Département Electronique et Energie

Spécialité Electronique et systèmes de l’énergie électrique

Graduation project from 10/10/2011 to 02/24/2012

Characterization of high voltage insulation planar transformer and flyback design tool

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Graduation project:

Characterization of high voltage insulation planar transformer and flyback design tool

1. Acknowledgements

First of all we want to thank Mr. Franck Labombe. Thanks to him we can have a closely contact with the Mors Smitt Relais Company and he gave us a lot of help in the domains of technology, the database of different materials. Without him we can't carry out our work so smoothly.

We also want to thank Mr. Ambroise Schellmanns who is our tutor in Polytech Tours. After we chose this subject as our graduation project we have several regular meetings with him, and during the last 4 months he gave us a lot of useful instructions.

We send our appreciation to the Mors Smitt Relais Company because it friendly provides an opportunity for students in Polytech Tours to accomplish their projects. For us this treasonable cooperation between school and company let us have in-depth study in the area of high voltage insulation planar transformer.

In the end we are grateful to the pleasant cooperation between us two. We worked hard and we successfully finished the scheduled tasks.

Summary

2. Introduction

First of all we want to give you a global view of schedule of our final year project :

	Octobre				Novembre				Décembre				Janvier				Février				Mars			
	40	41	42	43	44	45	46	47	48	49	50	51	1	2	3	4	5	6	7	8	9	10	11	12
Titre 1 : Transformateur d'isolement																								
Etape 1 : Essais électrique du prototype N°5		■	■																					
Etape 2 : Tolerance entrefer et collage			■		■	■																		
Etape 3 : Bilan des performances							■																	
Etape 4 : Process industriel									■															
Etape 5 : Dossier de fabrication (coûts, usage)									■		■													
Etape 6 : Applications aux alims multi sorties											■		■		■									
Titre 2 : Outil de dimensionnement																								
Etape 6 : Prise en main															■									
Etape 7 : Rédaction d'un cahier des charges															■		■							
Etape 8 : Réalisation de l'outil sous excel																	■		■	■	■			
Etape 9: Rédaction du rapport er poster																			■	■				

Réunion PFE avec M Lacombe et mise en marche des PFE

Réunion sur le site de MSR à Sablé sur Sarthe
Essais diélectriques et moulage
Jeudi 10 Novembre

Rédaction du rapport et soutenance finale

Table 1 : final year project planning

Our work is generally composed by two parts: One is experiment and industrializing a high voltage insulation planar transformer the other is designing a flyback database tool.

The products range Mors Smitt contains several embedded sensors, for example the MSAVDC. The MSAVDC (MS stands for Mors Smitt, current A, V voltage) provides a measurement representation of the DC current consumed by the railway rolling stock equipment on the catenary lines of supply (750VDC, 1500VDC and 3000VDC).

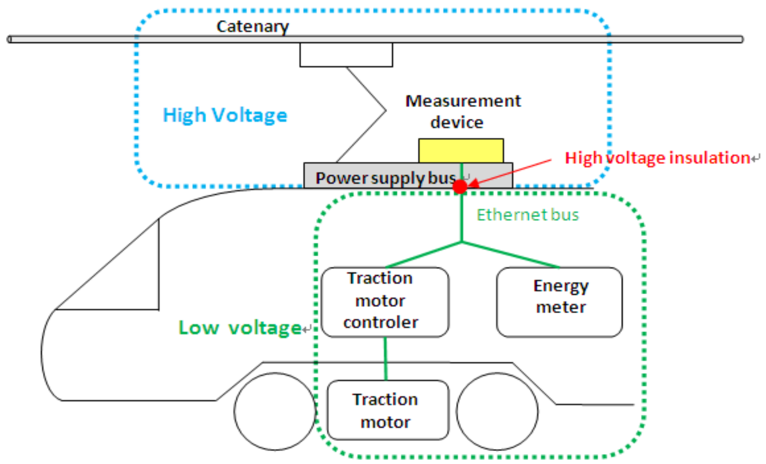


Figure 2 : train control synoptic with MSAVDC

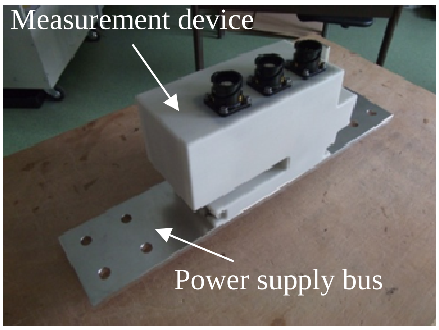


Figure 1 : global view of MSAVDC

Placed on the roof of the train, this system can be in direct contact with high voltage and ground. Therefore, it must be able to protect the external battery packs in order to ensure the safety of goods and persons on board. Moreover, it must meet the constraints of temperature and humidity which have a direct impact on the behavior of electronics inside the device.

According to the principle of shunt measurement, a voltage measurement of the current crossing a portion located in the power bus bar of the train is taking by two resistors. The connections for the measurement are also used to measure the temperature of the copper bus bar in order to correct the temperature drift. The system also includes an auto calibration system. Then, it is possible to calibrate the measurements by integrating the dimension variations of the section of the bus bar.

This analog information is converted in digital data form, and then transmitted thanks to an insulated bus between HV[1] and LV[2] printed circuits boards. It is an asynchronous serial communication type, ensuring a transfer of data bits one at a time, through a single transmission line (TX). The baud rate is set at 500kbits/s (cf. Appendix N°1).

3. Resume of previous work

During my last internship, I carried out a feasibility study of a high voltage insulation planar transformer for serial communication of MSAVDC in order to replace the existing solution. The internship result was the design of five prototypes within the constraints of operation and electrical insulation (cf. Appendix N°1).

The opto-isolator used for the high voltage insulation isn't able to ensure the high voltage required by the railway standards. That's why we studied about magnetic solution and more precisely planar transformer.

Compared with traditional transformer the planar transformer has absolutely many advantages:

- It decreases the volume of transformer and in this sense it is more promising to be used in integrates device electronics.
- We can fully control its electronic performance in the period of designing
- We have a better reproductibility because the characteristics of turns are strictly the same in a printed circuit board.

[1] HV : ***H**igh **V**oltage*

[2] LV : ***L**ow **V**oltage*

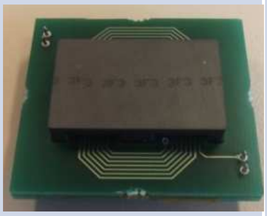
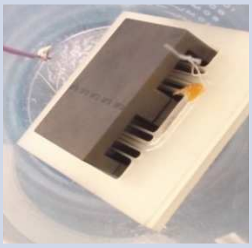
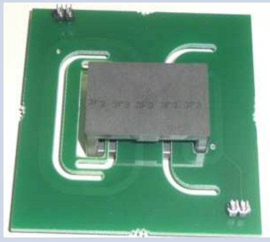
	Prototype N°1	Prototype N°3	Prototype N°4	Prototype N°5
Figures				
TTL compatibility	No	No	No	No
Maximum high voltage insulation	18,5kVAC during 5s	28,5kVAC RMS during 50s	28kVAC RMS during 60s	To be define
Maximum speed transfer	2MHz	1MHz	1MHz	To be define
Delay time	42ns	50ns	50ns	52ns
Consumed power	0,15mW	0,2mW	0,2mW	0,25mW
Operating temperature	-50°C ; 200°C	-50°C ; 200°C	-50°C ; 200°C	To be define

Table 2 : resume of prototypes previously designed

Although the prototype N°4 had the highest high voltage insulation, we decided to design an other prototype.

Teddy Bonnin's internship in last summer permitted to save us a lot of time for the preparation about the railway standards. So, we started from the experiments about prototype N°5 in the goal of precisely characterize and establish an industrial processing.

