Advantages of the self compensated audio transformers

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Summary of the presentation

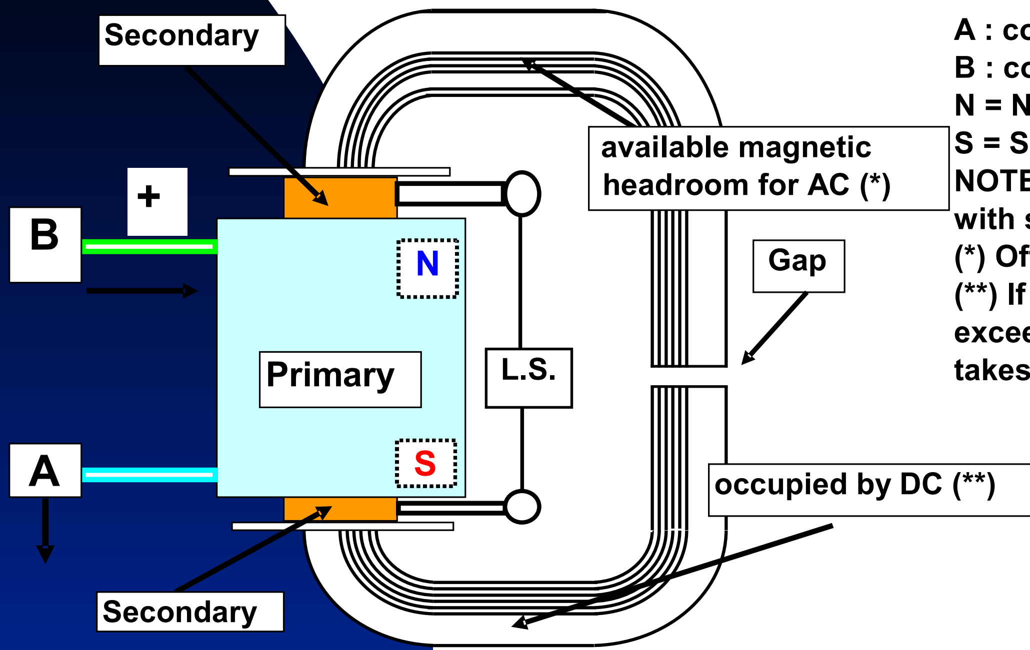
- Introduction
- The SE Gapped OPT
- The SE SC-OPT
- The SC-SCC-OPT
- THE Push-Pull OPT
- Influence of the coupling factor K
- Minimum Lp for f-3dB=20 Hertz
- Conclusions

Introduction

- Thank you for being here .
- This lecture compares the features of the classic audio output transformers (gapped single ended and push-pull), to some novel versions: the SC-OPT (Self Compensated Output Transformer) and the SC-SCC (Split Core Stereo Common Circuit), so far unknown to a large majority of Audiophiles.
- The reason why I am presenting these two novel versions, to this special ETF 2008 audience, is because I trust that, in some particular cases, they would profitably replace the use of the standard transformers, in no way affecting significantly the large share these occupy, thanks to their qualities.
- By explaining what, in my belief and experience, they are and they do, I hope to give the audio amplifier builders, two more options to choose from. In some cases, this would mean achieving better results in the amplifier's performance.
- We will examine first, the classic SE Gapped OPT, followed by the SC-OPT (self compensated, and therefore capable of working with valves operating at high idle currents: 200 mA and over). Then, we will consider the SC-SCC (using a common magnetic circuit for both channels), compared to the classic push-pull amplifier's output transformers.
- In no way, I intend to sustain that the new alternatives replace the glorious and familiar ones, indiscriminately.

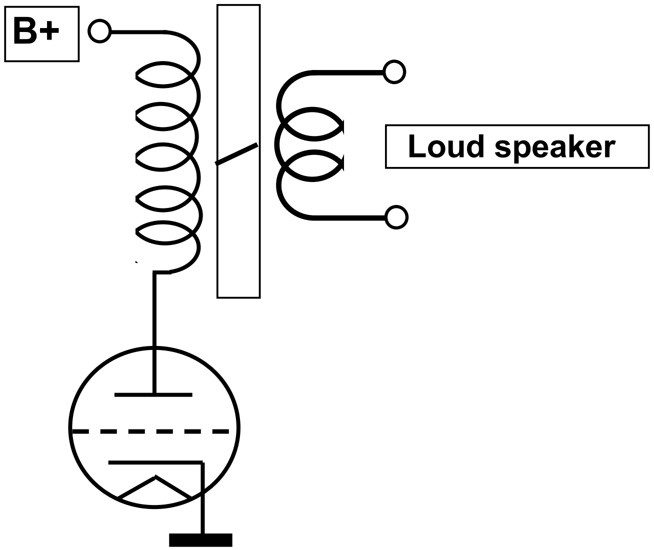
- As mentioned, the SC and SCC can only be useful in some particular cases. It is however a fact that the classic SE range of transformers available is limited, because it does not consider the case of valves working at high idle currents (200 mA and above) whereas the SC-OPT can go up and beyond 1A.
- This fact has given a great chance to the family of valves with low internal resistance, working at still DC condition above 100 mA, born and so far used mainly for stabilizing circuits.
- But there is more, as I will explain, and please believe me if I say that the resulting sound has nothing to envy to any other solution, according to many golden ears listeners.
- Some will object that the self compensation is not essential, and this is true, but think to the satisfaction to know that the SC not only achieves this, but also frees the SE amps from the power limits they always suffered from.
- As regards the SC-SCC (Split Core Stereo Common Circuit) do not forget the saving in cost and size that, in many cases are very important. One SC-SCC replaces Two push-pull OPTs
- May I add that I am grateful to Menno van der Veen and Pierre Touzelet for their continuous support and encouragement.

