The Evolution of TOA's Horn Speaker Driver Unit

- On the Road to the TU-660 -

We supply sound, not equipment.

www.toa.jp

TOA & Horn Speakers

TOA has been manufacturing horn speakers practically from the company's very beginning, over eighty years ago in 1934, and today we are recognized even among our longstanding industry contemporaries as a veteran of highest expertise in this field. By 1949 we had succeeded in developing Japan's first reflex-type horn speaker. We have always dedicated ourselves to being "an international company contributing to human society through sound and communication," valuing above all the physical craftsmanship that allows the delivery of the clearest possible sound information to listeners. In 1962, an inquiry from abroad led us to conduct transmission testing on an ultra-large PA system. This system, which used a 6.6-meter horn and a 4kW transistor amplifier, marked a transmission distance of 12 kilometers. This achievement would prove instrumental in laying out our destiny of long-running involvement in outdoor public address systems.

TOA-developed horn speakers were often painted blue, and they would become widely familiar as "blue trumpets" unique to TOA. In Indonesia, where we established both factory and sales facilities in 1976, TOA horn speakers became such a part of the public landscape that they were often referred to as "Toas." They are still a conspicuous part of everyday life there, most notably for public address among the country's many mosques.

Even today, horn speakers represent one of the fundamental shapes of public address speakers, offering a simple PA system that remains more indispensable than ever in delivering public announcements.

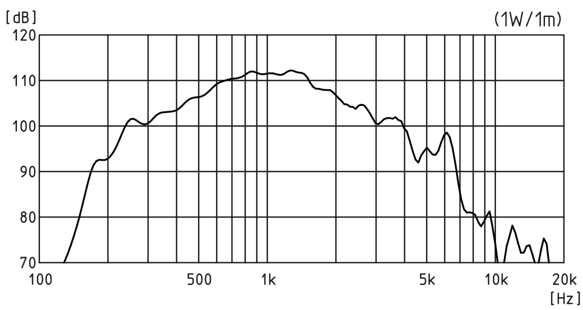
In Japan, too, where natural disasters are frequent, horn speakers are an essential component in the outdoor emergency notification systems used for broadcasting evacuation instructions and other vital information. Naturally, the demand for the clearest possible outdoor broadcasting sound is strong in this market.

In 2011, the Great Tohoku Earthquake caused a massive tsunami that devastated a great number of Japanese coastal towns and villages, taking the lives of many who were unable to escape in time. As this disaster unfolded, the sheer number of outdoor speakers calling out evacuation instructions caused pronounced sound overlaps that made their announcements difficult to hear. And in many cases, the speakers were simply swept away by the rushing waters. Reflecting on these systemic flaws, TOA has been developing long-range speakers capable of delivering clear announcements with fewer speakers over longer distances, and we have been testing these repeatedly in metropolitan environments to continue deepening our expertise in outdoor sound broadcasting and reinforcement.

Issues for Horn Speakers

Improvement of Articulation

Horn speakers are comprised of a driver unit and a horn, and thus achieve highest efficiency through impedance matching with the air. The sound pressure drops on both sides of the 1–2kHz range, however, resulting in certain distinctive audio characteristics that cannot be considered favorable in terms of creating good-quality sound.



Improving these high and low range frequency characteristics is one of the issues key to improving horn speaker sound quality. Particularly, we now understand that improving the high range contributes greatly to improving the articulation of outdoor broadcasts. Attenuation in the air is more conspicuous for the high frequency ranges.

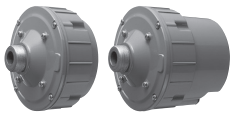
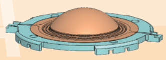
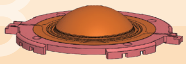
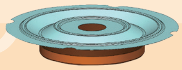
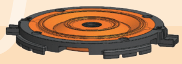
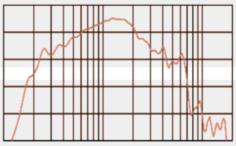
Improvement of Durability

Out in the field, there is also an inherent need to have horn speakers deliver higher volume and send the sound farther. Often, however, attempts to meet this need through excessive power input cause malfunction by damaging or even destroying the speaker's driver unit. Therefore, in addition to improving frequency characteristics, improving driver unit durability is also an issue requiring better solutions.

