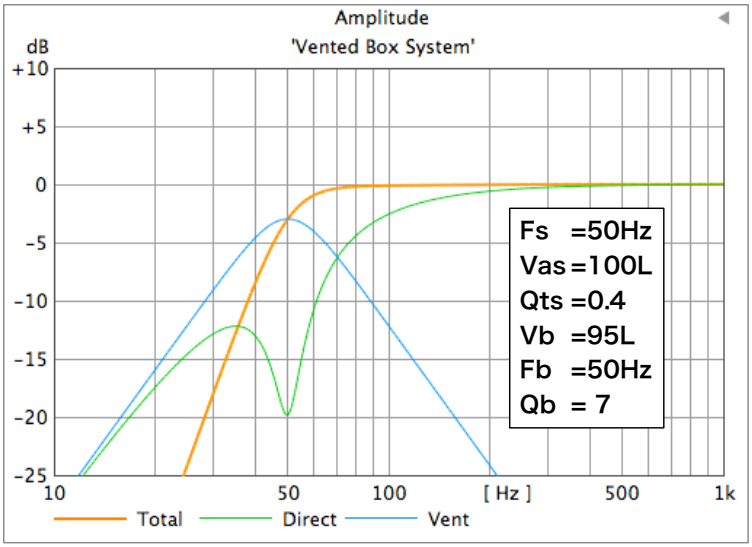


Fig4 Vented Box Characteristic Optimum

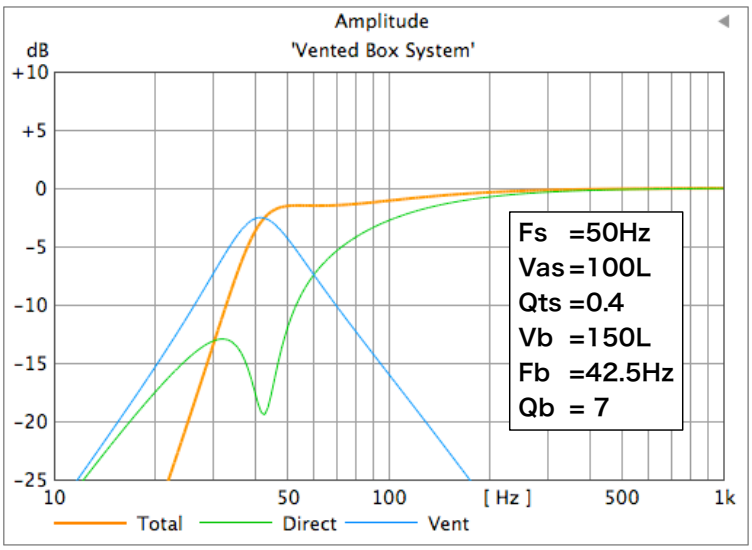


Fig5 Vented Box Characteristic Extend

First after determining the three parameters of Vb (box volume Liter) Fb (volume and resonance frequency Hz at vent) and Qb (Q due to loss component due to air leakage from box: usually 7) to obtain the desired characteristics Vent Menu → Vent Design Window to design each size and number of vents, and this is the end of the design process. Don't forget that this design procedure is the same throughout BoxDesigner. When designing a vent I am at a loss as to what kind of pipe to use but the pdf of "Vinyl chloride pipe/paper tube/void tube standards" can be downloaded on the “Archives” page of this site. "All of them are available at home centers and Hands.

For Alignment、
Optimum : Fourth-order Butterworth character
Extend : Set to extend the low range
Box Volume : Enter box volume and calc. opt Fb
Custom : Custom mode
We have set up four.
By the way in any method, the shortcut of Custom is set to "⌘ + 5" Key. In addition, when he clicks the "Calc." button in custom mode, the previous vent design will be initialized.
This is also true for systems with other vents. For more detailed design methods please refer to the attached sheet Design Method of Vented System.

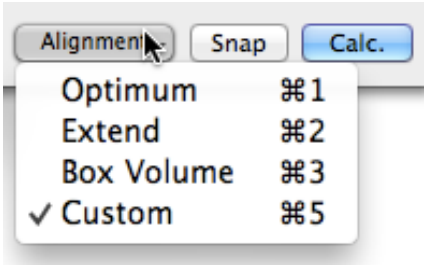
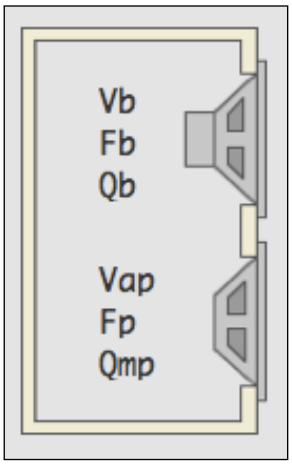


Fig6 Vented Box Alignment

Top

1－4. Passive Radiator System (Drone Cone System)



A passive radiator (drone cone) that removes the voice coil from the SP is used instead of the air column of the vent type vent (duct). The operating principle is almost the same as the vent method, but there is a slight difference in characteristics due to the dip that occurs at the resonance frequency of the passive radiator itself. It is often used by manufacturers but it is a method that is not often seen in homebrew articles. It seems that there are few corresponding design software it is difficult to design, and there are few products of passive radiator itself. The vented radiates the back sound inside the box from the vent but you can expect clear playback sound without it. In recent years, passive radiators have become easier to obtain and it seems that the number of self-made ones will increase. BoxDesigner supports this method at a high level, so I think it will be helpful for design and production. The “Speaker Data Folder” on the Download page contains the data of currently available Passive Radiator (hereafter PR) such as Dayton, Peerless, Seas, etc. Please make use of it.

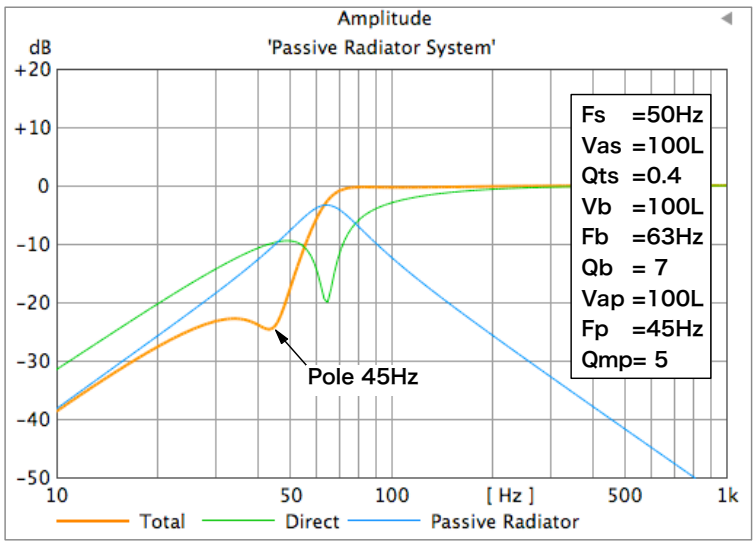


Fig7 Passive Radiator Characteristic Type1

The design method of the Passive Radiator System has the difficulty that it is not straightforward. First of all, is it difficult to find a PR unit that fits the SP unit to be used?
BoxDesigner calculates the optimum Vap (acoustic volume of PR) and Fp (resonance frequency of PR itself) with default values but there are few PR units that match those values and the matching range is severe so even if PR with a close value is inserted I don't have anything that fits so I think the best way is to try one by one.