The SE gapped OPT
Construction and operation

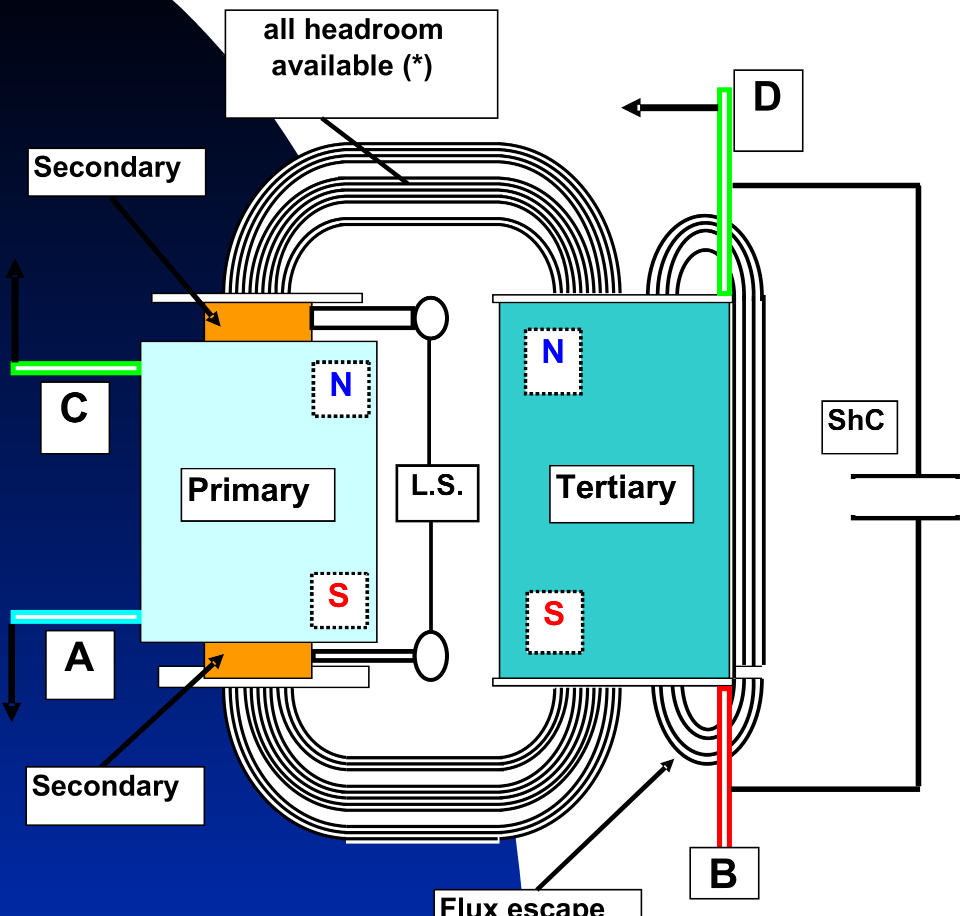


A : connected to anode
B : connected to B+
N = North pole
S = South pole
NOTE : Primary and secondary are tighly coupled, with several interleaved windings.
(*) Often less than half
(**) If the recommended maximum idle DC is exceeded, saturation of the magnetic core takes place, with bad distortion of the sound.

