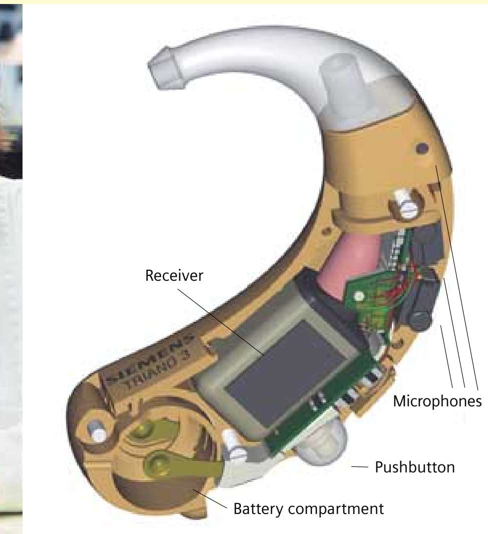
Electronic Ears

Siemens founder Werner von Siemens built a telephone amplifier for the hard-of-hearing way back in 1878. Over the past 125 years, these devices have evolved into high-tech mini-marvels that can handle even extreme acoustic challenges.



It's been a long road from the first hearing instruments to today's tiny models. In this 1922 ad, Siemens' Phonophor was packaged in an elegant handbag. In today's laboratories, hearing aids are manufactured under a microscope. Right: cross-secton of a Triano 3.

Whenever a hearing aid is sold anywhere in the world, the odds are good that it's from Siemens. For a century now, Siemens Audiologische Technik (S.A.T.) in Erlangen, Germany, has been the number one address for good hearing. About one in every three hearing aids sold anywhere in the world was designed here. But this level of success has taken a lot of hard work, because a good reputation and a far-flung dealer network don't necessary result in high sales. "In many countries, dealers are required to provide the hard-of-hearing with a choice of devices by different manufacturers," explains Dr. Gerhard Röhrlein, in charge of research and development at S.A.T.. After several days of hearing tests, the customer chooses the product that provides the greatest hearing improvement and feels best.

Telephone with Amplification. Siemens founder Werner von Siemens himself took an interest in helping people with hearing problems. In 1878, he built a telephone handset with powerful amplification for the hard-of-hearing. Since 1910, Siemens has been making "real" hearing aids that amplify ambient sound too — initially only for Siemens employees and their families. In 1913, an improved model named "Phonophor" was introduced to the market. It consisted of a battery, microphone and receiver — plus a handbag or carrying case (see poster, above). Starting in 1914, Siemens marketed Phonophor models with a proprietary miniature receiver. This insert receiver was not only less conspicuous but also located closer to the eardrum, so that the sound waves could produce greater effect. This "Ear-Speaker" was one of the first Siemens inventions specifically for hearing aids.

In 1924, a carbon microphone amplifier boosted sound by up to 46 dB. The abbreviation dB stands for decibel, a logarithmic unit of measure that's useful in technology but can be somewhat misleading. An increase of 3 dB corresponds to a doubling of the sound pressure. By way of comparison: The hand behind the ear amplifies by about 10 dB, the ear trumpet Beethoven had to rely on, by 25 dB. "Modern hearing aids can amplify sound intensity by up to 80 db," Röhrlein notes about the state of technology. "That's enough to help virtually deaf people live actively again."

Hearing aid manufacturers are constantly striving to exploit new technologies. In the late 1920s it was tube amplifiers with better sound — and a hefty weight. Not until the 1950s did miniature tubes allow devices to shrink to something hardly larger than a pack of cards. Next came transistor technology, and hearing aids shrank to the size of a pillbox. These Siemens devices were still sold under the name Phonophor.

Electronics in the Ear. Since the 1960s, electronics have migrated into the immediate vicinity of the ear. First in the form of the eyeglass hearing aid. But then Siemens developed behind-the-ear hearing aids that contained all the electronics and fitted snugly behind the ear. Today's in-the-ear hearing instruments can actually be contained entirely within the auditory canal. "They're virtually invisible in actual use — and that's an important selling point," notes Röhrlein. Both behind-the-ear and in-the-ear hearing instruments have their proponents. Only subjects with the most severe degrees of hearing loss may still encounter certain limitations with in-the-ear devices. Since the microphone and the sound transducer are separated by mere millimeters, there is a risk of feedback when the amplification is too great.