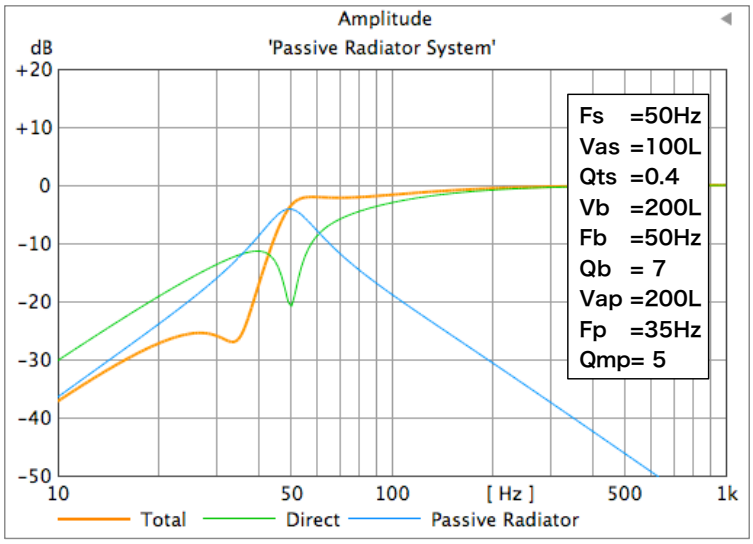


Fig8 Passive Radiator Characteristic Type2

Secondly once the PR unit is decided, the only parameters that can be changed are his Vb (box volume) and the number of PR units which makes the design difficult.
If you try to set the number of PRs to 2 it will fit surprisingly well but if there are no restrictions in terms of cost or size it will be a story. As mentioned above there is a dip (pole) at Fp and you may be a little disappointed that the low range does not extend as much as you thought.
To design the Passive Radiator first select the PR System of the desired SP unit in BoxDesigner then launch the Icon file of PR in PassiveRadiatorDB select the PR with a close value of Vap and Fp and click the "Send" button on the upper right Click. Then the Passive Radiator Data Enter Window will appear on the BoxDesigner side so click the "Apply" button to import the data. BoxDesigner automatically selects and adapts “Apply Entered P.R Unit”. After that change the number of Vb or PR look at the characteristics and if it doesn't work repeat the same.
Alignment is Fig9.
Please use the "PR_Calculator.app" posted on the "DOWNLOAD" page of this site as it can calculate the additional mass (grams) for the desired Fp.

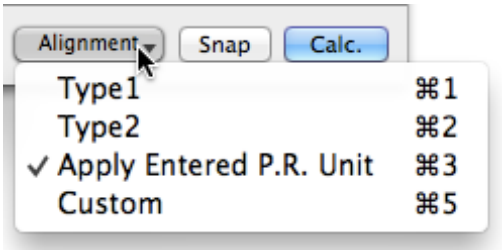
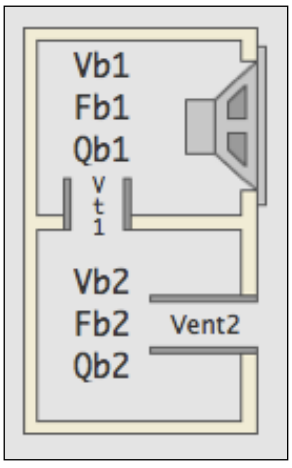


Fig9 PR System Alignment

Top

1－5. Serial Vented System (Double Bass Reflex System)



In general it is called a Double Bass Reflex System but I thought it lacked brains so I named it the "Serial Vented System". Other methods also give their own names without using street names. not bad. As shown in the left figure it has a structure in which another vent is attached to the vent. Although it is not often seen in manufacturers it seems to be a popular method for DIYers and it seems that FOSTEX has released a kit. Mr. Tetsuo Nagaoka's analysis is famous and it seems that many self-made groups are based on this.However the Nagaoka theory is based on experience and experiments and gives the impression that it lacks pure theoretical grounds. BoxDesigner creates calculation

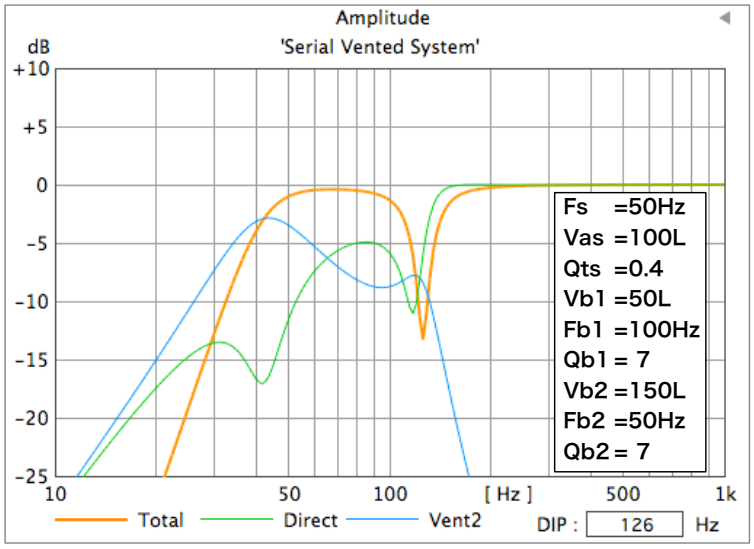


Fig10 Serial Vented Characteristic Type1

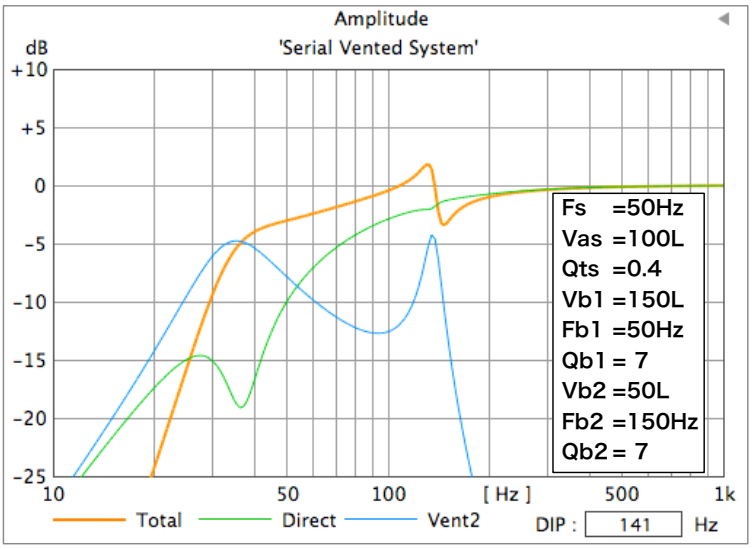


Fig11 Serial Vented Characteristic Type3

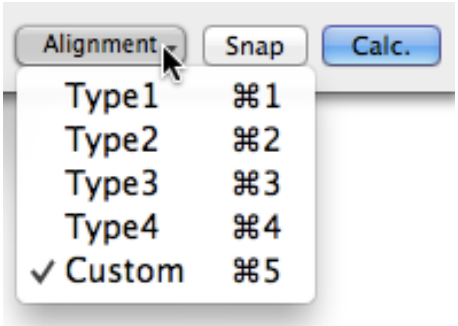
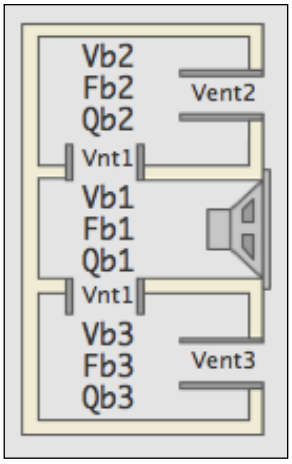


Fig12 Serial Vented Alignment

formulas from equivalent circuits based on T/S theory so we have confidence in its theoretical accuracy.
The disadvantage of serial vented is that there is a dip in the mid and low frequencies and the sum of the two volumes is considerably larger than the vented method.
If the resonance frequency of Vent1 is increased the dip point can also be raised but the operation becomes more like a simple vented system and becomes meaningless and the area of the vent that tunes to the high frequency becomes too large and deviates from reality. It's hard to avoid dips in a feasible range box.
Alignment has Type 1 to Type 4 and some of them have characteristics like Fig11 but it seems difficult to make them flat characteristics.
However steep dips like Fig10 don't bother me much from an audible point of view so I think this method is suitable for people who want to reproduce low frequencies as much as possible with a small-diameter unit.

1－6．Twin Serial Vented System（Twin W Bass Reflex System）



I chose this name because it has a structure in which a double bass reflex is used as a twin. The operation is quite complicated and it is a mistake to think that it is simply a stack of two double bass reflexes. The resonance of the four vents affects each other in a complicated way and with a simple setting many peaks and dips occur. The fact is that the author does not fully understand the operating principle. In fact, the idea of this system was borrowed from the MCAP-CR model of the "Multiple Degree of Freedom Bass Reflex Laboratory" and the original has a more complicated structure, and this is the simplest shape of the MCAP-CR model. It seems in the MCAP-CR type the two Vent1 have different dimensions but in this Twin Serial they have the same dimensions to avoid complication. My research so far is based on the conclusion that one volume resonates at one frequency even if multiple vents are installed, but what happens when the second and third volumes and the vent are connected is This is a subject for further research. Based on the resonance of Vb1 and Vent1 x 2 as a design method the resonances of Vb2 and Vent2 and Vb3 and Vent3 are considered separately. In reality they are complicated by mutual interaction, but for the sake of convenience we have no choice but to consider them separately.