The SE gapped OPT
Conventional representation

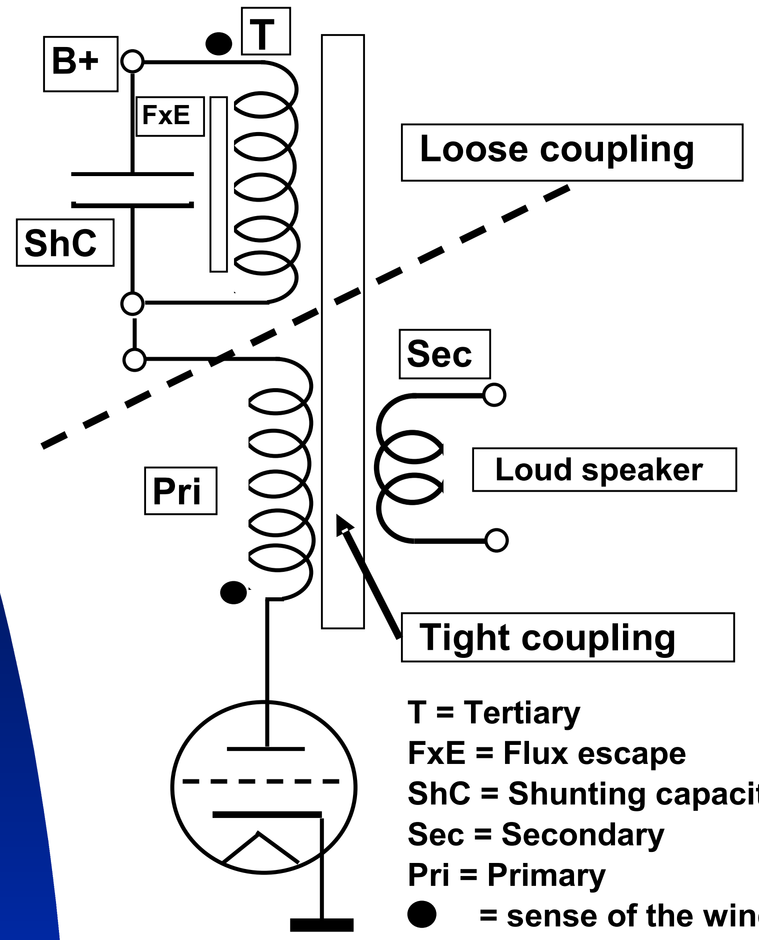


The SC-OPT OPT
Construction and operation



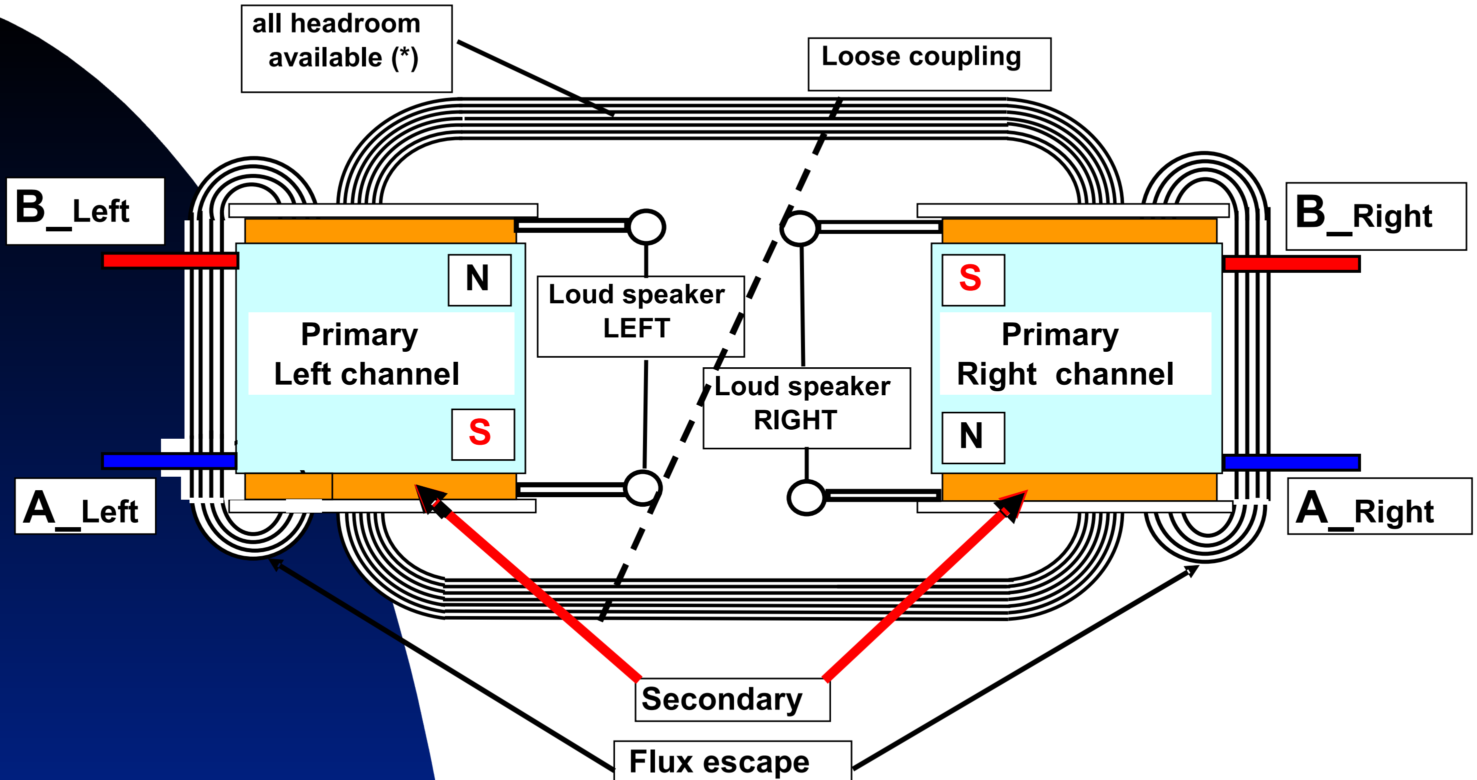
A : connected to anode
B : connected to B+
C : connected to D
D : connected to C
Also :
B : connected to the AC shunting capacitor ShC.
C+D : connected to the other terminal
Of the above capacitor
N = North pole
S = South pole
Flux Escape (FxE) = few turns of magnetic band
From the internal to the external side of the tertiary.
NOTE : If the windings are drawn next to each other,
this means that the coupling is tight.
NOTE : The tertiary can also have a secondary.
When short circuited the latter contributes .
to remove the opposing AC from the tertiary
(*) for A.C. provided the products Turns x Amperes
are the same in both opposing windings,
On the same circuit
OPERATION : Under the above conditions,
the DC offset takes place automatically and instantly.

