CCM FAMILY
Magnetic components for space applications
Optimized for multi output Flyback transformers

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ESA / SPCD 2022

SPACE PASSIVE COMPONENT DAYS

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SUMMARY

- **Introduction : evolution of magnetic components in space**
  - Definition – How to satisfy it?
- **Part 1 : Family qualification by ESA/CNES**
  - Why choose Technology Flow over QPL products?
  - Qualification steps
- **Part 2 : Performance characterization of CCM technology**
  - Thermal behavior
  - Frequency response and Current saturation (standard CCM inductors)
- **Part 3 : Optimization for multi output Flyback transformers**
  - The cross regulation problem or voltage deviations on some outputs
  - PhD thesis definition – Different stages of work – Present and future results
- **Conclusion**
  - Components that meet present and future customer needs

Discover

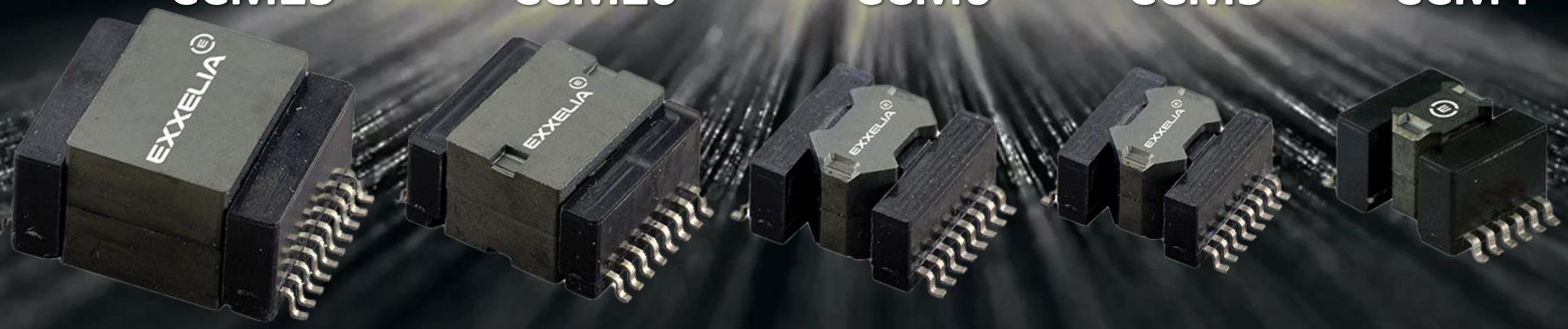
Chameleon
Concept
Magnetics

EXXELIA

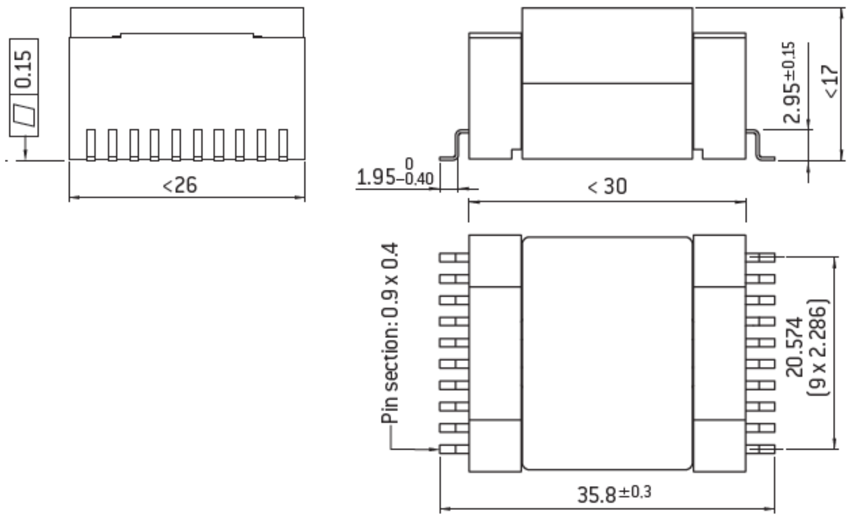
CCM Technology

- a SMD component with **5 sizes available ….. 6 soon (CCM30)**
- is done for **Harsh environments** and **High reliability applications**
- allows standard or custom **power inductors**
  Common/Differential Mode, Filtering, PFC chokes
- allows **custom design** of multi-outputs transformers
  Flyback, Forward, Push-Pull,… up to 200W (350W soon)

