VEF Vibration Isolation receivers

Introduction

The VEF Vibration Isolation receiver integrates a vibration-isolated EF receiver into an outer magnetic shielding case (see figure 1). In use, the VEF receiver can be directly mounted into a hearing aid housing and the required electrical connection made with standard wire. This eliminates the need for hearing instrument manufacturers to source and assemble additional flexible wiring, rubber boots, tubing, and external magnetic shielding to the receiver. Additionally, the VEF Vibration Isolation receiver's electro-acoustic and vibration performance is verified by Knowles Electronics prior to shipment, reducing the risk of feedback and closure problems during hearing aid assembly.

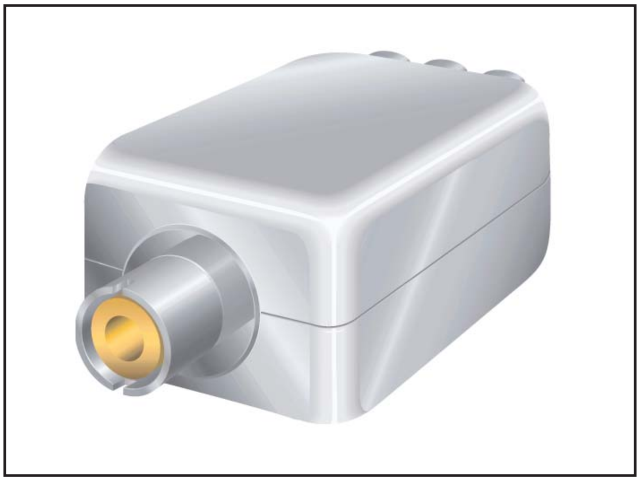

Figure 1: VEF Vibration Isolation receiver. The yellow sections are compliant rubber mounts that isolate the internal EF receiver from the outer metal shield.

Vibration Isolation Design

Mechanical vibration isolation is important because receivers generate undesired mechanical forces that propagate through the hearing aid. These forces, through a variety of transmission mechanisms, produce acoustic pressure at the microphone input port and accelerate the microphone case, creating a feedback loop. VEF Vibration Isolation receivers incorporate compliant rubber isolators to substantially reduce the mechanical vibration forces transmitted to the hearing aid (see figures 2 and 3). In principle, the VEF Vibration Isolation receiver's isolation system is an extension of traditional approaches that use compliant rubber

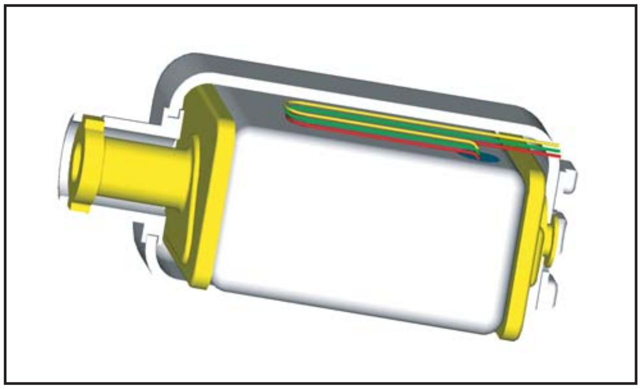

Figure 2: VEF Vibration Isolation receiver front cutaway. Note the rubber front tube mount that acts as both an acoustic outlet (sound port) and a vibration isolation mount.

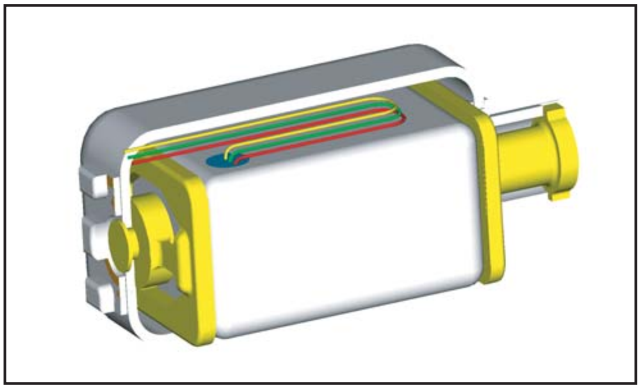

Figure 3: VEF Vibration Isolation receiver rear cutaway. Note the rear rubber isolation mount that isolates the internal EF receiver from the external metal case.

