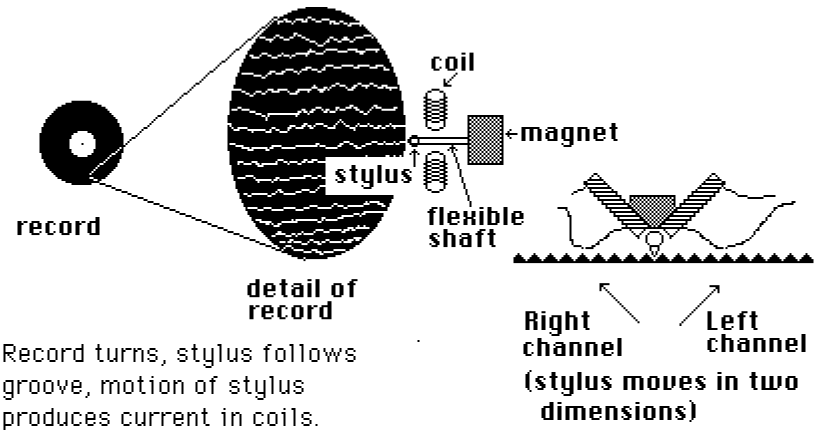
Analog Recording of Sound

Records



The basic principle of disk recording is very simple. Displacement of the microphone diaphragm is transformed into a wiggley groove on a moving piece of vinyl. A stylus tracing the wiggles exactly reproduces the motion of the diaphragm at the time the recording was made. Electricity is really incidental to the process, used as a convenient way to connect the microphone to the cutter and the pickup to the speaker.

Most of the development in record technology has been devoted to putting a lot of music on a single record. The obvious approach, slow speed and a narrow groove, reached a practical limit in the middle of the century with the 33 1/3 rpm microgroove record. At that speed, (9 inches per second in the inner part of the groove) a 20 khz signal has a wavelength of .0004 inch. It is very difficult to manufacture a stylus that would handle wavelengths smaller than that.

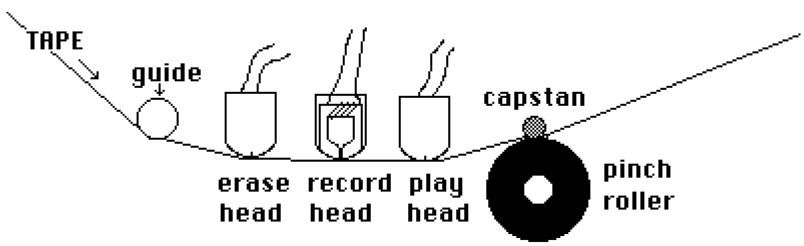
The major consumer of real estate on the record is low frequency content. This is because the amplitude of the electrical signal produced is proportional to the side to side velocity of the stylus. Given equal velocities, a low frequency wiggle will swing wider than one of high frequency because at low frequencies the cutter will not turn around as often as it does at high frequency. To counteract this effect, the low frequency content of the record is deliberately reduced, and this low end rolloff has to be corrected by a bass boost in the playback system.

The high frequency content is given a treatment opposite to that of the lows. High frequency information is emphasized during recording, and reduced during playback. This is an attempt to reduce the noise generated by the roughness of the vinyl. That noise is white noise, and as such sounds like a high frequency phenomenon. When the playback system reduces the high frequency content to its proper level, the noise in that range is reduced by the same amount.

The combination of bass roll-off and treble boost is called the recording characteristic, and the complementary response of the playback system is called RIAA equalization after the manufacturer's association which standardized this feature in 1956.

The LP is an endangered species with the advent of Compact Disk technology, but it will not disappear overnight. Even if no new records are produced, there are hundreds of millions in existence, including many unique performances and compositions.

Analog tape

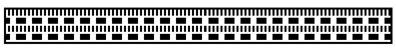


Tape deck mechanism

The principle of tape recording is just as simple as that of disk recording. The tape is a strip of plastic which has been coated with a material that is easily magnetized. (The most commonly used material is highly refined rust, or iron oxide.) The capstan is a spinning post. The tape is held tightly against the capstan by the pinch roller and dragged across the three heads at a steady rate.

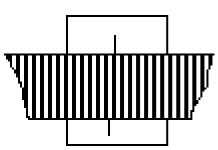
All three heads are essentially the same in construction: a C-shaped piece of metal with the very narrow gap of the "C" near the tape. A coil of wire around the metal can serve to either detect or produce magnetic fields at the gap. If a strong current is passed through the coil, a field is produced which creates a magnetic spot on the nearby tape. The amount of magnetism will be proportional to the amount of current. If the tape is moved and the current varied in a periodic way, a "track" of magnetic areas will be imprinted on the tape. All of this happens at the record head. When the tape subsequently passes the play head, the varying magnetic field on the tape produces a varying current in the play head coil, which can be detected by some sensitive electronic circuitry. (The erase head works just like the record head, but at a super high frequency which will not be recorded but which will obliterate any existing information.)