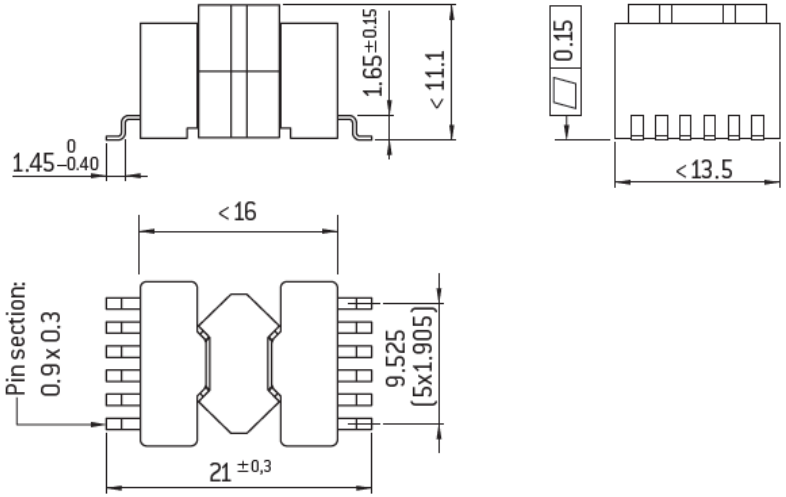
CCM25 CCM20 CCM6 CCM5 CCM4



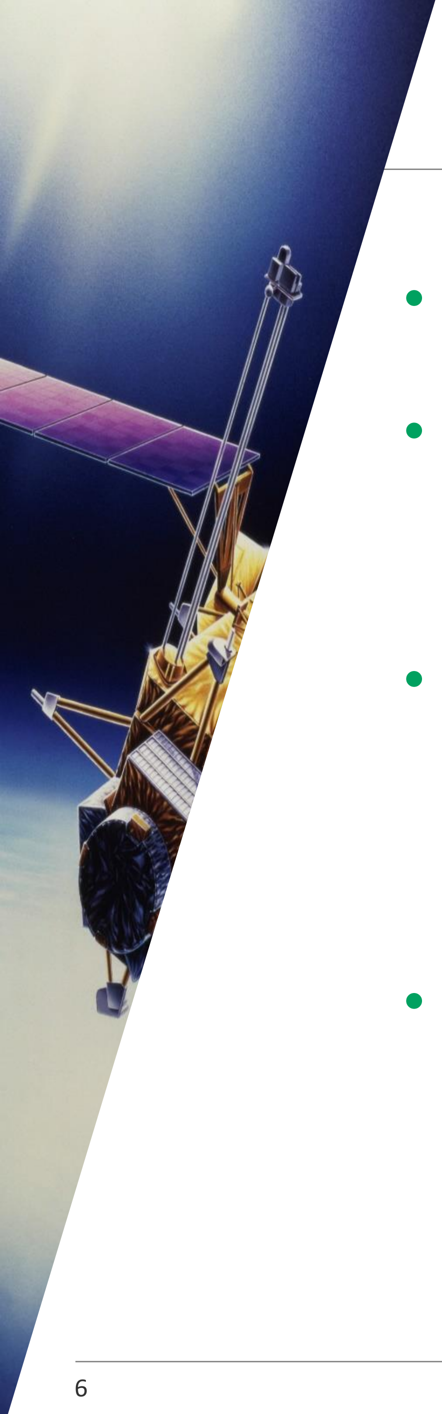
WHAT IS A CCM?



CCM25 dimensions



CCM4 dimensions



CCM family : INTRODUCTION

- What are the new technical needs and constraints for specific transformers?

- First : Applications with more outputs

  Need for **more In/Out pins**

  More different voltages and power levels

- Second : Increase in the power to volume and power to weight ratios

  We can no longer take large safety margins

  ==> need to know **all the technical limitations** of the product

  Reliability, internal heating, frequency response, current saturation

- Third : Development time is getting shorter

  Breadboards/Prototypes must work **the first time** ==> design method must be accurate

  Even specific products must avoid qualification time

  ==> have to be **already qualified before** BreadBoard/Prototype step

Part 1 : ESA qualification 1/3

- CCM family : What is this, and what is it for?

  Same technology for 5 shapes

  Ferrite circuit around windings wound in a bobbin, cabled on a leadframe and moulded

  For both standard and custom components

  Different types of functions : inductors (DMC, CMC), pulse/SMPS/measurement transformers

  ==> QPL qualification not adapted Technology Flow is better

- What is a Technology Flow?