Additionally, the events of recent years have brought us to understand that in the disaster prevention market, improving frequency characteristics not only improves articulation, it also has a positive impact on long-distance sound transmission capability.

The Process Leading to the TU-660

TOA horn speaker driver units can be divided into several generations based on their diaphragm materials and constructions. In the past, we used dome-type diaphragms made of phenol-impregnated Conex. In 2004, we switched the material to polyimide, and in our most recent TU-660 we have also changed the diaphragm construction from dome-type to ring-type. Each of these various changes have aimed to improve sound quality (frequency characteristics), product quality, durability, and productivity. The details of this development process are explained below.

	A	B	C	D	
	 TU-15/25/35/50 (1978) ~TU-730/750 (Japan 2000–present*) TU-630/650 (overseas 1998–2008) * TU-750 only	 TU-730A/730AM (Japan 2004–present) TU-631/651 (overseas 2008–present)	Start of R&D on driver unit using ring-type diaphragms (2012)	 TU-760 (Japan 2017–) TU-660 (overseas 2017–)	
Diaphragm construction	Dome 	Dome 	Ring 	Ring 	
Diaphragm materials	Conex (fabric), phenol (resin)	Polyimide	(multiple types studied)	Polyimide	
High Frequency Characteristics			Aim: To improve high range performance by reducing divided vibration with a harder structure	Adaptations to the phasing plug design further improves high range performance	Patent Pending
Low Frequency Characteristics		Material improves low range performance	Issue: Harder structure degrades low range performance.	Adaptations to the bottom plate design improves low range performance	Patent Pending
Quality & Durability	Phenol's susceptibility to humidity leads to deformation and greater chance of voice coil friction	Stable quality	Aim: To prevent voice coil friction by reducing divided vibration with a harder structure	Improved upper cover heat dissipation, further improving durability	
Productivity	Requires 1 month curing time	No curing time	No curing time	No curing time	

Part 01. Change materials A / B / C / D

Replacing Phenol-Impregnated Conex with Polyimide

✓ Improved product quality

Phenol's susceptibility to humidity makes it vulnerable to post-fabrication deformation of the dome shape, a flaw which can lead to friction between voice coil and magnet and eventual diaphragm damage. For this reason, we switched to polyimide that is more resistant to moisture than phenol.

✓ Improved productivity

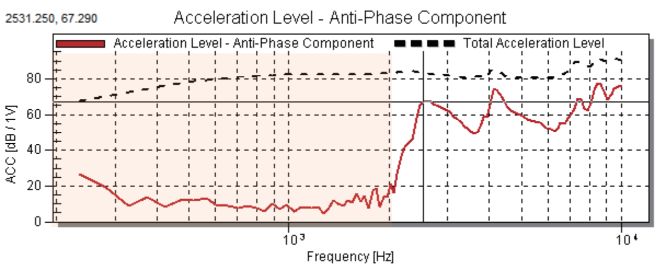
While phenol-impregnated Conex requires about a month of curing time before the diaphragm becomes usable, this process is unnecessary with polyimide, and the finished product is ready for actual use just two minutes after formation. The adoption of polyimide therefore greatly improved productivity.

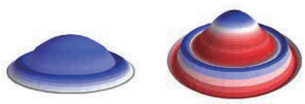
✓ Improved low frequency characteristics

Polyimide is made of softer materials than phenol-impregnated Conex. Generally, the more pliable the diaphragm material, the more suited it is to generating sounds in the lower frequency ranges. Therefore, our adoption of polyimide has allowed the production of sound offering a "thicker," more "solid" impression than previously available in horn speakers.

☐ Divided vibration and high frequency drop characteristics

The poor high range characteristics of horn speaker driver units result from the fact that the dome-type construction makes it more likely for divided vibrations to occur. "Divided vibrations" refers to the various vibrations occurring within the diaphragm when it does not vibrate in a uniform manner. When certain surfaces within the dome surface are vibrating in opposition to other surfaces on the diaphragm, the speaker will have difficulty sending out a clear sound. This phenomenon occurs most conspicuously from a certain frequency up through the high ranges. The relative softness of polyimide materials renders them more vulnerable to such divided vibrations. Improving the high frequencies against this problem is a subject for efforts going forward.





