

Development of Premium Subwoofer based on Time Domain Theory

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Abstract

With the adoption of a new approach, Time Domain theory, which is completely departing from conventional concept, ECLIPSE TD series have earned high reputation since its debut in April 2001, not only for home use but also for various other uses. April 2006 saw the release of new ECLIPSE TD audio system, with a large subwoofer uniquely featured with two built-in 25cm-aperture speaker units. This new ECLIPSE TD audio system comes as a combination of a new subwoofer and conventional speakers, and has been introduced as a representation of a completion of the theory that lies behind all ECLIPSE TD audio systems. The sound quality was highly praised in audio magazines upon its release and was granted various top-class awards among all the audio systems available on the market. This paper describes unique structure and technologies adopted for this subwoofer, while providing background of the development and comparisons with the conventional subwoofer.

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Introduction

Since its release in April 2001, our home audio systems, ECLIPSE TD series, have been highly praised in audio magazines and others. They have now been used widely not only by audiophiles but also by worldwide top artists, while being used regularly in the top studios throughout the world.

The conventional speaker units (TD series) were created with the aim to reproduce the movement of air more faithfully, by employing full-range speaker system, meanwhile, by employing a single-unit speaker for reproducing all ranges of sounds. However, this time, we have adopted the technology based on Time Domain theory in the bass region for our new subwoofer, in order to cover as wide bandwidth as possible. As a result, the newly developed product, as a stereo system and a surround sound system, can cover almost full frequency bandwidth by being placed together with our conventional speakers.

This paper shall explain Time Domain theory, which is a central theme for our ECLIPSE TD audio systems, while giving a brief overview on our product technology to realize this theory. Then it shall go on to explain our newly developed technology for our new subwoofer as an improvement of our conventional technology, and finally, introduce some of the examples of high reputation we earned in relation to this product.

2 Current Circumstances for ECLIPSE TD Series

2.1 Product Structure of the TD Series

The product structure of all the ECLIPSE TD audio systems thus far has consisted of four full-range speakers (TD712z, TD510, TD508II, TD307) and one subwoofer (TD316sw). All these models have been developed based on the same concept in sound creation.

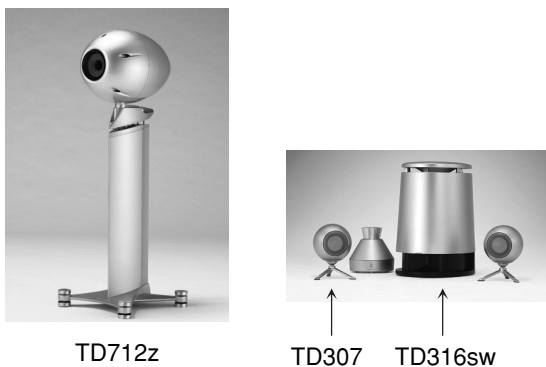


Fig.1 Photos of ECLIPSE TD series

2.2 The Concept Underlies ECLIPSE TD Series

Many of existing audio products have been created with a focus on providing "a solution to reduce sound distortion and be able to provide as widely as possible from low tone to high tone". This focus led us to put our efforts into creating a sound impression in consideration of "frequency characteristics." On the other hand, we have come to attach an importance to the new concept,

Time Domain theory, for the ECLIPSE TD series, trying to provide a solution to "reproduce movement of air as accurately as possible." In the past, there were some theories and products that paid attention to time, yet, this Time Domain theory pays further thorough attention to time, and consider that the accurate reproduction of input waveforms within time domain are ideal for sound reproduction. Then, in order to verify the accuracy of waveforms, impulse response is used. Impulse includes all the frequency components; therefore, if impulse can be reproduced accurately, any waveforms can be reproduced.

