Development of Flat Panel Speaker for Personal Computers

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Abstract

As manufacturers develop space-saving PCs with thinner display panels, demand is also increasing for slimmed-down speakers, to unify the design and feel of the entire PC package. Together with NEC, Fujitsu began working on a thin-speaker solution in 1997. Applying technological expertise provided by the UK electronics firm New Transducer, the Fujitsu and NEC successfully developed and are now marketing NXT flat-panel speakers for the PC.

We took advantage of years of accumulated technology in quality sound reproduction - while also exploiting the anisotropic characteristics of materials from which the diaphram is constructed - to design a speaker that satisfies both size and quality requirements. The super-slim design is less than one-third the depth of present box-shaped PC speakers, and realizes a 13% reduction in width compared to conventional flat-panel speakers.

At the same time, we have attained the best sound quality among small NXT speakers by improving the diaphragm and equalizer.

The following report presents in more detail this high quality sound reproduction speaker, which is capable of satisfying the requirements of today's PC market.

1. Introduction

The use of the sound feature on personal computers (PCs) is becoming more common with the growing popularity of the Internet and software games. Consequently, more frequent PC speaker use is anticipated. In the meantime, demand is increasing for speakers offering a good balance in terms of sound quality, design, and cost.

Currently, PC speakers are mostly box-shaped speakers housing amplifiers. In spite of the hurdles presented by constraints on size and emphasis on desktop units, numerous superior products have been developed. Moreover, with manufacturers making headway in developing space-saving PCs with even thinner display panels in recent years, demand is also growing for slimmed-down speakers to maintain a sense of balance and harmony in terms of the design and "feel" of the PC package as a whole.

Conversely, it used to be difficult to develop slim speakers unsurpassed in terms of thinness, while maintaining sound quality. So far, a number of slimming techniques have been employed with the aim of creating thinner speakers. One of these techniques involves making the cone-shaped diaphragm of the speaker shallower. However, using this technique led to excessive distortion and sound pressure that was too low.

Against this backdrop, the NXT speaker technology announced in 1996 involved a new approach to the vibration modes of the diaphragm. To obtain superior acoustical characteristics from a flat diaphragm, the distributed mode had to be used in the most efficient manner possible. NEC and Fujitsu have already used this technological approach to market speakers for space-saving PCs. Recently, we developed a flat panel speaker for release as a new product by further slimming down its shape and by making improvements in terms of quality. These improvements are described in the sections that follow.

2. NXT Speaker

2.1 Features

NXT technology was developed by New Transducers Limited, a UK electronics firm that holds the patents to this technology.

The features of conventional speakers and those of NXT speakers are described below.

To generate sound waves, conventional speakers use the piston movement of a diaphragm to cause the air to vibrate, as shown in Fig. 1. With the outer rim of the diaphragm supported by a frame, the diaphragm center, which is supported by springs called dampers, is driven. To ensure that the diaphragm executes the piston movement while maintaining its shape, it is generally made in the shape of a cone so that it maintains stiffness in its direction of vibration.

As shown in Fig. 2, however, if the directivity is to be maintained, the high frequency sound pressure falls in directions other than the direction in which the speaker center axis points. Additionally, it is difficult to make cone-shaped diaphragms slimmer.

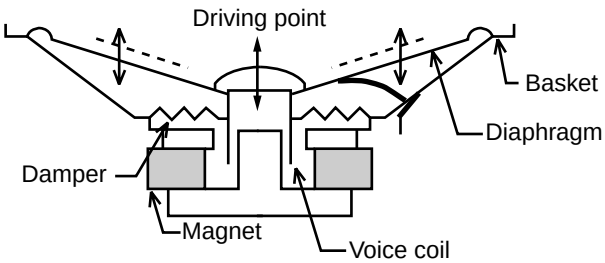


Fig. 1 Conventional speaker (cross section)

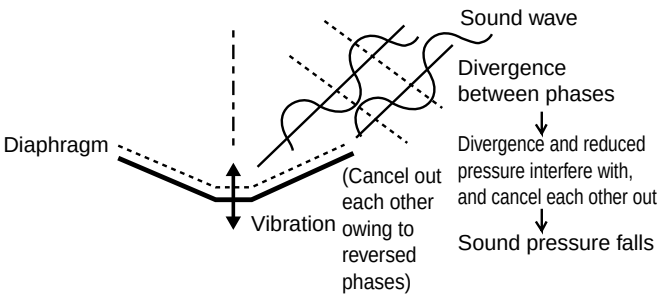
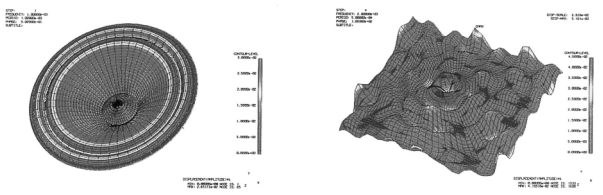


Fig. 2 Directivity

By eliminating all of the above-mentioned weak points associated with conventional speakers, NXT technology has made it possible to create slim speakers by using a flat panel for the diaphragm.

