HC series High-Output Receivers

Introduction

The HC series High-Output receiver is a small receiver intended for ITE, ITC, and CIC hearing instruments where high sound level output and high efficiency are required. The HC receiver was developed to provide higher maximum output and efficiency than FC or EH series receivers for the same package size. The outside of the HC receiver is exactly the same size and shape as the FC receiver so it will fit into the same applications. Other HC improvements include greatly improved cover strength and a 15% lower first resonance frequency (now 2.7kHz). The maximum output of the HC receiver matches ED receiver performance with the HC receiver being 33% smaller.

Model	Maximum output, 500 Hz	Efficiency 500 Hz, dB per mWatt	Peak frequency, voltage drive	Size (HxWxL) in mm
HC-3724	116 dB	108 dB	2880 Hz	3 x 3.5 x 5.2
FC-6171	112 dB	105 dB	2560 Hz	3 x 3.5 x 5.2
FC-3265	110 dB	103 dB	3121 Hz	3 x 3.5 x 5.2
ED-1992	116 dB	108 dB	2320 Hz	3 x 4.3 x 6.3

Table 1: Summary of HC receiver advantages versus overmagged FC receivers (FC-6171), standard FC receivers (FC-3265), and ED receivers (ED-1992). Notice that the HC receiver maximum output is equivalent to the ED receiver maximum output in a package size only 2/3 as large.

Design Basis

The HC receiver has a larger motor inside the same FC receiver sized case. To accomplish this, all of the internal components are redesigned, with the exception of the sound port tube and the terminal pads. The HC cover is 40% thicker than the FC receiver cover to give greater case strength. The diaphragm, reed (armature), and magnets are all larger than those used in the FC receiver. A new reed geometry was developed which reduces internal stiffness and maximizes magnetic flux paths to create 40% more force output from the same size motor. Additionally, advanced technology originally developed for the FH receiver series is incorporated to the HC receiver design.

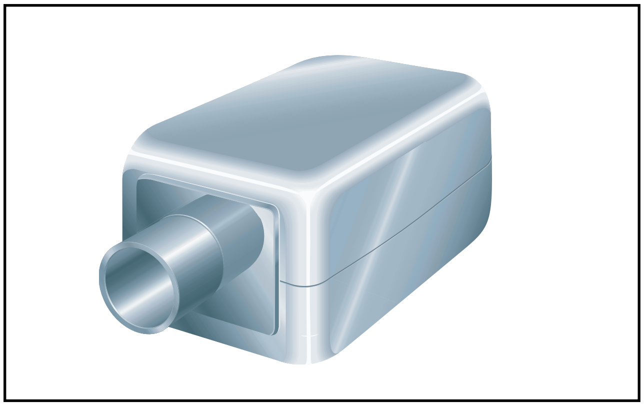

Figure 1: HC-3724 receiver. Notice that all dimensions are identical to the existing FC receiver package.

Detailed Performance Information

The following curves show the performance of the HC receiver family. Comparison curves of two FC receiver models are provided for reference. The FC-3318 is representative of the majority of standard-response FC receivers. The FC-6171 is representative of the popular "overmagged" (more highly magnetized) FC receivers and is a Type III damped unit (multi-pierce diaphragm). Unless otherwise stated, all curves were measured using 10mm x 1mm tubing connected to a 2cm³ (2CC) cavity. Further information about Knowles testing procedures can be found in Appendix A.