  Exxelia must prove that CCM technology is space compliant

  1st step Evaluation (Exxelia), 2d step Qualification (ESA/CNES)

  Exxelia has to define : bill of materials
  manufacturing process
  design rules
  and **list of tests to be performed**

Part 1 : ESA qualification 2/3

- Bill of materials

  3 key raw materials : Bobbin, leadframe and magnetic circuit

  Other materials : wires, solid insulation, glue/resin/varnish, weld, ink, package

- Manufacturing process

  3 key steps : winding, cabling, moulding

  Other steps : gluing, assembling, marking, testing, packaging

- Design rules

  all theoretic actions the designer has to do upstream to prevent surprises downstream

- Test campaigns

  All those in Charts F4 SG1, SG2 and SG3

  Thermal shocks, Temperature rise, Overload, Soldering heat, Vibrations, Mechanical shocks Operating life, Permanence of marking, Solderability, Terminal strength, Dielectric, Moisture

Part 1 : ESA qualification 3/3

- Summary of work carried out

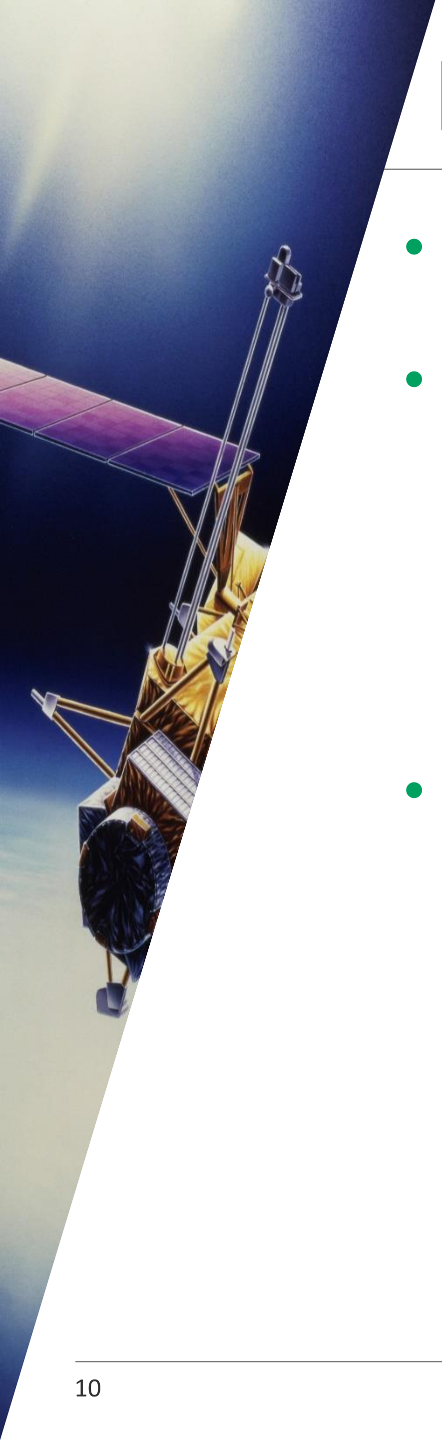
  - More than 100 components designed, manufactured, and tested
    many configurations of functions / shapes / tests
  - Some components destroyed to identify safety margins
    on thermal, mechanical, dielectric aspects
  - Evaluation took several years to complete

Result : Qualification was successful on first try

- Conclusion

  Respecting BOM, process and design rules qualified ...

  Exxelia has the right to offer any function in CCM shapes without any mandatory testing for customer



Part 2 : CCM technology performances 1/7

- Security margins must be reduced

- Ok, but to get close to the limits, you have to know them!

  Maximum permissible loss value → leads to internal heating (Tmax < 125°C)

  Maximum operating frequency → above resonant frequency component is no more inductive

  Saturation curve → which inductor value at which excitation current?

- How can these characteristics be determined?

  analytic calculations, software simulations, experimental measurements?

  We decided to carry out 3 experimental campaigns :

