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THE MAGNETISM BEHIND TAPE RECORDING

Magnetic recording is by far one of the greatest achievements of the past century. It has enabled people to conveniently record on low-cost magnetic tapes or disks, which just as easily as they can be recorded, can be erased and reused numerous times.

Believe it or not, the technology for magnetic recording has been around since the turn of the twentieth century when Valdemar Poulsen invented the first recording machine.[1] It was not until the German military began employing it in World War II, however, that its use became widespread. Since then the original version has been modified many times to improve both the length of the tape and the quality of the recording.

The simplest and most common example of magnetic recording and playback in our everyday lives is the tape recorder, a simple diagram of which is shown below.

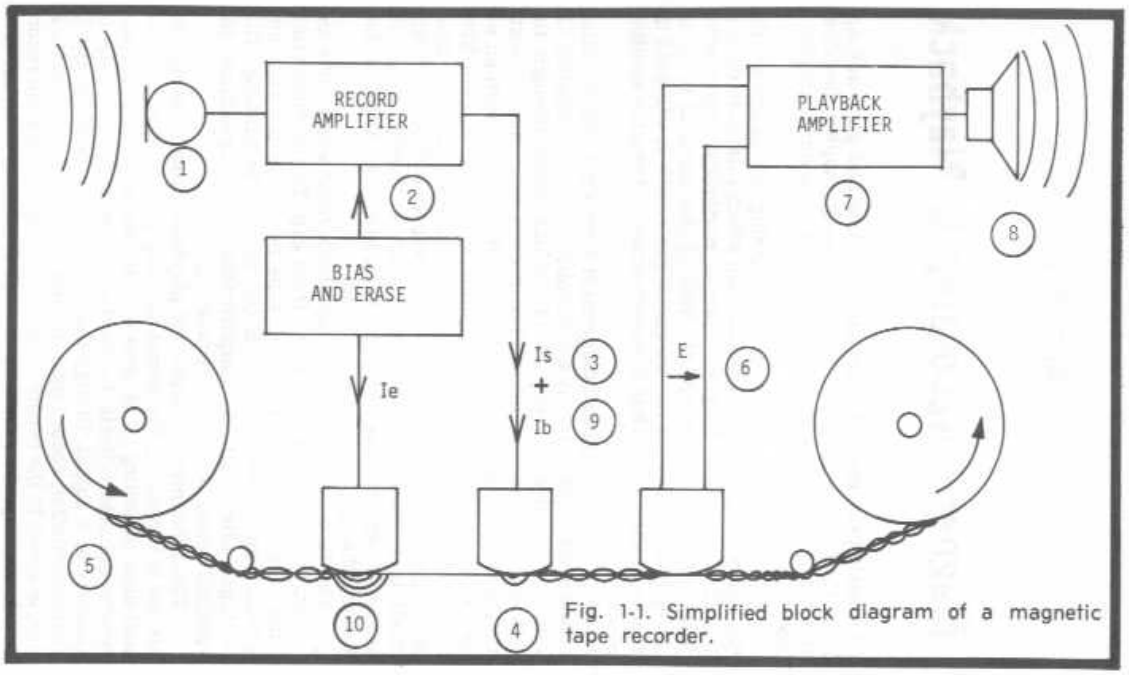

Fig. 1-1. Simplified block diagram of a magnetic tape recorder.

Jorgensen, Finn. *Handbook of Magnetic Recording*. Blue Ridge Summit, PA: Tab Books, 1970. 10.

[1] Jorgensen, Finn. *Handbook of Magnetic Recording*. Blue Ridge Summit, PA: Tab Books, 1970. 5.

All the basics behind magnetic recording and playback can be found in analyzing this simple device. A tape recorder such as the one shown above can be used for either audio or data recording, both of which entail recording entire input waves. Digital recording, in contrast, records only the presence or absence of the input signal. So while digital recording will not be directly addressed here, all of the principles brought forth concerning audio and data recording are still applicable.