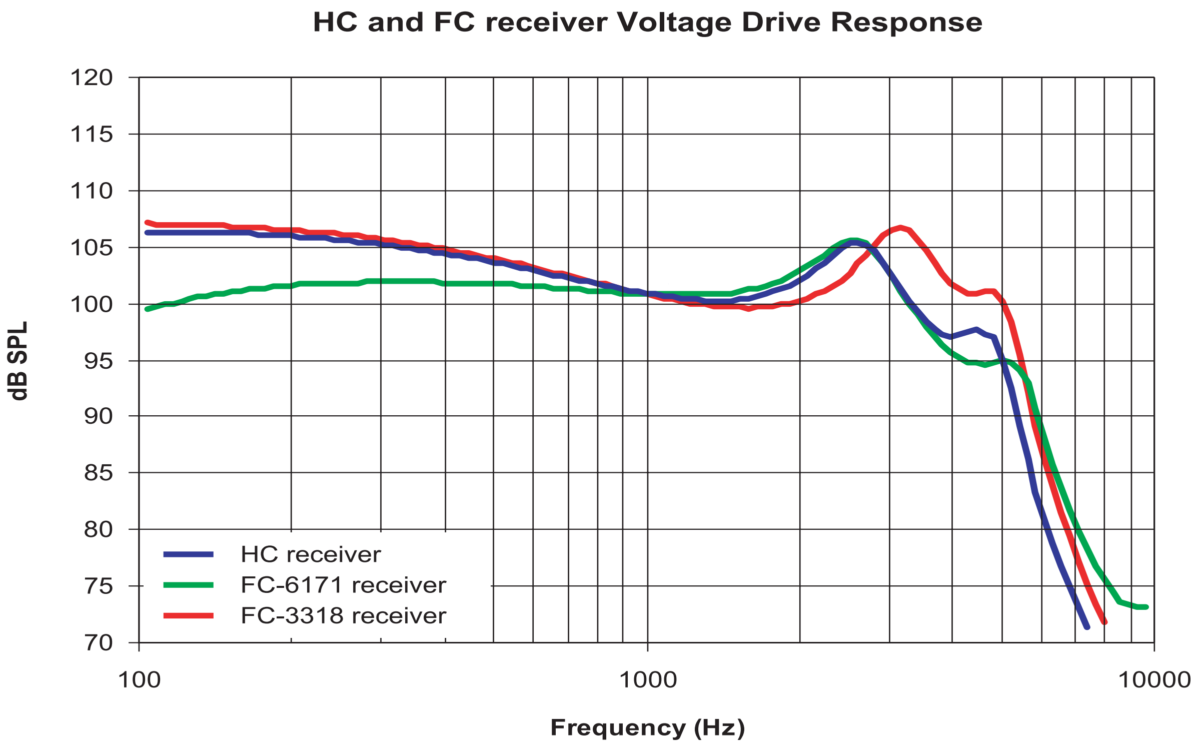

Figure 2: Response using low-impedance (voltage drive) source

Figure 2 (above) shows receiver response when driven from a low impedance (constant voltage) source. The response curves for the FC receivers have been adjusted (normalized) to match the level of the HC receiver curve at 1kHz so that the differences in response curve shape are easier to compare. The HC receiver low frequency response is similar to that of the standard FC receiver (FC-3318). The HC response curve shown in Figure 2 applies to all standard response (undamped) HC receiver models. The drive voltage will depend on the impedance of the particular model, but the input power will always be 0.215mW at 1kHz.

Figure 3 (below) shows the response of the HC and FC receivers when driven from a high impedance (constant current) source. Again, the levels of the FC receivers are adjusted (normalized) to match the HC receiver level for easy of comparison. The HC receiver curve is similar to the overmagged FC receiver (FC-6171) curve for this drive condition. Again, the HC receiver curve will be the same for all standard response models, provided the drive current will supply 0.215mW at 1kHz.

Figure 4 (next page) shows a comparison of the receiver efficiencies. The HC receiver efficiency is similar to the overmagged FC receiver (FC-6171) at high frequencies, but is greater at low frequencies due to the lower resistive losses in the HC receiver design. The HC efficiency is more than twice (>3dB higher) that of the standard FC receiver (FC-3318), offering a 2:1 savings in battery life. The efficiency of all standard response HC receiver models is the same, regardless of the coil impedance.