4. Study of the prototype N°5

4.1 Description of the prototype

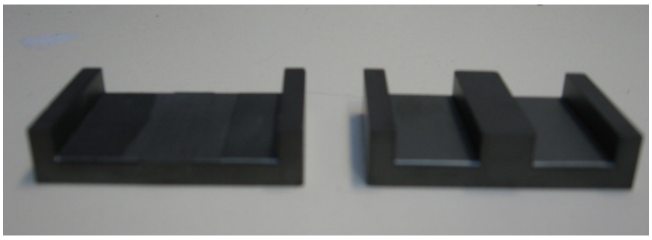


Figure 3 : C core and E core

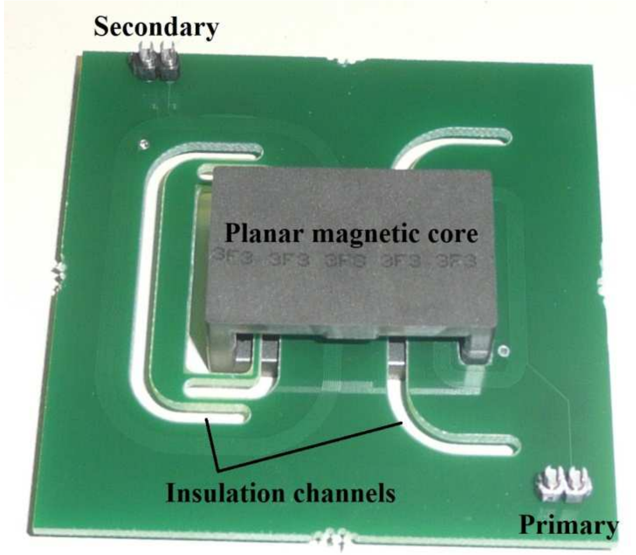


Figure 4 : global view of prototype N°5

As Figure 3 shows, the central leg of ferrite is cut off and we translate E type ferrite to the C type. Therefore, we can increase the distance between primary and second windings and in this way we can get the insulation length longer to protect our model. Furthemore, the narrow tracks in line with the insulation channels which we have opened up permitted to enhance the length of leakage line in the surface of epoxy (cf. Appendix N°2 : prototype N°5).

A complete characterization of this transformer will be described in the next part of this report in the goal of estimate the magnetic coupling and the signal quality.

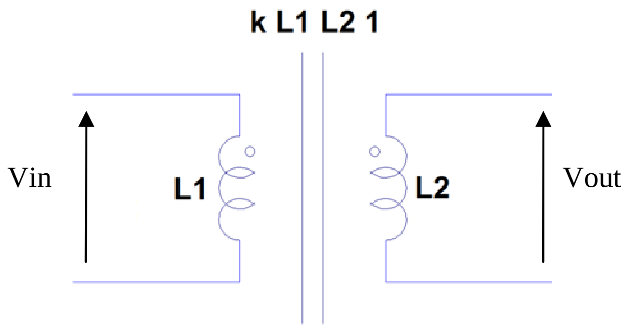
4.2 Transformer model

This chapter discusses the modeling of high voltage insulation transformers. Section 4.2.1 introduces the ideal transformer circuit. In Section 4.2.2 we speak about detailed modeling issues of non-ideal transformers, such as capacitive coupling, leakage inductance etc. Then, a transformer circuit model is also presented. Finally, the minimum insertion loss is introduced in section 4.2.3 as to characterize the performance of transformers.

4.2.1 Ideal model

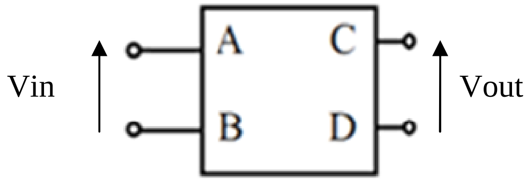
The ideal transformer model is based on two assumptions :

- All the flux is confined to the core.
- There is no power loss in the ideal transformer.



L1 and **L2** are the self inductance of primary and secondary. L1 is more precisely the magnetizing inductance

k is magnetic coupling between primary and secondary



A transformer can be modeled by the matrix below

Figure 5 : ideal transformer model

the leakage of magnetic flux. Furthermore, a high voltage insulation planar transformer includes parasitic capacitance, resistances (ohmic loss) and skin effect (high frequency operating).

4.2.2 Real model

According to the thesis Schellmanns [3], we can use the model with three capacities for operating frequencies not exceeding 2MHz (Figure). Then, two basic studies are distinguished to determine all elements of the model:

- Magnetic study
- Electrostatic study

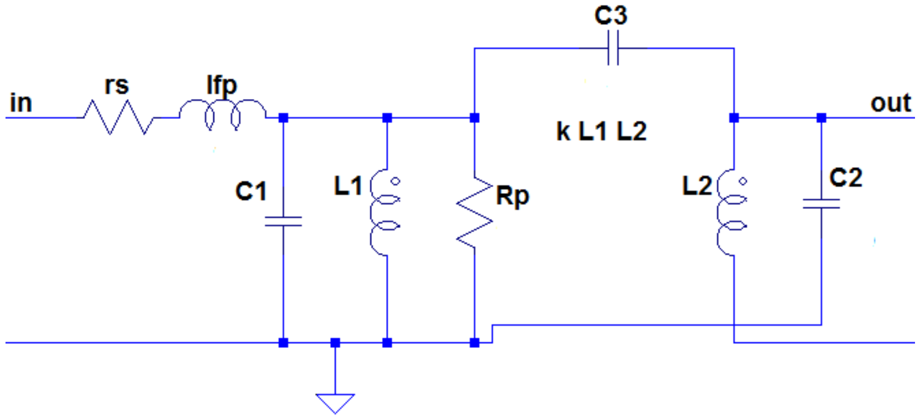


Figure 6 : chosen mathematics model

Parameters	Nomination
C1, C2, C3	Windings capacities
R_p	Resistor from open circuit primary
r_s	Serial resistor reduced to the primary
l_{fp}	Leakage self inductance reduced to the primary
L1	Magnetizing self inductance from open circuit secondary
L2	Magnetizing self inductance from open circuit primary
k	Magnetic coupling

Table 3 : parameters listing and determining

4.2.2.1 Magnetic study

	L1	L2	lp	Ls
Primary open circuit		■		
Secondary open circuit	■			
Primary short circuit				■
Secondary short circuit			■	

Table 4: measure process for inductances

Thanks to the impedance analyzer AGILENT 4294A 40Hz-110MHz, we have identified all these parameters following test conditions (cf. Table)

Secondary open circuit, measurement from primary

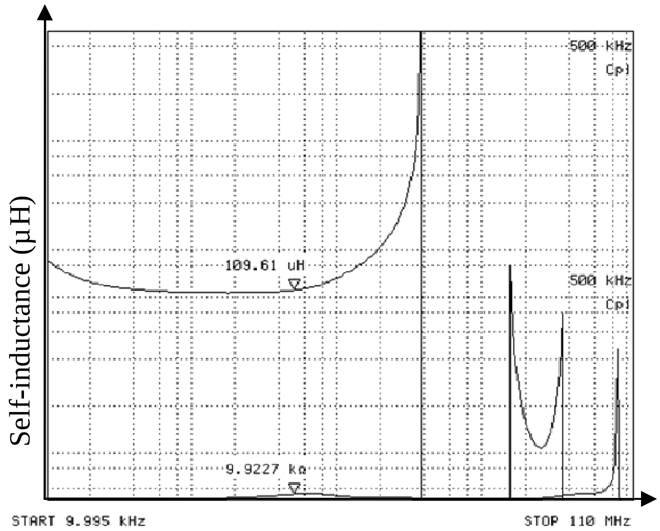


Figure 7 : Lp-Rp representation

Lp-Rp representation permits to extract exactly the self inductance L1 value. Loss is representated by a resistor Rp in parallel. For a frequency of 500 kHz, we have:

L1 = 109.6µH and Rp = 9.92kΩ.

Primary short circuit, measurement from secondary

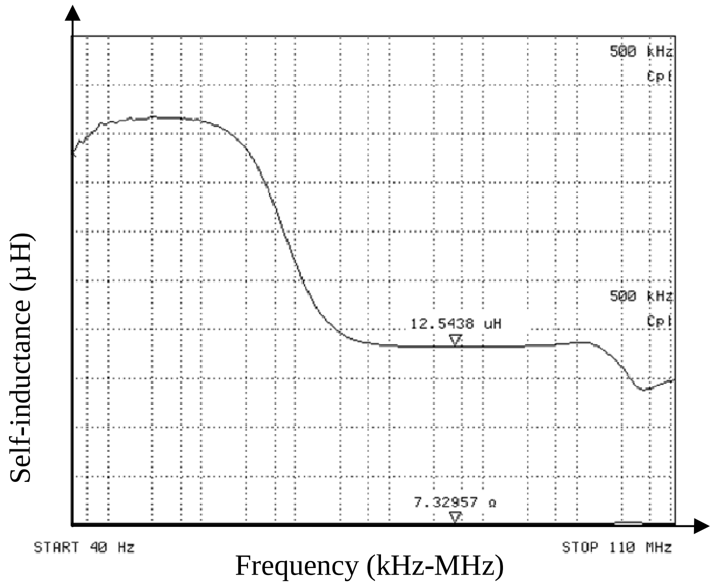


Figure 8 : Ls-Rs representation

The leakage self inductance measurement must be achieved in high frequency in order to avoid magnetizing self inductance effect.