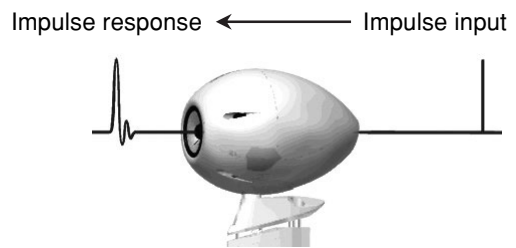


Fig.2 Impulse response

Here, we shall explain impulse reproduction from an aspect as "movement of air". Below shows the modeled appearance of waveform of a sound and its particles in the air. The condition ①, where there is no sound, shows the particles uniformly in place. However, the condition ②, where there is a sound such as sine wave, shows irregularity, some sparse portions and dense portions in terms of particles. Finally, under the condition ③, it goes into high-compression instantly, revealing the difficulty in accurate reproduction of a sound. However, at the same time, this means that if this difficult impulse waveform can be reproduced as accurately as possible, any waveforms can be reproduced.

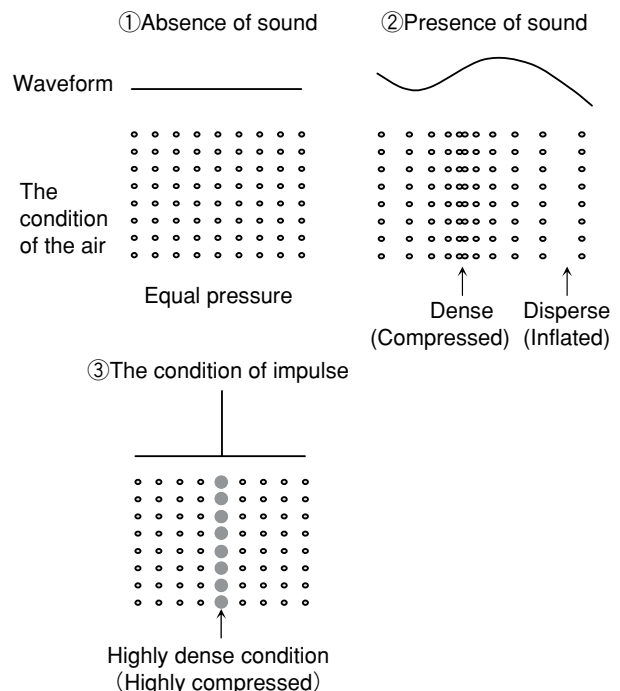


Fig.3 Waveforms of sound and the conditions of air

2.3 Unique Technique Used for ECLIPSE TD series

One major cause that a waveform gives an adverse effect on its accuracy of sound reproduction, occurrence of "reverberation" due to speaker enclosure is noted. There are three main technologies that we have employed to overcome this problem of "reverberation", corresponding to their major factors: vibration, reflection, and resonance. Our technologies mentioned below are all based on the concept to reduce the volume of these three factors. (Fig. 4)

1. Grand Anchor

According to the conventional method, a speaker unit is mounted directly onto the enclosure. However, with the new structure, a speaker unit (TD series) is supported by a stand indirectly through a diffusion stay and a grand anchor, which helps to reduce vibrations (occurrence of unnecessary sound) each other as a reaction.

2. Floating Structure

Furthermore, a speaker unit is separated from the enclosure; thus prevents the occurrence of unwanted sound generated by vibration transmission.

3. Eggshell Enclosure

Both the standing waves (resonance) generated from the interior of enclosure and the diffracted effect (undesired reflection) caused by round baffle are prevented by the eggshell enclosure.

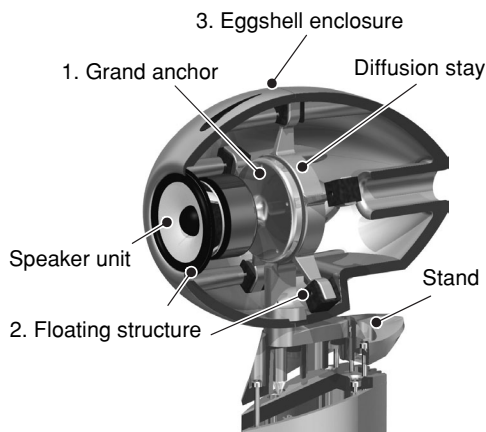


Fig.4 Internal structure of TD712z

2.4 Sound Characteristics of ECLIPSE TD Series

ECLIPSE TD series, aimed at reproducing most accurate waveforms possible, shows the following three major sound characteristics.