THE SC-OPT
Conventional representation



T = Tertiary
FxE = Flux escape
ShC = Shunting capacitor
Sec = Secondary
Pri = Primary
● = sense of the winding

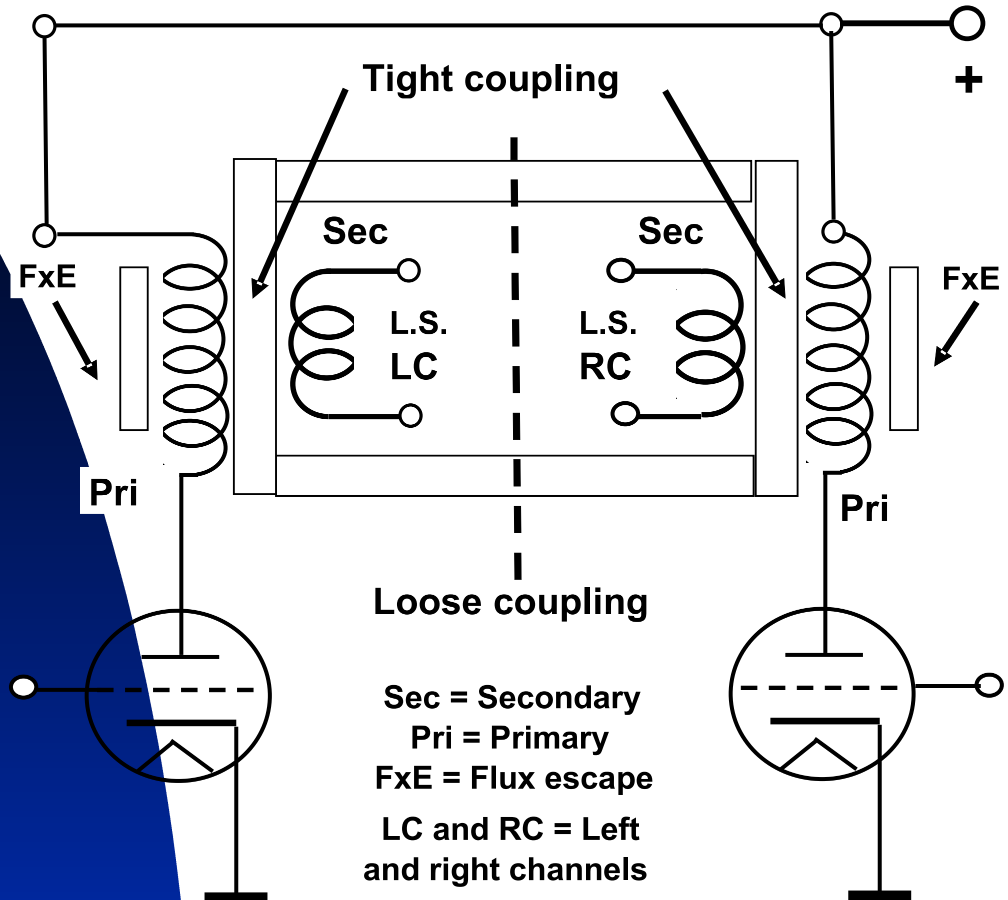
The SC-SCC-OPT
Construction and operation



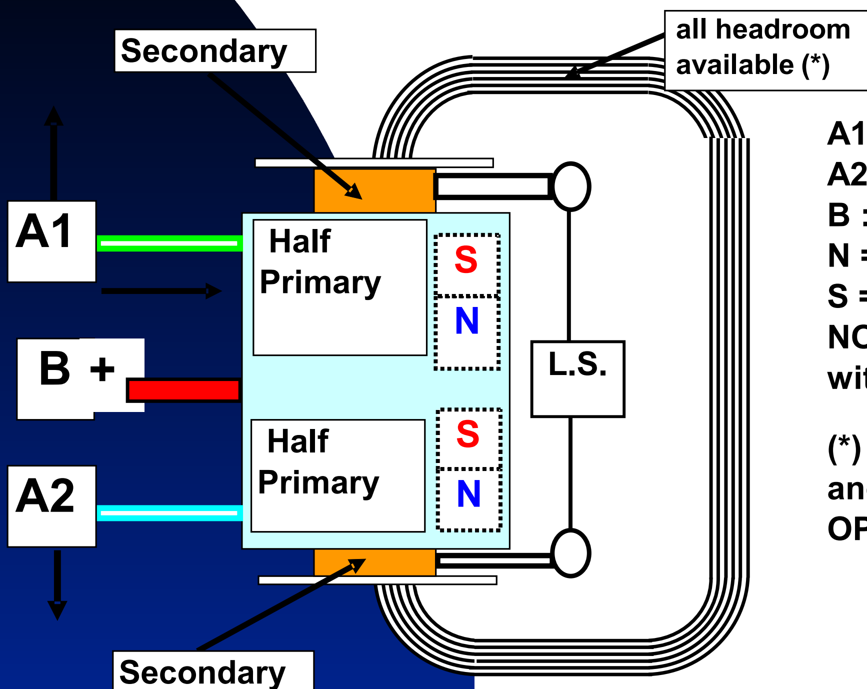
A_Left : connected to anode(s), left valve(s)
A_Right : connected to anode(s), right valve(s)
B_Left and B_Right : connected together and to B+
N = North pole S = South pole
Flux Escape (FxE) = few turns of magnetic band from the internal to the ext. sidesof the tertiary's bobbin

