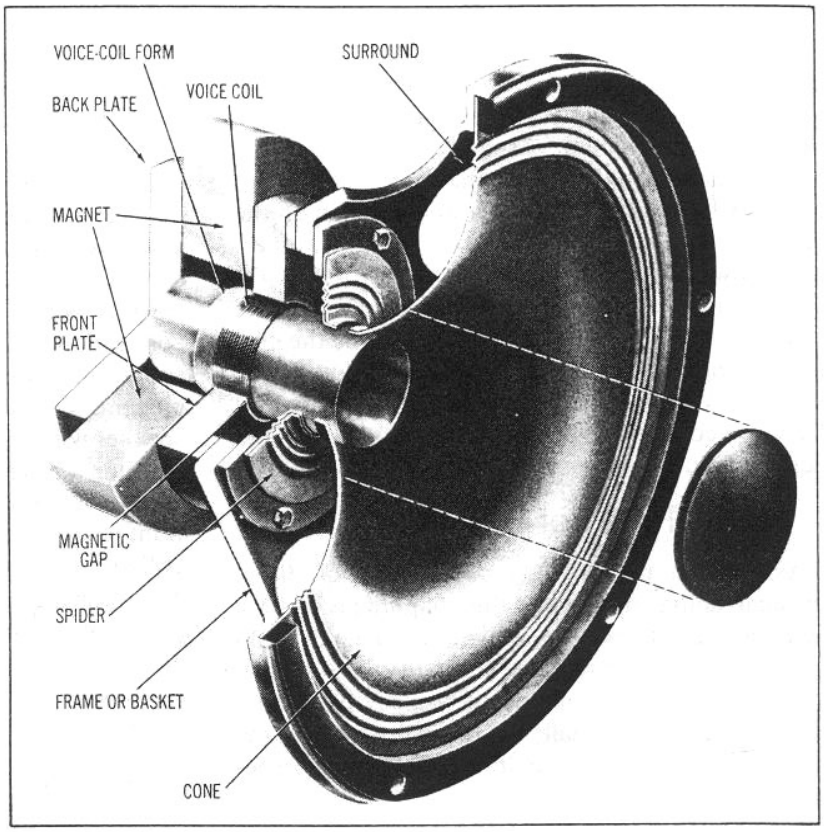

Fig. 1. A cutaway view of a conventional driver (full-range or low frequency) showing the various internal parts. Other types of dynamic drivers, such as tweeters, contain essentially the same parts, although they differ somewhat in appearance and costruction

LOUDSPEAKER FAILURE

Its causes and prevention

By Peter W. Mitchell

CAN you damage your loudspeakers by playing music too loud? Yes, and you don't need a super-power amplifier to do it. Even a low- power amplifier can cause damage if it is regularly pushed beyond its maximum power-output capability. But you needn't panic; such damage doesn't happen very often. Still, for your peace of mind, as well as to protect the investment you have made in high-quality speakers, you might like to know what causes loudspeaker failure in general and what you can do to prevent it in your system. To show how and where damage can occur, we'll begin with a review of loudspeaker anatomy.

Anatomy

Most loudspeaker systems consist of one or more drivers installed in an enclosure. By driver, I mean a woofer, a mid-range, or a tweeter. The driver (see Figure I) consists of several parts, most prominent of which is the "diaphragm," the shallow cone or rounded dome that is visible when the enclosure's grille is removed. Attached to the back of the cone or dome is a cylindrical bobbin on which is wound a coil of fine wire, the voice coil. The voice coil fits into a narrow circular slot in an assembly consisting of a permanent magnet and a surrounding structure of soft iron. The slot, or "gap," has to be narrow in order to concentrate the magnet's field on the voice coil. A circular piece of spring-like corrugated fabric, called a spider, is used to guide the movement of the voice coil so that it remains centered in the narrow slot of the magnetic assembly. Woofers (low- frequency drivers), tweeters (high-frequency drivers), and mid-ranges are all made this way, though they differ in details. (This description, of course, applies to "dynamic" speakers, which represent the vast majority of speakers sold today. Electrostatic loudspeakers and a few other novel types are constructed differently.)

