INDUCTORS FOR PASSIVE FILTERCIRCUITS

1.1. Air-Core Inductors

An inductor is in principle nothing else but wound up wire. A winding form, mostly made of synthetic material, is only necessary for winding reasons. Inductors that are built like this are called air core inductors. The effectiveness of the inductor relies on the generation of a magnetic field by the conductor, through which an electric current flows through. Once the conductor is wound up first a conductor loop and then an inductor is attained. *(Figure 1.12)*

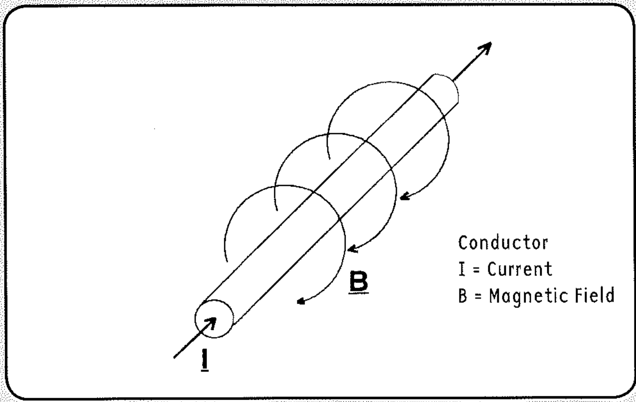

FIGURE 1.11.

Inside the cylindrical inductor a largely homogeneous magnetic field B (T) (unit Tesla), which runs for the denoted current flow in the direction of the arrow, is present *(Figure 1.13)*. The reversal of the current direction also reverses the direction of the magnetic field.

A reversal, or rather a constant alteration of the current, which occurs in music signals, results in a constant change of the magnetic field. Here the inductor shows an interesting behaviour: A changing magnetic field (magnetic flux density change) causes in the own turns of the inductor an induction voltage, which takes a retarding effect on the current change that induces it.

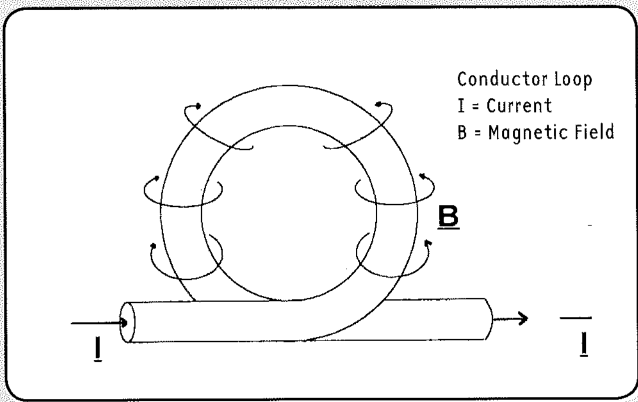

FIGURE 1.12.

The faster the change of the current direction occurs (high frequencies), the more pronounced is this effect. The inductor then operates like a resistor. The alternating current resistance of an inductor is also called inductive resistance.

The electric variable that describes the effect of an inductor is the inductance L (Measuring unit Henry).

In addition to the inductive resistance the inductor possesses another resistance (direct current resistance or DC-resistance), which follows from the limited conductivity of the wound up wire. An air core inductor can be largely characterised in the audio frequency range by the inductance I and the DC-resistance R0.

1.2. Core Inductors

If a magnetic material is brought into the magnetic field of an inductor, the magnetic flux density (B) will change. Under the influence of the magnetic field the "magnetic dipoles" present in the substance realign themselves in the direction of the field and increase the magnetic flux density and so the inductance of the inductor. The increase in inductance depends on the core material used as well as the structural shape of the core.

- **Core Materials**

As core materials ferromagnetic materials (e.g. iron) or ferrimagnetic materials (ferrites) are preferably utilised.

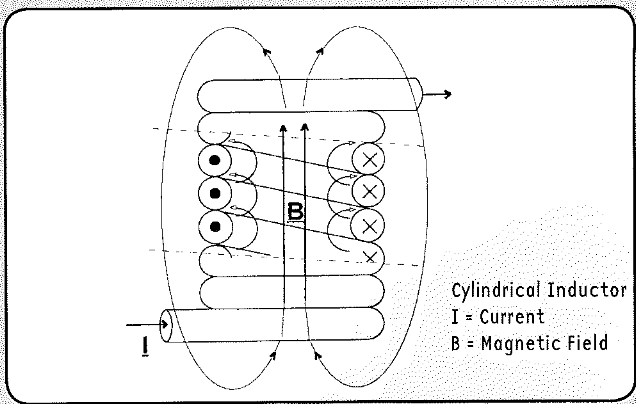

FIGURE 1.13.