MAGNETIC RECORDING

Figure 1-1 is a simple diagram of how magnetic recording works (here on a tape recorder). Basically, the process begins with a microphone (1) or other input device receiving an incoming wave signal. This signal is then passed through an amplifier (2), which prepares the signal for recording and sends it out along a recording current (3) to the record head. The current creates a magnetic field in the air gap (4) in front of the record head, penetrating the tape passing through and recording the input wave. In addition, the recording process is made much more effective by erasing or demagnetizing the tape (10) before recording to it.[2]

To understand more completely how this process occurs there are a few essential topics that must be explored and explained, namely the properties of the magnetic materials used to make the tape recorder and the techniques used to reduce noise during recording.

Magnetic Materials

There are basically three types of metallic materials: non-magnetic, soft magnetic, and hard magnetic. Examples of each can be found in the following table:

Non-magnetic	Soft Magnetic	Hard Magnetic
copper aluminum brass	mu-metal permalloy transformer laminations	alnico iron oxide

Jorgensen, Finn. *Handbook of Magnetic Recording*. Blue Ridge Summit, PA: Tab Books, 1970. 11.

Non-magnetic materials, of course, are those that cannot become magnetized. The distinction between soft and hard magnetic materials, both of which can become magnetized, is made by the material's ability to retain its magnetism outside of a magnetic field. A simple experiment can be conducted to determine which of these three types of magnetic material a specific sample is.

Taking a current-carrying coil of wire, we know that within the coils a strong magnetic field is created. Thus, by placing our sample inside of the coils we can easily determine if the material is magnetic or not. Then we remove the current, thereby also removing the magnetic field. With the absence of the magnetic field, a soft magnetic material will quickly lose its magnetism, whereas a hard magnetic material will retain it for a very long time.[3] A measure of how well the sample holds this magnetization is called remanence.[4]

The record heads in tape recorders contain metallic cores made of soft magnetic material, allowing the magnetic field created by them from the incoming current to continuously change. A form of permalloy therefore is often the material chosen to construct record heads.[5] In contrast, the recording tapes are coated with hard metallic material. This is because with any other material the magnetic information stored on the tapes would be instantly lost after the they passed the record head. Iron oxide is currently

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[2] Jorgensen 9.
[3] Jorgensen 11.
[4] Jorgensen 13.
[5] Mallinson, John C. *The Foundations of Magnetic Recording*. 2nd ed. New York: Academic Press, Inc., 1993. 40.

the most common material used to make magnetic recording tapes, although other magnetic materials may provide higher quality (chromium for example).

Bias and Noise

"The quality of a recording depends on the linearity between the field strength in the record gap and the magnetization or remanence left on the tape."[6] Because there is no perfectly hard magnetic material, remanence often distorts the waveform of the record current and renders any audio or data recording completely useless. So something must be done to either correct or counteract the flaws created by remanence. The term we use for this correction is bias. (An interesting note here is that because of the differences between digital recording and audio or data recording described earlier, digital recording requires no bias because it does not feel the effects of remanence.)

In earlier tape recorder models, remanence was offset by applying an additional DC current through the record head.[7] This current served to adjust the linearity between the magnetic field strength and the remanence and to reduce the distortion of the input waves, but it still did not cancel out a large portion of the imperfections.

Then in the late twenties AC bias, a technique which can reduce almost all tape remanence and background noise, was developed. The details behind AC bias are extremely complex and not all are completely understood as of yet. However, we do know that by adding an alternating electric field the imperfections in the recording technique are effectively canceled out and the initial remanence on a tape is gradually reduced to zero. And by setting the AC bias field to oscillate at several times the frequency of the highest audio or data frequency to be recorded, a very high-quality

[6] Jorgensen 13.
[7] Jorgensen 15.

recording can be made. For optimal performance, one must also make sure to set the amplitude of the AC bias at the appropriate level for the thickness of the tape.[8]

Going back to Figure 1-1, AC bias (9) sufficiently reduces background noise by leaving the record head in a neutral magnetic condition when no signal is present. It also is often used to erase magnetic recordings before they pass under the record head. Any remaining noise on a tape after applying AC bias is usually directly related to irregularities in the magnetic coating on the tape itself.[9]

MAGNETIC PLAYBACK

Magnetic recording is truly a novel idea, but without magnetic playback, the means by which we can retrieve sound or data that has been magnetically recorded, it would all be pretty useless.