With NXT technology, vibrations are applied to specific points on the flat-panel diaphragm to generate bending vibrations in the diaphragm. At any frequency, numerous vibrations in random phases are distributed over the entire diaphragm. In other words, multiple-point sound sources are created over the entire diaphragm.



Conventional speaker (Piston vibration mode)

NXT speaker (Distributed mode)

Fig. 3 Vibration mode (simulation)

If the vibration points and the dimensions and materials of the diaphragm are optimally selected, no resonance point appears at a specific frequency, but multiple-point sound sources can be obtained on the flat panel diaphragm as described above. In a sound pressure that can be obtained by synthesizing multiple- point sound sources, fine peak-dips (peaks and valleys) appear in terms of frequency response due to phase interference among point sound sources. However, the lack of a specific large resonance point exerts no adverse effect on the hearing aspect, and thus flat sound pressure frequency response as a whole can be obtained.

Additionally, the NXT speaker provides broad directivity because the sound pressure does not fall due to the phase interference in the inclined direction shown in Fig. 2.

Furthermore, sounds radiated from both the front and rear of the diaphragm do not cancel each other out because they do not have a reversed-phase type of relationship as is the case with a conventional speaker. This eliminates the need for a speaker box, enabling us to slim down the speaker.

In short, NXT technology provides a flat panel speaker with good acoustical characteristics, by replacing conventional speaker technology under which a speaker diaphragm moves in a piston-like way to generate sound, with a distributed mode over the entire panel surface that is used efficiently.

2.2 Structure and Operating Principles

Fig. 4 shows the structure of a NXT flat panel speaker.

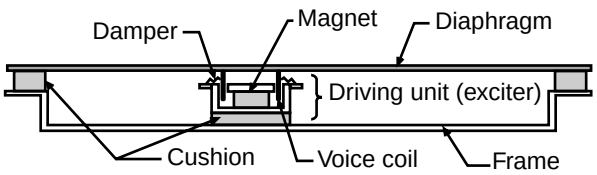


Fig. 4 NXT flat panel speaker structure (cross section)

The four points on the outer rim of the diaphragm (flat panel) are connected via the cushion to the frame.

The driving unit (exciter) that vibrates the diaphragm is cemented to the vibration location at the rear of the diaphragm. The vibration location is an optimal position used to generate a uniform distributed mode on the diaphragm, calculated on the basis of a design technique developed by New Transducers Limited.

The rear of the exciter is joined via the cushion to the frame.

The exciter has the same structure as that of the magnetic circuit and the voice coil in a conventional dynamic speaker. The exciter, upon receiving the input of amplifier output signals (sources of sound such as music), generates in the voice coil a magnetic driving force in accordance with the Fleming's left-hand rule.

The driving force is conveyed to the diaphragm, causing a bending vibration in the diaphragm. Consequently (if the requirements are optimally defined), the distributed mode described above occurs, moving the air to generate sound waves.

3. Goals and Challenges in Development

The goals of our product development efforts were improvement of sound quality and a slimmed down speaker.

(1) Improving the sound quality

For an NXT flat panel speaker, the acoustic characteristics are essentially determined if the diaphragm size and the vibration point location are defined on the basis of the calculation method established using NXT design know-how. For the product under review with a small diaphragm area, however, the design technique defined using the above know-how does not always apply. The desired characteristics cannot be easily obtained if we design a speaker on the basis of the prescribed method alone.

Thus, in developing this speaker, we considered how we would optimize the materials used for the diaphragm and the diaphragm size, how the diaphragm would be supported, and how electric circuits would be used for optimum tone control.

(2) Slimming

In NTX flat panel speakers, the diaphragm shape required to obtain good acoustic characteristics by generating uniform distributed mode over the surface of the diaphragm is predetermined in accordance

with a certain rule. However, we would not have been able to slim down the speaker by following the recommended NTX method because the diaphragm would not have been sufficiently long and narrow if we had.

Thus, we proceeded with our development efforts, considering how we would secure sound quality using diaphragm dimensions outside the scope of those recommended for the slimming-down process.