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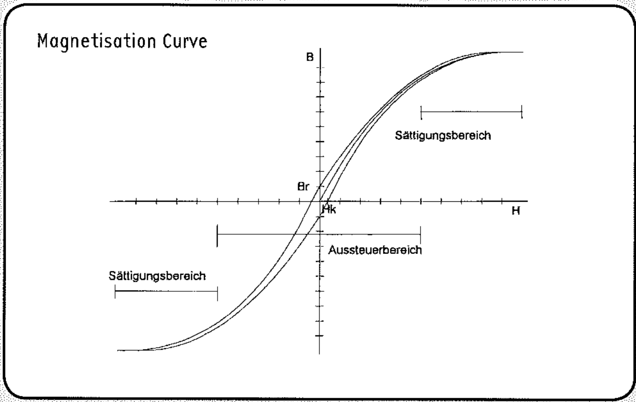

FIGURE 1.2.

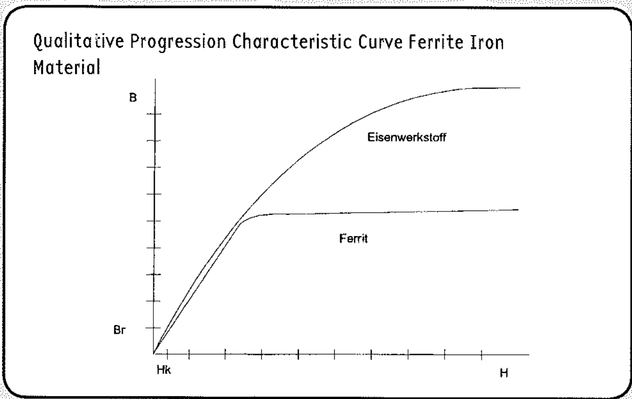

FIGURE 1.3.

• Ferromagnetic Materials

All iron materials belong to the group of ferromagnetic materials. The inductor cores consists mostly of compression-moulded, sintered iron powder within an insulating matrix or of layered, insulating sheet iron, which is utilised in a similar way in the transformer construction. (The insulation reduces eddy current losses, which appear during magnetic field changes).

• Ferrimagnetic Materials

Magnetically soft ferrites (as well as the so-called magnetically hard materials that are, e.g., atng used for permanent magnets) belong to the material group of the oxide ceramics. As oxide ceramic ferrite is predominantly made up of oxygen. The electrical conductivity is very low.

Ferrites are generated from a compression moulded powder. The raw parts are later annealed in a furnace (sintering) whereby they reach their final size and properties.

• Magnetic Properties

One demand on the core material is that to change the magnetic field should be easy, i.e. without large energy loss, because it should be used for alternating current appliances (audio frequency). A second demand is a linear magnetisation characteristic. I.e., the inductance increasing action of the material should also stay constant at increasing currents up to the saturation region. If that is not the case non-linear distortions are the result. It the current is increased even further the saturation state of the core material is reached. When this occurs no more magnetic dipoles can be oriented in the direction of the magnetic field.

• Difference Ferrite – Iron Material

The saturation inductance (saturation magnetic flux density) reaches values of around 0.5 Tesla in ferrites compared to 2.3 Tesla in metals. The Curie temperature, which is the temperature where the magnetic material loses its magnetic characteristics, lies at the most at 500°C for ferrites and at up to 900°C for metals. The specific electrical resistance in ferrites can be up to 1012 higher. This keeps eddy current losses small.

• Ferrites and Iron Materials in Audio Appliances

JEvery non-linearity in the magnetisation trajectory of a core material leads to distortions. Here there are two areas that need to be looked at separately. There is the control region, which is relevant to small and medium currents, and the saturation region, which needs to be looked at for large currents *(Figure 1.2.)*.

When ferrites and iron materials are compared concerning the linearity of the magnetisation curve *(Figure 1.3.)*, the following can be established: High grade manganese zinc ferrites (e.g. I.T. HQ-models)

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posses a linear characteristic curve in the control region, which results in a good distortion behaviour at small and medium outputs. Iron materials exhibit in the wider control region (higher saturation induction) slightly larger discrepancies from linearity. This leads to a somewhat increased level of distortions at small outputs compared to the ferrites. The advantages of iron materials lie clearly in the handling of high and very high outputs. (I.T. conductors with cores made of iron materials are the transformer inductors FE96 and FE130, the COROBAR inductors and the TOROBAR ring core inductors.

• Core Types

In addition to the material characteristics the core type plays a crucial role in the performance of an inductor. The characteristic curve of an inductor can be tuned within broad limits by the core type. In the following figure the core types common to the audio field and their characteristical data can be found.

It can be seen that the inductance of an inductor at a given number of turns is the bigger the more the core encloses the coil. From this naturally follows vice versa that, e.g., the bell core inductor exhibits the smallest DC resistance.