The signal applied to the record heads is equalized in a manner similar to LPs, for essentially the same reasons. The equalization is varied according to speed and type of tape. That is automatic on most decks, but must be set manually on some cassette decks.


Magnetic patterns on the tape

This drawing shows how the magnetic fields are oriented on a stereo tape. You can see four tracks, two of which are played when the tape is going one direction, the other two when the tape is reversed. (Multi-track tape decks use all four tracks or more at one pass. There are also formats which use only one or two tracks, recorded on the entire width of the tape.) The width of a single track is an important factor in the strength of signal that can be recorded, which ultimately limits the noise of the system. The width of a track depends on the width of the tape as well as the number of tracks; various sizes ranging from 1/8 inch to 2 inches are used, recording up to 24 tracks.

The distance between spots in a single track is the wavelength of the signal, which depends on the frequency of the signal and the speed of the tape. The higher the frequency of the signal, the shorter the wavelength (a familiar formula). There is a limit to how small the shortest spot of magnetism can be; namely the width of the gap in the recording head. The practical result of this limitation is that the highest frequency that can be recorded is limited by the speed of the tape. Again, various standards are in use, from 1⁷/8 to 30 inches per second.

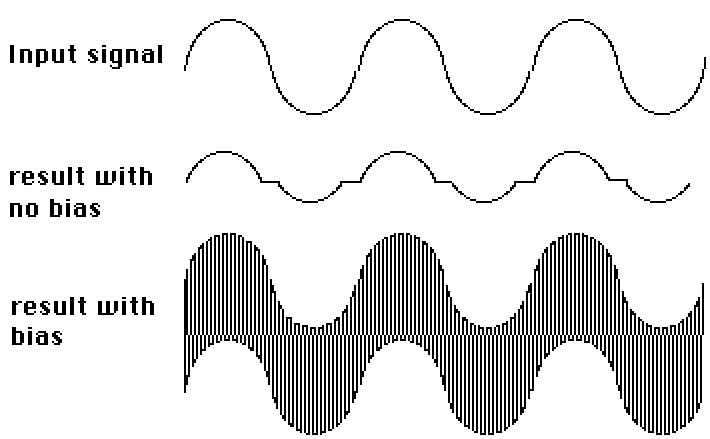

azimuth error

This drawing shows another feature of the magnetic spots. At high frequencies, the magnetic domain is a rather slender, tall shape, almost a line. If that line is not exactly the same angle as the gap in the play head (which is supposed to be perpendicular to the tape), the energy represented by the magnetism will not be accurately detected, resulting in a reduced output signal. Low frequency signals are not affected by this factor (known as azimuth adjustment), so the net result is a loss of highs. In a cassette system, this alignment is a function of the plastic shell, and is generally rather sloppy in all but the most expensive tapes.

AC Bias

Tape recording would be a very low fidelity business without AC bias. The process of magnetization is linear only when applied to fields of medium strength. There is a limit to the strength of field that the tape can accept. Once the tape is completely magnetized, no amount of extra current in the head will increase the resultant field. That condition is called saturation. As the strength approaches saturation, there is a gradual falloff in the effectiveness of the magnetization process. This results in a phenomenon called "soft clipping", which is definitely distortion, but as distortions go is reasonably unobjectionable. Incidentally, since the record equalization increases the high frequency content of the signal, this clipping will happen to the highs first: that is why a cassette seems to lose its top end response when it is recorded "hot".

Clipping is something we live with in all electronic systems, and is easy to avoid; simply keep the gain down. Another region of nonlinearity is more difficult to deal with. The magnetization process produces field regions that alternate in polarity: one north, one south, north again, and so forth. In between there are regions where the field strength is zero. When the oxide is not magnetized, a fair amount of current is required to produce any magnetization at all; this leaves a flat spot in the middle of the waveform, as illustrated in the second waveform in the diagram below.



We avoid the effects of this nonlinear region by adding a very high frequency (over 100 khz) bias signal to the signal we are trying to record. The result is the third waveform. The center of the bias frequency is distorted, but the original signal, which is the shape of the overall waveform, is clean. The playback head cannot respond to the bias signal, and simply returns the original. The amplitude of the bias signal has to be carefully adjusted to provide a distortion free recording. Many tape decks (especially cassettes) offer a switch to make a coarse change in bias for different tape types, but a finer calibration is really required for optimum results.

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