1. The sound clarity is higher

(Minute sounds that were covered up previously by unwanted sound are now detectable by the human ear.)

2. The impression of speed and tightness in a sound are heightened

(The rise time and fall time of playback are both shortened.)

3. Increased spatial reproducibility

(The listener is now less aware of the existence of speakers, which means they enjoy sound impression as if it is coming directly from the space to their ears.)

Conventional ECLIPSE TD series, with these distinguished sound characteristics, have been praised highly

in various magazines in Japan, while receiving a "FIVE STAR" rating in "What Hi-Fi?", a popular audio magazine in the United Kingdom. Moreover, the recognition reached to the extent that the series have gained popularity among top artists and have been introduced into top studios. For example, John Williams, the classic guitarist, now uses ECLIPSE TD series regularly as Public Address system when he holds a concert.

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Development Background

3.1 Development Background of New Subwoofer

High level of spatial reproducibility, a sound characteristic of ECLIPSE TD series, is more noticeable when a surround sound source is obtained, where the sound exists in the surrounding area of listeners. However, our lineup did not include a subwoofer for the top-end model, TD712z, in order for our users to be able to listen to 0.1ch sound as a part of the most popular 5.1ch surround sound system. Therefore, there has been a consistently strong market demand on the availability of a subwoofer for TD712z. This led us to start developing a high-power subwoofer that responds to the market requirements and beyond.

3.2 The Problems over Conventional Subwoofers

We had successfully controlled unnecessary vibration for TD316sw (the subwoofer for the current ECLIPSE TD series) by adopting a floating structure and attaching a grand anchor, whose aperture were only 16cm, relatively small in size. This is due to the need that the subwoofer would have to be used together with TD307, which are 7cm-aperture speakers. Under this circumstance, 16cm-aperture speaker units seemed optimal to be adopted. (Fig. 5)

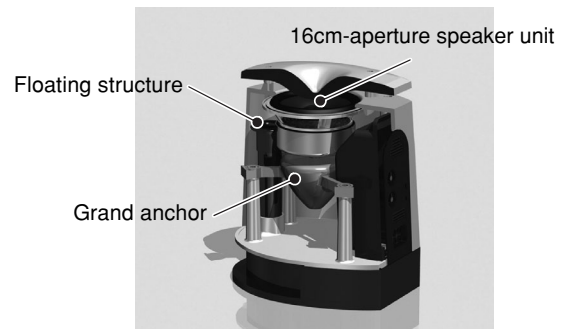


Fig.5 Internal structure of TD316sw

However, the subwoofer we were aiming to develop this time would need approximately 30cm-aperture to achieve the required result. Thus, the following challenges are assumed that may arise by adopting such a large aperture for speaker units.

1. Improvement of speaker units in transient responses

The bigger the aperture of a speaker unit is, the heavier the weight of a vibration system becomes, which would then lead to a deterioration in quality in transient responses.

2. Suppression of the increase in reaction of speaker units

The bigger the aperture of a speaker unit is, the more

reactions of a speaker unit would become generated. This means that in order to suppress these reactions, it would require an extremely heavy anchor, thus, it would naturally lead us to decide bigger outside dimension for our prospective products, in order to secure the sufficient space to store the anchor in an enclosure. Naturally, the weight for an entire subwoofer would become extremely increased.

4 General Outline of New Subwoofer

In order to overcome the problems mentioned in Section 3.2, the following measures were considered and examined in terms of their actual effects:

1. The development to improve the speaker units in terms of transient response
2. The development of a structure for a speaker unit that can reduce reactions of speaker units

The development process shall be described in detail in the following part of this section.