In our case, frequency is up to 500 kHz so we can extract rigorosly the leakage self inductance and parasite serial resistor values:

l_{fp} = 12.54 µH and r_s = 7.33Ω.

Primary open circuit, measurement from secondary

This measurement permits to identify strictly the magnetic coupling k. It is obtained by following formula:

$$k = \sqrt{\frac{L1 - lfp}{L2}}$$

Following to the previously results, the magnetic coupling k can be defined. Then, for a frequency up to 500kHz, we note k = 0,94. This value comes up of the distance between the two windings. Although magnetic core (cf. Appendix Prototype N°5) has a good ability to concentrate the flux in high frequency operating, the leakage inductance is sufficiently large to reduce the magnetic coupling.

4.2.2.2 Electrostatic study

For the identification of electrostatic parameters, the external terminals of the component must be carefully identified. The Cp-Rp parallel representation is used for extract directly the capacitors values.All notations of measurement configurations arepresented in Figure 7.

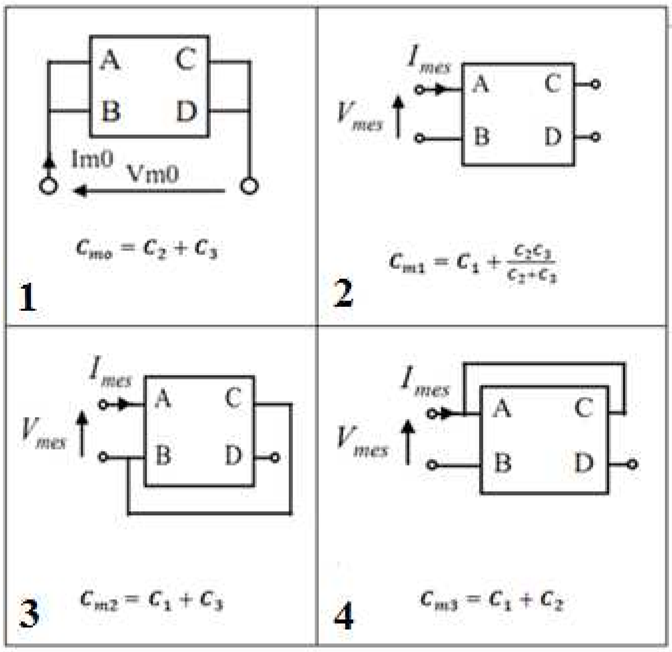


Figure 9 : mathematics modeling to measure parasitics capacitances

Measurement 1 permits to notice the insulation capacitor value taken between the two windings in short circuit. The others are necessary to deduct the remaining capacitors. Thus:

$$C_1 = 74pF,\ C_2 = 13pF,\ C_3 = -27pF$$

Following the previous characterizations, we load to the diagram below:

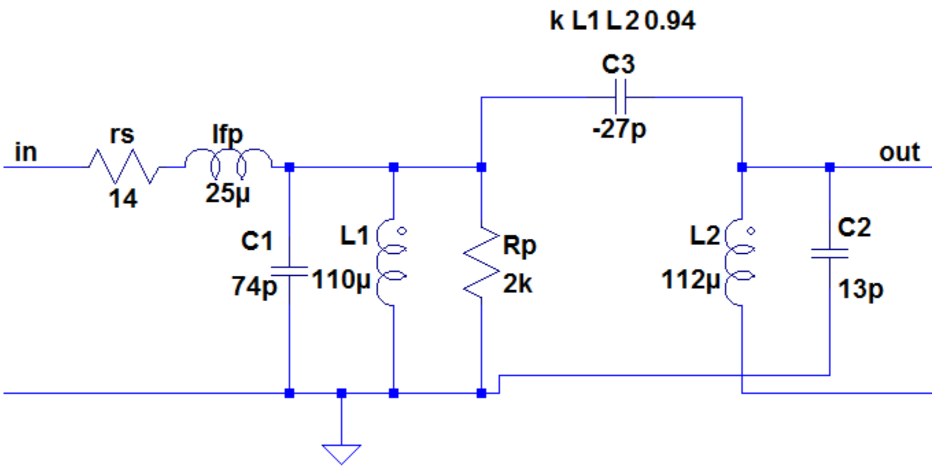


Figure 10 : mathematics model following characterization

4.3 Characterization conclusion

Thanks to LTspice simulator and excel, we compared the results of simulation and experiment by applying an AC voltage (amplitude 5V and frequency 500kHz) in input. So, we mesured the open circuit voltage in output :

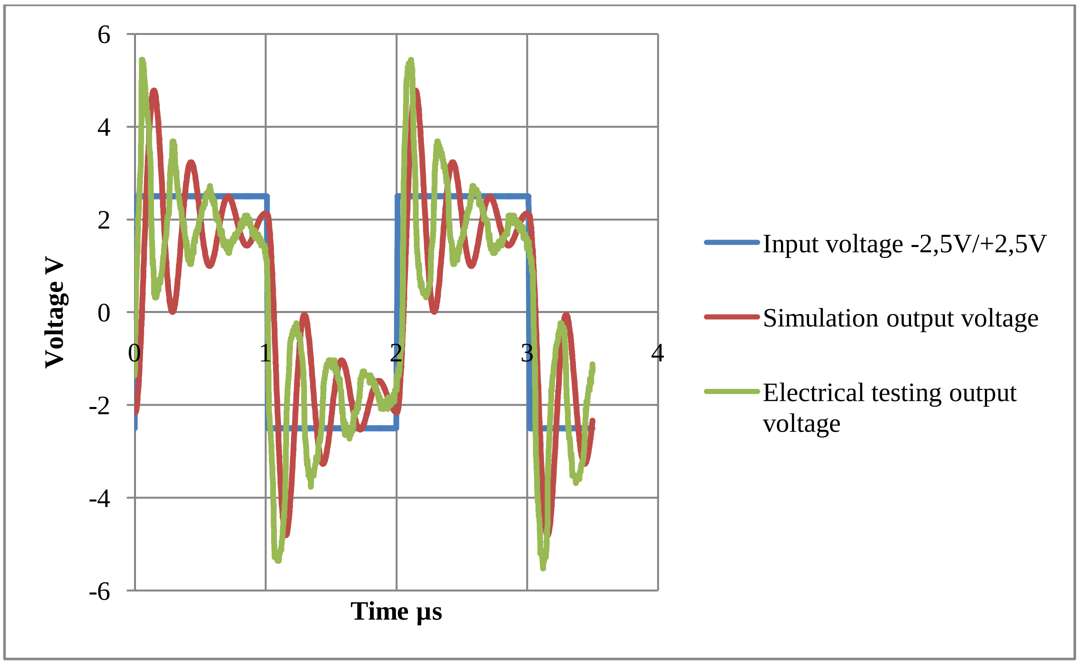


Figure 11 : comparison between simulation and electrical testing

The comparison between simulation results and reality has proven that our magnetic modeling is relatively close to gain and overshoot voltage. However, the pseudo period curves is noticeably different, the capacitance modeling is then not sufficient. Nevertheless, the capacitance analysis has shown the importance of printed circuit board design. Although the high proximity between windings added to the high frequency operating increases the parasitics capacitances values, it is essential to reduce the winding size in order to have the best insulation (cf. Appendix prototype n°5).