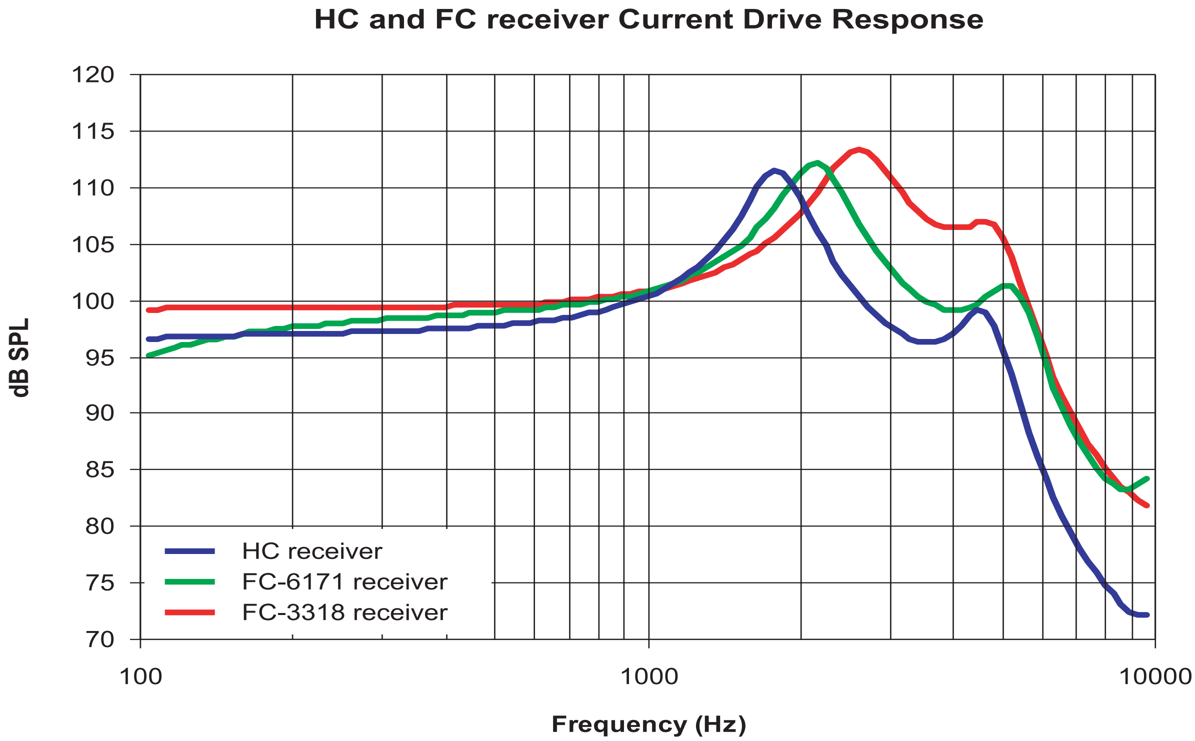

Figure 3: Response using high-impedance (current