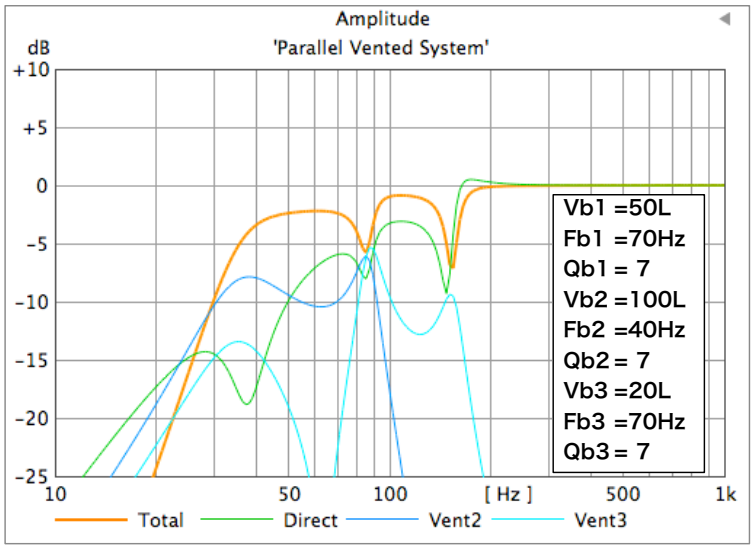


Fig13 Twin Serial Vented Characteristic Type1

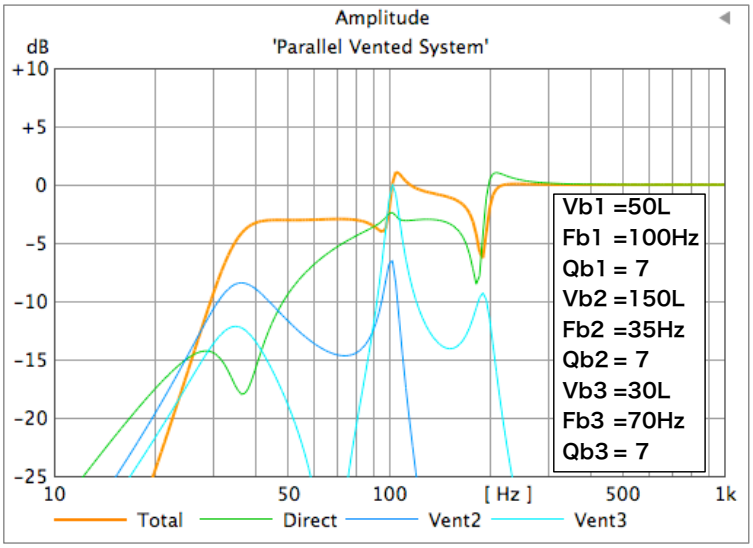


Fig14 Twin Serial Vented Characteristic Type2

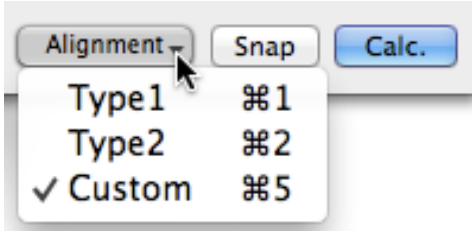
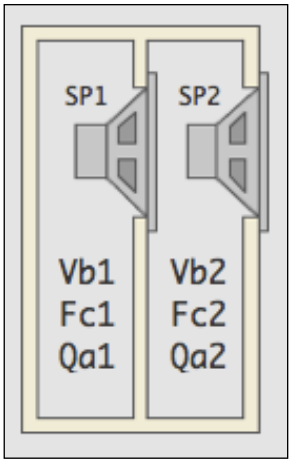


Fig15 Twin Serial Vented Alignment

There are two types of Alignment Type1 and Type2 so it would be interesting to create an original based on this or create a new characteristic by trial and error. Since there is no algorithm to calculate the characteristics we expect the user's challenging spirit.。

1－7．Complex Closed System



In this method, another sealed box is installed on the back side of the sealed box to reduce the volume limitation of the low frequency amplitude of the front SP and extend the low frequency reproduction. Roughly speaking, compared to a sealed box at 70Hz-6dB with the same total volume he is lower at 60Hz. I don't think there is much point in making this kind of improvement using two SPs. For now, we can only set the front and rear SPs to the same unit, but I think we can expect further improvements if the rear unit has a larger diameter. However it is up to the infinite baffle characteristic of the maximum front SP. This method is described in Olson's Acoustic Engineering (1959 Japanese edition) under the name "Composite Direct Emission Loudspeaker Method". I remember seeing a product like this in a magazine 50 to 60 years ago but it is almost impossible to find it now so it seems that there is not much merit in commercializing it. Fig16 is a comparison with an infinite baffle when the rear volume Vb1 is the same size as Vas. See Fig17.

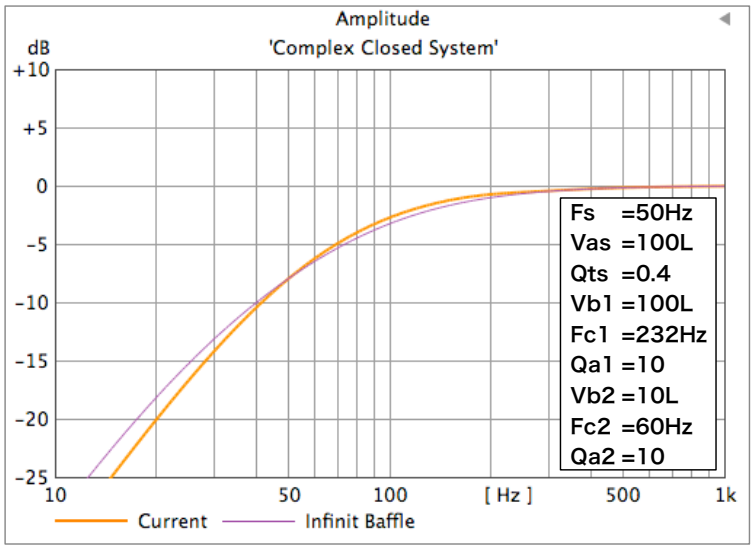


Fig16 Compared to Complex Closed and Infinite Baffle

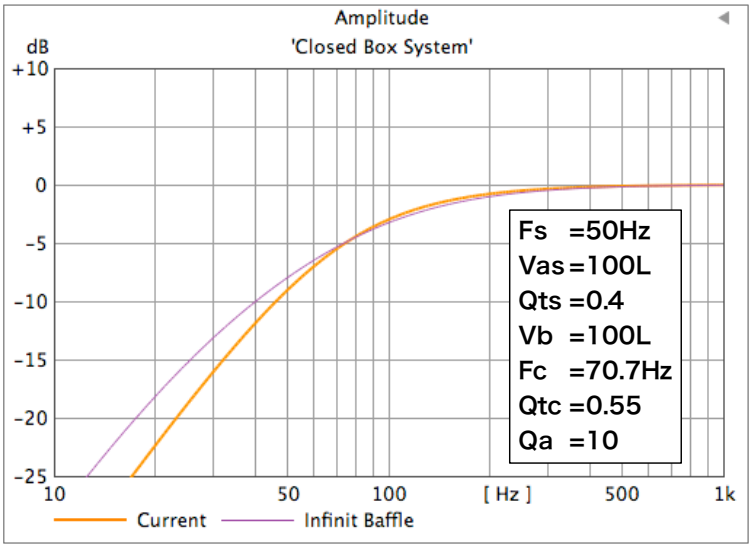


Fig17 Compared to Closed Box 100L and Infinite Baffle

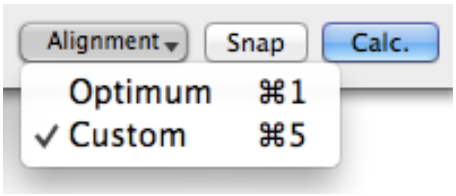
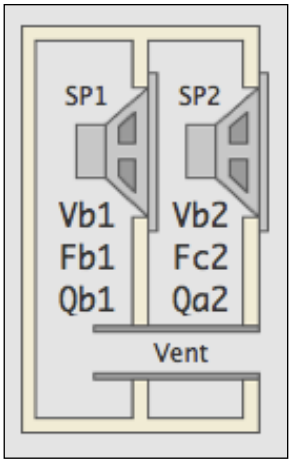


Fig18 Complex Closed Alignment

When I checked the library I found a production article named "Active Back Pressure Control" (ABC SP) in "Invitation to Hi Fi Speakers" in 1992. It is an evaluation that the sound quality is neat although the bass does not come out. I think that it is suitable for those who want to obtain the characteristics of a pseudo-infinite baffle.