4.4 Electrical test

Following the characterization of the prototype and the previous work during Teddy's internship, we decide to apply a TTL input voltage of 500kHz with the circuit below:

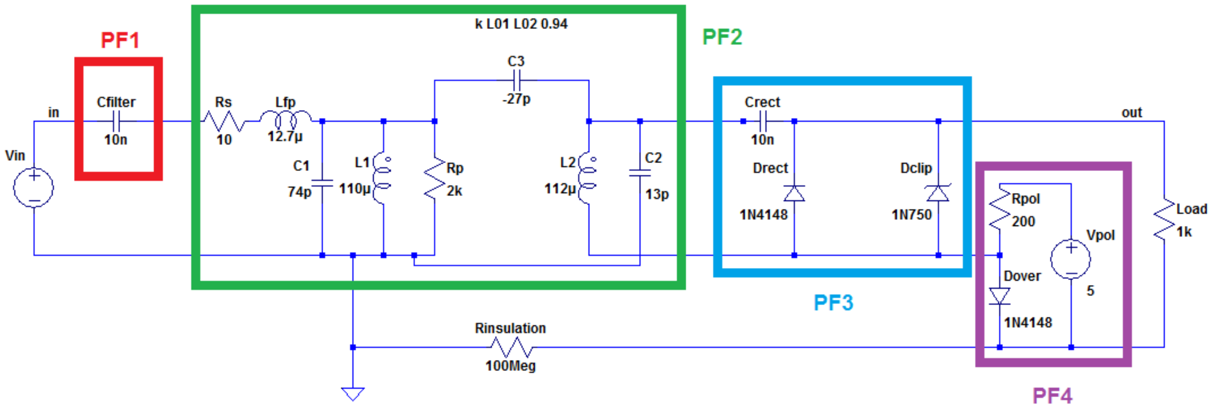


Figure 12 : electrical testing circuit

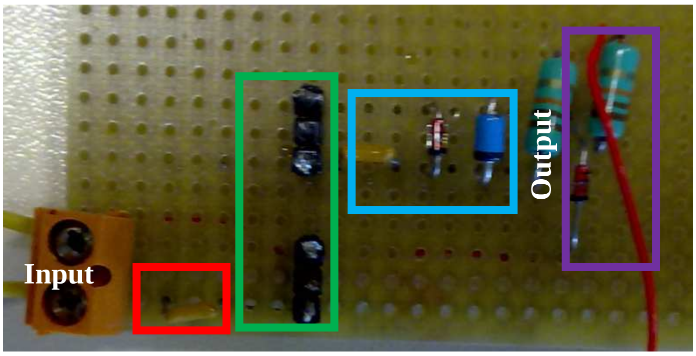


Figure 13 : electronic circuit for testing

Principal Function 1: pass high filter to eliminate continuous signals

Principal Function 2: prototype N°5 model

Principal Function 3: rectifier and clipper circuit

Principal Function: offset voltage

The load in ouput corresponds approximately with input impedance of RS232 receiver

The results of the experiment can be opposite with simulation for the goal of check out transformer model in real conditions.

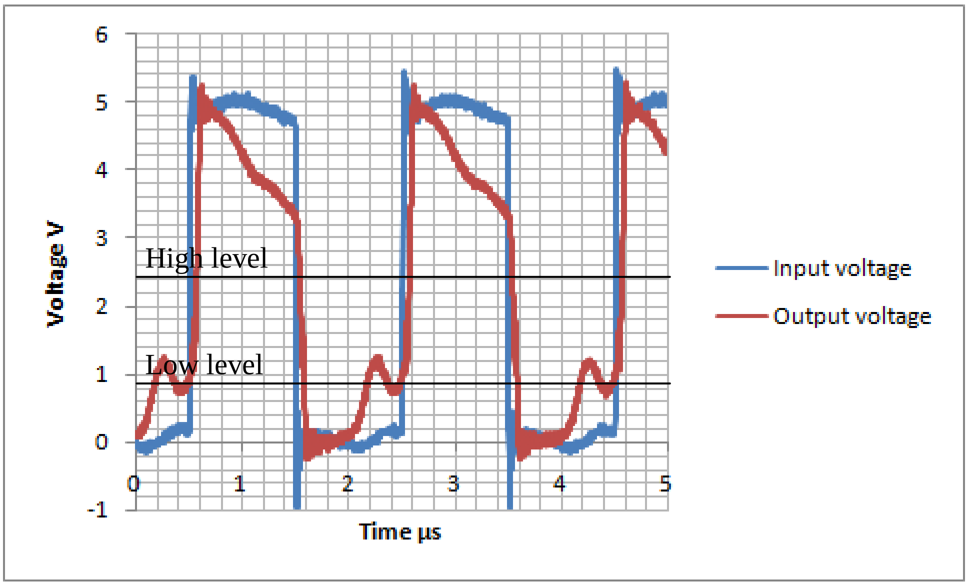


Figure 14 : experiment results

From oscilloscope and LTspice, data are imported in software Excel and in this way, we can see the results much clearer. Because of standard analyses (Annex N°1) the high level and low level are already well defined. From the Figure 8 we can observe that the delay time between high level and low level is very short, so it has a very high quality require to the planar transformer. The zener limit the maximum voltage due to leakage inductance. What's more, the role of components is to increase the drop of voltage but fortunally it is always higher than the high level. For the low level, near the time to exchange to high level, there are perturbations and perhaps they are caused by LC resonance. Furthermore these perturbations can disturb the two logic state and cause a lost of information.

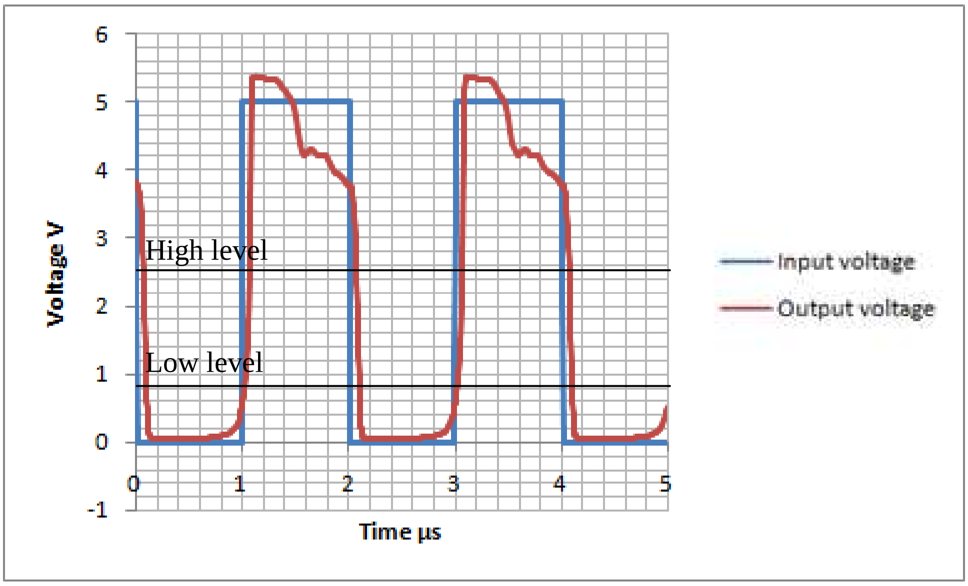


Figure 15 : simulation results

The output has a voltage drop about 1.2V and this is very closely to the experiment results. However, for the low level it is smoothly and increases quickly to the high level. We think the reason is that in our mathematics model we have chosen the simplier component like zener or diode, and in this way avoiding the perturbations in reality.

In order to prepare the industrial process, tolerance testing must be achieved. Compared the output voltage without air gap or shift, the curve shows that if the existence of shift doesn't affect much of the output result. It just drop

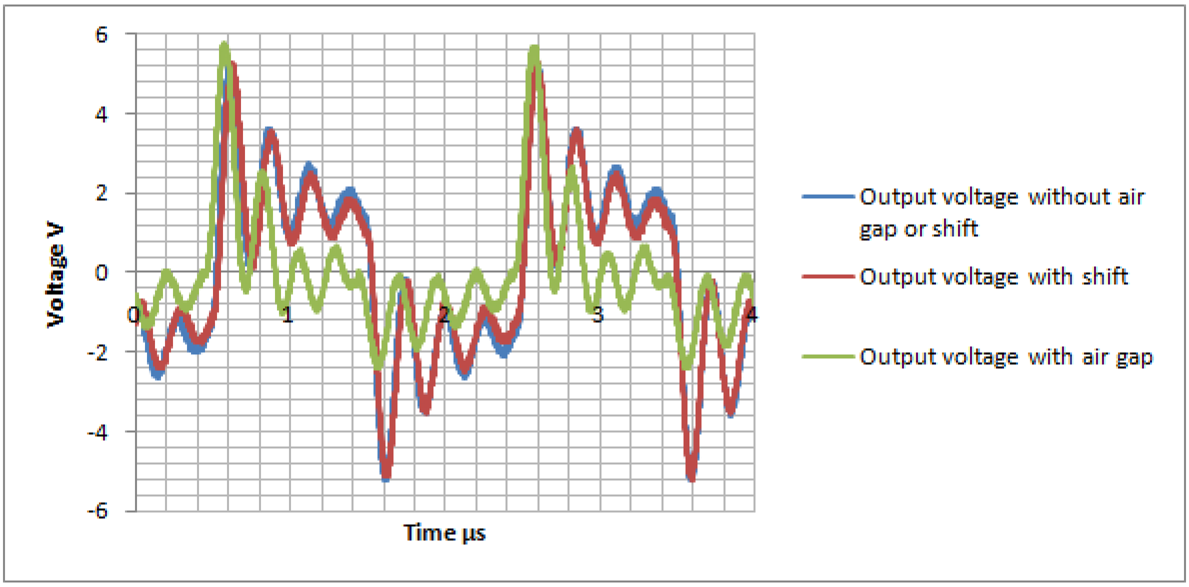


Figure 16 : effect of shift and air gap on output voltage

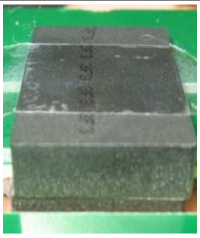
	Compared the output voltage without air gap or shift, the curve shows that the existence of shift doesn't affect much of the output results. It just has a little of voltage drop. Because of this, in the industrial process we suppose that the tolerance of shift can reach to 50%.
	After adding a gap of just 2 paper with the thickness of 0.3µm the output voltage has an obvious drop. So through this experiment we can clearly see that planar transformer is sensitive to gap. In the part of flyback we will carefully studied this question.