NOTE : If the windings are drawn next to each other, this means that the coupling is tight for AC, on condition that primary turns and idle DC are the same
OPERATION : Requires inverted signals in the primaries, for strong bass

THE SC-SCC-OPT
Conventional representation



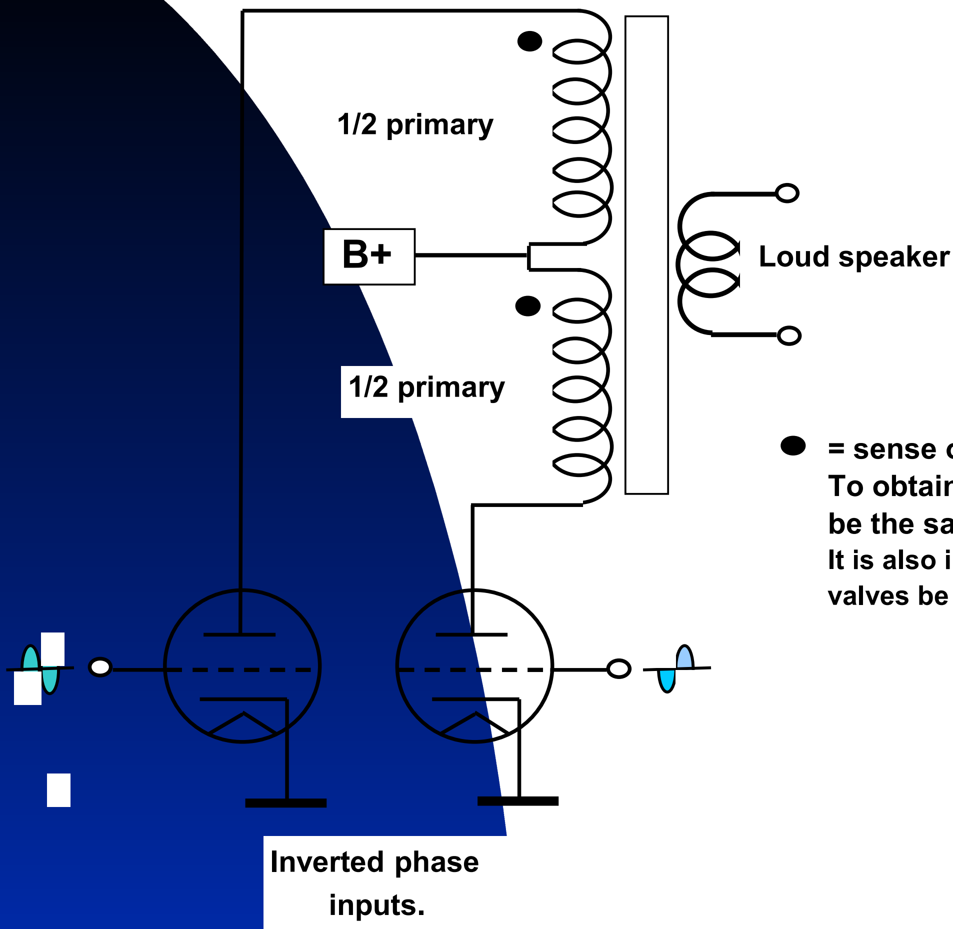
PUSH-PULL OPT
Construction and operation



A1 : connected to the anode(s) of valve(s) 1.
A2 : connected to the anode(s) of valve(s) 2.
B : connected to B+
N = North pole
S = South pole
NOTE : Primary and secondary are tighly coupled, with several interleaved windings.

(*) for AC, on condition that number of primary turns and idle DC currents are the same.
OPERATION: Requires inverted signals in the primaries.

PUSH-PULL OPT
Conventional representation



● = sense of the winding

To obtain the DC offset the idle currents of the valves must be the same.

It is also important that the amplitudes of the signals in the two valves be the same, otherwise the harmonic distortion increases.