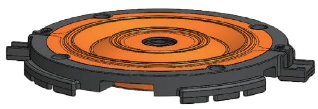
The diagram above shows a graphical representation of the state of reverse vibrations at two different frequencies. The lower frequency is on the left, the higher frequency on the right. Vibration is shown in blue, reverse vibration in red. This shows that areas of reverse vibration increase suddenly at the border of certain frequencies.

The Process Leading to the TU-660

Part 02. Change diaphrogms A B C D

Studying the use of Ring-Type Diaphrogms in Horn Speaker Driver Units

Ring-type diaphragms are used in tweeters employed in large-scale sound reinforcement systems and in the pure audio field. TOA has been attempting to use these in full-range (wide reproduction frequency band) applications.



Ring

✓ Improved high frequency characteristics

Since ring-type diaphragms have a more symmetrical construction than dome-type ones, divided vibrations are less likely to occur, and therefore they are a good candidate for extending reproducible frequency toward the high ranges.

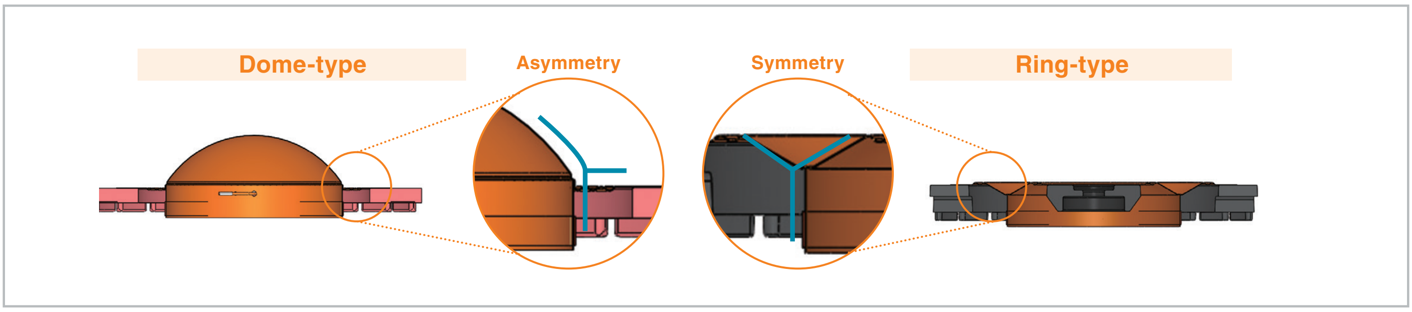
The diagram shows the differences in vibration between dome and ring diaphragms, low frequency vibration on the left, high frequency vibration on the right. Here we see reverse vibrations (red) occurring in the dome diaphragm at the higher frequency, whereas the ring diaphragm is relatively free of these and provides almost uniform vibration.

✓ Improved durability

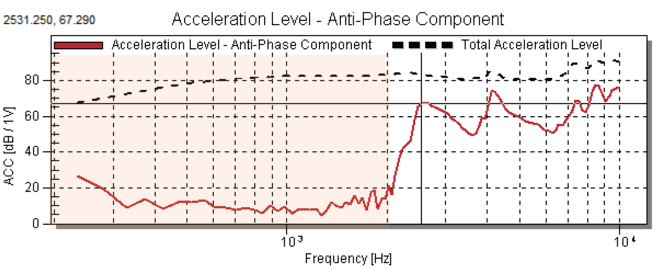
The occurrence of reverse vibration when under excessive input load is one cause of axial deviation, and we think reducing this will help improve durability.

☐ Effects on low ranges

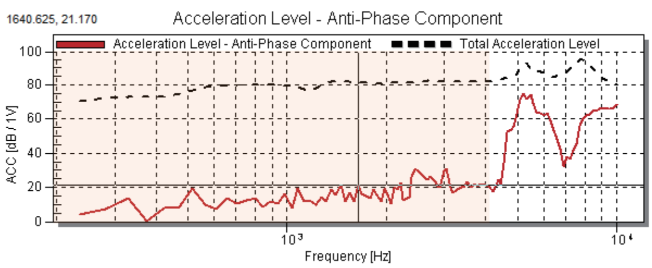
While the adoption of ring diaphragms does improve the high ranges, they are not inherently well suited to reproducibility in the low ranges. The dilemma is that while the adoption of polyimide improves the low ranges, the ring construction itself results in poorer low range output.