drive) source

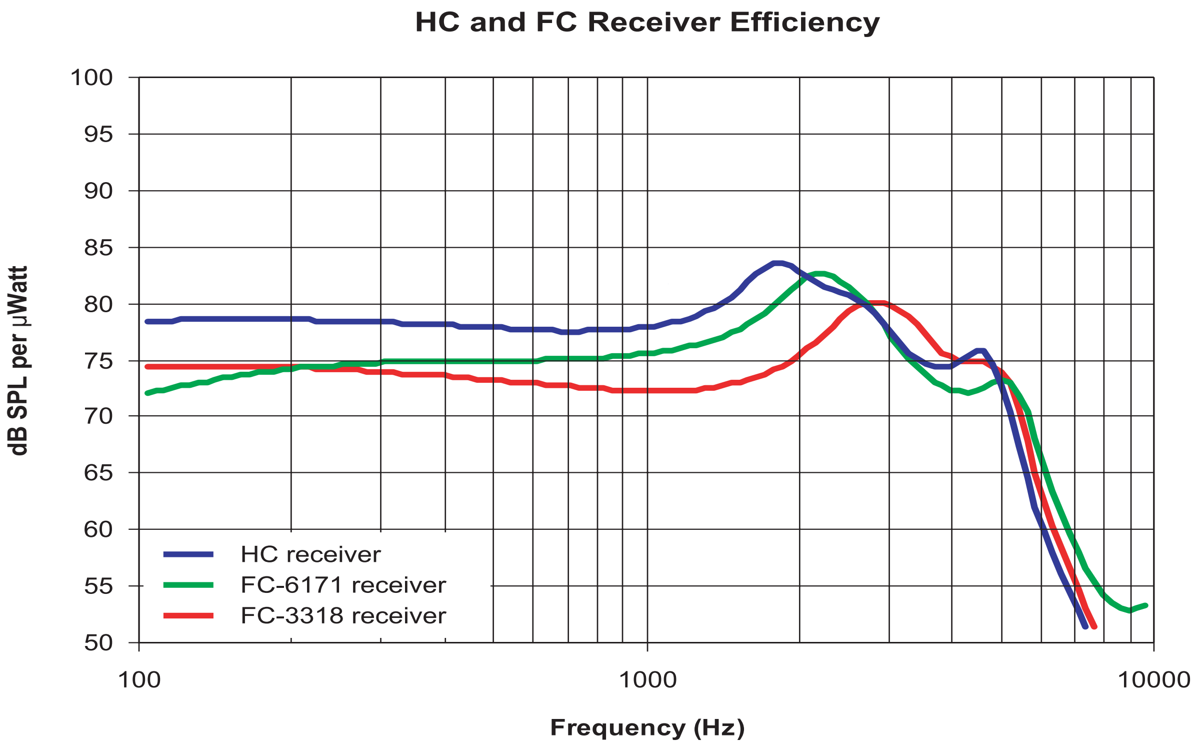

Figure 4: Efficiency (SPL per : W)