  1 Thermal resistance determination for each of 5 shapes

  2 Inductance versus frequency curves for standard inductors

  3 Inductance versus current curves for standard inductors

Part 2 : CCM technology performances 2/7

- Thermal resistance Rth of CCM4, CCM5, CCM6, CCM20 and CCM25

- Definition of test conditions

  Use of inductors with one winding

  connected to all pins one side

  Measurements in vacuum are very complex

  ==> in natural convection in the air first

  Copper losses (heating source) only

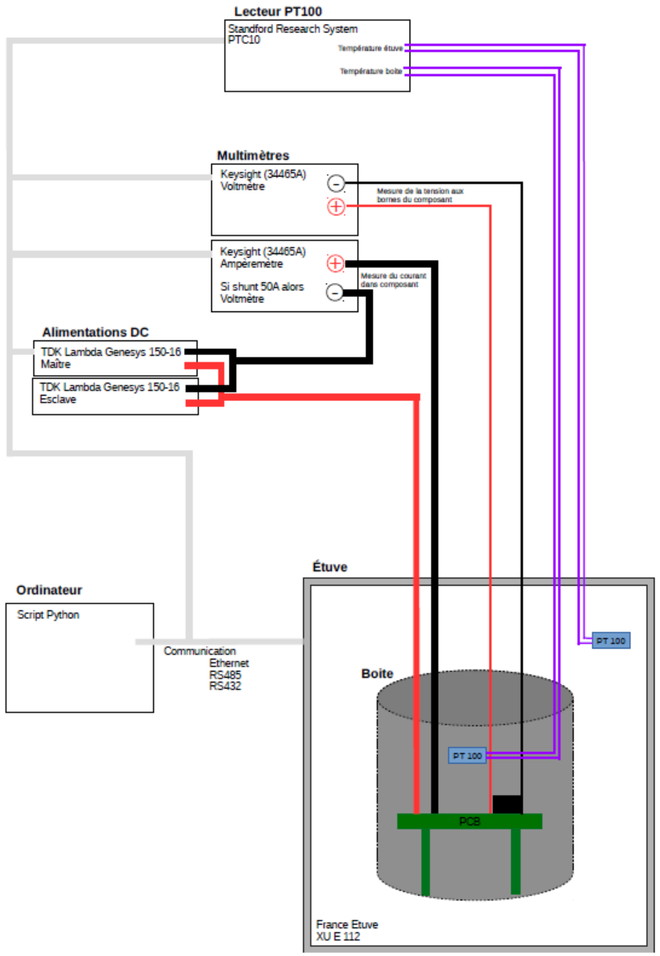
  ==> DC current excitation / measurement of Rwind

  Component on PCB / all pins soldered

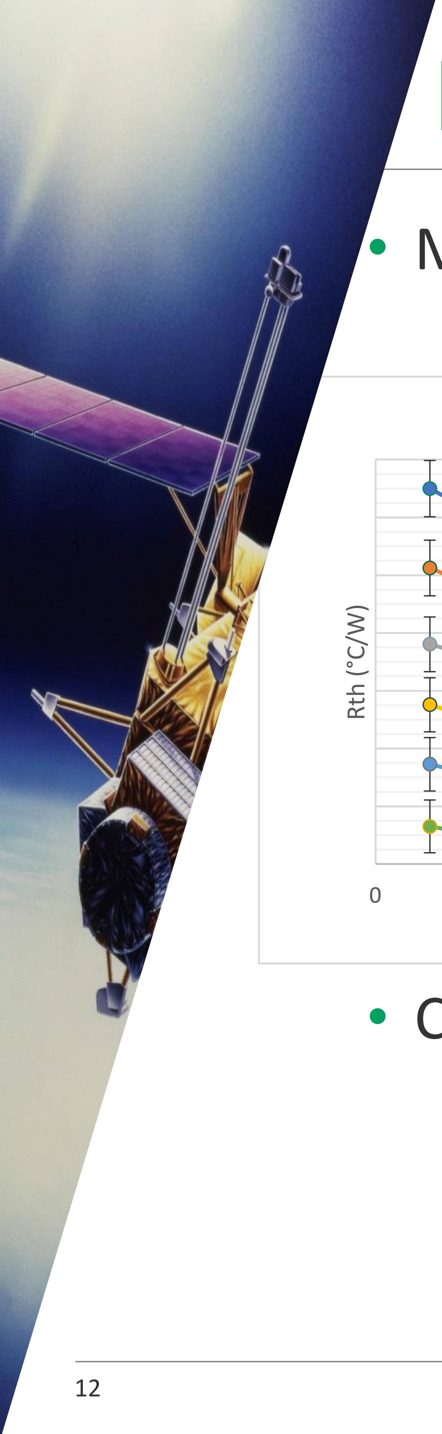
  / no glue / no copper except for large current paths