"boots" and tubes. The receiver is suspended between two points inside the outer metal shell by a front tube mount and a rear terminal mount. The front tube mount serves as both an acoustic outlet and an isolation mount. The rear mount also provides appropriate clearance for the flexible lead wires to run from the inner EF receiver to the outside solder terminals. The entire receiver and suspension assembly was analyzed using finite element techniques to optimize the VEF system for the inner EF receiver's specific vibration response characteristics.

Vibration Isolation Measurement

There are a number of ways to measure vibration isolation, including open loop gain, laser velocity measurements, and force measurements. The open loop technique is often used as a definitive measure of the isolation in a complete hearing aid. Hearing aid isolation, however, is strongly dependent on the system acoustical and mechanical properties such as housing geometry, mass distribution, transducer type and location, acoustic sealing, etc. In order to focus on the receiver vibration independent of the hearing aid system, Knowles utilizes laser velocity measurements and force measurements. While laser measurements can yield insights into receiver and isolator performance that are useful for design purposes, force measurement remains an inexpensive, accurate, and rapid vibration characterization method.

Figure 4 depicts a typical force measurement. A piezoelectric force sensor is fixed to a stationary base. The VEF receiver is oriented such that the diaphragm normal vector is along the force sensing direction (vertical orientation in Figure 4) so that the maximum force output is measured. The receiver is attached to the sensor using a thin, stiff layer of wax or cyanoacrylate to reduce the effects of fixturing on the measurement. A spectrum analyzer is used to measure the frequency response magnitude of the force cell output with respect to the receiver input drive voltage.

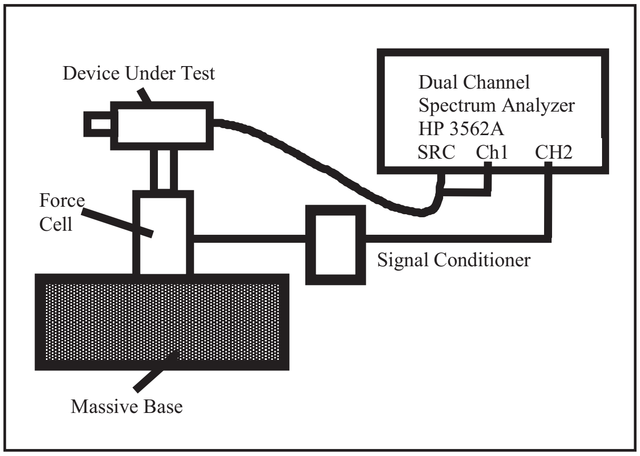

Figure 4: Typical receiver force measurement system.

Figure 5 compares the force output of a standard EF receiver to that of the VEF Vibration Isolation receiver. The force was measured normal to the diaphragm with a free air acoustic load. Notice that EF force magnitude rises with frequency up to the receiver's primary mechanical resonance at 2.3kHz. The peaks at 4.3kHz and 7kHz are an acoustic resonance and a secondary mechanical resonance, respectively. In contrast, the VEF Vibration Isolation receiver's force output decreases with frequency above the suspension system 140Hz resonance, illustrating the effect of the rubber isolation system. The three receiver mechanical and acoustic resonances are still visible above 1kHz, but are all attenuated by 40dB to 50dB.