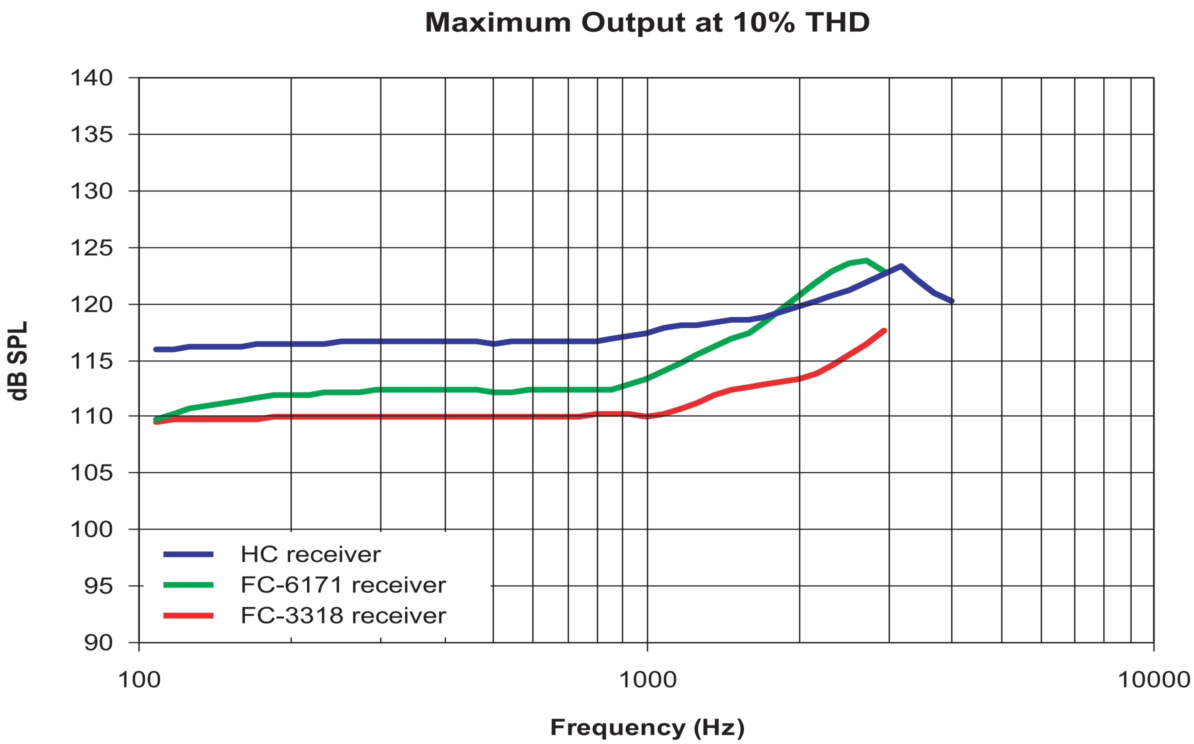

Figure 5: Distortion limited output

Figure 5 (previous page) shows the maximum output level that is achieved with a low-impedance source (voltage drive) before 10% distortion is reached. The HC receiver offers a dramatic improvement over previous FC receiver designs, with 6dB of improvement over the standard FC receiver (FC-3318). The HC receiver can produce sound level similar to the ED receiver, but in a 33% smaller package. The maximum output of all standard response HC models is the same, provided the amplifier can deliver sufficient voltage to drive the receiver to saturation. More information on the relationship between the required drive level and receiver impedance is provided in the "Choosing an Impedance" section.

Figure 6 (below) shows the loudest sound the receiver can produce in a hearing instrument if the amplifier is driven completely into clipping. The curve shows the sound level produced when the receiver is driven with a 2.6Vp-p square wave signal, the highest voltage that can be achieve with a fresh Zinc-Air battery and an H-bridge amplifier design. Unlike the previous graphs, the curve applies to only one HC model, the HC-3724. The level and shape of this curve depends on the impedance of the HC receiver model selected. Low impedance models will be limited by the maximum output level of the transducer while high impedance models will be limited by the maximum voltage of the amplifier.