The combination of voice coil and magnetic as- sembly constitutes an electric "motor" designed to be driven by the output of an audio amplifier. The amplifier, in sending an audio signal to the speaker system, causes an electrical current to flow in the voice coil - a small current for small signals, a rather large one for loud musical passages. The flow of the current causes a varying magnetic field to be formed about the voice coil, and this field, because of its interaction with the driver's magnet, causes the coil to move rapidly backward and forward (vibrate) in the magnetic assembly's slot. And since the coil is attached directly to the diaphragm, it also moves, in turn imposing its vibratory motion on the air in the form of rapid pressure variations, otherwise known as sound.

The louder the sound a given speaker system is called upon to produce, the greater must be the current flowing through its voice coil and the longer the back-and-forth motions (excursions) performed by the voice-coil/diaphragm assembly. These are the factors of most concern to us.

Types of Damage

Aside from the obvious possibilities of direct physical abuse (rupturing the diaphragm with a well-placed kick, or dropping the whole loudspeaker down a flight of stairs), there are two common sources of loudspeaker damage: excessive voice-coil excursion (especially in the woofer) and the buildup of excessive heat in the voice coil (especially in the tweeter).

***Excursion.** For music reproduced at average home loudness levels, the back-and-forth excursion of the voice coil is only a small fraction of an inch. This usually leaves enough excursion in reserve to handle the loudest musical moments on modern recordings, or even to permit a substantial increase in the volume-control setting. But if you ever do drive the voice coil beyond its design range, several things can happen. The voice coil may be driven all the way back into the slot in the magnet structure, so that it strikes the back plate of the assembly. This voice-coil "bottoming" is quite audible, often taking the form of a rapid clacking or clicking or even a hair-raising "blatt." Another possibility is that excessive excursion will drive the voice coil so far forward that it pops out of its slot and fails to re- enter it properly. This often results in permanent misalignment. The voice coil then rubs against the internal parts of the magnet assembly, causing a scraping or a rattle on certain notes. Another possibility is that the coil could become jammed in the slot, preventing further movement altogether. Excessive excursion may also stretch or tear the fabric spider that holds the coil centered in the gap, or it may similarly damage the diaphragm where it is bonded to the metal frame of the driver. Finally, there are the wires that carry the electric current to the voice coil from the speaker's input terminals (or from the crossover); if the coil is vibrating back and forth too vigorously, these wires are flexed excessively and may fray and finally break. Figure 2 on the following page illustrates some of these mishaps. Of these excursion problems, voice-coil bottoming in the woofer is by far the most frequent, the result of playing music too loud. The other kinds of damage mentioned above usually require drastically excessive excursion. For instance, if you install standard a.c. plugs and extension sockets on your speaker wires in order to permit convenient disconnection of the speakers for house cleaning, sooner or later someone will make the mistake of plugging a speaker line into an a.c. wall socket. The speaker will absorb over a thousand watts of power, emitting a brief but very loud death rattle-and the demise is not covered by the warranty. So if you want to have quick-disconnect plugs in your speaker lines, use any kind of connector (phone plugs or dual banana plugs) other than the a.c. type. (Incidentally, speaker drive signals themselves pose no shock hazard, so you needn't worry about exposed wires or pins as long as they don't touch each other and short-circuit the amplifier.)

***Heat.** When you play music loud, your amplifier puts more electrical current through the voice coils of your speakers. Now, whenever an electrical current flows in a wire, some heating occurs, and the greater the current the hotter the wire becomes. This is why house wiring is equipped with fuses or circuit breakers, to stop excessive current safely before it can overheat the wires in your walls and start a fire. There's not too much danger of fire inside your loudspeakers, but it is possible, by persistently playing music at excessive loudness levels, to build up enough voice-coil heat to melt the insulation of the voice-coil wires, thus causing a short circuit, or to char the voice-coil form and the adhesive bonding the wire. Tweeters are particularly susceptible to this kind of damage, since their design requires low-mass voice coils with thin wire that heats up all the more quickly.

General Precautions

In the preceding paragraphs I may have painted a frightening picture of loudspeaker vulnerability. Actually, high-fidelity loudspeakers are not all that fragile; in fact, they could be considered the most reliable component in an audio system. But their design is optimized for reproducing recorded music in the home, and the likelihood of damage goes up when a speaker is fed signals its designer did not anticipate for it.

At mid-range frequencies, where most music (and especially recorded music) has its greatest concentration of sonic energy, a good speaker can play loud enough to satisfy practically anyone. In fact, for much music, even small speakers can safely be driven by surprisingly powerful amplifiers.