The front and rear two SPs are basically connected in parallel.

1－8．Complex Vented System



A vent is attached to the volume on the rear side of the above-mentioned Complex Closed to make it a bass reflex type and it was also mentioned in the above-mentioned ABC SP article but there was no production article. It may be worth making unexpectedly because it is a rare method. Fig19 shows Optimum characteristics and Fig20 shows vented characteristics with the same total volume.
An acquaintance made it with his FOSTEX 10cm unit (FF105WK) and it had a total volume of about 5 liters and was playing a reasonable bass. Since the SP on the rear side is responsible for the bass reflex operation and the SP on the front side is responsible for the closed operation it seems to be advantageous for distortion. Currently, SP1 and SP2 which are the same as Complex Closed, can only be set to the same unit but there is a possibility that the playback band can be lowered by increasing the rear diameter and lowering the bass reflex resonance. In Fig 19 Vb2 is small so SP1 (Direct) is affected by the bass reflex operation of SP2 causing a dip. This means that the operation of the front and rear SPs can be separated to some extent so it is possible to create sounds unique to this method.

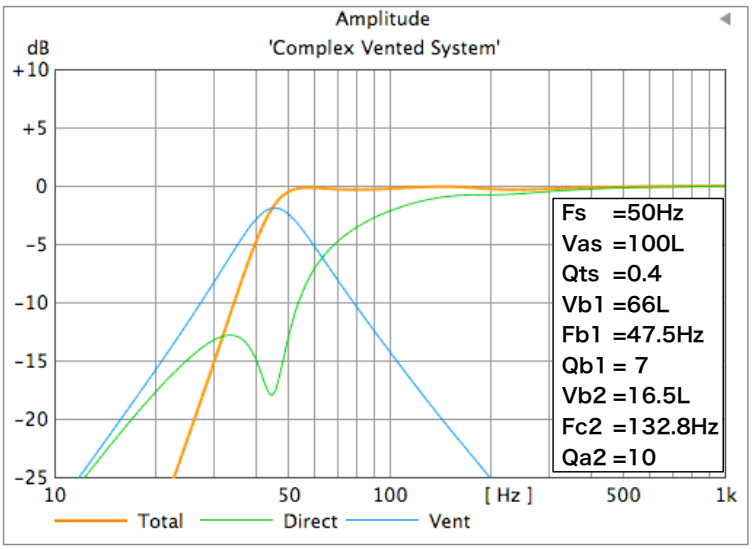


Fig19 Complex Vented Characteristic Optimum

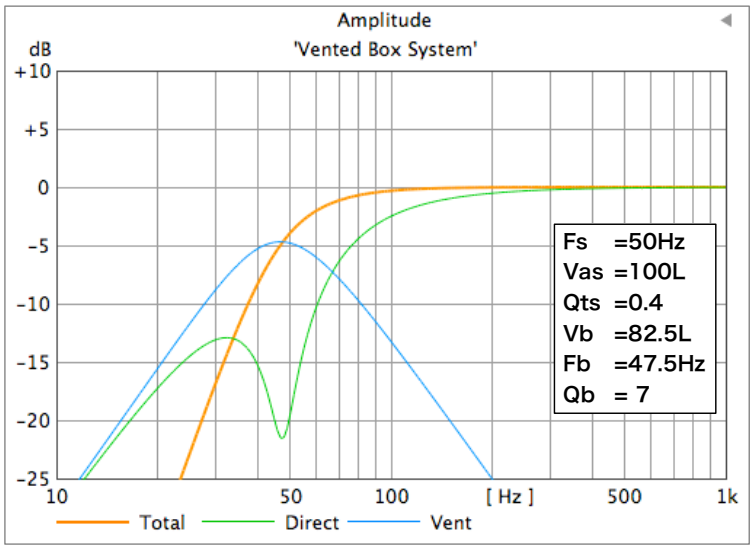


Fig20 Same Vb・Fb characteristics at Vented

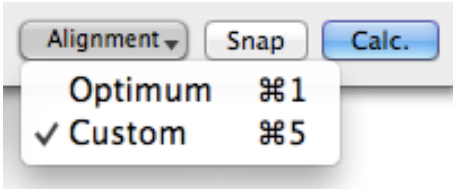


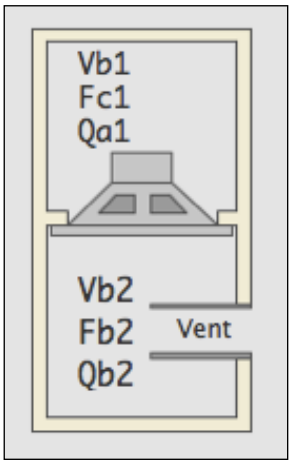
Fig21 Complex Vented Alignment

Although it is an irregular method it may be possible to cut the mid-high range sound leaking from the vent and improve the sound quality by passing the low-pass filter only to SP1. The front and rear two SPs are basically connected in parallel.

2. Band Pass System

A Band Pass system is a method in which the speaker unit is not visible from the outside and is built inside. It becomes a characteristic that decreases with frequency. It is so called because its characteristics are equivalent to those of band-pass filters in electronic circuits.

2－1. Kelton System



The Kelton method is a method that uses only the output from the vent as a result of attaching SP to the partition of the closed box and the vented box as shown in the left figure and has long been called ASW (Acoustic Sub-Woofer).
Even now there are many products such as add-on subwoofer and 2･1ch. As an advantage since the output has a bandpass characteristic it is possible to expand the low range simply by adding it without modifying the existing equipment. The disadvantage is that the efficiency will be low so it will be necessary to add a power amplifier for Kelton and if you want to use 2･1ch you will need a low-frequency mixing circuit for L and R and matching with the mid-high. It makes me want to put in a high-cut/low-cut filter to achieve that.

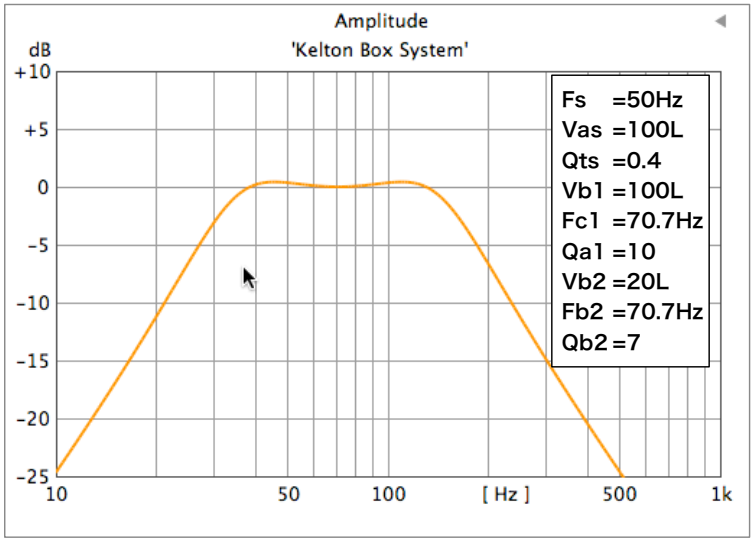


Fig22 Kelton System characteristics Type1

I would like to add a low-cut filter at least to cut the low range of the mid/high range SP to eliminate the overlap with Kelton and to protect the input of the mid-high range SP.
In addition the internal mid-high frequency components leak from the vent, but it may be said that the advantage is that the leakage can be reduced by using the high-cut filter.
Such processing cannot be done with the normal vented method. The design point of the Kelton system is to select a unit with parameters that match this system and to increase the volume of the sealed part as much as possible to lower the tuning frequency of the vented part and lower the playback band. By entering the volume “Vb1” in “Closed Volume” of Alignment “Fb2” is also changed at the same time. When Fc1=Fb2, the characteristic becomes flat. Depending on the unit the volume of the vented part may be too small to make it realistic so be careful.
The production article has been uploaded to our website so I think it will be helpful.