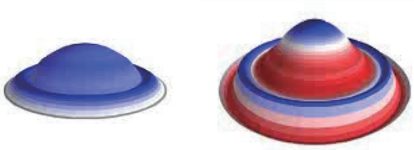


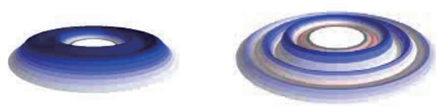
Dome-type diaphragms



Ring-type diaphragms







The diagram shows the differences in vibration between dome and ring diaphragms, low frequency vibration on the left, high frequency vibration on the right. Here we see reverse vibrations (red) occurring in the dome diaphragm at the higher frequency, whereas the ring diaphragm is relatively free of these and provides almost uniform vibration.

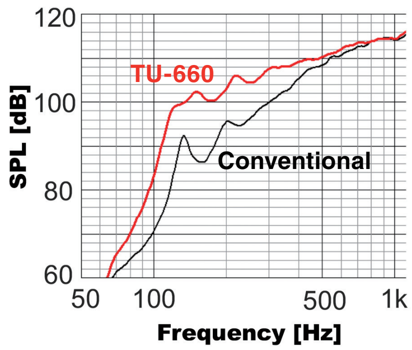
Part 03. **Finding a solution** A B C D Birth of TU-660

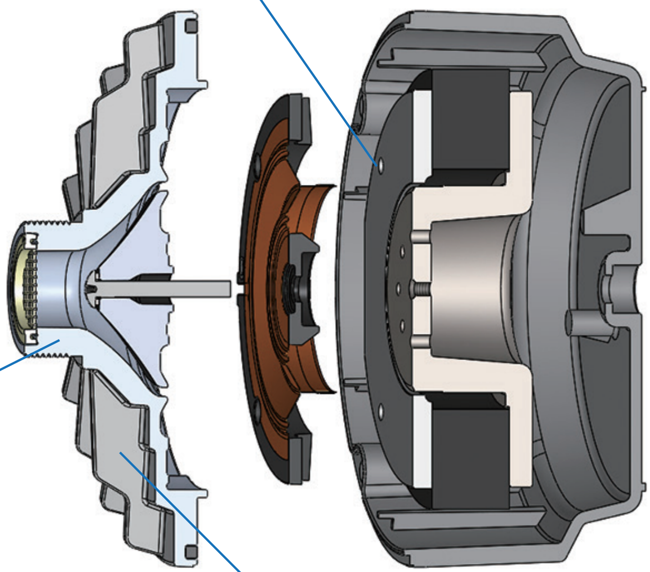
Take advantage of the improved quality, durability, and productivity obtained by using polyimide, and maintain the high range performance benefits of ring-type diaphragms, but also find a new way to improve low range frequency performance.

Patent Pending

Improving low range characteristics

Driver units now have a hole in their bottom plate, which allows air to flow through. This leads to flexibility in the vibration systems containing air, leading in turn to improved low range reproduction performance. A long trial-and-error process resulted in an understanding of the optimum design for this, and we have applied for a patent on this completely new method of dealing with the low range problems associated with ring-type diaphragms.

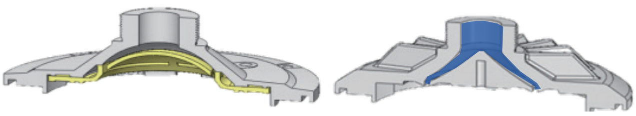




Patent Pending

Further improving high range characteristics

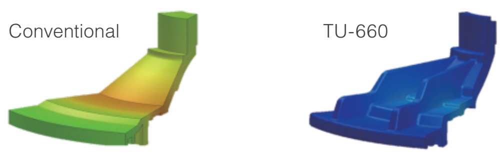
We've also incorporated an innovative new idea into the design of the phasing plug. Usually this area is a bottleneck for the sound path, so gradually widening it achieves high efficiency. On the flip side, the process of widening the sound path also loses high range performance. In other words, there is a trade-off between high efficiency and high range performance.



The TU-660 follows this construction, but makes a bold adjustment to the usual approach, changing the orientation of the air passageway toward the exit and making it narrow gradually, a design that overcomes the deterioration of high range performance usually occurring during the process.