But with loud signals at very low and very high frequencies, a speaker can run into severe problems. It is characteristic of loudspeakers that, the lower the frequency of a musical sound, the greater is the excursion needed to produce a desired sound level. A good loudspeaker can safely play tympani drum beats (with a fundamental frequency of, say, 200 Hz) as loud as you please. But to reproduce a bass drum (perhaps around 50 Hz) at equivalent loudness levels would require upwards of sixteen times greater voice-coil/cone excursion, which may run the voice coil out of the gap or "bottom" it.

Usually the smaller and less expensive a loudspeaker is, the less power-handling capacity it has at extremely low frequencies. (Don't confuse this with frequency response. There are some compact, low-cost speaker systems that respond down to the lowest frequencies and reproduce a bass drum well at musically satisfying levels in a conventionally small listening room. But they won't shake the floors nor fill a large hall with adequate bass levels.)

Since excessive excursion is the result of too much signal at the lowest frequencies, woofer damage can be avoided by a straightforward rule: don't turn up your volume and bass controls too much at the same time. Feel free to use as much amplifier bass boost as you like at moderate loudness levels, and feel free to crank up the volume control to a saisfyingly loud level with just moderate bass boost. But high volume and high bass boost together are a prescription for danger. When a woofer is overdriven it may exhibit audible distress signals: clicking (voice-coil bottoming) or buzzing. If you hear these noises, turn down the controls fast!

There are other potential sources of excessive low-frequency input. If you leave the volume and/or bass controls turned up high while lowering the phono stylus to a record groove or while tuning rapidly across the FM dial, strong low-frequency pulses can be generated that may cause enormous woofer excursions and possible damage. Some tape recorders and amplifiers may also produce low-frequency thumps during switching. And, of course, connecting or disconnecting any shielded cables should never be done with the system turned on. Finally, cleaning the phono stylus with your equipment on and switched to the phono input can produce massive low-frequency signals, even if the proper technique is used (brush only from back to front, not side-to-side). If you have rugged speakers and a low-to-medium power amplifier, these various low-frequency impulses may prove to be annoying rather than dangerous. But if your amp is rated at 100 watts or more per channel, you should definitely write to the manufacturer of your speakers and inquire about fusing your speaker lines. Remember that many amplifiers can pass large signals with frequencies far above and below the range of human hearing, so it's sometimes what you don't hear that proves damaging in the end. Fuses may protect your speakers against these unperceived intruders. In addition, with all amplifiers it is wise to make a habit of turning the volume control down before operating any other control in the stereo system.

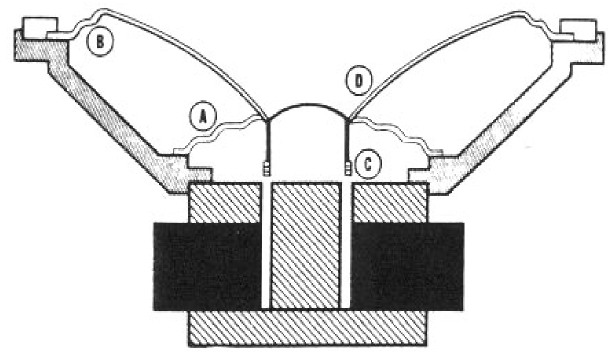

Fig. 2. Profile of an overdriven cone driver. The inner (A) and outer (8) suspensiuns are contorted or torn hy excessive excursions. The voice coil (C) may be permanently driven out of its gap, damaged hy mechanical and/or thermal stress, or separated from the cone (D).

The principal factors in tweeter failure are heat and broken connecting leads. A good tweeter can accommodate astonishingly large bursts of momentary power, but sustained high-frequency signals can burn it out or cause its wires to break from continuous rapid flexing. It is fortunate that the power- handling capability of tweeters is well matched to the sonic characteristics of most music. Those instruments which can generate large amounts of high-frequency energy (bells, cymbals, and other percussion instruments) usually do so only in brief bursts with rest periods between notes. Instruments that can produce continuous high-frequency sounds (piccolos, organ, violins) usually do not do so very loudly. Most classical, jazz, and even rock music is therefore no threat to your tweeters even if played at high volume levels. But beware of music containing repeated or sustained sounds that are both high-pitched and very loud, as these can melt tweeter voice coils at high volume-control settings. For example, in some rock recordings the engineers compress the dynamic range to a nearly constant volume level, so that your tweeters are not given time to cool between bursts of maximum energy. With these recordings you shouldn't attempt to approach the sort of sustained high loudness levels that are heard in clubs and at highly amplified concerts unless you are confident of your speakers' capabilities in this regard. Uncompressed high-fidelity recordings, on the other hand, not only sound more lifelike and have more impact than compressed recordings; they are also generally safer to play at high volume levels because they have a high peak-to-average ratio. Even though the peaks may draw the full power of the amplifier, they will do so only briefly, whereas the long-term average levels will be considerably lower. On the other hand, one tends to set the volume control somewhat higher for uncompressed music since the average level is lower, so when a loud, uncompressed peak comes along, it may blow the speaker fuses.