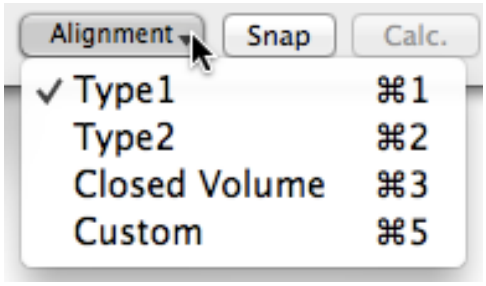
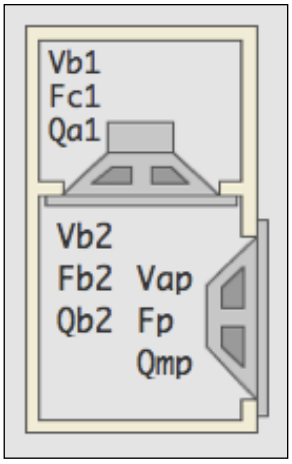


Fig23 Kelton System Alignment

2－2. Passive Kelton System



Passive Kelton System is a method in which a passive radiator (PR) is attached instead of the vent of the Kelton System mentioned above. The concept is almost the same as the Kelton method but there are characteristics and quirks unique to PR so caution is required. The advantage over the Kelton method is that there is no leakage of the internal mid- high frequency components and only radiation from the PR can be obtained and there is no air column resonance due to vents and a straightforward high-frequency roll-off can be obtained so there is no need for a high-cut filter and sound quality may be improved as well.

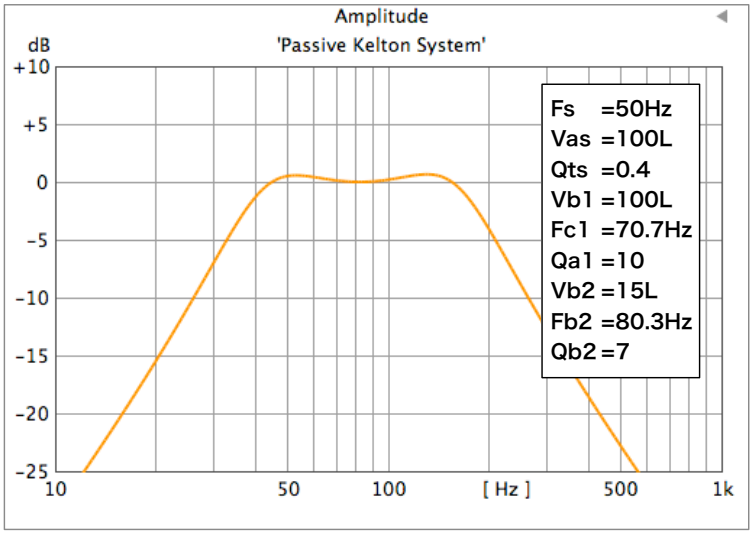


Fig24 Passive Kelton characteristics Type1

The disadvantage is that the PR cost increases and it is difficult to find a suitable PR like the high pass type. Depending on the product there are things that can change Fp by adding weights, and at this time adding weights will lower Fp but Vap will not change. It seems that the diameter of the basic PR should be the same or larger than that of the SP unit and there are many cases where one or two sizes larger are suitable. It may be possible if two PR units are used. Similar to the Kelton system if the volume of the sealed part (Vb1) is increased the characteristics will shift to the lower side. How to take in PR unit data is the same as 1-4 Passive Radiator System. Alignment is Fig25.

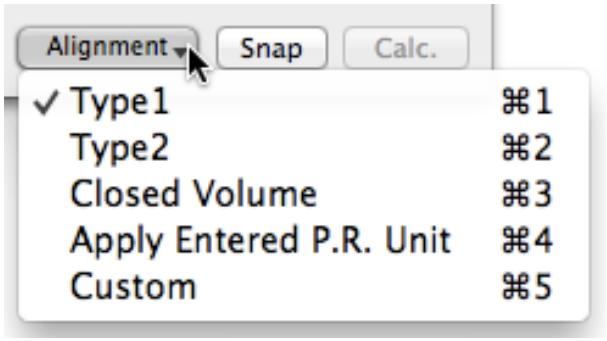
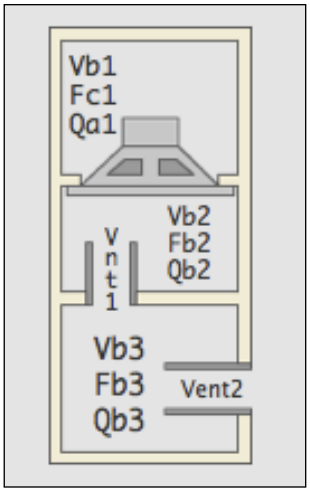


Fig25 Passive Kelton Alignment

In recent years, it has become easier to obtain various passive radiators so I'm thinking of using this system for my next subwoofer. We believe that the Kelton type subwoofer is simple and easy to make and that there are few failures.
⌘3 "Closed Volume" is an alignment that optimally adjusts other parameters when the closed volume is arbitrarily entered. The same is true for the aforementioned Kelton System. Please use the "PR_Calculator.app" posted on the "DOWNLOAD" page of this site to calculate the additional mass (grams) for the desired Fp.

2－3．Serial Kelton Type1 System



It is a modified Kelton type with a double bass reflex (Serial Vented System) attached to the lower structure. As with Kelton increasing the closed volume will shift the characteristics to the lower side. The drawback of the Kelton type is that the low frequency limit depends on the closed volume.
This time we revamped the alignment of this Serial Kelton Type 1 and the next Type 2 to reproduce lower frequencies. There are five parameters Vb1, Vb2, Fb2, Vb3 and Fb3 that are related to the changeable volume and tuning frequency. However, the total capacity of the three is rather large, so it may not be very practical from that point of view, but it may be an interesting system to try and challenge yourself. The bandwidth is about 2.74oct.
The dip of Vent1 is Fdip = Fb3 (70Hz).
In addition the parameters of the units used in this explanation are different from the real ones for the sake of clarity and the characteristics of the actual units are shifted to the lower side where they can be used as a low frequency system.
Mr. Tetsuo Nagaoka who researched it announced it under the name of his "Double Resonance Woofer".
Alignment is Fig27.
Since this method is complicated the alignment of "Closed Volume" is not set but it is a future task.

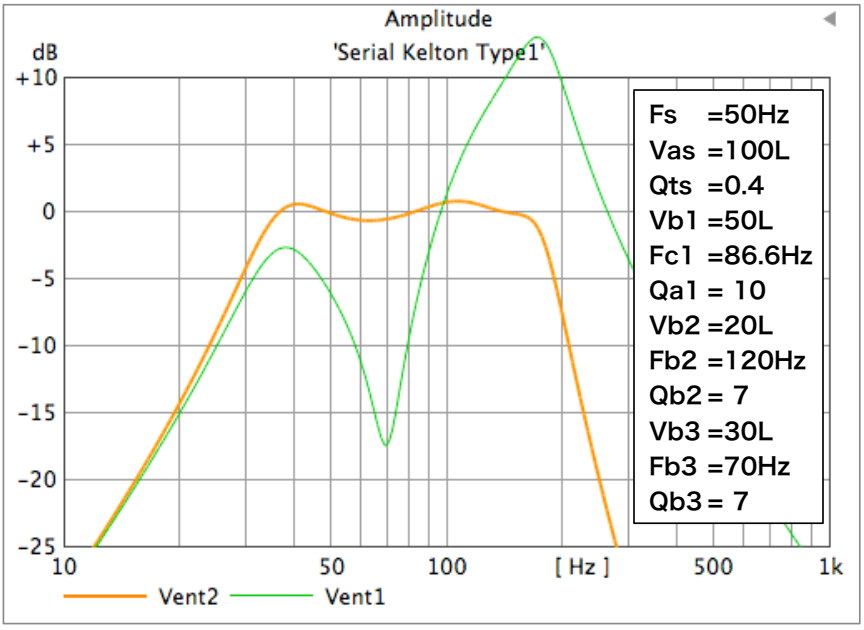


Fig26 Serial Kelton Type1 （⌘ 1） characteristics

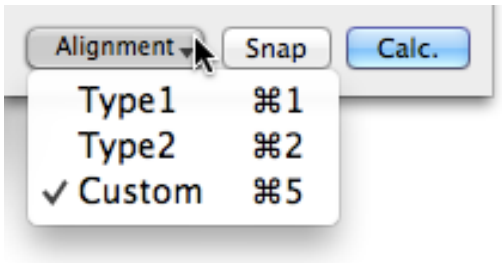
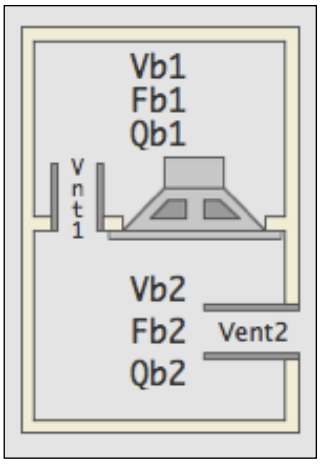