Further Improving Durability

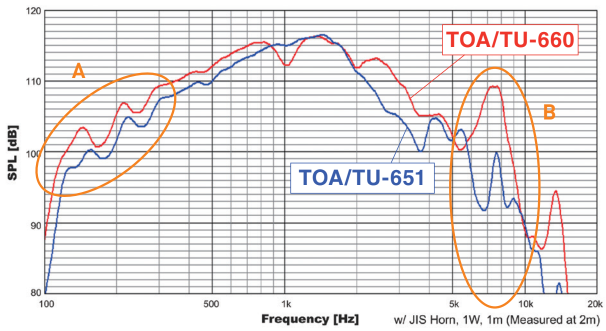
Coil burnout under excessive input loads is caused by the heat generated by the driver unit. When the heat resulting from excessive input is sustained, it can build up to the point that it melts the resin insulating the coil wires from one another, causing them to short circuit. This means that finding ways to make heat dissipate away from the coil is one important factor underlying speaker durability.



In the TU-660 we added a heat-dissipating fan at the upper cover and increased the surface area, and these two measures combined have doubled heat dissipation.

TU-660 Advantages as seen in Measurement Data

Fig. #1 Comparison of frequency characteristics against conventional models



Area A

TU-651 (dome x polyimide)

Low frequency characteristics improve significantly when phenol is replaced by polyimide. To compare with phenol characteristics, see Area C in the Fig. #2.

TU-660 (ring x polyimide)

The ring-type diaphragm is less well suited to low frequency reproduction, but the addition of a vent hole improves the low range. This also improves sound pressure level by 3 dB (equivalent to a two-fold increase in amplifier power) over the TU-651.

Area B

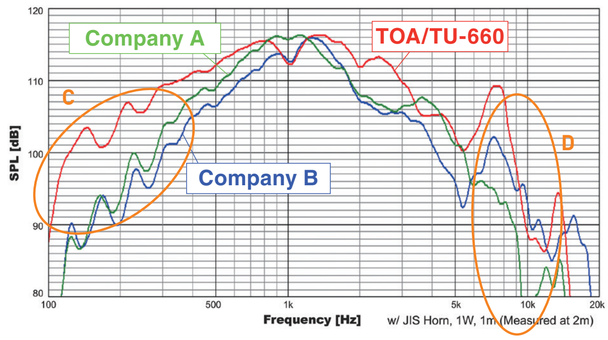
TU-651 (dome x polyimide)

In actual practice, this configuration shows a major dip in the high range. This is attributable to divided resonances caused by the driver, and it does not improve even when parametric EQ (PEQ) is used.

TU-660 (ring x polyimide)

Sound is reproduced strongly up through 8kHz, which is the TU-660's most major improvement. The dip occurring just before 8kHz can be raised using the PEQ.

Fig. #2 Comparison of frequency characteristics against other company's models



Area C

Company A (dome x phenol)

It is clear how poor phenol is when it comes to low range reproduction. TOA avoids this problem by using polyimide instead. See Area A in Fig. #1 for a graph of TU-651 characteristics.

TU-660 (ring x polyimide)

While the ring-type diaphragm is disadvantageous for low range reproduction, the addition of a vent hole improves the low range. There is no comparison to phenol.

Area D

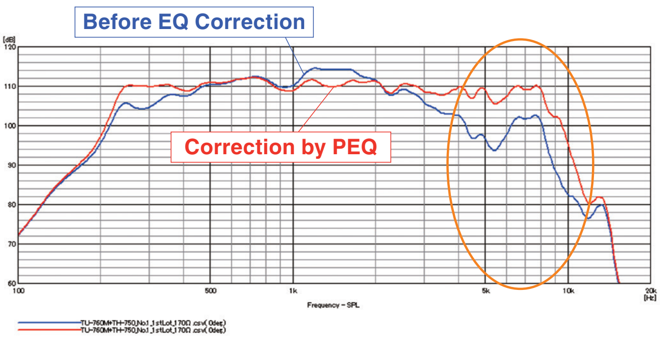
Company A (dome x phenol)

Major drop observed above 5kHz.

TU-660 (ring x polyimide)

The TU-660's most major improvement are its reproduction of sound up through 8kHz. It may be possible to raise the dip occurring just before 8kHz using PEQ. In a driver unit incapable of reproducing sounds in this range, such a dip cannot be raised even using PEQ.