Air Core Inductor

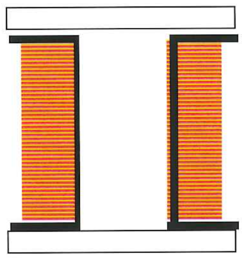
I.T. Model	LU 44/30
Wire-Ø/mm	0.95
Number of Turnsl n/1	120
Ro/Ohm	0.33
Inductance. L/mH	0.35

Bar Core Inductor

I.T. Model	CO 44/36
Wire-Ø/mm	0.95
Number of Turns n/1	120
Ro/Ohm	0.33
Inductance L/mH	1.05

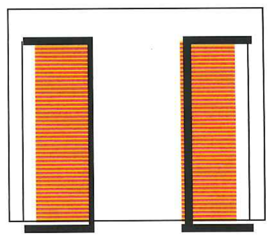
Mushroom Style Core Inductor

I.T. Model	HQP 43/40
Wire-Ø/mm	0.95
Number of Turns n/1	120
Ro/Ohm	0.33
Inductance L/mH	1.65



Bobbin Style Core Inductor

I.T. Model	HQG 52/36
Wire-Ø/mm	0.95
Number of Turns n/1	120
Ro/Ohm	0.33
Inductance L/mH	3.00



Bell Core Inductor

I.T. Model	HQ 43/45
Wire-Ø/mm	0.95
Number of Turns n/1	120
Ro/Ohm	0.33
Inductance L/mH	2.325

1.3 Description Key of I.T. Inductors

- **LU** – Air Core Inductor
- **HQS** – HQ Pin Core Inductor
- **HQR** – HQ Tube Core Inductor
- **HQP** – HQ Mushroom Style Core Inductor
- **HQ** – HQ Bobbin Style Core Inductor
- **HQG** – HQ Bell Core Inductor
- **CO** – Corobar Pin Core Inductor
- **DR** – Ferrobar Bobbin Style Core Inductor
- **FE** – E-Core-Inductor (Transformer Inductor)

LU 32/26

A B C

A: Description

B: Diametre/mm (for the E-core Cover Length)

C: Height/mm

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1.4. Areas of application for I.T. Inductors

From this table the technical characteristics of a certain inductor model can be read off. To do this read the column from the inductor model downward.

Example 1: You look, e.g. for the characteristics of the inductor model Ferrobar DR 56/35: Look for DR 56/35 in the row model. Downward you find in the first row a (1) next to inductor > 6.8 mH. Every other (1) in a column then shows a characteristic that this inductor model exhibits for inductance values > 6.8 mH. The (1) stands for inductor greater than 8mH. In the same way you can proceed for (2) (2.7mH – 6.8mH) and (3) (< 2.70 mH).

An inductor for precise requirements can also be found using this table.

Example 2: You look for an inductor with an inductance of 4.7mH, for performances around 300 Watt, with a medium DC resistance and low distortion values. For inductance values between 2.7 and 6.8 mH the label is the (2). Now you go into the row performance < 400 Watt. Now you find the (2) only with the four types that can be considered for theses specifications. In the row "DC Resistance medium" you find the (2) only under "COxx/xx 1.40mm". I.e. the inductor that meets the requirement is a Corobar inductor (Type COxx/xx).

	LU 32/26 0.71	LU xx/xx 1.0-mm	LU xx/xx 1.4-mm	LU xx/xx 2.0-mm	HQS 32/26	Entzerrerspulen	COROBAR 1.40-mm	HQP 44/35	HQP 56/35	HQ 40/30; HQ 43/45	HQ 58/45	FERROBAR DR 44/38	FERROBAR DR 56/35	HQG 36/26	HQG 52/36	HQG 70/43	TORROBAR TO 1000	FE 96	FE 130
Inductor->-6.8-mH				1		1	1		1		1		1		1	1	1	1	1
Inductor 2.7-6.8-mH		2	2	2		2	2		2	2	2		2	2	2	2	2	2	2
Inductor-<-2.7-mH	3	3	3	3	3	3	3	3	3	3		3	3	3	3		3	3	
Performance-<-60 Watt(8 Ohm)	3				3									2					
Performance-<-100 Watt(8 Ohm)		2	1						1	2	1		1.2	3	1.2	1			
Performance-<-200 Watt(8 Ohm)		3	2	1			1	3	2.3	3	2	3	3		3	2		1	
Performance-<-400 Watt(8 Ohm)			3	2			2									3	1	2.3	
Performance-<-600 Watt(8 Ohm)				3			3										2.3		1.2
DC Resistance very small				3									3		3	2	3	3	1.2
DC Resistance small			3	2			3		3	2.3		3	1.2	3	1.2	1	1.2	1.2	
DC Resistance medium		3	2	1	3		1.2	3	1.2					2					
DC Resistance large	3	2																	
DC Resistance very large						1.2.3													
no distortions	3	2.3	2.3	1.2.3															
very small distortions							3		3	2		3	2.3						
small distortions					3	1.2.3	1.2	3	1.2	1	2		1		3	2.3	1.2.3	1.2.3	1.22
medium distortions											1			.2.3	1.2	1			
Inductor for equalisation purposes					1.2.3														
Parallel inductor High Note	3	2			3														