(3) Development target values

In considering our development goals, we defined the target values as follows:

- Output sound pressure level: 75 dB/wm or more
- Playback frequency band: 200 Hz to 20 kHz
- Sound quality evaluation point: 0.5 point improvement in a 1-to-5 scale, compared with a conventional NXT speaker for PCs
- Width: 100 mm
- Thickness (flat panel section): 30 mm or less

4. Examining the Speaker Specifications

4.1 Performance-Related Items

The following shows the major factors affecting the performance of NXT flat panel speakers.

(1) Diaphragm material (bending stiffness, plane density)
(2) Diaphragm size (area, aspect ratio)
(3) Position of the driving point where the exciter is joined to the diaphragm
(4) Diaphragm outer rim support position
(5) Support cushion hardness
(6) Exciter weight
(7) Exciter minimum resonance frequency
(8) Frame stiffness
(9) Frame rear opening ratio

The following describes some of those items we examined on a selective basis in achieving our development targets.

4.2 Diaphragm Material

(1) Material types

NXT flat panel speakers require a diaphragm made of a material that is light and has an appropriate degree of bending stiffness.

To obtain sound pressure, the diaphragm must be light and have a large area. To secure a broad playback frequency band, the diaphragm would require a large area.

Table 1 shows the diaphragm material types that can be considered as candidates and how they affect the sound quality.

Table 1 Diaphragm materials under consideration and how their use affects sound quality

Material name	Sound quality	Remarks
Polystyrene foam	Clear tone	Inexpensive and easy to procure
PET foam	Negligible distortion but low sound pressure	–
Polypropylene foam	Good quality but not so transparent. Low sound pressure	Poor adhesive characteristics
Polypropylene	Insufficient sound pressure. Gloomy sound. (Unacceptable)	〃
ABS	Insufficient sound pressure (Unacceptable)	Thin board not strong enough
Glass fiber	Insufficient sound pressure	Expensive
Carbon fiber	Well balanced sound	Expensive

For a large-sized product with a diaphragm area ranging from 0.5 to 1 m^2, some of the items shown in Table 1 can be selected on the basis of the sound quality targets. However, a PC speaker can have an extremely small diaphragm area of 100 to 150 cm^2, which severely restricts us in terms of the allowable cost of such materials. Accordingly, we are limited in terms of choices of materials that we can use for a marketable product. For the product under review, we have selected polystyrene foam with fine quality paper bonded on both sides.

We selected this material because it is light (specific gravity of about 0.05 to 0.1) and thus even a small diaphragm area is not likely to cause a low sound pressure. Additionally, the anisotropy of this material (having different stiffness in different directions of a board) is effective in realizing a slim shape. Furthermore, this material is low in cost and can be easily procured.

(2) Polystyrene foam

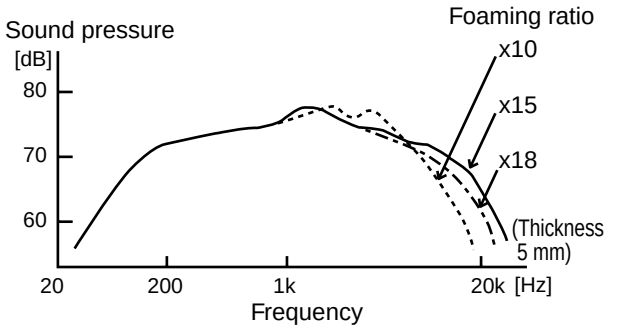
As described earlier, the diaphragm must be light and have an appropriate bending stiffness. The polystyrene foam attributes that meet these requirements are mainly foaming ratio and thickness. From the point of view of lightness of weight, the higher the foaming ratio and the less the thickness, the better. However, the bending stiffness would be that much less. The sound pressure level at higher tones (sounds at higher tone frequency) falls if the bending stiffness is too small. Thus, we had to determine a foaming ratio and the thickness that would allow us to maintain the balance between lightness of weight and bending stiffness.

Fig. 5 shows the correspondence between the sound pressure frequency response and the foaming ratio

when the thickness is held constant.

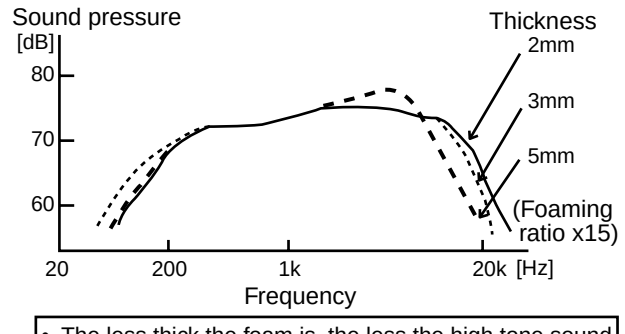
Fig. 6 shows the correspondence between sound pressure frequency response and the thickness when the foaming ratio is held constant.