Effect of the coupling coefficient « K »

The formulae

1) for 2 windings is series aiding

$Lt = L1+L2+2M$

$M = K*(\sqrt{L1*L2})$

2) for 2 windings in series opposing

$Lt = L1+L2-2M$

$M = K*(\sqrt{L1*L2})$

The references are :-

Lt = Resulting Inductance (henry)
The sign + is for series aiding.
The sign minus is for series opposing
L1 = inductance n°1 (henry)
L2 = inductance n°2 (henry)
M = Mutual Inductance (henry)
K = Coupling factor (between 0 and 1)

Calculation of Lt- from → L1 *100* henry
→ L2 *100* henry

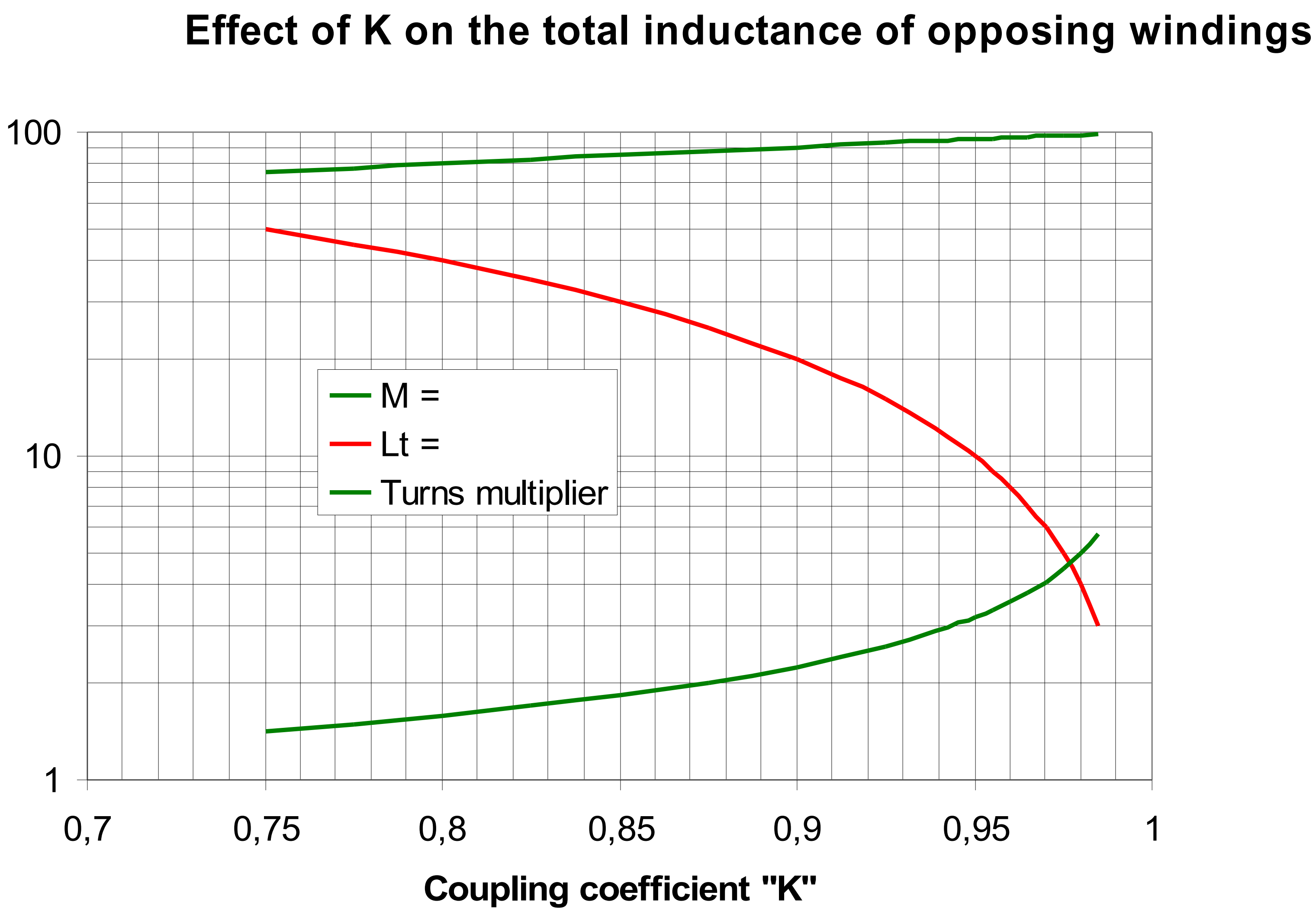
with

K	M =	Lt =	Turns multiplier
0,75	75	50,00	1,4
0,775	77,5	45,00	1,5
0,8	80	40,00	1,6
0,825	82,5	35,00	1,7
0,85	85	30,00	1,8
0,875	87,5	25,00	2,0
0,9	90	20,00	2,2
0,925	92,5	15,00	2,6
0,95	95	10,00	3,2
0,955	95,5	9,00	3,3
0,96	96	8,00	3,5
0,965	96,5	7,00	3,8
0,97	97	6,00	4,1
0,975	97,5	5,00	4,5
0,98	98	4,00	5,0
0,985	98,5	3,00	5,8