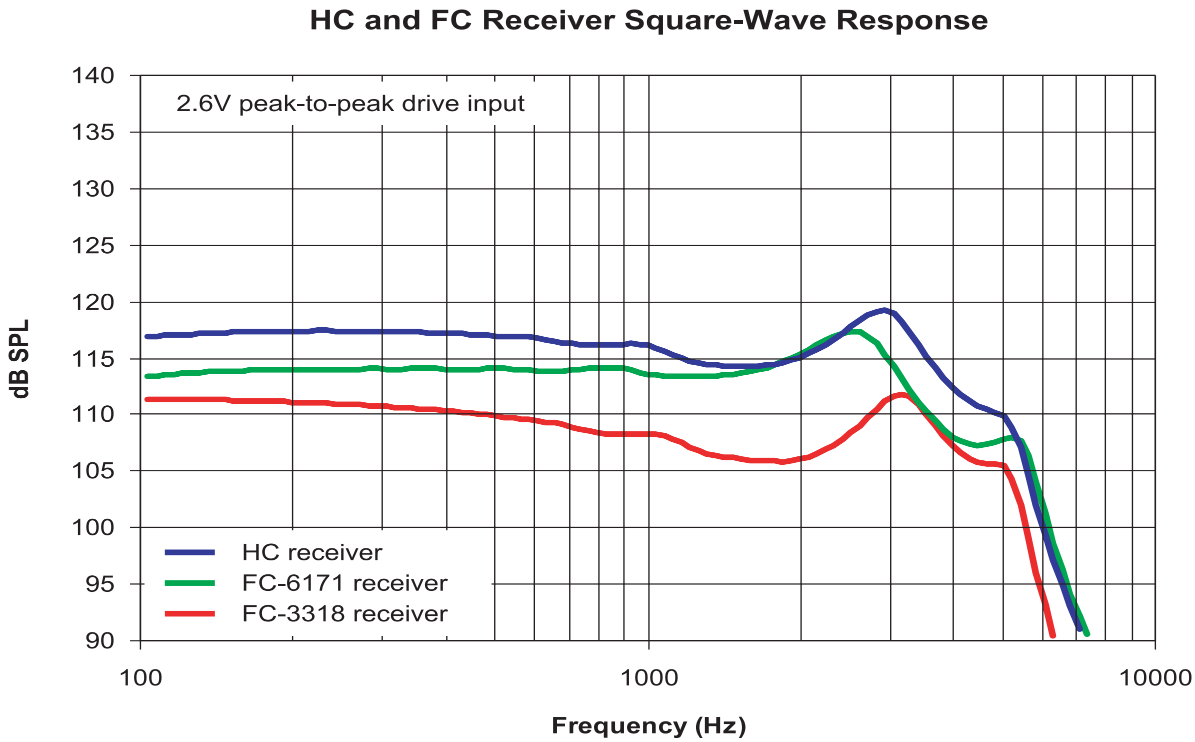

Figure 6: Battery voltage-limited output (varies with HC model coil impedance)

Acoustic Tubing Impact on Response

Figure 7, below, shows the response of the HC receiver into an IEC-711 ear simulator. The blue curve shows the response with 10mm x 1mm tubing. While this tubing is commonly used for test measurements, it is longer and thinner than the tubing typically used in actual hearing instruments. The green curve shows how a shorter tube (5mm x 1mm) raises the resonance frequencies, especially on the second resonance peak. If a larger diameter tube is used (5mm x 1.5mm), the frequency of the second resonance peak moves higher, but there is little effect on the first resonance peak frequency. These curves apply to all standard response HC receivers and are based on a constant voltage source drive and an input power of 0.375mW at 1kHz.

Choosing a Coil Impedance

The impedance of the HC receiver must be chosen carefully in order to achieve the full benefit of the high output design. The impedance of any receiver rises steadily with frequency, so at high frequencies it is usually the available drive voltage, rather than receiver mechanics, which limit peak sound output levels. A combination of high receiver impedance and limited amplifier voltage can prevent enough power from being delivered to the receiver to drive it into saturation.