Fig. 5 and 6 show the bias when the diaphragm area is small (about 100 to 150 cm^2) as is the case with the product under review.



• The sound pressure having high tonal characteristics drops less at the foaming ratio of 15 times. This is because the material is lighter than at a foaming ratio of 10 times. At 18 times, the material is even lighter but the stiffness drops, reducing the high tone sound pressure.
• Note: The results shown in this figure is changed if conditions other than the foaming ratio (such as the diaphragm area and the exciter specifications) are changed

Fig. 5 Relationship between diaphragm foaming ratio and frequency response



• The less thick the foam is, the less the high tone sound pressure drops. This is presumably because the weight reduction effects are larger if the thickness is reduced. (However, owing to strength considerations, the diaphragm cannot be thinner than 2 mm.)
• Note: The disposition shown in this figure is changed if conditions other than the thickness (such as the diaphragm area and the exciter specifications) are changed

Fig. 6 Relationship between diaphragm thickness and frequency response

Additionally, in consideration of the diaphragm surface design, we have employed a polystyrene foam material with fine quality paper bonded to it. The bonding of paper may affect the performance in a number of ways depending on the diaphragm area and the polystyrene foam specifications but, for the product under review, has exerted no adverse effect particularly regarding sound quality.

In view of the above points, we selected the most suitable of the existing polystyrene foam materials.

In terms of acoustic performance, we feel that, in the future, we will be able to secure even better candidates for the diaphragm material that will allow us to improve even further the flat panel speaker quality, while lowering costs. This will be possible if we include in our search materials that are newly developed (i.e., if we do not confine our search to only existing materials).

4.3 Diaphragm Size

The diaphragm shape of the NXT flat panel speaker is fixed to a certain aspect ratio. If we had employed this ratio, the product under review would not have been as slim as we had intended. If we reduce the diaphragm width while following the NXT design technique, the height gets that much smaller. Thus, the diaphragm area becomes too small to secure the required sound pressure and playback frequency band described earlier. Since our target is performance equivalent to that of existing box-shaped speakers, the sound pressure level must be at least 75 dB/wm, and the playback frequency band must be from 200 Hz to 20 kHz. Using the combination of the diaphragm material and the exciter to be employed for the product under review, the diaphragm area must be at

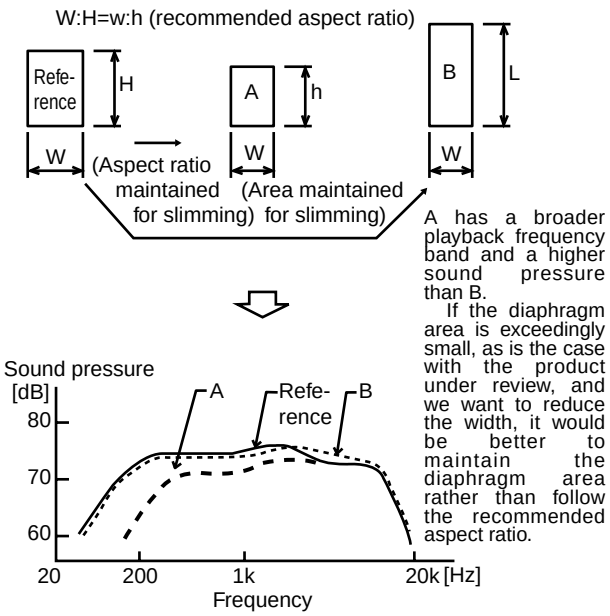


Fig. 7 Diaphragm size

least 100 to 150 cm^2. Fig. 7 shows the cases where the width is smaller, the aspect ratio is maintained, and the area is maintained. As you can see from this figure, the aspect ratio had to be reviewed.

In consideration of the widths of a PC display and a desk on which it is placed, the outer width of the speaker must not exceed 100 mm. Thus, we decided on a diaphragm width of 92 mm. This is a 13% reduction in width compared with that of the NXT flat panel speaker that currently on the market. We decided on an optimal value for the diaphragm height ranging from 1.5 to 2 times the width, that would make the speaker appear slimmer than existing products.