4.1.1 Improvement of Speaker Unit in Transient Response

Under the conventional concept, it requires about a 38cm-aperture speaker unit to extend the playback frequency range in the bass region. However, the usage of such a large aperture speaker unit will result in the speaker unit's low performance in transient response, which causes a delay in a sound playback in the bass region when being used together with other speakers, such as TD712z. In order to secure the playback frequency range in the bass region, while heightening the level of performance in transient response, two 25cm-aperture speaker units, which are relatively small for this type of subwoofers, are adopted. This means that we secured the space that was originally needed for a 35cm-aperture speaker unit, while also realizing a sound playback with a better transient response.

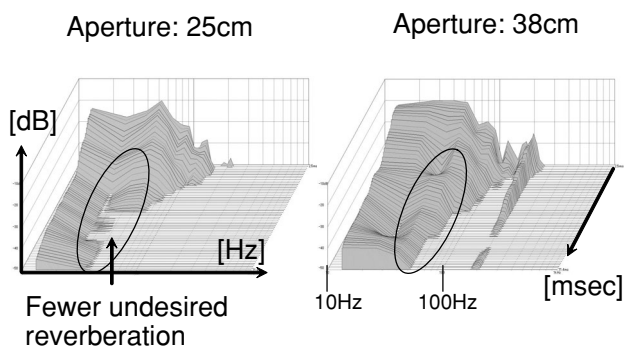
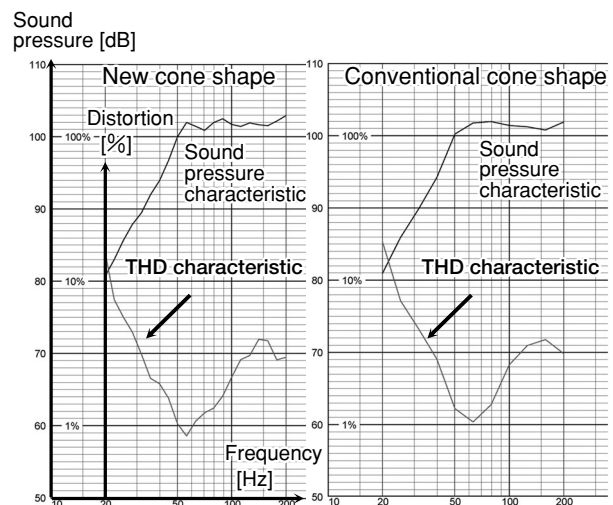


Fig.6 Comparison of cumulative spectra (at the falling edge)

4.1.2 Cone Shape

Conventional speaker units (TD series) have been made in curved cone shape, but this time, for new speaker units, the cone shape has been optimized. As a result, sound distortion at the time of playback was reduced in the bass region, which accounts for up to approx. 30% of the distortion for the conventional speaker units (TD series). (Fig. 7)



The distortion is reduced at the arrow part.
Fig.7 Comparison of Distortion (THD) Characteristics

4.2.1 Structure to Suppress Reactions of Speaker Unit

In order to suppress the reaction generated when the speaker cone presses the air, the conventional speaker units (TD series) required a grand anchor, whose mass is several hundred times bigger than that of the speaker unit's vibration system. (Refer to Fig. 8)

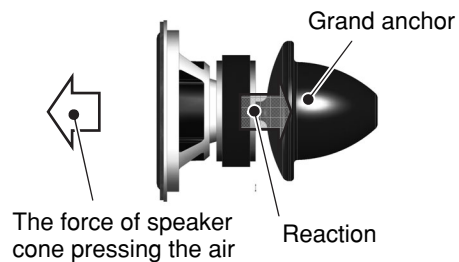


Fig.8 Conventional structure

However, this means that an extremely huge 'grand anchor' will be necessary if the same structure is employed by applying for 25cm-aperture speaker units. Thus, we have adopted a new structure for the new subwoofer that can cancel out the reactions from both sides, by binding the two speaker units' backsides with aluminum shaft. The new structure requires two speaker units that are joined opposite each other, which, due to this structure, resulted in the following. (Fig.9)

- 1) Vibration through overall enclosure are reduced into minimum, because two speaker units absorb each other's vibration reaction
- 2) Gross weight of the products are reduced, because the 'grand anchor' used for the conventional speaker units (TD series) are now unnecessary.