Table 5 : effect of paper gap and a shift

4.5 Dielectric test

The dielectric tests are used to verify electrical insulation in printed circuit boards and transformers. This experimental method can tell the engineers in which situation the product will work out. We have carried out two kinds of dielectric tests: planar transformer in the air and in the resin (Araldite). For the second situation we have tested Prototype N°5 windings on two faces and on the same face. The two faces windings seem the best solution because the distance between primary and secondary into epoxy substrate become longer.

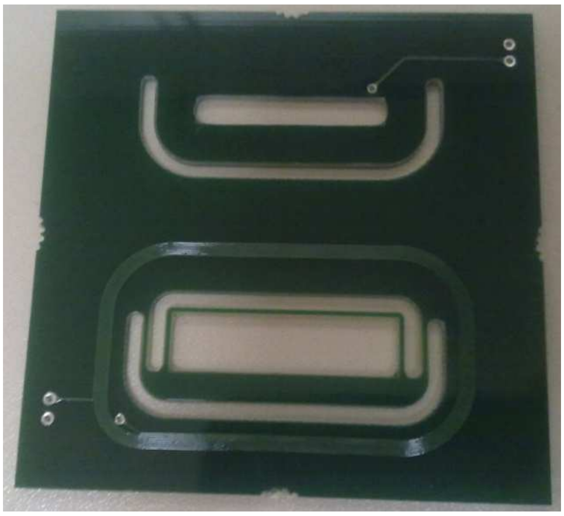


Figure 17 : windings on two faces

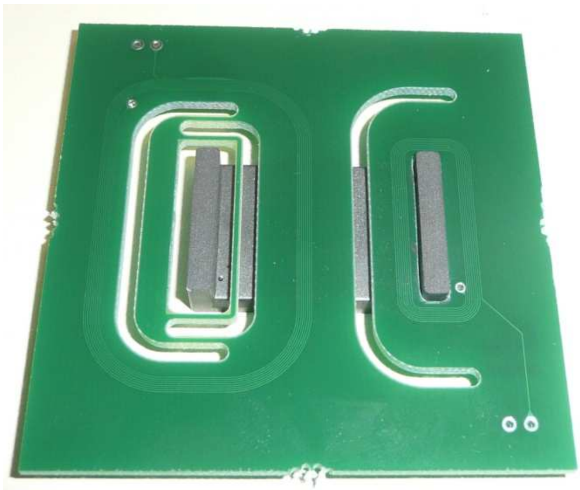


Figure 18 : windings on the same face

Through these photos (screenshot from video) we can see that there are two weakest points. The channels force the current pass through the magnetic core because for the high voltage the creepage distance is relatively gigantic. We can see that there is ruin point in the angle of magnetic core because its small conductivity repulses the electrons.

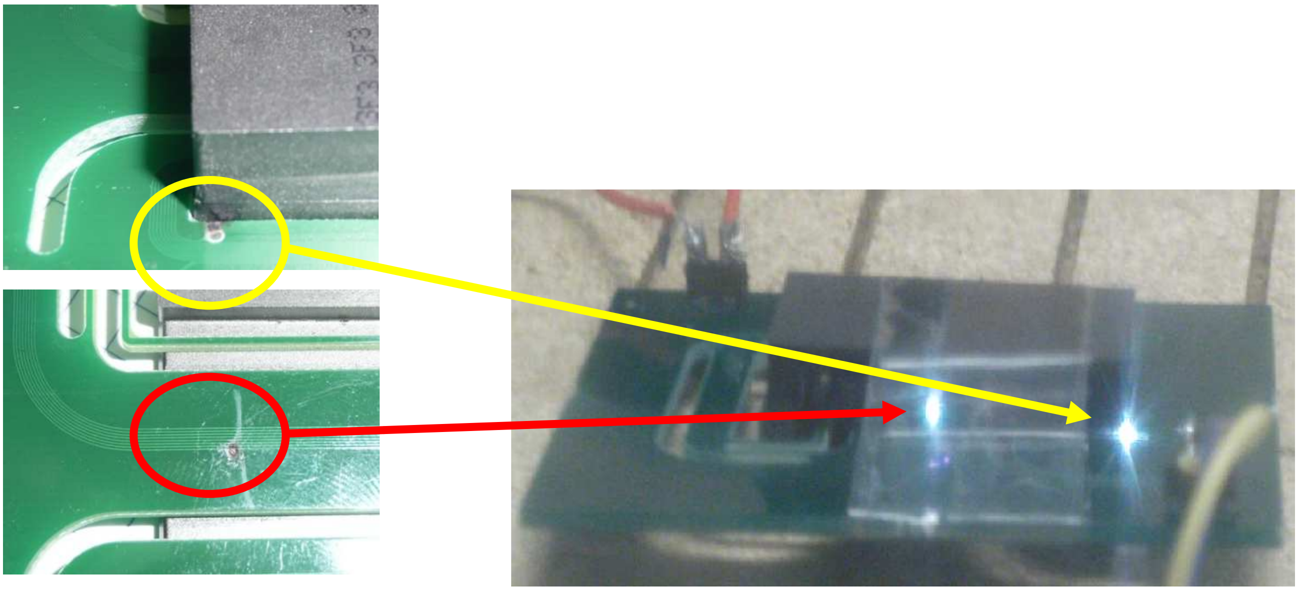


Figure 19 : clearance effect in planar core

This video we have taken lasts for 14 seconds. Type of magnetic core is E32 and test voltage equals to 10kV. From it we can clearly see that there are points are the most weakest. The raison can be explained as below:

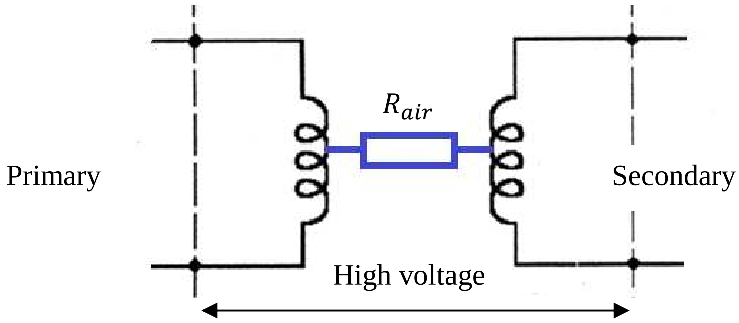


Figure 20:equivalent graph for air gap

In the situation of ultrahigh voltage the air between the primary and secondary are turned as a resistance, because air atom is not longer a neutral molecule but decomposed as electric hydroniums. The magnetic field energy is not exchanged in its normal way because magnetic core can't work correctly. The ultrahigh voltage goes through from primary to secondary. Because dimension of the air resistance is much smaller compared with the great voltage, the great current will ruin the planar transformer in a very short time (just several seconds in our experiment).

As we know already in the real working environment, humidity and dusty are very dangerous to the planar transformer. Not only will they reduce the using life of our product but also will they cause some dangerous situation for the people and goods around. So we choose the dry-type transformer: put the planar completely in the resin and using this method to against the adverse ambient conditions. Moreover, the resin can insulate more than 80 kV for a distance of 1mm. Finally, the resin must be characterized with depresure and temperature parameters because the dielectric strength changes directly with them.