  Component in a (pierced) box inside a ventilated oven / temperature controlled

Measurement bench

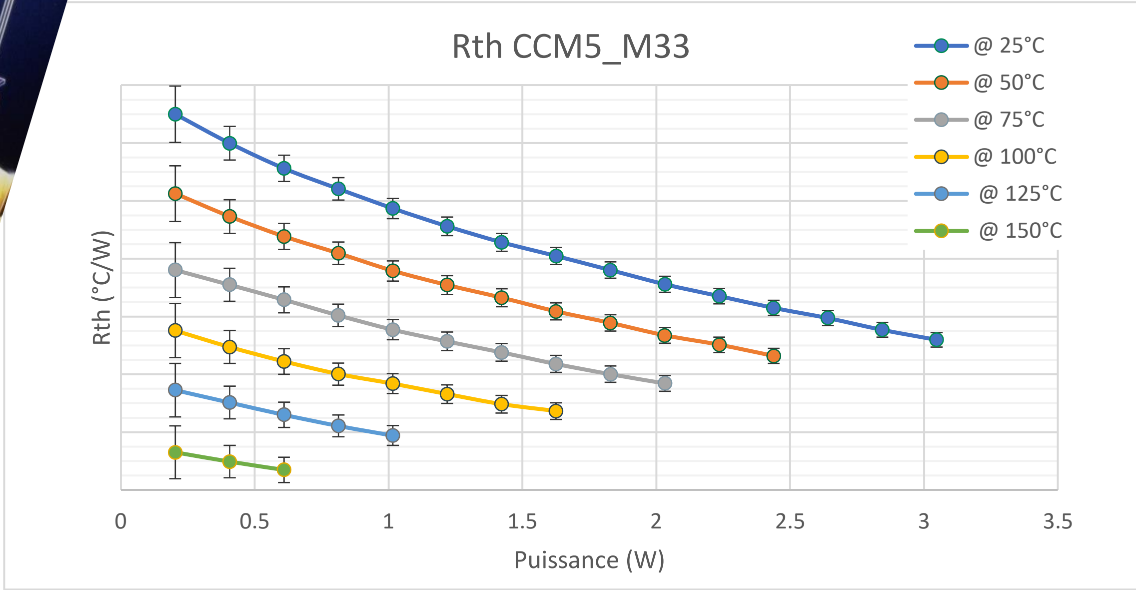


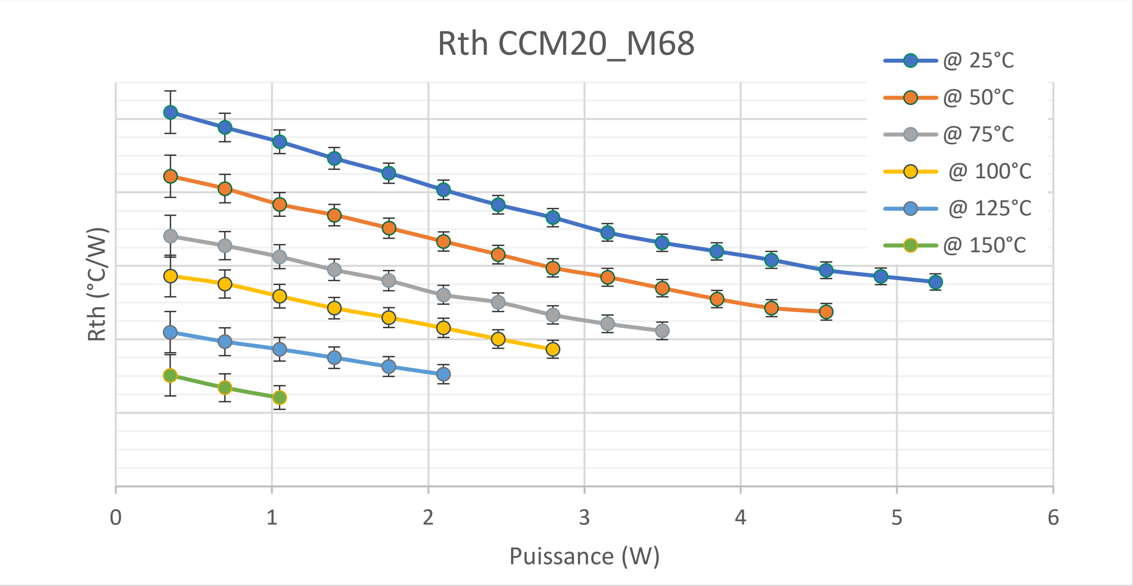
Part 2 : CCM technology performances 3/7



- Measurements realised for each of 5 shapes

  2 L values / 5 Tenv : 25, 50, 75, 100, 125 and 150°C / up to 15 meas. points for each Tenv





- Complements and further work

  Results applied for all CCM components / We have a math model air convection ➔ vacuum

  3D simulations in progress to validate these curves … 1st results are promising

  Measurements in vacuum are planned

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Part 2 : CCM technology performances 4/7