Figure 6 (next page) shows the VEF mechanical vibration isolation in the direction normal to the diaphragm. Isolation is the ratio of the standard EF force measurement to the VEF receiver force

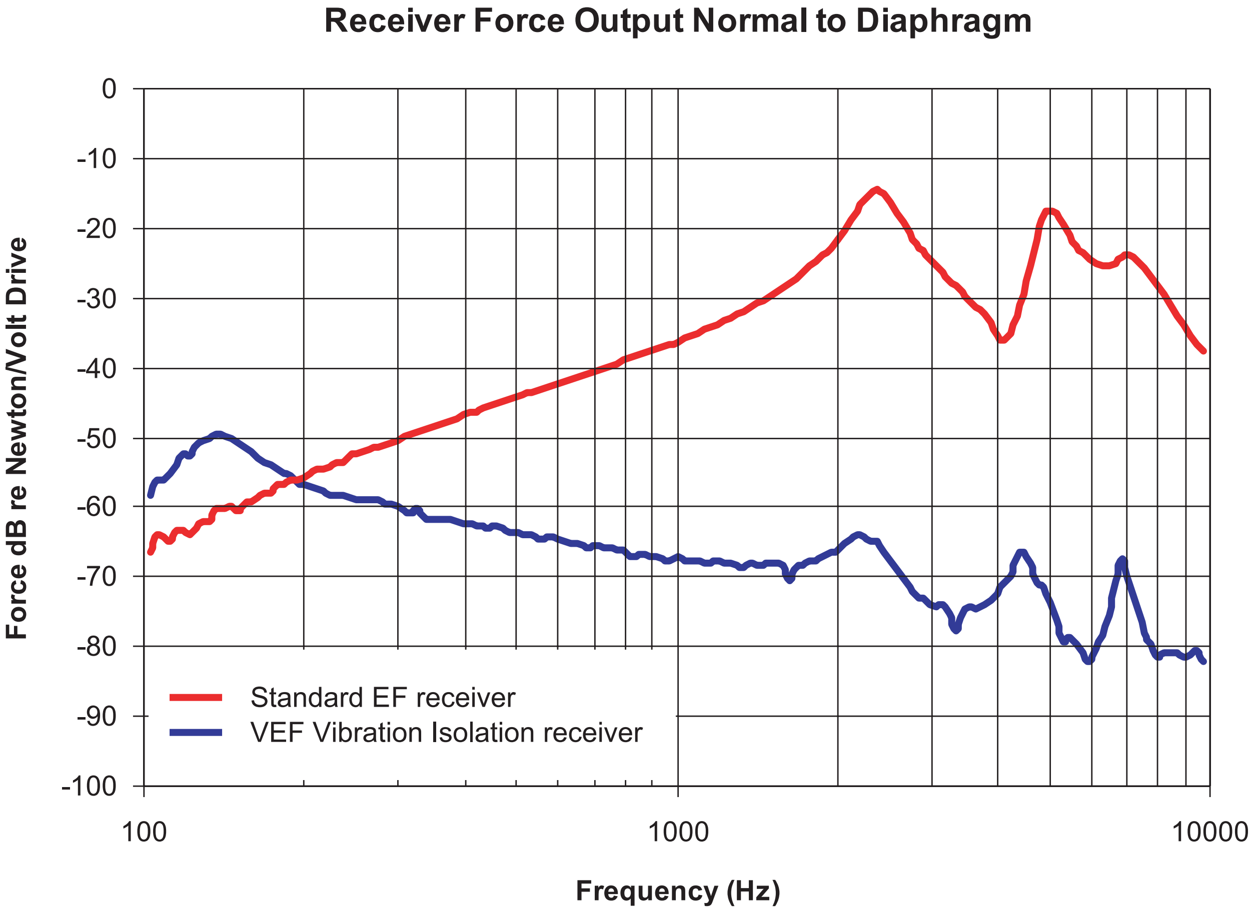

Figure 5: Standard EF receiver force output versus VEF Vibration Isolation receiver force output. Note the VEF suspension system resonance at 140Hz and the decreased vibration output at higher frequencies.

measurement from Figure 5. The isolation level climbs at approximately 40dB per decade (12dB/octave), reflecting the operation of a second-order mechanical isolator with a 140Hz resonance. The loss of isolation around the 140Hz suspension resonance is not typically considered problematic in hearing aid systems. Also, local isolation minima (e.g., the notch near 4.3kHz) typically correspond to regions of relatively low force output.