We carried out our work in Mors Smitt RelaisCompany. The conditions are written in the table below

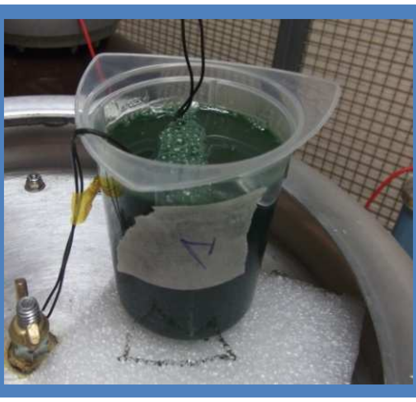
	**Prototype N°5 windings on two faces**	**Prototype N°5 windings on the same face**
Deal with resin	Clean out the surface of planar and then put it in the environment of 0.1 bar for an hour	
Breakdown voltage after disposed in 25kVAC 50Hz for 60s	25kVAC 50Hz	50kVAC 50Hz

Figure 21 : resume of dielectric test for different windings configurations

As we have mentioned, theoretically the prototype N°5 with windings on two faces should have better performance in the support high voltage ability than prototype N°5 with windings on the same face. But the result is inverse and it just has a half ability of the other. To get rid of the error which we maybe commit, we would like to make five others experiments. An order has been sent about one month (email was sent in 25 January) and this part come to be finished completely as soon as possible.

4.6 Industrial processing

Next we are interested in the industrial process and we use the method of value engineering. It is a systematic method to improve the "value" of goods or products and services by using an examination of function.

This method follows a structured thought process to evaluate options as follows:

4.6.1 Gather information

The choice of planar transformer is due two main reasons. First is that this is a good choice for in the area of technology to replace the widely use of opto-insulation. The other is its great advantages, for example the longer using life, its possibility in mass production, reducing the price and so on.

4.6.2 Analyse

The materials we need are the magnetizing material to make the core and in our situation it is 3F3, printed circuit board and dielectric resin.

4.6.3 Generate

First of all we need to command the proper type of magnetizing core 3F3 and then have its central leg cut off. If it is necessary we will add a process to make it sure because this step is very important for the next. Next, for the printed circuit board without been put the core we need to examine very carefully to make sure the size is within error tolerance. To check up also if there are two solenoids are connected together because if they are wrongly printed together it will cause the problem of short circuit. To set these two parts together we need to pay attention because the magnetizing core is very fragile. Because we use two C type cores face to face the percentage of dislocation should be controlled within 50%. For the fixation objective a collage is necessary and it should stand high temperature about 70°C and hot water about 50°C. And material of this collage shouldn't be very rigid because it has the risk of break the board.

To realizing the resin planar transformer we need to carefully clean the surface of board with flux off and core because it is necessary to lengthen the using life. Then we put totally in the resin and apply the environment of 0.1 bar in about one hour and until there is no more bubbles overflow the liquid surface.

4.6.4 Price estimate

Before we carry out the mass production in marketing it is necessary to value the prix of each planar transformer. And it is mainly consisted by three parts:

- The fabrication of ferrite core.
- The perforation in the high voltage board of MSAVDC.
- The add of dielectric resin (Araldite).

Items	Estimate price
Ferrite core E32/6/20	5€
Fabrication of ferrite	8€
Perforation in high voltage board of MSAVDC	-
Add of dielectric resin	2€
Sum of Prototype N°5	15€

Table 6 : estimating price

5. Flyback design tool

In order to design easily, we have built a tool from flyback application note [dondon] with database software access and excel software. The flow chart shows the process we designed our tool (Annex 3).

All the MS Relais measurement systems require a design of switch mode power supply. The railway standards compel a galvanic insulation between the high voltage catenary and the low voltage battery. Thus, some flyback power supply is used for low power and high voltage insulation (FPGA[3], analog input/output…).

[3] FPGA : ***F****ield* ***P****rogrammable* ***G****ate* ***A****rray*

Parameters	Nomination
Input voltage	[50-90] VDC
Output voltage	[12-24] VDC
Voltage undulation	1%
Maximum current	0.5A
Insulation between primary and secondary	1500VAC 50Hz during 60s
Insulation between two secondaries	750VAC 50Hz during 60s

Figure 22 : resume of flyback design parameters

The results of this design tools are:

- Shape core definition
- Ferrite choice
- Self inductance calculation
- Conductor size
- Winding organization

6. Conclusion

The work about characterization and industrial process of high voltage insulation planar transformer has last for about 5 months during our schedule of graduation project.

This work based on the summer internship of Teddy, which is about the feasibility of high voltage insulation planar transformer, is an advantage for us to comprehend fully the planar technology and insulation standards. Among the types of prototypes N°1, N°3, N°4 et N°5 we chose the last design because it is promising for its well performance of insulation and easiness fabrication process.We focus on the tests of prototype N°5 and we have successful carried out the electric tests and dielectric tests about it. This is the first courageous step for us. However, because of delay of deliver goods:

- 5 planar transformers for insulation testing to have a conclusion of its general character.
- 1 planar transformer to has accelerating test of temperature.

We don’t finish the dielectric test of it but as we have done it one time in Mors Smitt Relais we already know the methodology.

In conclusion, the planar transformer has a great advantage in the competition of classic transformer:

- Integration of product in the measurement systems to get the high voltage insulation.
- Respect to the restricts of railway standards.
- small volume and stable performance.
- Long service life.

	Prototype N°5
TTL compatibility	No
Maximum high voltage insulation	**50kVAC 50Hz Must be confirm**
Maximum speed transfer	**800kHz**
Delay time	52ns
Consumed power	0,25mW
Operating temperature	To be define after temperature test

Table 7 : resume of prototype N°5 characteristics

Annex 1: requirements and standards analysis

	Values
Operation frequency (kbits/s)	500
Signal de transmission	TTL (0V-5V)
High logic level	2.4V
Low logic level	0.8V
Insulation technology	Inductive
High voltage insulation	25kV RMS during 60s
Température de fonctionnement (°C)	[-50 ; 80]

Table 8 : requirements of MSAVDC serial communications

Over thirty standards (railway and others) constrain the design of MSAVDC. The table opposite shows the standards for high voltage insulation of the serial communication.

Document reference	Document designation	Origin
NFC 93703 Octobre 1989	Electronics components- PCB requirements User guide for design	UTE
NFC 93713 Janvier 1989	Electronics components- PCB requirements	UTE
NF EN 50124-1 September 2005	Railway applications - Insulation coordination – Part 1 :Basic requirements - Clearance and creepage distances for all electrical and electronic equipment	UTE
NF EN 50124-2 Septembre 2005	Railway applications - Insulation coordination - Part 2: Overvoltages and related protection	UTE
NF EN 60077-1 Novembre 2002	Railway applications – Electric equipment for rolling stock. – General service conditions and general rules	UTE

Table 9 : reference standards applied of the insulation transformer

NFC 93703et NFC 93713

These standards lays down class for PCB in the goal of estimate insulation, parasitic capacitances, the peaking effect.

	1st class	2nd class	3rd class	4th class	5th class
Minimal conductor width (mm)	0.8	0.5	0.3	0.25	0.15
Minimal distance between conductors and pads[4](mm)	0.7	0.5	0.25	0.23	0.2

Table 10 : design rules for PCB

NF EN 50124-1-2

It involves electrical insulation for rolling stock. Then, a detailed procedure permit to calculate the clearance and creepage distances.

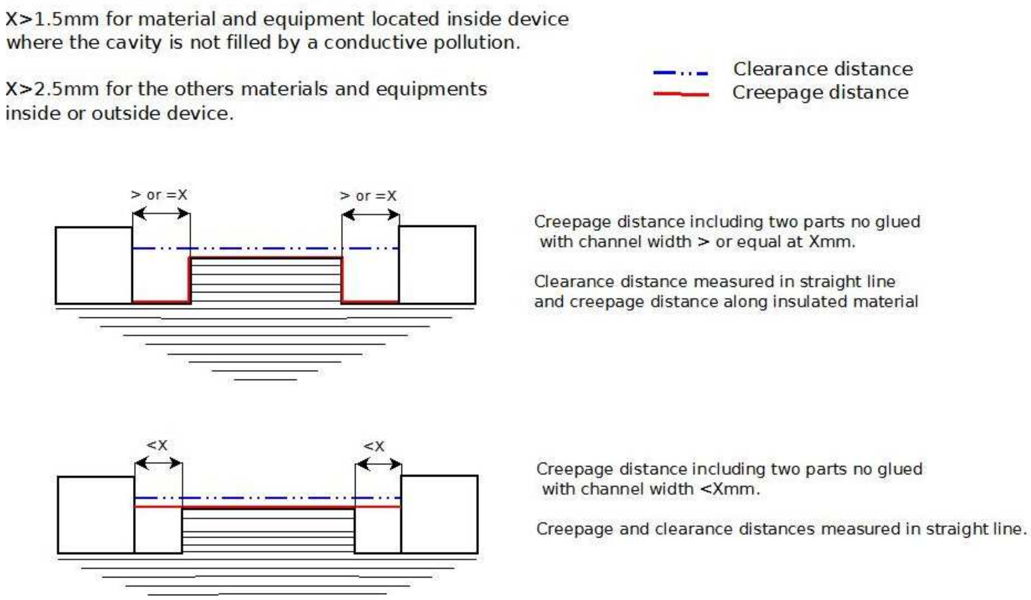


Figure 23 : creepage and clearance distances for PCB

NF EN60077-1

It is a standard for determine the insulation testing voltage. It depens also on associated equipment (rolling stock or fixed facilities). The tesing voltage must be applied in 10s then maintained during 60s. In this case, nominal voltage of the DC bus is 3kV RMS and the insulation testing voltage is fixed around 20kVDC RMS for rolling stock. Nevertheless, customers requirements compels an insulation voltage of 25kVAC RMS during 1s in order to overcome of overshoot voltage generated by disjunction of power supply station at the time of 25Kvac RMS catenary falls.