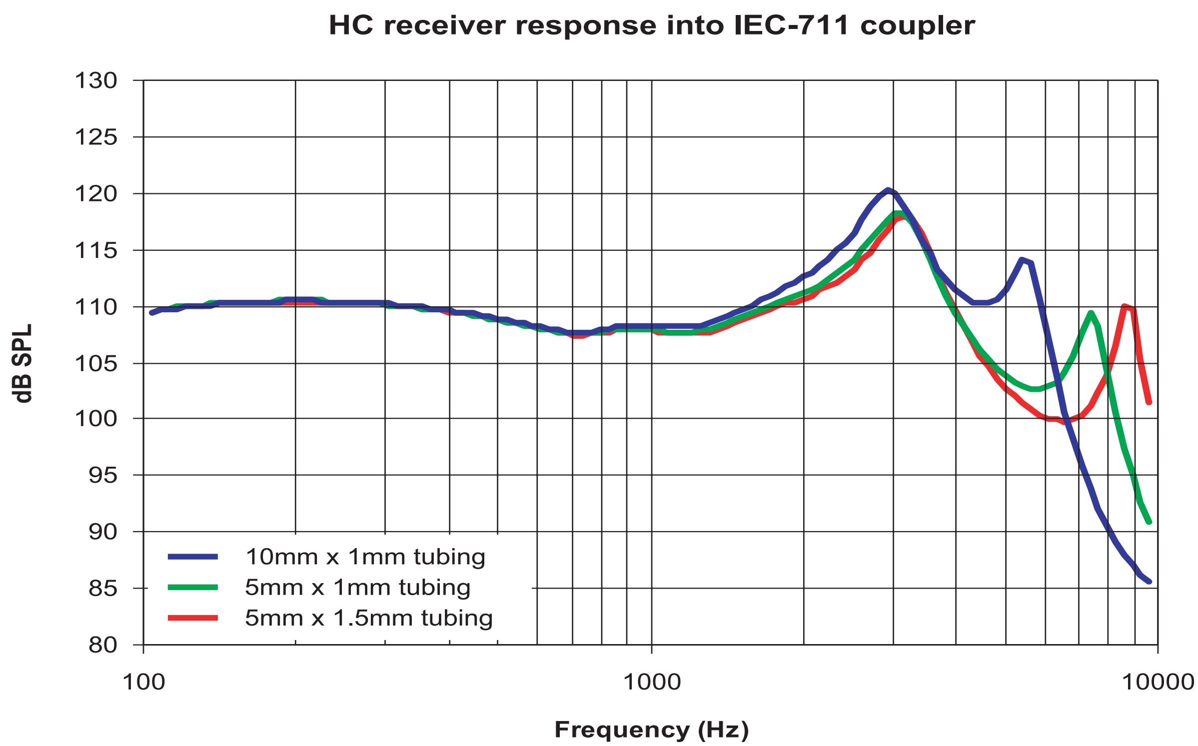

Figure 7: HC receiver voltage drive response into IEC-711 ear simulator with various lengths of acoustic tubing

Considering the above, changing from the FC receiver to the HC receiver alone with the same impedance coil may not provide the desired increase in maximum output because the drive voltage may still be limited. To obtain the full benefit, it is necessary to specify a lower impedance design. A lower impedance design raises the idle current of switching amplifiers and increases the impact of any resistive losses in the battery and the amplifier. The HC receiver does have higher efficiency than the FC receiver (see Figure 4) which more than offsets these losses.

To guide the designer in choosing the appropriate HC receiver model, Figure 8 (below) shows how different coils yield different maximum outputs. Each curve represents a different coil impedance. The curves overlap when the maximum output is limited by receiver mechanics and they separate when drive voltage limits the output. The coils for the HC receiver are designed in 3dB impedance steps; this translates to 1.5dB sensitivity steps. With this wide range of nominal sensitivities available, costly and time-consuming custom coil designs are unnecessary.