Magnetic Isolation

Magnetic isolation is important since receivers produce undesired time varying magnetic fields outside their cases. These fields may be sensed by the hearing aid telecoil and could create spurious input signals or cause a feedback loop. The VEF Vibration Isolation receiver features two levels of magnetic isolation. The case of the internal EF receiver acts at the primary

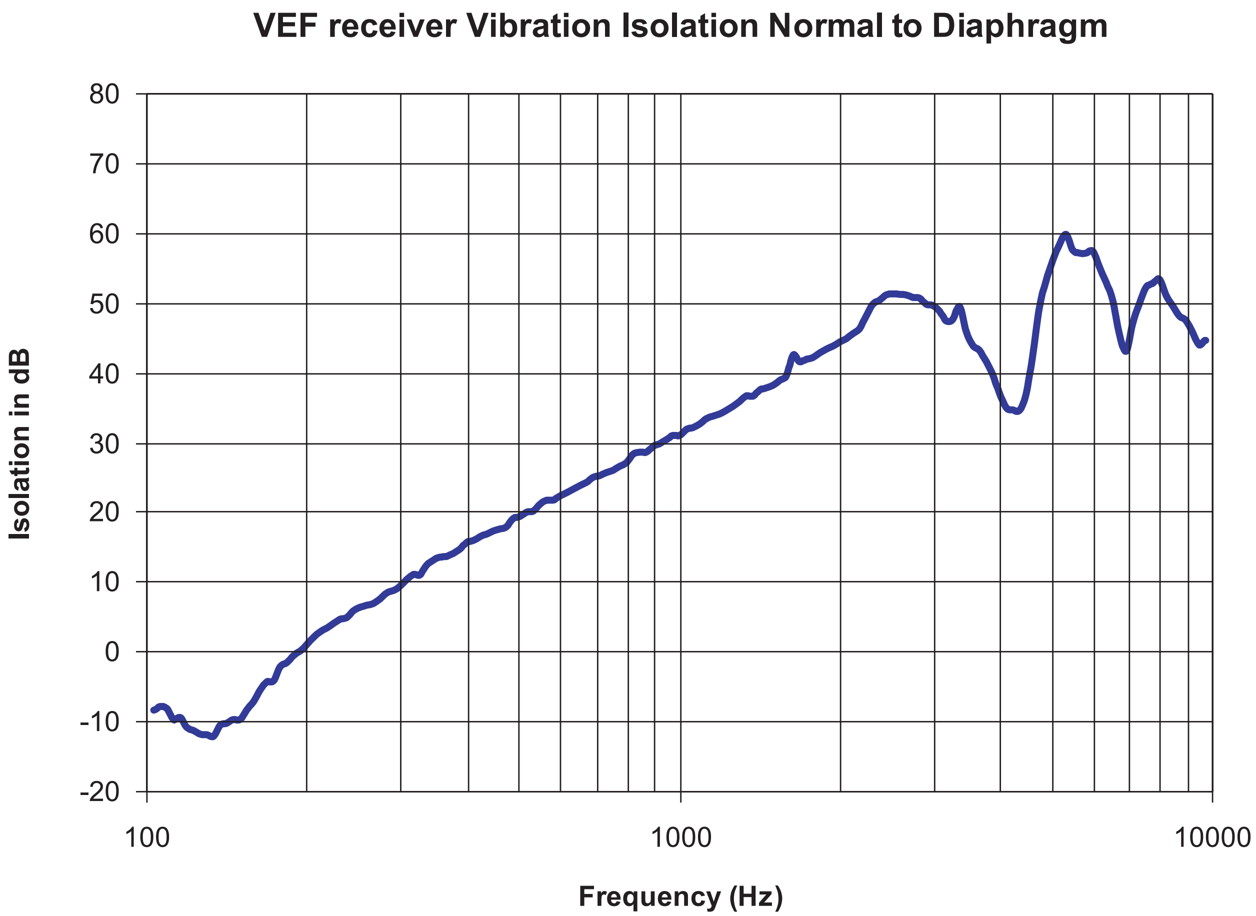

Figure 6: VEF receiver vibration isolation characteristic. Note the increase in vibration isolation with increasing frequency and the impact of receiver mechanical and acoustic resonances at 2.3kHz, 4.3kHz and 7kHz.