[4] Taking leading between layers tracks

Annex 2: design of prototype N°5

Datasheets extracted from Ferroxcube ferrites and accessories

SELECTING THE CORRECT CORE TYPE

The choice of a core type for a specific design depends on the design considerations and also on the personal preference of the designer. Table 1 gives an overview of core types as a function of power throughput and this may be useful to the designer for an initial selection.

Each of the core types has been developed for a specific application, therefore they all have advantages and drawbacks depending on, for example, converter type and winding technique.

Table 1 Power throughput for different core types at 100 kHz switching frequency

POWER RANGE (W)	CORE TYPE
< 5	RM4; P11/7; T14; EF13; U10
5 to 10	RM5; P14/8
10 to 20	RM6; E20; P18/11; T23; U15; EFD15
20 to 50	RM8; P22/13; U20; RM10; ETD29; E25; T26/10; EFD20
50 to 100	ETD29; ETD34; EC35; EC41; RM12; P30/19; T26/20; EFD25
100 to 200	ETD34; ETD39; ETD44; EC41; EC52; RM14; P36/22; E30; T58; U25; U30; E42; EFD30
200 to 500	ETD44; ETD49; E55; EC52; E42; P42/29; U67
> 500	E65; EC70; U93; U100; P66/56; PM87; PM114; T140

Choice of ferrite for power transformers and inductors

A complete range of power ferrites is available for any application.

3C90

Low frequency (< 200 kHz) material for industrial use.

3C91

Medium frequency (< 300 kHz) material with loss minimum around 60 °C.

3C92

Low frequency (< 200 kHz) material with a very high saturation level. Specially recommended for inductors and output chokes.

3C93

Medium frequency (< 300 kHz) material with loss minimum around 140 °C.

3C94

Medium frequency material (< 300 kHz).
Low losses, especially at high flux densities.

3C96

Medium frequency (< 400 kHz) material. Very low losses, especially at high flux densities.

3F3

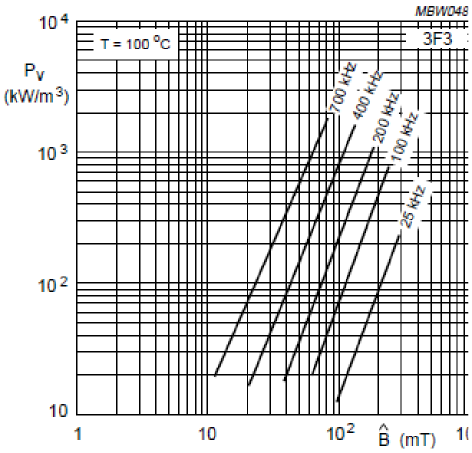
High frequency material (up to 700 kHz).

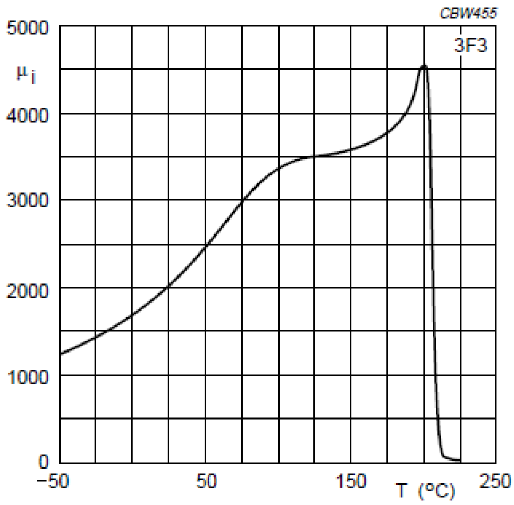
3F35

High frequency material (up to 1 MHz).
Very low losses, around 500 kHz.

3F4

High frequency material (up to 2 MHz).
Specially recommended for resonant supplies.





Prototype N°5

Planar transformer insulation for RS232 communication at 500kHz

- Nomenclature

Désignation	Quantity	Manufactuer	Reference Farcell
Material 3F3 AL5000 nH/tr²	8	Ferroxcube	E32/6/20-3F3

- Sizing

The magnetic material 3F3 is widely used by supplier Farnell and is compatible with the planar core. His performance in high frequencies which can reaches as high as 700kHz is also very important. The previous results lead us to sizing the inductance in the primary transformer and they are:

Lp= 120µH.

Calculating the number of solenoid: N= 8 spires

Because the desired transformer coefficient is 1, we need 8 solenoids in the primary and secondary.

- Manufacturing specification

There is a two-layer design for the prototype N°5. It is glass epoxy: 50EPGC2CU, classe 2, thickness 1,6mm. It will include:

PRIMARY

- 4 primary circuit boards positioned on the top face and summarized by the following table:

Situation	Winding Principe	Number of layers	Number of solenoids	Printed circuit class	Track width	Track thickness	Self
Primary	PCB	1	8	5	0.1mm	35µm	120µH

SECONDARY

- 4 secondary printed circuits positioned on the bottom face with the following characters :

Situation	Winding Priciple	Number of layers	Number of solenoids	Printed circuit class	Track width	Track thickness	Self
Secondary	PCB	1	8	5	0.1mm	35µm	120µH

We have four prototypes N°5.

<u>- Insulation</u>

Windings	Insulation
Primary → Secondary	25000VAC

<u>- Additionnel Information</u>

- Vacuum impregnation and pressure by a minimum insulation class E.
- Set the input and output circuits 2.54 mm in the sockets and in this way it can solder resistors and other passive components.
- Varnishing the tropicalization on both sides.
- There is no limit of prototype height.

