Magnetism

Hysteresis Loop

A lag between cause and effect.
With magnetism it is the amount that the magnetization of a material lags the magnetizing force due to molecular friction.
Magnetization is applying the coil of wire with a current flowing through it.
A hysteresis loop which is formed when you plot magnetizing force H (the power of the electrical current) against flux density B (the power of the magnet) through a complete cycle of AC.
Diagram 1.
Diagram 2. Start with current I over time t. Start increasing current. Current goes positive, go positive on the H side of B vs. H plot. B took a while to get started but it started increasing. The flat portion of the B/H curve indicates saturation (the flux density stays the same despite increasing current). The material is magnetized as much as possible.
Then, start decreasing current from the peak. *Diagram* 3.
Remanance or retentivity. How much the magnet retains magnetic force when the magnetizing current drops back to zero.
Diagram 4. Current going negative. Applies coercive force to the magnetic force at zero current. Pulls the magnetic force back to zero/nothing.
Diagram 5. Current going from most negative back to zero.
Diagram 6. Current going from zero back to positive.

Magnet Strength and Remanence

If material has less remanence, the hysteresis curve will be thinner, since the amount of magnetism remaining in the magnetic material at zero current is a lot smaller.
Strong magnets include speaker magnets, motor magnet.
Weak magnets include refrigerator magnets.
Advantages of strong magnets: desirable for permanent magnets and magnetic recording and memory devices.
Advantages of weak magnets: transformer and motor cores to minimize energy dissipation with the alternating fields associated with AC electrical applications.
Where in electronics we use low remanence materials: record/playback head, transformers.
Takes less power to get a weaker magnet to saturate.
A low remanence material would take less current to magnetize, a high remanence material would take more current to magnetize.
This example assumes we apply enough current to saturate whatever magnetic material is being examined.
The remanence point is that point along the B axis (where H = 0).
The area of the hysteresis loop is related to the amount of energy dissipation upon reversal of the magnetic field. Narrow hysteresis loop implies a small amount of dissipated energy in repeatedly reversing the magnetization.

Recording on Tape (Biasing)

Magnetism curves are curves, not linear. Would make a bad linear amplifier. *Diagram* 7. Modifying the signal like this creates distortion.

DC Biasing

To adjust to move to the linear range of the magnetic curve, we must **bias** (set a DC bias voltage) to get to the linear range. Diagram 8.

AC Biasing

Can use the positive and negative sides of the B-H curve using an **AC Bias Voltage** to double our output. Switch at about 40 kHz. Switches our audio: puts a bit on the positive voltage part, and another bit on the negative voltage part of the curve. Diagram 9.

The original tape recorders had a reel. The reel pulled the tape. Only used one side (the positive side) of the magnetic curve. Once they started wanting to record music, went to AC bias since could get twice the amplitude with the same material. It's a little more work.

Could DC bias it, but studies show that it would be less than half the quality that provided by AC bias.

The audio signal is modulated onto the 40 kHz signal. Not amplitude modulation, just adding the two signals together. The two signals are not mirror images of each other like they would be in AM. The two signals are in phase with each other. The 40 kHz waveform is distorted on output, but it gets filtered out since we don't hear 40 kHz.

The amplitude of the “carrier” remains constant; just the minimum and maximum voltages of the 40 kHz waveform change, in this sort of application. Compare with modulation/mixing, where the amplitude of the carrier (the difference between maximum and minimum voltage) is modified to follow the audio signal being modulated on the carrier.

Crossover distortion – where the signal crosses over the zero point. The carrier keeps the wanted signal from traversing the nonlinear portions of the magnetic response curve.

Magnetic Heads

Core material (usually pressed powdered iron). Put in contact with material with magnetic domains so we can align the domains in various degrees to capture various information. Tape head put in contact with tape. Domains are randomly oriented when demagnetized. When record, shift some domains on one direction or the other.

Diagram 10. Cassette head stack. Turn tape over and record left and right channels on the other side.

Biasing

Orient magnetic domains in the tape. Get regions of net positive magnetization and net negative magnetization. The signal is the envelope shape on a high frequency bias signal.

Pro machines have three heads: erase, record, playback.

- Erase head uses the 40 kHz signal, high amplitude, high frequency AC signal to erase.
- Record head takes the bias and the music signal. Only puts the audio changes down since it doesn't respond to the high frequency of the bias. The gap is too wide to record the high frequency bias.
- Playback head detects only those changes in the audio range. Playback head doesn't respond to the high frequency AC signal.

Erase

The gap in the erase head is wider than those in the record head. The tape stays in the field of the head longer to thoroughly erase any previously recorded signal. It's like moving a tape cartridge slowly away from the degaussing machine. Recording amplitude of some erase heads is in the hundreds of volts. The erase head is physically separated from the other two heads by a lot more distance than the separation between the playback and record heads.

Erasing

Done by the erase head. Bias frequencies range from 70 kHz to 150 kHz, but within the recorder the frequency must be kept stable.

The erase signal relatively strong, ensures tape driven into saturation when passing erase head. Due to high frequency and inductance of the erase head, signal voltage often several tens of volts at the erase head.

Gap relatively wide (100 micrometers to 400 micrometers). Sometimes multi-gap heads used. Ensures tape driven several times (10 to 50 times) into saturation while it passes the gap. How would a multi-gap head be structured? Steve isn't familiar with more than two. He's seen two cores, pointed in the same direction, in tandem with each other.

Magnetic field strength H in recording head will cause certain magnetic flux density B in the core and in the tape at the gap. When a certain point of the tape moves away from the gap, the residual flux B will remain in the tape.