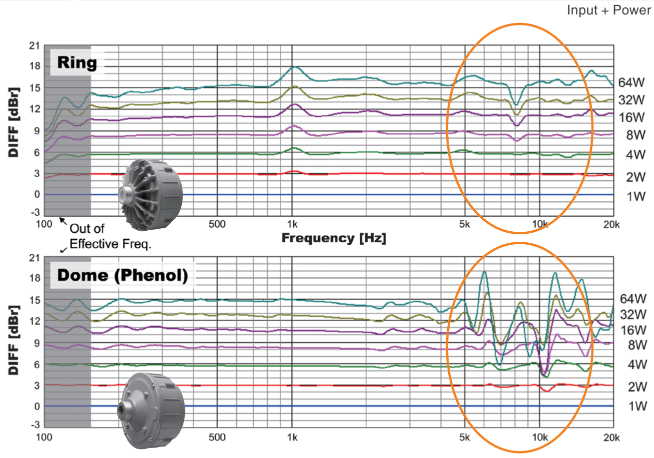
Fig. #3 Correction by PEQ



Because the TU-660 allows high range reproduction, it is possible to use EQ to raise SPL around 5–8kHz. Further, by suppressing SPL around 1–2kHz, flat characteristics can be achieved even in a horn speaker.

This solid reproducibility in this range doesn't merely improve sound quality, it also improves the sense of sound pressure and long-distance transmission capability, ultimately linking to improved articulation.

Fig. #4 Comparison of linearity with conventional products

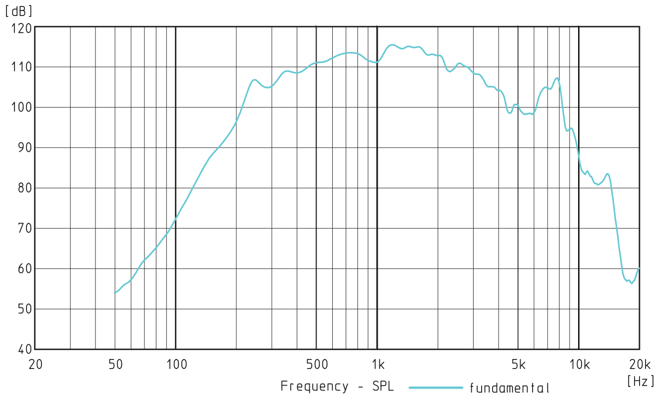


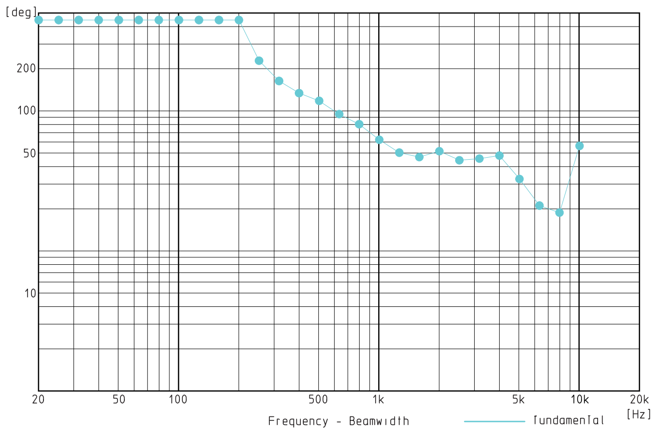
The graphs above compare the linearity of frequency characteristics against input power levels for the ring-type TU-660 construction (above) and dome-type construction of other driver units (below).

When output increases, the volume does not necessarily increase while maintaining the same frequency characteristics, and at some points there are significant changes in these characteristics. The graphs above show the differences in frequency characteristics between those for each applied input power and those recorded when 1W input is applied. With the ring diaphragm, there is hardly any change in these characteristics even as input power increases (indicating high linearity), whereas with the dome diaphragm, even as input power increases, output does not increase correspondingly on the high range side, suggesting a deterioration of articulation in the case of loud sound.