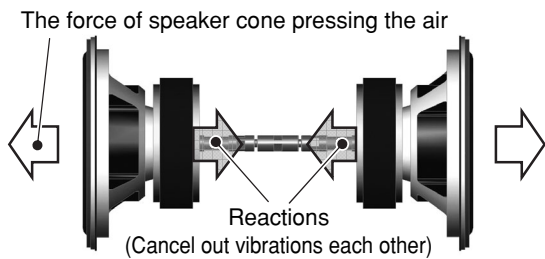


Fig.9 Structure that two back sides jointed facing opposite

4.2.2 Floating Structure

Furthermore, we adopted a floating structure for a new subwoofer in order to heighten the level of control effect over undesired vibration, as it was already adopted for TD712z and others. However, unlike conventional speaker units (TD series), we have adopted the structure without a 'grand anchor' and a diffusion stay for new subwoofer. Furthermore, we developed a new structure that can fixate the speaker units using the floating structure.

Firstly, an aluminum shaft, which joins together the speaker units facing opposite each other, is fixed in a way that it is received by a hole made through a supporting plate inside the enclosure. Secondly, fiber-material buffers are placed on the respective contact part of aluminum shaft with the two supporting plates. Furthermore, two speaker units are touched with the frame and the enclosure indirectly through resin-material buffers. Thus, the speaker units and the aluminum shaft are both separated from the enclosure, which we now call "a floating structure". (Fig.10)

We have adopted 30mm-thick MDF, designed to control undesired vibration as well as resonance, which will be generated if a hard case is used.

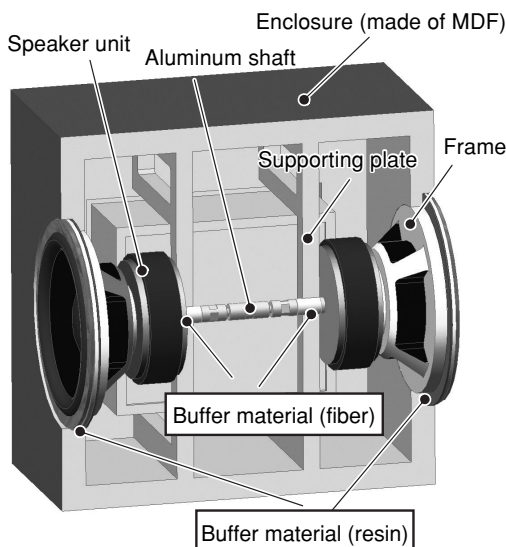


Fig.10 Floating Structure

By adopting this structure, transmission of vibration from speaker unit to enclosure can be suppressed. As a result, 93% of the vibration on the wall of the enclosure is now reduced; this means new products come with only 7% vibration of that of conventional speakers (38-aperture

subwoofer sold as aftermarket product). (Fig. 11)

(Below is the result observed when pink noise was reproduced at the level of 90dB SPL in our "Studio f").

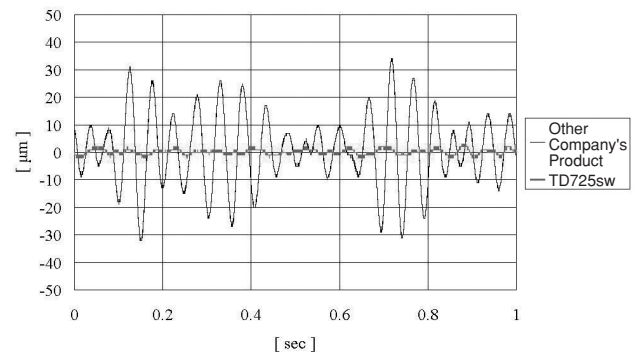


Fig.11 Comparison of the enclosure vibrations

4.3 Major Specifications

The appearance (Fig.12) and the major specifications of TD725sw, are shown below.