K	M =	Lt =	Turns multiplier
0,99	99	2,00	7,1
0,995	99,5	1,00	10,0
0,996	99,6	0,80	11,2
0,997	99,7	0,60	12,9
0,998	99,8	0,40	15,8
0,999	99,9	0,20	22,4
0,9991	99,91	0,18	23,6
0,9992	99,92	0,16	25,0
0,9993	99,93	0,14	26,7
0,9994	99,94	0,12	28,9
0,9995	99,95	0,10	31,6
0,9996	99,96	0,08	35,4
0,9997	99,97	0,06	40,8
0,9998	99,98	0,04	50,0
0,9999	99,99	0,02	70,7
1	100	0,00	Impossible

Effect of K on the total inductance of opposing windings

Effect of the coupling coefficient « K »



Primary inductance required to obtain low frequency with different valves

The formulae (*)

Calculating the lowest frequency at -3dB.

$$f_{-3L} = \frac{Z_a}{2\pi L_p} \cdot \frac{\beta}{\beta + 1}$$

$$\beta = \frac{R_i}{Z_a}$$

The references are :-

f_{-3L} = Lowest frequency required (Hz)

Z_a = Primary's impedance (ohms)

L_p = Primary's inductance (H)

R_i = Internal resistance of the valve (ohms)

The formulae (from above) re : $\beta = R_i \;/\; Z_a$

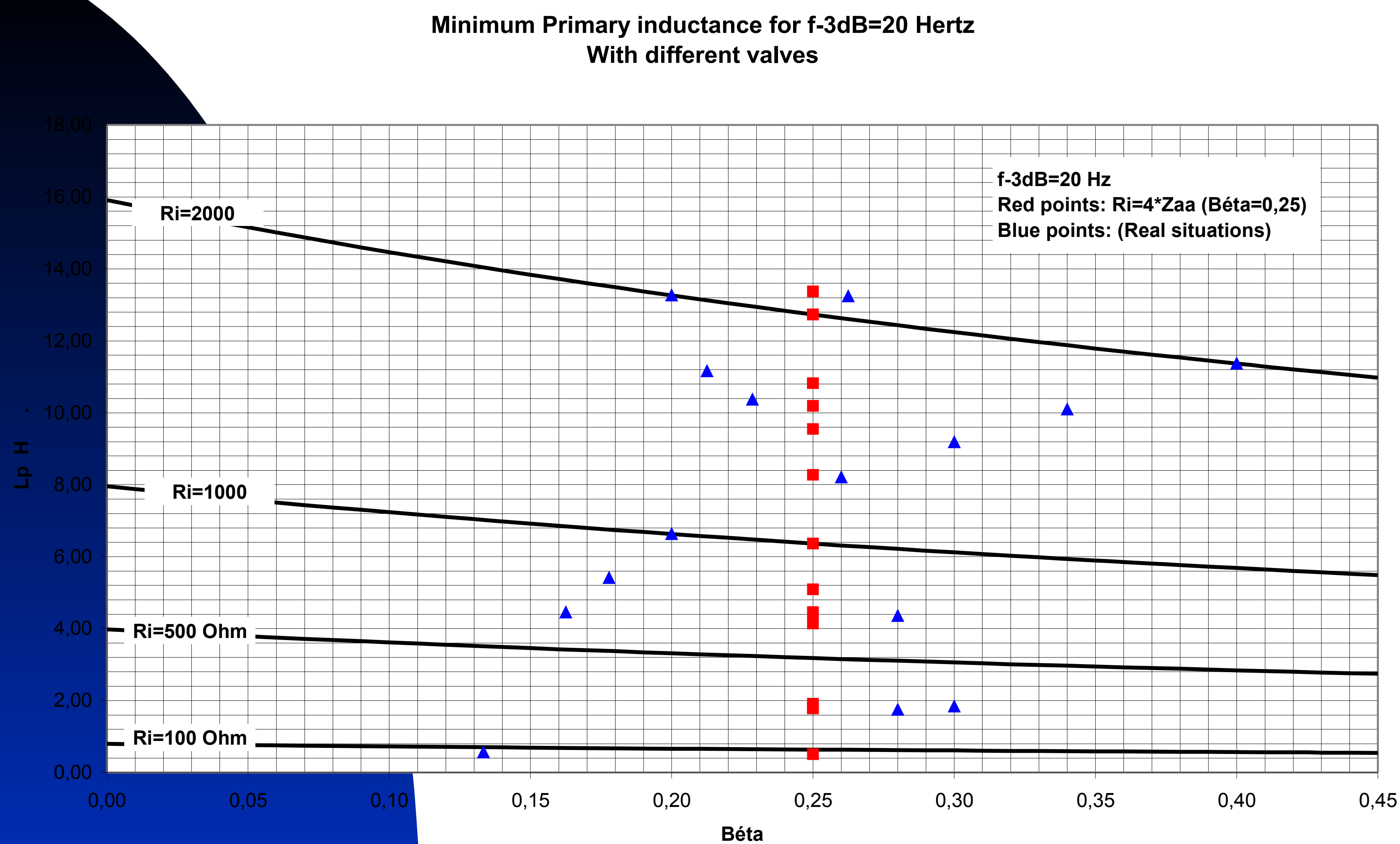
$$L_p = (\beta \cdot Z_a) / [(6{,}28 \cdot f_{-3L}) \cdot (\beta + 1)]$$