shield. The outer case of the VEF receiver is constructed of 0.25mm (0.010") thick "mu" metal (80% nickel, 20% iron) to provide additional magnetic shielding. This eliminates the need to install additional shielding plates or build the receiver into an external magnetic enclosure.

The VEF receiver's full-coverage magnetic shield also offers additional acoustic and mechanical benefits. The entire outer case is acoustically sealed, greatly attenuating any sound radiating or "leaking" from the internal rubber sound tube (front suspension sound tube assembly). The outer case also provides a well-defined means of mounting the VEF receiver into hearing aid housings.

Acoustic Performance

The VEF Vibration Isolation receiver consists of a typical EF receiver mounted within the vibration isolation system. Therefore, VEF receivers exhibit the same electro-acoustic performance as standard EF receivers, including frequency response, electrical impedance, distortion characteristics, and efficiency. Please note, however, that the high level of mechanical integration and optimization places significant constraints on some types of features and modifications. This is addressed in more detail in the "Application Guidelines" section.

Mechanical Package

The VEF receiver is packaged for direct mounting into hearing aid housings. No additional rubber boots, flexible tubing, magnetic shielding, or delicate wiring is required. The acoustic connection is made at the port tube, which is rigid for easy sealing. All delicate Litz wiring and wire loops needed for vibration isolation are already completed inside the VEF receiver. Electrical connections are made by simply soldering standard wire to the VEF terminal pads.

Application Guidelines

The VEF receiver suspension system is highly integrated with the port tube and case, resulting in a compact, vibration-reduced receiver system. This level of mechanical integration and optimization, however, does place constraints on custom modifications for specific applications. Some changes that are normally straightforward with traditional receivers may be difficult to implement in the VEF Vibration Isolation receiver.

Coil changes are commonly requested and are straightforward to accomplish since they do not affect the vibration isolation system. The same coil modifications that are possible in EF receivers are also feasible in VEF receivers. Common changes include impedance changes, DC resistance changes, two or three terminal configurations, and shock protected coils. The simplest approach involves reproducing the electro-acoustic performance of an existing EF receiver (e.g., EF-1937) in a VEF receiver (e.g., VEF-1937). Note that two terminal models may offer marginally better vibration isolation due to the simplified internal wiring.

Electrical terminal changes may be possible depending on the specific nature of the desired modification. Terminal location feasibility is influenced by internal wire routing and clearance considerations. Specific proposals for terminal location or design changes should be discussed with Knowles Electronics engineering.

Acoustic damping changes that are possible include No damping, Ferrofluid damping, and Type III damping (barometric multi-pierce). Ferrofluid damping and Type III damping are possible since they are modifications to features inside the internal EF receiver. Type I damping (screen damping) is not possible since the damping screen (located in the sound port tube assembly) requires rigid acoustic tubing to hold the damping screen and would interfere with the vibration isolation suspension system. The standard VEF receiver is undamped.

Mechanical changes to the port tube type, layout, and location are strongly discouraged. Note that this differs from standard receiver practice where a wide variety of port tube types and locations are available. Port tube changes to the VEF receiver are not practical since the port is an integral part of the vibration isolation system. For example, in order to make the front suspension as compliant as possible, the rubber front acoustic tube extends into the outer case metal port tube (see Figures 1 and 2, page 1, for detail). Changing the port may require changing the entire suspension system, potentially compromising vibration isolation.

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