Tapes must have a relatively high remanence in order to store as much magnetic energy as possible.

Recording

The small part of the tape becomes in essence part of the record head so it takes on the magnetic value generated by the record head.

Add bias and signal, impress on record head.

Record head's magnetic field alters polarization (not physical orientation) of the tape's magnetic particles so that they align their magnetic domains with the imposed field.

The stronger the field, the more particles align their orientations with the field until all particles are magnetized.

The retained pattern of magnetization stores the representation of the signal.

Playback

Problem: magnetization of tape is proportional to recorded signal, but induced voltage in the coil is proportional to rate at which the magnetization in the coil changes. As tape passes the head, the induced voltage will depend on tape speed. In other words, playback is our challenge.

This means that for a signal with twice the frequency, the output signal is twice as great for the same degree of magnetization of the tape. For example, record 1 kHz and 2 kHz at 1 volt, but if you play them back, the 2 kHz signal will be twice as loud as the 1 kHz signal.

Useful example of Faraday's law: the rate at which the magnetic field changes.

Playing back a tape at fast speeds does increase the playback volume. You may have heard that when you fast forward a tape in a player that plays back the audio while it fast forwards. The VU meter will peg also.

Just like we have gamma correction in the camera for CRT response, we have a correction for magnetic response on playback.

It is therefore necessary to compensate for this increase in signal to keep high frequencies from being boosted by a factor of two for each octave increase in pitch. This compensation process is called **equalization**.

Factor of 3 dB for each octave. **Tape has a factor of 6 dB per octave**. Why is it 6 dB and not 3 dB? 3 dB plus 3 dB? Steve will find out. Put this in your notes. It's the difference between voltage and power. Voltage is 10 log, power is 20 log.

Audio reference is 1 kHz at 0 dB.

Repro Head

Spacing loss increases exponentially with increasing distance as a ratio of the wavelength of the signal. Start to lose signal exponentially as tape moves away from head linearly. So, head must be in contact with the tape at all times.

High frequencies more susceptible to dropouts. Spacing loss expressed as 54.6 dB/wavelength distance, meaning that almost 60 dB of dropout is produced if the tape is separated from the head by the wavelength of the signal of interest. This is a huge difference.

Gap Loss (decrease in output signal due to the length of the gap). Gap loss reflects the fact that the reproduce head responds to the average flux in the gap. Diagram 12. Therefore, *if the wavelength of the signal just equals the gap length, there is no signal produced*. The head can't detect the change at that frequency. The signal wavelength must be larger than the gap. At low frequencies this also results in a series of peaks and dips in the frequency response known as **head bump**. The tape runs across the gap. Video recorders need a pretty small gap.

Bel

Named for Alexander Graham Bell.

Decibel measures how one power compares with another. It is not a direct measurement of power. The two powers being compared might be the input and output signals of an amplifier. Output usually bigger than input. It is always a comparison. Decibel is one-tenth of a bel.

Formula

DB = 10 log (P_2/P_1) –put this in your black book.

P1 = reference power

P2 = power being compared

Decibels usually rounded to the nearest whole number.

Advantages of using Decibel

Convenient to use dB to cover wide variety of signal levels.

Power levels above reference are positive, power levels below reference are negative.

Cover wide signal level range using small number range. For example, power out of a radar antenna might be 30 kW while the echo from a distant target could be 0.1 micro watt. These become 45 dBW and -70 dBW. The symbol dBW is referenced to a ratio over one watt.

Components will have individual gains and /or losses for each unit.

Expressed in dBs, these can be simply added/subtracted to give overall gain/loss. Simpler than using ordinary numbers which would have to be multiplied or divided to achieve the overall figure.

Example

An amplifier has input signal of 2 micro watts and an output signal of 50 watts. Its power gain is 50 W divided by 2 micro watts, or 25 million. In decibels, this would be 74 dB.

Can do by **10 ln (P2/P1) / ln (10)**.

Example 2

If a signal of 600 mW is fed into one end of a long cable and only 250 mW emerges at the other end then the gain of the cable is 0.417 in ordinary numbers or -4 dB. Can be described as a loss or attenuation of 4 dB.

Example 3

An amplifier of power gain 20 followed by an amplifier of power gain 30 will, in combination, give an amplifier with a power gain of 20 * 30 or 600 times.

In decibels, the first amplifier has a gain of 13 dB and the second has 14.8 dB giving a total of 27.8 dB when the decibels are added.

The Anti-Log

The reverse log function is called the anti-log and is marked 10^X. The anti-log function is required to change decibels back into ordinary numbers.

Formula: **P2/P1 = anti-log (dB/10)**

Find the anti-log function on your calculator. Might be: LOG^{-1}, 10^X, ALOG.

A gain in dBs of 26 dB can be converted into a number representing power gain or loss, using the formula, as follows: power ratio = anti-log (26/10) – anti-log(2.6) = 400.

Ratio Decibel Equivalent

Ratio	Decibel
1 (equal)	0 dB
1.26	1 dB
2	3 dB
4	6 dB
10	10 dB
20	13 dB
100	20 dB
10^3	30 dB
10^6	60 dB
10^9	90 dB

When the decibel value is negative, then it means to divide by the ratio concerned.

Since decibels are combined by adding a ratio of times 20, which can be thought of as x2 and x10, is the sum of the decibel equivalents, 3 dB and 10 dB = 13 dB.

As a rough guide, one decibel represents a 26% increase in power level. However the increases are compounded so 2 dB is not 52%, it is 1.26^2 or a increase to 1.58 (58% increase). 3 dB is 1.26^3 or an increase to 2.00 (an increase of 100 % - a doubling of power).