Primary inductance required to obtain low frequency with different valves

Calculation of the inductance Lp required to obtain f_{-3L} = 20 Hertz

Valve type	Ref	Ri kohms	Za kohms	β =	Lp *H*
6C33C-B	1	0,08	0,6	0,13	*0,56*
6080	2	0,28	1	0,28	*1,74*
6AS7	3	0,28	1	0,28	*1,74*
6336	4	0,3	1	0,30	*1,84*
KT100	5	0,65	4	0,16	*4,45*
2A3	6	0,7	2,5	0,28	*4,35*
300B-6B4	7	0,8	4,5	0,18	*5,41*
EL34-KT77-6AC7-12B4	8	1	5	0,20	*6,63*
807-KT88-6BX7-6550	9	1,3	5	0,26	*8,21*
EL34Tr	10	1,5	5	0,30	*9,19*
GM-70	11	1,6	7	0,23	*10,37*
845	12	1,7	8	0,21	*11,16*
6L6-KT66	13	1,7	5	0,34	*10,10*
SV811	14	2	10	0,20	*13,27*
6BL7-6BQ5-6V6-EL84	15	2	5	0,40	*11,37*
SV572	16	2,1	8	0,26	*13,24*
211	17	3,3	10	0,33	*19,75*

Primary inductance required to obtain low frequency with different valves



Conclusion

- From the above presentation of the novel transformers and their characteristics, we can summarize as follows:
- **The SC-OPT** provides a desirable feature: offsetting of the idle anode DC instantly and automatically, and, consequently, frees the magnetic space of the core, so that almost the full headroom is available for the AC signal.
- This results in doubling the core area of the transformer, allowing a large extension of the power range that was difficult, if not impossible, to achieve with the gapped single ended opt.
- Powerful, low anode voltage valves, up till now used for stabilizing circuits, suddenly become the best choice to operate with the self-compensated OPT.
- Indirectly, the construction of the primary/secondary bobbin is liable to extend the range also at the high frequency end, due to the fact that less inductance, i.e. less turns are required, reducing the stray capacity loss.
- On the other hand, using the SC-OPT with valves (single or paralleled), having a total internal resistance in excess of 300 ohms, is not recommended, because of the difficulties to extend the bass range.

- **The SC-SCC-OPT** has a different personality. It does not achieve self compensation of the idle DC and it requires phase inversion at its input, like the classic push-pull transformer.
- On the other hand, it provides almost the same power as the latter and easily reaches the low bass area still being quite extended in the high frequencies side.
- Its advantage is the lower cost (one magnetic circuit against two for the P-P) and reduced bulkiness.
- However, even if limited to frequecies below 200 Hz, some cross-talk takes place and, to the purist, this needs to be cancelled. It is possible to do it with an adequate electronic circuit acting as a Crossed Negative Feed Back, but, so far, only one listener complained and it was a guy specializing in car audio.
- In fact, when you sit at about three meters from the loudspeakers, the cross-talk is unnoticeable. Not surprising, because it seldom exceeds 4% in terms of voltage, at the stated frequency of 200 Hz. Obviously, in terms of power or in listening level, this is even less.

- **Concerning the sound**, it is surprising how neat and detailed the music, coming from an amplifier equipped with the **SC-OPT**, is. Highly emotional.
- As for the **SC-SCC**, it fills the stage with a consistent, continuous sound that gives the listener extreme satisfaction. The single ended characters of the combination remain and, therefore I thought of it as a double ended OPT.
- Finally, **the loose coupling** being compulsory with both these novel output transformers, the question is: “How to achieve it” .
- As you can imagine, it is as difficult as trying to get a very tight coupling and even more, I would say.
- The distance between the windings is part of the answer
- (between primary, with its interleaved secondary, on one side, and the tertiary, on the other side).
- But what improves drastically the situation is the **“flux escape”** that consists in filling a slot, left between the tertiary’s bobbin (somewhat wider than the primary’s one) and the iron, with few turns of magnetic band, from the inside to the outside. This is also applied to the SC-SCC, with the same results.

- To give you an idea, when measuring a primary without flux escape, if you read, for instance, 2 Henry, as soon as you fit the first turn of magnetic band, the inductance grows and when the flux escape is completed with five turns, the initial figure has almost doubled.
- The explanation lies in the fact that a tight coupling means that most of the magnetic lines are common to the windings concerned. By introducing this "flux escape" you make a diversion of these lines and reduce those in common.
- I hope this quick survey gave you an idea of these new products as alternative opportunities for your amplifiers.
- You will find some notes here, available.
- If you need more details, please do not hesitate to contact me at the following address :-
- A2Belectronic@wanadoo.fr and www.polisois-audio.com
- Thank you,
- Ari Polisois