Fig27 Serial Kelton Alignment

2－4．Serial Kelton Type2 System



This is also a variation of the Kelton type but it has a shape with a vent between Vb1 and Vb2.
It can be seen that the dip in the Vent1 characteristic shows that the entire system resonates at one frequency.
The dip frequency is Fdip=Fb2/(1+Vb1/Vb2)$^{0.5}$=46.1Hz
Alignment Type1 has almost the same bandwidth (about 2.74oct) as Serial Kelton Type1 mentioned above.
Compared to Serial Kelton Type1 the total volume is about 90% so this one can be made a little smaller and the efficiency is about 0.5dB higher. The 2-cabinet system with one SP unit seems to have the best volumetric efficiency among the band-pass types and can reproduce low frequencies with a small volume and wide bandwidth.
However when designing the vent it becomes difficult to compromise between the diameter and the air vibration velocity inside the vent.

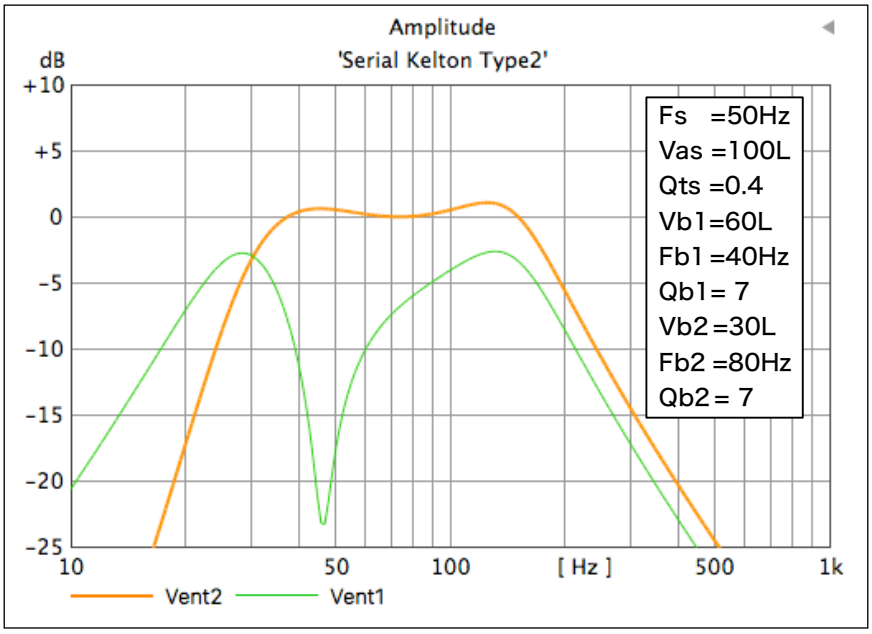


Fig28 Serial Kelton Type2（⌘１）characteristics

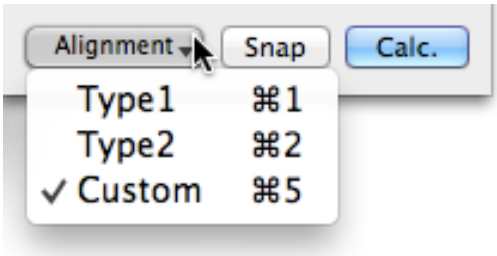
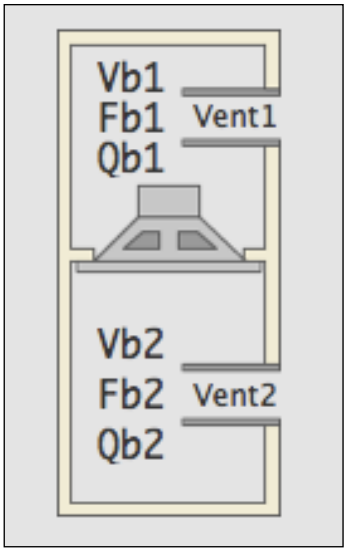


Fig29 Serial Kelton Alignment

In the band-pass type there is a trade-off relationship between bandwidth and efficiency which is the same as the GB product of operational amplifiers and the acoustic theory of SP is the same.
There are four degrees of design freedom Vb1, Fb1, Vb2 and Fb2 which makes it difficult but it seems relatively easy to manufacture as it is almost the same as the double bass reflex (Serial Vented System).
As with Serial Kelton Type1 this method has not been sufficiently analyzed so it will be a future issue. Alignment is Fig29.

2－5． Twin Vented System



It may be better to call this method a tandem system. I remember seeing it frequently in magazines about 30 years ago. Mr. Tetsuo Nagaoka also announced it under the name of "Push Pull Woofer" and BOSE also made it under the name of Acoustimass. (For professional use it still exists.) I remember seeing a photo and blueprint of a fixed subwoofer in a music hall in the United States installed in place of the side speakers. In the United States it seems that DIY challenges have been made even for equipment sound so it seems that the practicality is high for the DIY group. However in the characteristic example of Fig30 Vb2 is quite large as his 200Liter so it tends to be too large for home use regardless of equipment use.

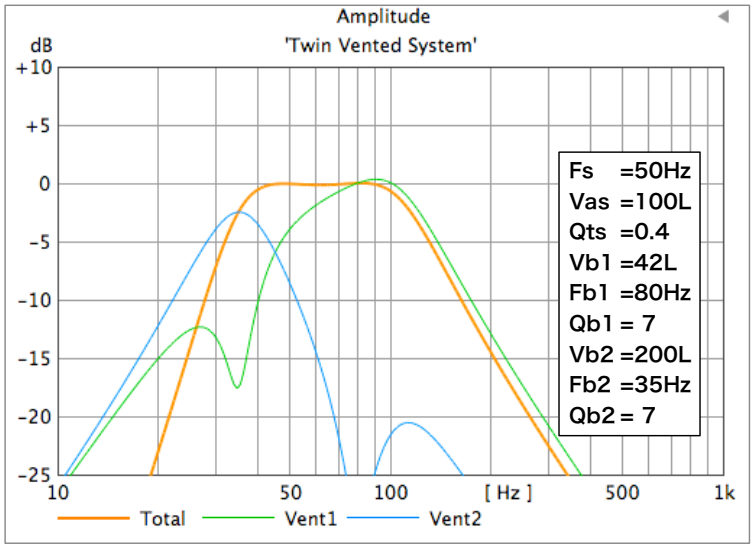


Fig30 Twin Vented characteristics (⌘1)

As a countermeasure, if Vb2 is set to 60 to 80%, the bandwidth will be narrowed, but it can be done within the practical characteristics, but it is still 50Liter less. (Fig31)

In order to align by itself is it possible to adjust the interval between Fb1 and Fb2 increase/decrease Vb1 and Vb2 at the same rate or increase/decrease Vb2 alone?