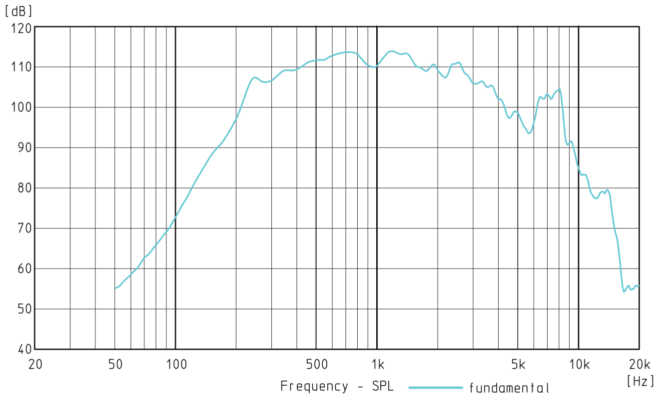
TU-660/660M Characteristics Diagrams

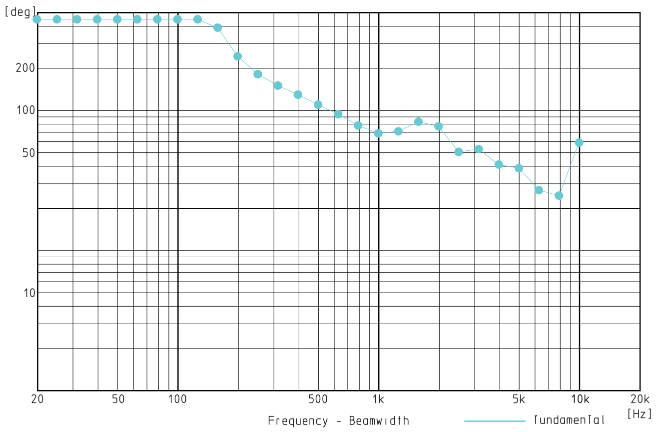
TU-660/M with TH-650





TU-660/M with TH-660





TU-660/660M Specifications

DRIVER UNIT 60W
TU-660

	TU-660
Applicable Horns	TH-650, TH-660
Rated Input	60 W
Rated Impedance	16 Ω
Sensitivity	110 dB (1 W, 1 m) (When operated with JIS C 5504 standard horn.)
Frequency Response	150 Hz -8 kHz (When operated with JIS C 5504 standard horn.)
Dust/Water Protection	IP65 (When a driver is operated with a horn.)
Horn Coupling	1 -3/8 18 threads (inch screw)
Polarity	Hot: Black, Com: White
Operating Temperature	-20 °C to +55 °C (-4 °F to +131 °F) (no condensation)
Finish	Flange: Aluminum, gray, powder coating Rear cover: ABS resin, gray Screws: Stainless steel Speaker cable: Polyvinyl chloride insulated cabtyre cable (6 mm (0.24") in diameter, 600 mm (23.62") in length)
Dimensions	ø139 x 108 (D) mm (ø5.47" X 4.25")
Weight	2 kg (4.41 lb)
Option	Driver unit cover: UC-200A Matching transformer: TM-30T, TM-60T

DRIVER UNIT 60W WITH TRANSFORMER
TU-660M

	TU-660M
Applicable Horns	TH-650, TH-660
Rated Input	60 W
Line Voltage	100 V line or 70 V line
Rated Impedance	100 V line: 170 Ω (60 W), 330 Ω (30 W), 670 Ω (15 W) 70 V line: 83 Ω (60 W), 170 Ω (30 W), 330 Ω (15 W), 670 Ω (7.5 W)
Sensitivity	110 dB (1 W, 1 m) (When operated with JIS C 5504 standard horn.)
Frequency Response	150 Hz -8 kHz (When operated with JIS C 5504 standard horn.)
Dust/Water Protection	IP65 (When a driver is operated with a horn.)
Horn Coupling	1 -3/8 18 threads (inch screw)
Polarity	Hot: Black, Com: White
Operating Temperature	-20° to +55 °C (-4 °F to +131 °F) (no condensation)
Finish	Flange: Aluminum, gray, powder coating Rear cover: ABS resin, gray Screws: Stainless steel Speaker cable: Polyvinyl chloride insulated cabtyre cable (6 mm (0.24" lin diameter, 600 mm (23.62" lin length)
Dimensions	ø139 x 151 (D) mm (ø5.47" x 5.94")
Weight	2.7 kg (5.95 lb)
Option	Driver unit cover: UC-200A

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Specifications are subject to change without notice.
(1712) 833-61-100-38-01