- Frequency behavior for CCM4, CCM5, CCM6, CCM20 and CCM25 standard inductors

- Definition of test conditions

  Use of inductors with one winding

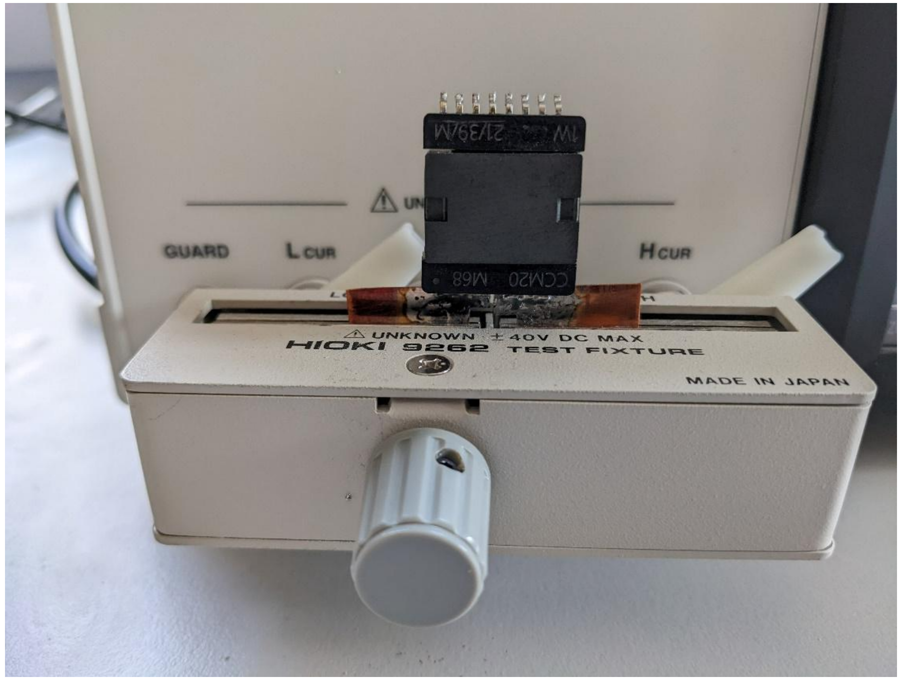
  connected to all pins one side

  Constant excitation, between 100µT and 1mT

  Components soldered on a brass plate

  RLC meter calibrated after 1 hour functioning

Measurement device



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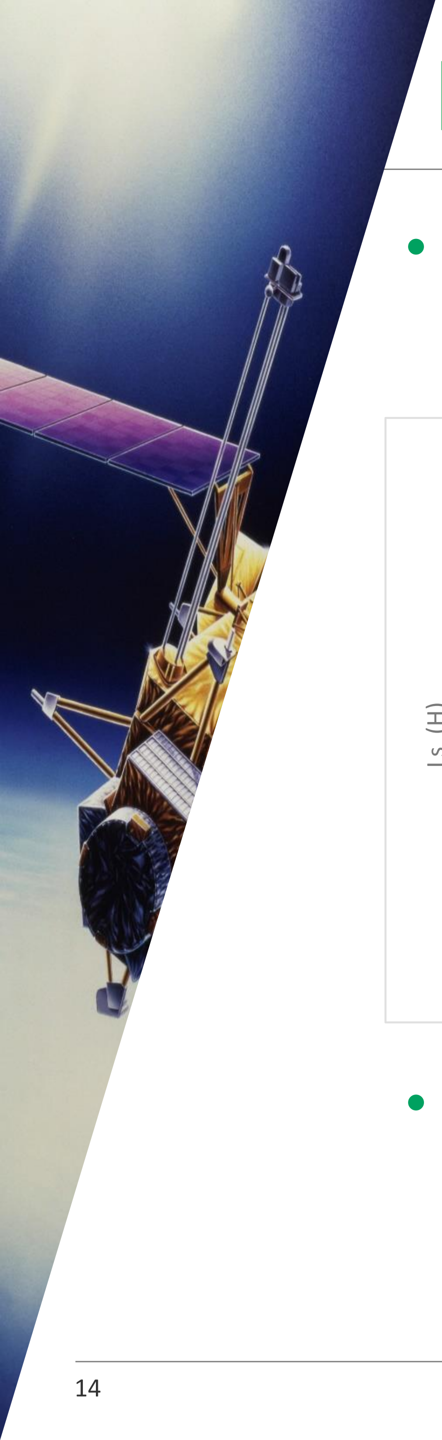
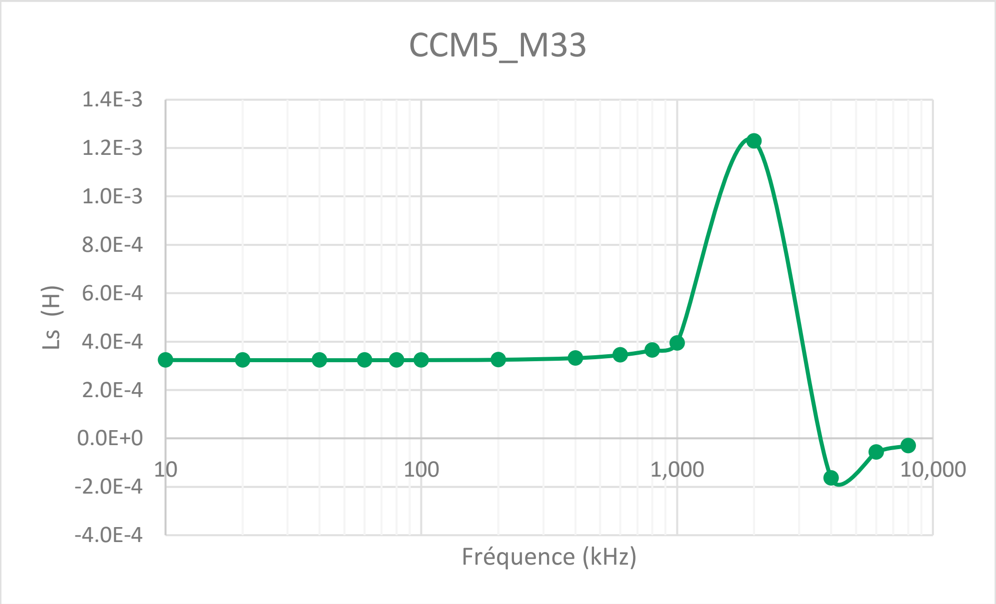
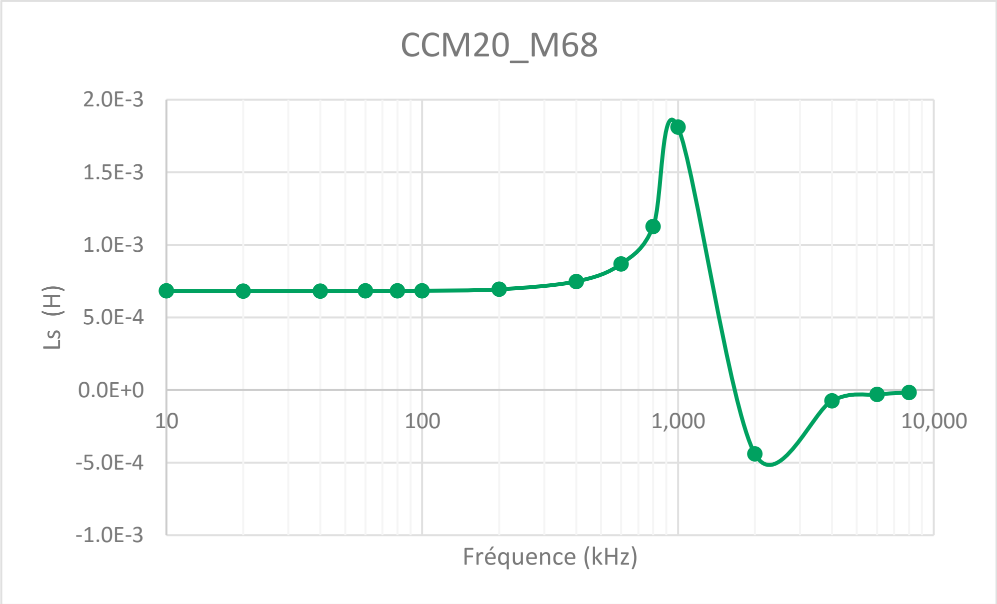
Part 2 : CCM technology performances 5/7



- Measurements realised for each of 5 shapes

  2 L values / up to 15 meas. points for each inductor value





- Result overview

  Majority of inductors are usable at least up to 1MHz

  All of inductors are usable at least up to 400kHz

Part 2 : CCM technology performances 6/7

- Saturation behavior for CCM4/5/6/20/25 standard inductors

- Definition of test conditions

  Use of inductors with one winding
  connected to all pins one side

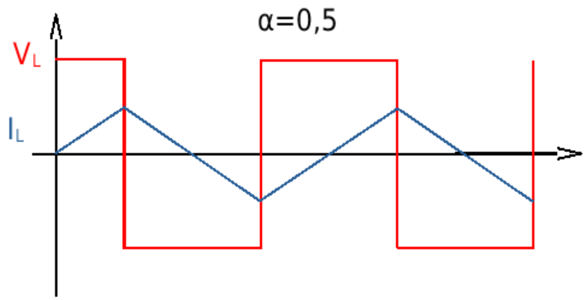
  180° phase shift full bridge DC supply