Looking at Figure 1-1 again, we see the tape passing over the playback head, a device very similar to the record head with a soft magnetic core and an air gap in front. The magnetic field lines or flux from the recorded tape permeate the core of the playback head to produce an induced voltage (6). This induced voltage is then passed through an amplifier (7) and the original sound is reproduced through a speaker (8).[10]

Industry Standards and Equalization

Overall, the playback process is much simpler than the recording process of the tape. However, it may not be as simple as it looks. The speed at which the tape passes under the playback head obviously has a direct effect on the frequency at which the

[8] Jorgensen 18.
[9] Jorgensen 18.
[10] Jorgensen 9.

sound is reproduced. So the tape recorder industry sets standards for the tape speed of commercial recorders.[11]

Also, "the voltage induced in the playback head is not only proportional to the tape flux but also to the frequency."[12] So in order to attain a constant output voltage over the entire range of frequencies, the amplitude must be made greater in areas of high and low frequencies. This process of increasing the amplitude is known technically as equalization.[13] Unfortunately, equalization almost always produces additional noise at low and high frequencies. Therefore, standard practice is to boost the record current in areas of high and low frequency to lessen the amount of required playback equalization. The audio industry has also had to set standards for the amount of boost added because too much could cause an overload and create distortion.[14]

Quality and Track Width

Signal-to-noise ratios are used to evaluate the quality of audio recorders. The ratio is exactly what it sounds like: "the separation between the maximum record level and quiescent noise level."[15] Some typical signal-to-noise ratios for recorders are given in the following table:

Ratio	Model
35-40 db	Old 78 RPM (phonograph) recorder
50-65 db	Modern LP (phonograph) recorder
35-45 db	Inexpensive home tape recorder
45-55 db	Good home recorder (2 tracks)
50-65 db	Professional recorder
65-75 db	High-quality studio recorder

Jorgensen, Finn. *Handbook of Magnetic Recording*. Blue Ridge Summit, PA: Tab Books, 1970. 22.

[11] Jorgensen 19.
[12] Jorgensen 19.
[13] Jorgensen 21.
[14] Jorgensen 22.
[15] Jorgensen 22.

An important thing to note is that signal-to-noise ratios are always reduced by at least 3db each time the track width is cut in half.[16]

Originally, magnetic tape was 1/4" wide and had only one track which could be used. Later the track was split in two so that the tape could be played and recorded in one direction, flipped over, and then played and recorded again in the other direction. Then with the advent of stereo recordings, which recorded on two tracks, magnetic tape was soon split into four tracks with stereo recording taking place in both directions. Following directly from this same idea comes the eight tracks that used to be so popular in automobiles.

The problem with breaking up the tape into several tracks is, as presented before, the loss in the signal-to-noise ratio or the quality of the recording. For most of us consumers this small loss in quality is more than made up for by the increased length in recordable tape. However, for many professional recording studios it is not and so they normally opt for the higher quality tape, usually made wider to begin with and not split into as many parts.

Magnetic recording plays an extremely large role in America today. While tape recorders such as the ones presented here are somewhat out of date, replaced by newer digital technology, the principles behind how they operate still hold true. And who knows, in twenty years maybe eight track players will make a come back. Then again, maybe not.

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[16] Jorgensen 22.

Bibliography

Jorgensen, Finn. *Handbook of Magnetic Recording*. Blue Ridge Summit, PA: Tab Books, 1970.

Mallinson, John C. *The Foundations of Magnetic Recording*. 2nd ed. New York: Academic Press, Inc., 1993.