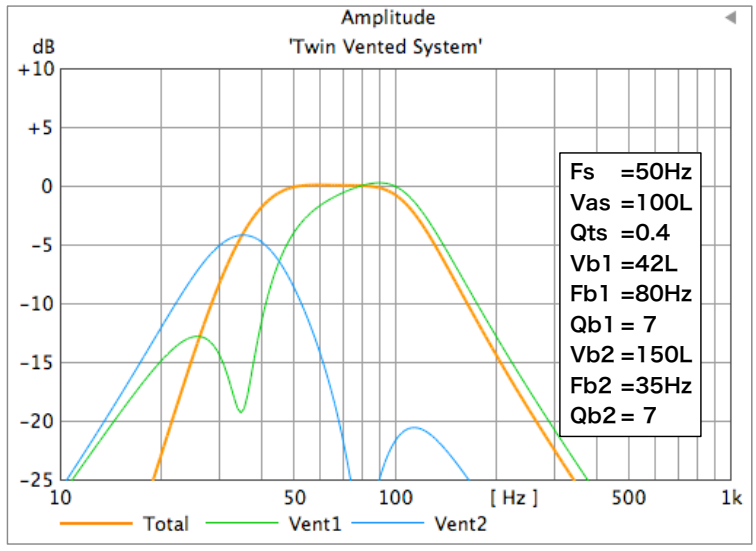


Fig31 Twin Vented characteristics (Vb2 -50L)

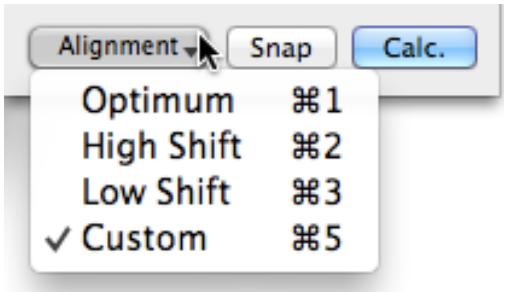
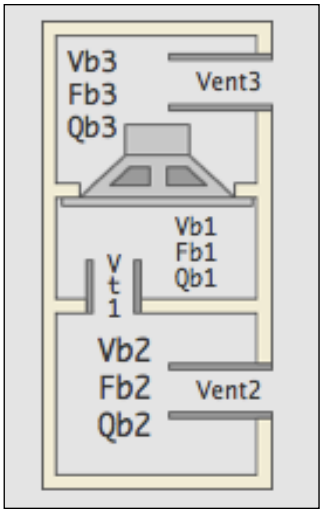


Fig32 Twin Vented Alignment

By the way, the Vb1 side and Vb2 side are opposite in phase on the front and back of the SP, so if the capacitance and frequency on both sides are the same, they cancel out and become silent in principle. Alignment is Fig 31.

High Shift and Low Shift are the characteristics of translating the frequency.

2－6．Twin Serial Band Pass System



A bass reflex and a double bass reflex are attached to the front and rear of the SP unit.
There may be one somewhere, but I've never seen it before so I'll just say it's the author's original.
However I think that it is quite troublesome to produce a box with this structure.
The point to note in designing is that if you design it easily it is easy for him to have dips in the characteristics as shown in Fig34.
Other band-pass methods do not cause such dips even if they are designed easily but they do occur due to structural reasons so be careful.
Fig33 shows a nice adjustment of the parameters to cancel out the dip.
It is recommended for those who want to challenge difficult systems because the playback band is relatively wide compared to conventional band-pass types.
Alignment is Fig35.
⌘2 Dipped corresponds to the characteristics in Fig34.

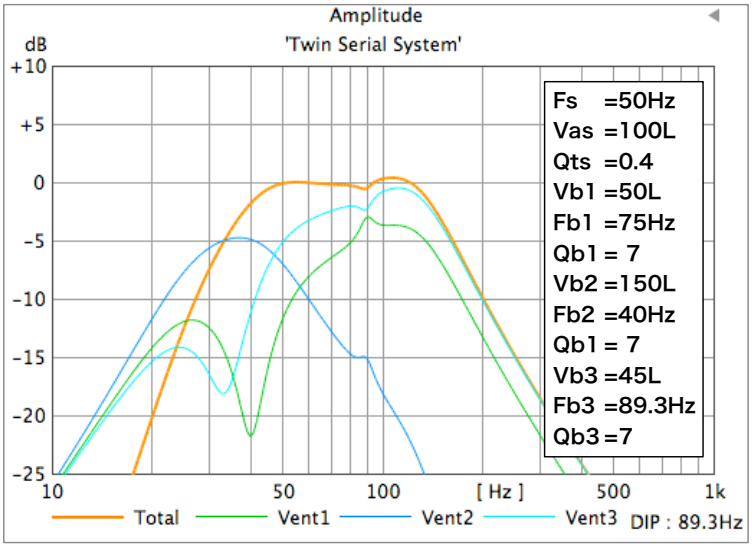


Fig33 Twin Serial System characteristics (⌘1)

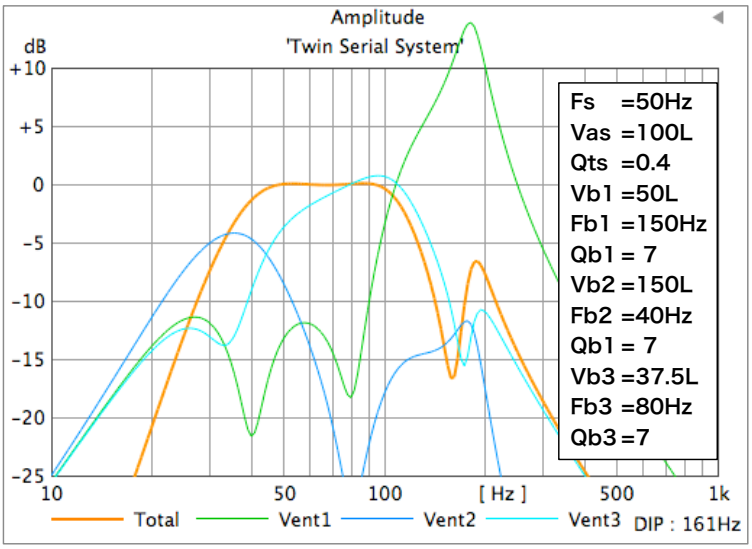


Fig34 Twin Serial System characteristics (⌘2)

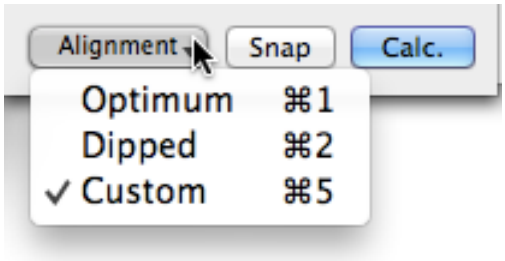
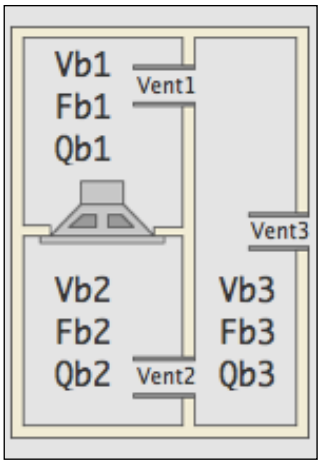


Fig35 Twin Serial Alignment

2－7．Delta Vented System



I named it delta vented because the vent arrangement is triangular. It seems that Mr. Tetsuo Nagaoka also came up with the idea, but it seems that it has not reached production. BOSE also made a subwoofer under the name Acoustimass. I was impressed by the demonstration machine which allows you to see the internal structure with a skeleton (acrylic?). The basic structure is that Vent1 is tuned high Vent2 is set low and Vent3 (output) is set in the middle to obtain bandpass characteristics and it is characterized by wide band characteristics. Even if Vent1 and Vent2 are exchanged they will have the same characteristics. It is also an advantage that the total volume is smaller than the above-mentioned systems in spite of having three volumes. It will be difficult to make but he has a proven track record with BOSE so I think it's worth trying DIY. I don't know what kind of volume ratio BOSE has but I remember using a unit of 16 cm or less (high Fs) so even a relatively small unit can play to the lower end.