Since using too great a height, in particular, sometimes adversely affects the sound pressure and playback frequency band in addition to causing unnatural sounds to be heard, we also placed emphasis on hearing evaluation. As a result, we determined that a diaphragm height of 144.5 mm would be most appropriate.

4.4 Diaphragm Outer Rim Support Position

The method of supporting the diaphragm outer rim of the NXT flat panel speaker affects sound quality.

The best support position logically determined on the basis of the NXT flat panel speaker design technique sometimes does not apply to speakers like the one under review that has a small diaphragm area. Limits have also been placed on the support location to ensure strengthened support from a structural standpoint.

Thus, we determined a support position while maintaining the diaphragm support strength and making allowances for the "feel" of the bass and narration voice playback.

4.5 Sound Quality Tuning Using an Electric Circuit

As described in the previous section, we attempted to secure speaker sound quality by making the most optimal settings for those factors affecting the sound quality, under restrictive conditions in which we had to develop a slim speaker with a minimal diaphragm area. Additionally, we adopted sound quality tuning using an electric circuit (fixed equalizer) for the product under review. We provided equalizer response for an amplifier for use in combination, to correct the sound pressure at the desired frequencies that were beyond the control of the speaker.

For this speaker, the points for correction include boosting the "feel" of the bass and suppressing the midrange tone that is too pronounced.

For PC speakers, the sound quality of narration is usually considered important but the music sources cannot be ignored either. For the product under review, we succeeded in obtaining the desired sound quality by using an equalizer to tune the sound while maintaining the balance between these two sources.

5. Major Specifications

Table 2 shows the major specifications of the NXT flat panel speaker that we have developed. The speaker is shown in Fig. 8.

Table 2 Major specifications

Item	Specification
1. Technology	NXT flat panel speaker
2. External dimensions	W: 100, H:185, D:78.7 mm (flat panel section D: 27.7 mm)
3. Diaphragm	Size: 92 x 144.5 mm/Material: Polystyrene foam (with paper bonded on both sides)
4. Voice coil impedance	8Ω
5. Output sound pressure level	75d B/Wm
6. Playback frequency band	200～20k Hz
7. Amplifier	Output: 1W x 2 channels/With power switch, volume control, power indicator

Fig. 8 External appearance

6. Sound Quality Evaluation

Fig. 9 shows the directivity characteristics data for an NXT flat panel speaker compared with that for a conventional speaker. As described in the beginning of this report, NXT flat panel speakers have a wide range of directivity. The data shows that the high tone sound pressure drops little even in a direction inclined from the front. When going from the front of the diaphragm in a direction that is 60 degrees inclined, in particular, almost no drop occurs in the sound pressure and a natural and expansive sound can be obtained.

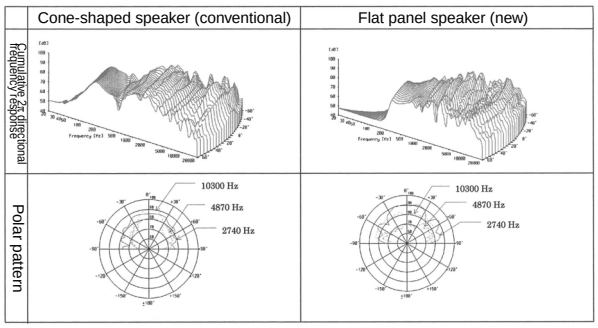


Fig. 9 Directivity characteristics

This speaker will be able to accommodate PC sound sources that are expected to be more varied in the future. The speaker will also be able to provide a well-balanced quality of sound, covering a wide range of sources including announcements and a variety of music genres.

We succeeded in improving the sound quality evaluation point for the product under review by 0.5 point, compared with the conventional NXT flat panel speaker for PCs (Evaluation scale ranging from 1 to 5).

7. Afterword

In the past, PC speakers were generally secondary devices used infrequently. However, with the distribution of music over the Internet on the increase and DVD and other media enjoying wide use, demand is growing for better sound quality and slim, space-saving PC speakers. Against this backdrop, we were able to get excellent results in developing a slim and compact product offering good sound quality, by applying NXT flat panel speaker technology.

This speaker was released with Fujitsu's '99 summer and winter PC models.

We feel that, in the future, users will expect more value-added features for PC speakers based on new technologies and concepts, while continuing to attach importance to lower prices. We intend to further promote research and development in the field of component engineering, to ensure that the development process is smooth, starting from the planning stage.

Lastly, we would like to express our thanks to the people at Fujitsu Limited and New Transducers Limited who provided us with support and cooperation in developing this speaker.

Reference Documents

NXT Flat Panel Speaker Technical Literature (New Transducers Limited)

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