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For nearly three decades, engineers had to be satisfied with relatively minor improvements, because they couldn't fit more than four transistors plus a few coils and capacitors into these instruments. A new era began in 1996, when the first all-digital hearing instrument arrived in the market. A digital hearing aid not only amplifies sound, it recomputes it. "In most cases a person with hearing loss can no longer perceive the high notes," explains Röhrlein. "Speech and music therefore sound muted, and as hearing loss progresses, they become unintelligible."

A digital hearing aid amplifies the affected frequency bands quite selectively. In the Triano, Siemens top-of-the-line device, three microphones provide the data input (see illustration above). If necessary, ambient noises can be filtered out mathematically. And thanks to directional microphone technology, a user can pick out what another individual is saying among a cluster of people. The signal processors in these devices have a respectable computing power of several million operations per second.

Digital technology, however, did pose a real challenge for engineers, since the voltage and capacity of the batteries are limited. Even a brand-new hearing aid battery packs only 1.6 volts, and often puts out as little as 0.9 volt during operation. "But standard components used to require three to four volts," explains Röhrlein. "And our chips had to work on a mere 0.9 volt. Very few companies were able to make such silicon wafers." But patients were ecstatic. Much like the equalizer in a stereo system, the amplification of the hearing instrument can be adapted by the acoustician to the entire tonal spectrum of the individual patient's hearing deficiency.

When Hearing Aids Go Wireless. Still more advances are in the works. In the foreseeable future, microphones will no longer be separate components but will be integrated into the chip. That will save space and improve sound quality. And there will be further advances in ease-of-use. Users of dual hearing aids, for instance, have always had to manually adjust the volume or the programs of both devices when a change was necessary. Yet physicians and acousticians believe that dual devices are a necessity: The brain can only relearn how to hear correctly in stereo.

In the future, dual hearing aids should therefore be able to communicate easily with each other through wireless signals. This convergence of hearing aid and wireless technology presents a new challenge, because engineers have to cram the antenna and the wireless electronics into the same space with all the other components.

But there's the promise of a dual pay-off too, because wireless communications can be used to connect hearing aids to other devices. As a result, the hearing aid could become the headset of a cell phone, and perhaps shift its image away from healthcare and toward lifestyle. Perhaps people would then be less likely to put off dealing with hearing problems. Because unlike glasses or contact lenses, hearing aids continue to have a negative image. "Today it takes ten to 15 years on average," says Röhrlein, "before someone with hearing problems decides to take a professional hearing test." ■ *Bernd Schöne*

CUSTOMIZED HEARING AIDS — SCULPTED BY LASERS

Today's hearing aids can be concealed within the ear, thanks to ever smaller electronic components. The shell is now customized to fit the patient, designed in a computer, and sculpted to perfection by a laser. "The advantage of this new process is a better fit and improved patient comfort," explains Gerhard Hillig, president of "Forum besseres Hören" (Improved Hearing Forum), established by 14 hearing aid companies active in the German market. If the device can be made just a millimeter smaller than in the past, due to more precise dimensions, it can be concealed several millimeters deeper within the auditory canal. Siemens and its partners have perfected a new manufacturing method for this process. First the audiologist or acoustician makes a cast of the patient's auditory canal. Then this cast is precisely measured by a laser, and the data are entered into a CAD program. This initial design is then perfected by a technician, who can observe the model while rotating it about any axis on a display screen, to ensure that it will fit precisely within the virtual canal. In addition, the position of the chips must be established and the course of the ventilation channels optimized. Then a powerful laser comes into play, which slowly sinters a nylon powder to precisely create the shape of the hollow housing. This process takes four hours but can produce 200 housings simultaneously.