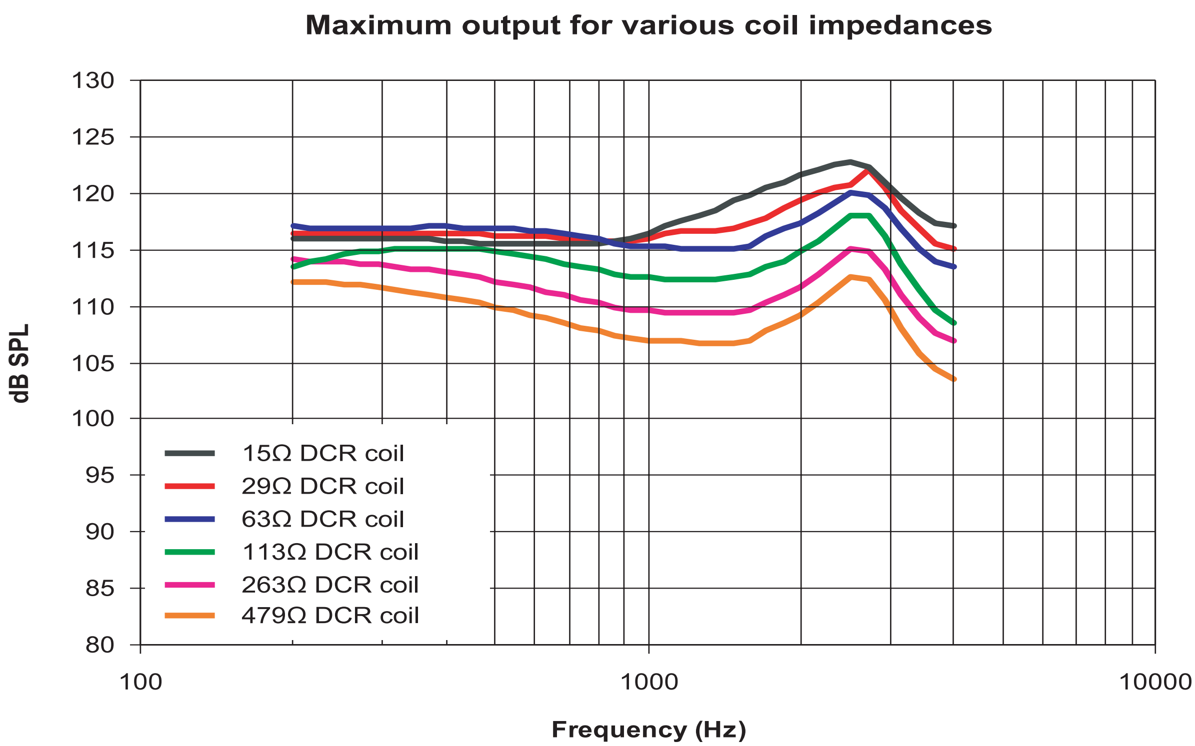

Figure 8: HC receiver coil impedance versus THD-limited maximum SPL output. Measured with 10mm x 1mm tubing into 2CC coupler, with amplifier at clipping, 10% THD limit.

Vibration

Since the HC receiver has a larger motor with 40% greater moving mass than the typical FC receiver, the HC receiver will have higher vibration versus the FC receiver. It is recommended that designs be tested and optimized for maximum gain before feedback if an HC receiver is being fit into a hearing instrument that previously used an FC receiver.

Damping

The HC receiver can feature all of the damping options common on Knowles receivers. Type I (screen), Type II (screen plus internal damping), Type III (internal damping), and ferrofluid damping can all be used with on the HC receiver. The designer should note, however, that any type of damping will decrease the maximum output available at the resonance peaks.

Appendix: Notes on Testing

All level measurements are made using an RMS reading voltmeter with a measurement bandwidth of 4Hz to 50kHz. Measurements made with an averaging voltmeter or a narrower bandwidth may yield different results, especially for the square wave response test. The low impedance source has an output impedance of less than 1S. The high impedance source has an output impedance of 5kS to 10kS.
Efficiency of Knowles receivers is defined as the sound pressure obtained for a constant power input where the power is measured by multiplying the RMS current and RMS voltage applied to the receiver. This is not a true measure of the power input as phase information is ignored. However, it does give a good representation of the battery consumption in an actual hearing instrument where there are resistive losses in the battery and the amplifier. Efficiency is measured with the receiver driven at its nominal drive current, well below its saturation point. For the HC receiver, this operates the unit near 105dB SPL at 1kHz.

Harmonic distortion is measured using a spectrum analyzer. The level of the first 10 harmonics is divided by the level of the fundamental tone. Only harmonics are included in this measurement; noise is excluded.

The maximum output of Knowles receivers is measured by adjusting the input drive level at each frequency until the receiver output contains 10% THD. If the 10% limit cannot be reached at the highest allowable input voltage, the SPL at the highest allowable input voltage is recorded instead. A maximum input of 3Vrms was used to collect data for this application note. Although this represents a level significantly higher than can be achieved in a hearing instrument, the goal of the measurement is to show the receiver limitation without imposing amplifier limitations.

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NOTE: Specifications are subject to change without notice. The information on this Application Note reflects typical applications. Specific test specifications defining each model are available by requesting Outline Drawing Sheets 1.1 and Performance Specifications Sheets 2.1 of that model number. Knowles' responsibility is limited to compliance with the Outline Drawing and the Performance Specification application to the subject model at time of manufacture.