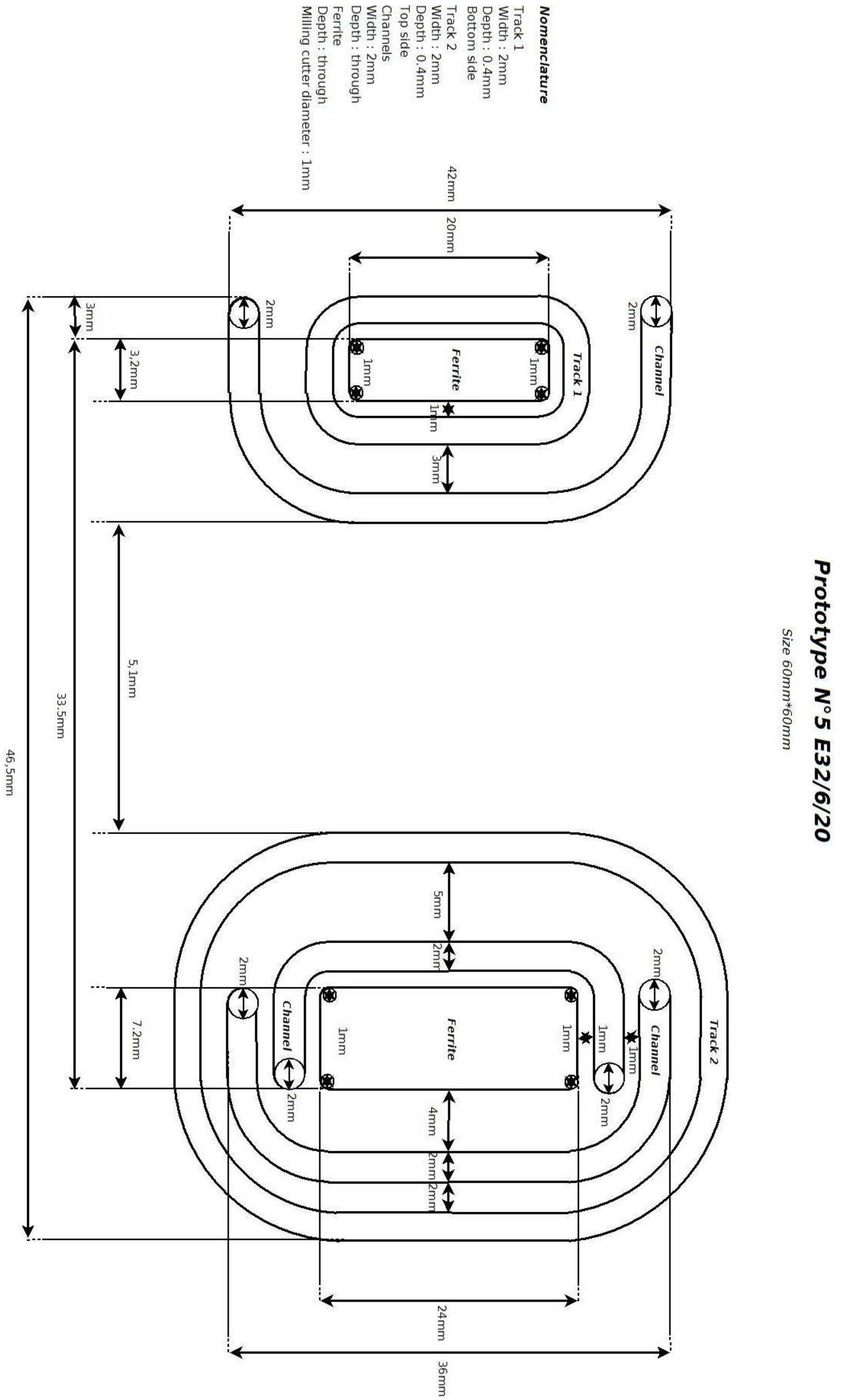


Figure 24 : size of prototype N°5

Annex 3: flow chart of flyback design tool

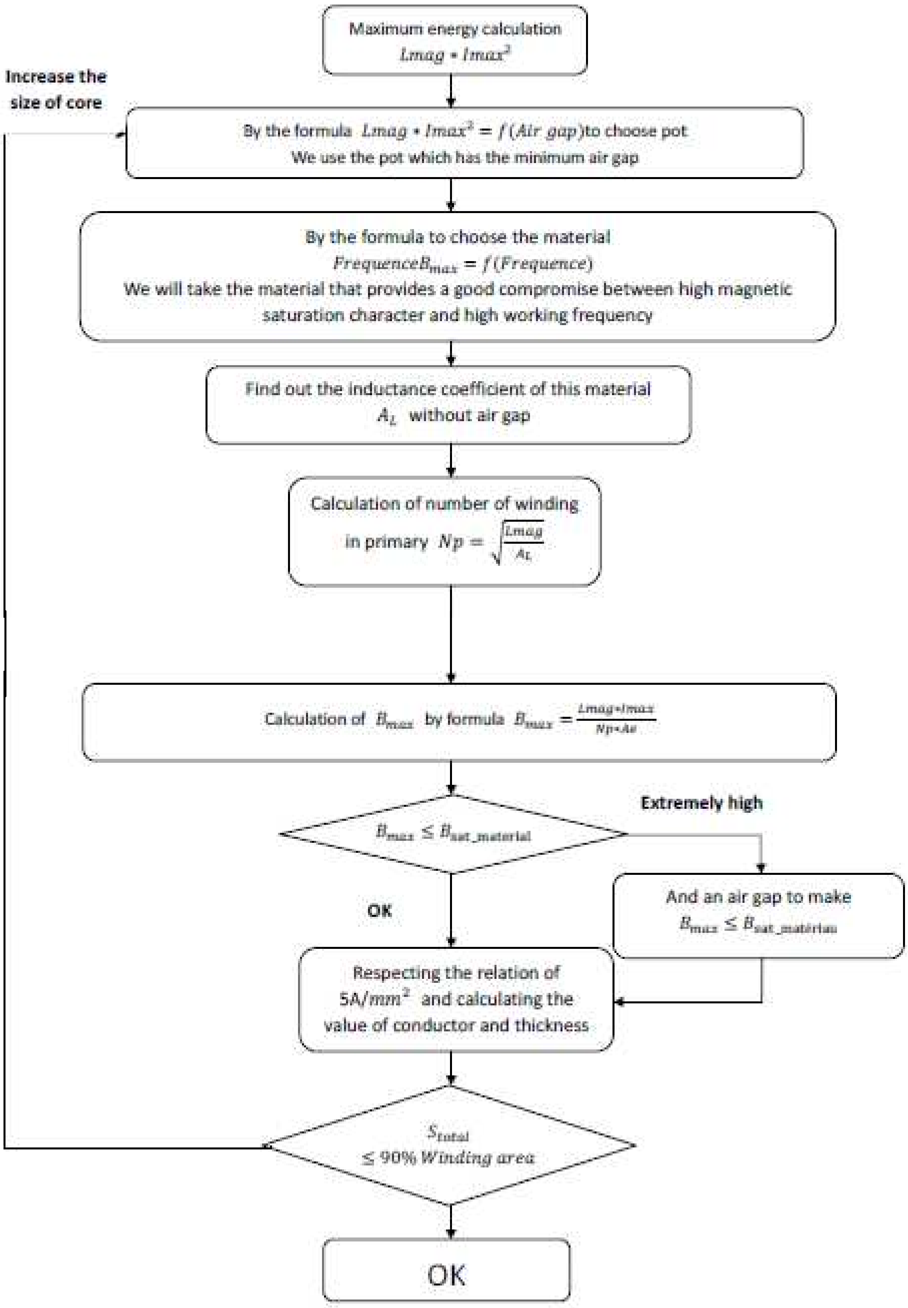


__Figure 25: flow chart of flyback design tool__

7. Bibliographic

[1] FERROXCUBE. – *Design of planar transformer*. Application note, 1996.

[2] BEAUCLAIR (F.), DELVINQUIER (J.P.). et GROS (J.P.). – *Transformateur et inductances*. Les techniques de l'ingénieur, 1998.

[3] SCHELLMANNS (A.) – *Modélisation des transformateurs multi enroulements en hautes fréquences pour la CEM*. Thèse de Doctorat, Université de Grenoble, 1999.

[4] DONDON (P.) – *Alimentation à découpage flyback 2000*
uuu.enseirb.fr/~/dondon/puissance/flyback/Flyback.html

[5] LEBOURGEOIS (R.). – *Ferrites doux pour l'électronique de puissance*. Les techniques de l'ingénieur, 2005.

[6] MULTON (B.). – *Composants passifs (magnétiques et capacitifs) de l'électronique de puissance*. Cours de l'ENS Cachan – antenne de Bretagne, 2008

[7] FERROXCUBE. – *Soft ferrites and accessories*. Data handbook, 2009

[8] LAI (D.K.). – *Contribution à l'optimisation du dimensionnement de composants passifs intégrés à l'électronique de puissance*. Thèse de Doctorat, Université de Grenoble, 2010.

8. Résumé

L'industrie ferroviaire est sans cesse sensible à l’innovation technologique. Réduire et maîtriser la consommation énergétique des trains est une des priorités pour les entreprises de ce secteur. MS Relais participe activement à ces évolutions en développant, entre autres, plusieurs dispositifs de mesure de la consommation énergétique des trains. Ces produits nécessitent un isolement galvanique haute tension fiable et durable pour garantir la sécurité des biens et des personnes à bord.

Dans l’optique de valider notre projet de fin d’études, nous devions caractériser le transformateur planar d’isolement haute tension pour la communication série du MSAVDC ainsi que concevoir un outil de dimensionnement pour des alimentations de type flyback suivant les contraintes ferroviaires. Le résultat est une étude précise sur la conception, l’analyse et l’industrialisation du prototype sélectionné suite à l’étude de faisabilité réalisée précédemment. Enfin, un fichier excel regroupant une base de données complète sur les types de noyaux magnétiques employés pour les alimentations flyback, a permis de réaliser un outil simple et efficace pour les initiés ou les non initiés.

Mots clés : ferroviaire, transformateur d’isolement, technologie planar, haute tension, communication série asynchrone, alimentation flyback, outil de dimensionnement.

Keywords: railway, insulation transformer, planar technology, high voltage, asynchronous serial communication, flyback power supply, design tool.