Unlike acoustic musical instruments, electronic music synthesizers such as the Moog can generate sustained high-frequency sounds at any level the composer desires, and so may exceed the performance capabilities of high-fidelity loudspeakers. Brief beeps and whistles that sweep up and out quickly are usually no problem, but if the music contains continuous high whistles, play it safe and moderate the volume level. Another way you might melt your tweeters' voice coils is by feeding in sjn- gle-frequency test tones from a signal generator or test record with the volume control turned up to help you hear the highest tones clearly. Test tones are hazardous for several reasons. First of all, unlike music signals, they are continuous, and the tweeter doesn't get a chance to cool off between notes. Secondly, because of the nature of the human hearing mechanism, the ear finds the true intensity of single-frequency tones difficult to judge. They often sound much softer than music at the same levels, thus tempting one to increase the amplifier output to a level beyond what the speakers can tolerate. Tape recorders that let you hear the tape while in fast-forward or rewind must also be used with care; if you leave the volume up, the near-ultrasonic twittering can be very hard on tweeters, even if it doesn't sound very loud to your ears.

If you find that, at the loudness level you enjoy, the sound takes on a biting, harsh, or gritty texture it lacks at lower levels, then you may be driving your amplifier into distortion. The strident quality is caused by clipping, which generates lots of spurious high-frequency energy. ("Clipping" is what an amplifier does to the musical signal when driven beyond its rated power output.) If you find this biting edge on the sound attractive (some do) and continue operating your stereo system this way, you are gambling with the life of your tweeters. They can reproduce short bursts of high-frequency energy brilliantly, but a continuous diet of clipping distortion is murder. This is a situation where a high-power amplifier, reproducing the signal loud and clear, can actually be safer than a lower-power amp which is continuously driven into distortion. According to one manufacturer, more tweeters are damaged by moderate-power amplifiers than by super-power amps operating cleanly. Therefore, as you turn up the volume, listen to the quality of the sound. As long as it sounds at least as clean as it did at lower levels, you're safe. But the intrusion of an edgy or distorted quality that gets rapidly worse as volume increases is a danger sign. Incidentally, if your amplifier has provisions for plugging in an electric guitar or electric bass, don't play such instruments loudly through your stereo speakers. Recordings of these instruments (which have been subjected to various limiting processes) can safely be played through high-fidelity speakers, but special instrument speakers are needed to handle the direct output from the electric instruments themselves unless they are played very softly. Of course, if you want to play even recorded rock music at the loudness levels encountered in the front row at a rock concert, you need speakers designed specifically to produce those sound-pressure levels. Practically no conventional high-fidelity loudspeaker can.

Specific Tips

As I have indicated, high-fidelity loudspeakers made by reputable manufacturers can safely be used with amplifiers of any power rating to play most kinds of music as loud as most people want to hear it in their homes. Much of the time, there is no need to be at all concerned with the power-handling capabilities of loudspeakers. But if you want to protect your speakers from accidents and from extreme conditions, follow these sensible rules:

1. Don't install standard a.c. plugs on your speaker wires.
2. Be alert for the danger signs of an overdriven stereo system: clicking or buzzing from the woofer, and strident or gritty treble that clears up at lower loudness levels.
3. Turn down the volume when changing records, tuning FM, flipping switches, fast-winding a tape, etc.
4. At high volume levels don't use excessive bass boost, especially with small speakers.
5. Don't play FM interstation hiss or high-pitched electronic music at very loud levels, and don't play test tones at even moderately loud levels.
6. If you are using a very high-power amplifier, follow

your speaker manufacturer's recommendations about fusing. (There's no easy formula for calculating the proper fuse for a given speaker.)

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