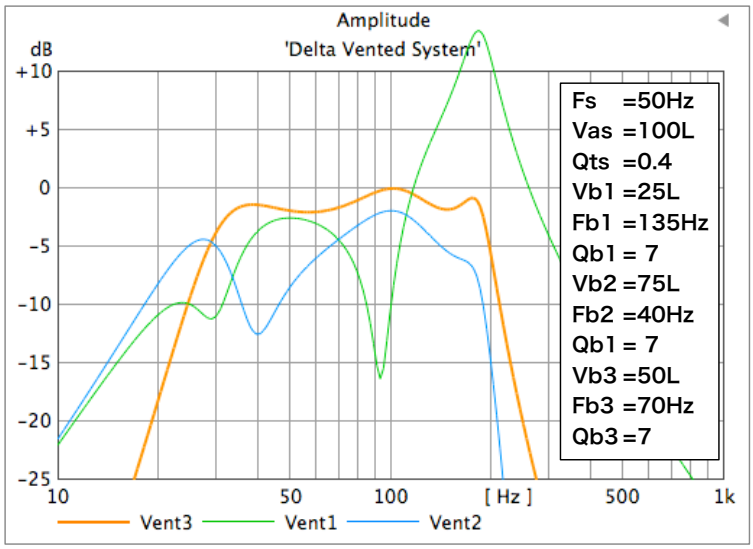


Fig36 Delta Vented System characteristics (⌘1)

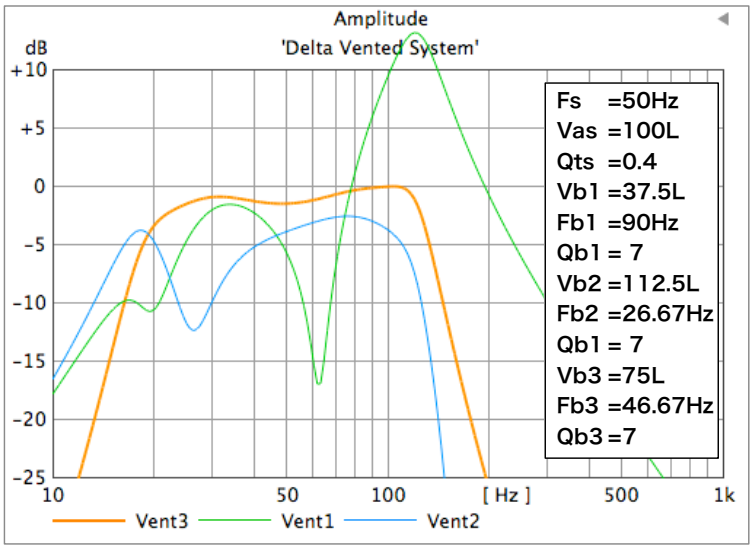


Fig37 Delta Vented System characteristics (⌘3)

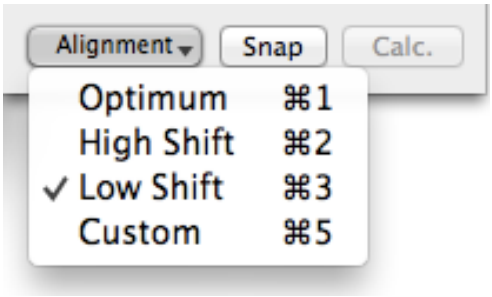
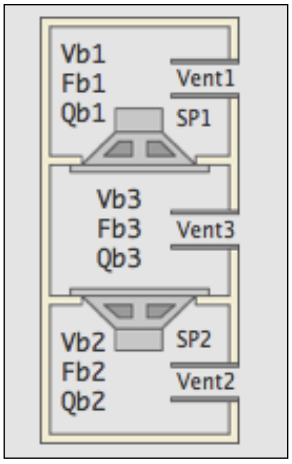


Fig38 Delta Vented Alignment

Alignment corresponds to Fig38 and characteristic ⌘3 of Fig37 corresponds to Low Shift. Alignment in this case is obtained by multiplying the Optimum value by 1.5 for Vb and dividing Fb by 1.5. It is better not to change the ratio between Vb1 and Vb2 and Vb3 too much.

2－8．Triple Vented System



This is a system that uses 2 units and uses the output from 3 vents. Although it is rarely seen for consumer use it is occasionally seen in professional sound equipment. After all it seems that the high power by using two matches the professional specification. As a way of thinking there is a method of tuning each of the three vents differently and it has a method of tuning Vent1 and Vent2 the same but in this case it will have the same characteristics as the Twin Vented and CP will be better for high power. In addition the above-mentioned it has a method of exchanging the reproduction band of the set of Vent1 + Vent2 and Vent3 but the total volume is the same. This Alignment can be reproduced with ⌘1 and ⌘2. A way to tune the three differently is built into ⌘3 and ⌘4. These Alignments make it possible to obtain a very wide band but also increase the volume that covers the lowest frequencies. Not only in the world of speakers there is a trade-off relationship between low-frequency limit and efficiency/volume and it cannot be helped in terms of the laws of physics. (GB product (Gain x Band width) constant rule) A unit with the same diameter and a low Fs is a physical phenomenon in which the efficiency decreases. Units with low efficiency also require a large cone stroke (Xmax). Alignment is Fig41. This concludes the explanation of the 16 types of methods but I plan to add them to the Archives as needed if there are new discoveries or ideas.

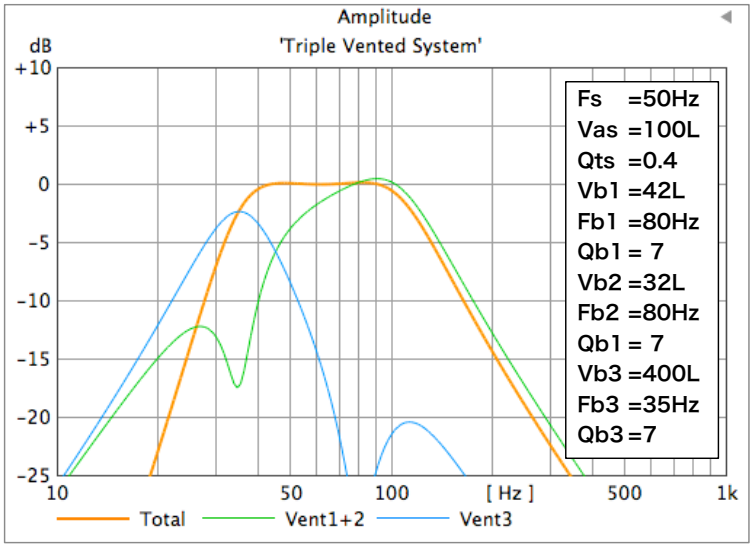


Fig39 Triple Vented System characteristics (⌘1)

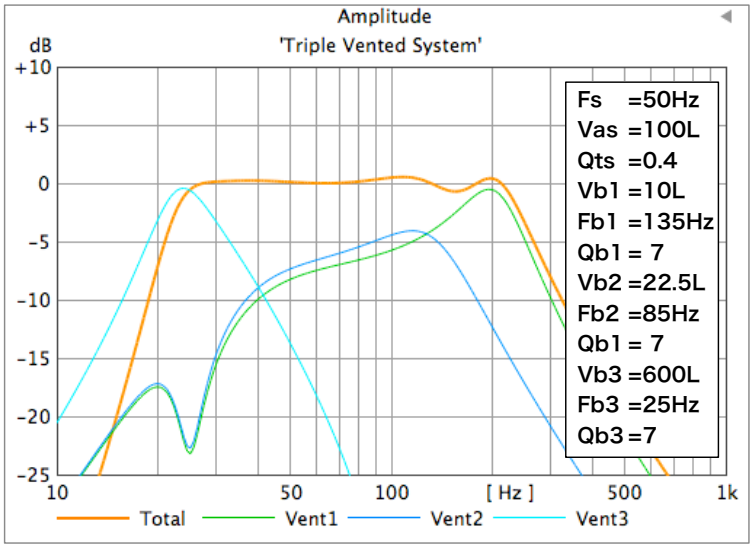


Fig40 Triple Vented System characteristics (⌘4)

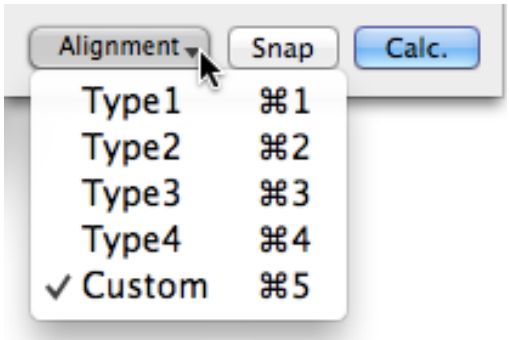


Fig41 Triple Vented Alignment

Reported by Yoshiyuki Hasegawa（長谷川 義之）：

2019/04/01—2020/06/01—2021/07/01—2023/02/18