Fig.12 Appearance (with Remote Control Unit)

- Speaker units: 25cm-aperture × 2 units
- Output of built-in amplifier: 500W
- Frequency response: 20Hz~200Hz
- Outline dimensions: W517 × D503 × H473 (mm)
- Mass: Approx. 42kg

The appearance of our new subwoofer is cubic in shape, which is different from the image of other products for ECLIPSE TD series. However, we adopted this shape, as it is efficient in securing the maximum volume due to its less influence from standing waves generated inside the enclosure, or diffraction phenomena generated in the corner of an enclosure at 200Hz and below, the playback range of subwoofers.

Moreover, highly efficient digital amplifier is adopted as built-in amplifier for new subwoofer. As a result, it has a capacity for sufficient sound volume (500W as maximum rated output), while saving electric power during non-operating time.

MDF stands for "Medium Density Fiberboard". It is a material that is made of wood chip. First, wood is decomposed into a fiber form, and the fiber chips are glued together. MDF possesses appropriate amount of internal loss, thus, it tends not to cause undesired reverberation.

5 Development Result

TD725sw has earned high recognition since its release in April 2006, as a product sharing the same acoustic characteristics as one of ECLIPSE TD series.

5.1 Audio Quality

We have achieved the following two objectives in terms of audio quality.

1. The subwoofer's transient response ('stop and start' rapid impulse motion) is very fast and exactly as we have aimed at, while the degree in its ability of expression in the bass region is very high, especially when the recording of percussion and string instruments are played.
2. The vibration on the enclosure is controlled to the extent that is not detectable even when touched by hands, the vibration transmission to the floors and other places by physical contact is small. As a result, the sounds are played at low-pitch tones with fewer noises. New products require less worry in regard to the method to be installed. Furthermore, they also require less worry in relation to the place they are installed, as they cause less sound leakage outside the listening room.

5.2 Reputation in Domestic and Overseas Magazines

The audio quality mentioned in Section 5.1 has resulted in earning a worldwide recognition. As of September 2006, new ECLIPSE TD audio system (or subwoofer alone) has been granted the following awards:

1. Magazine: "What Hi-Fi?" (United Kingdom)

Rated as five star (October 2006)

2. Ongen Publishing Co., Ltd. (Japan)

- Visual Grand-Prix 2006: Silver Prize
- First Prize for Subwoofer Sector
- Home Theater Grand Prize
- Critics Grand Prize

3. Magazine: "Hi-Vi" (Japan)

Awarded First Prize for Subwoofer Sector
(Best buy for Summer 2006)

6 Conclusion

As above, this paper has mainly introduced our newly developed subwoofer, while describing our product technology based on Time Domain theory.

Audio systems are the products that reflect individual tastes, since people, as individuals, may possess diverse preferences in audio quality. In other words, the accuracy of sound reproduction based on Time Domain theory does not necessarily mean that would meet the needs of all individuals. Traditional audio systems, with a focus on frequency characteristics, were the fruits of our efforts aimed at achieving a sound with frequency characteristics, a punch, and a full impact employing the powerful characteristics of audio systems that attract people. On the other hand, the products based on Time Domain theory have been created with the aim to achieve a natural audio quality. This natural audio quality, however, may give traditional audio enthusiasts an impression that the sound lacking a punch. In turn, however, it offers many other things, such as comfort, truly natural sound of music instruments, a clear and crisp sound as a result of speedy 'stop and start' that are considered as important by musicians, while also revealing the level of techniques employed during the performance.

This means that the listener can experience skills of worldwide top-class performing musicians at home. Thus, children who want to be a musician in the future and want to improve their level of their musical skills can be helped, while some music enthusiasts who want to enjoy live music can listen to the sound that is almost equivalent to the one in a concert. From this time on, our aim is to apply this technique not only for home use but also for vehicular use, while keeping in mind to develop a new product that may lead us to earn another worldwide recognition.

Profiles of Writers



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Entered the company in 1997. Since then, engaged in the development of milliwave radar systems, and then the development of speakers for home-use in 2001. Currently in the Acoustic System Planning Department of Audio Business Division, CI Group.



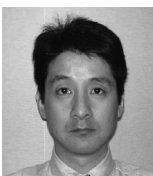
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