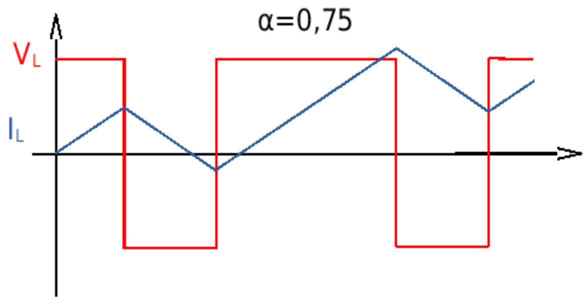
  DC+AC (300kHz) excitation with duty cycle > 0,5

  ΔI constant as long as no saturation

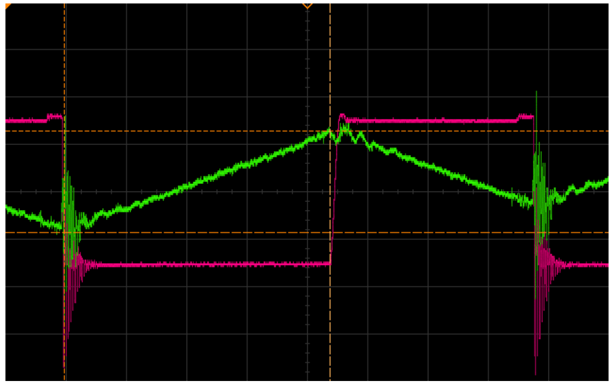
  Period nb controlled to achieve desired DC current

  L value measured with
  current rise slope

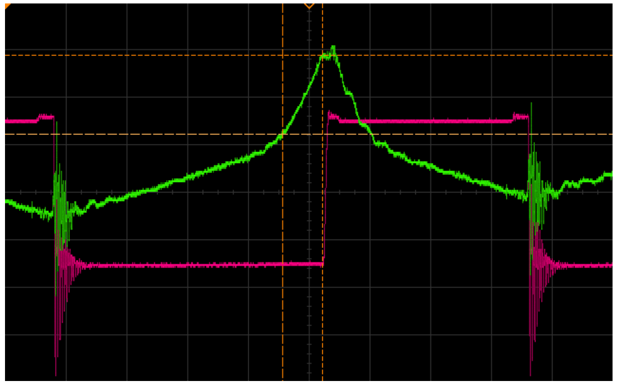




Without saturation

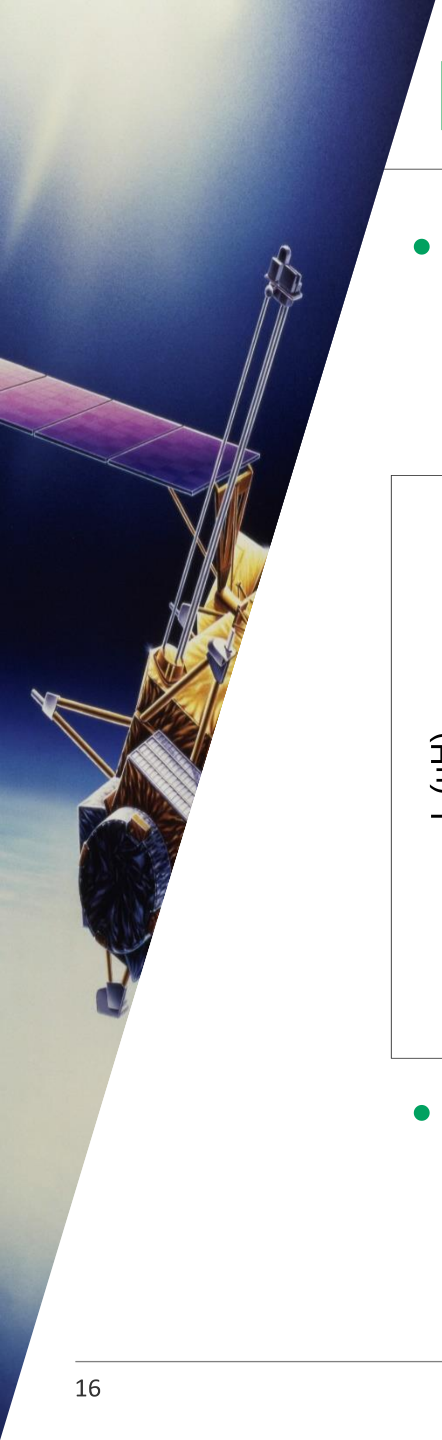


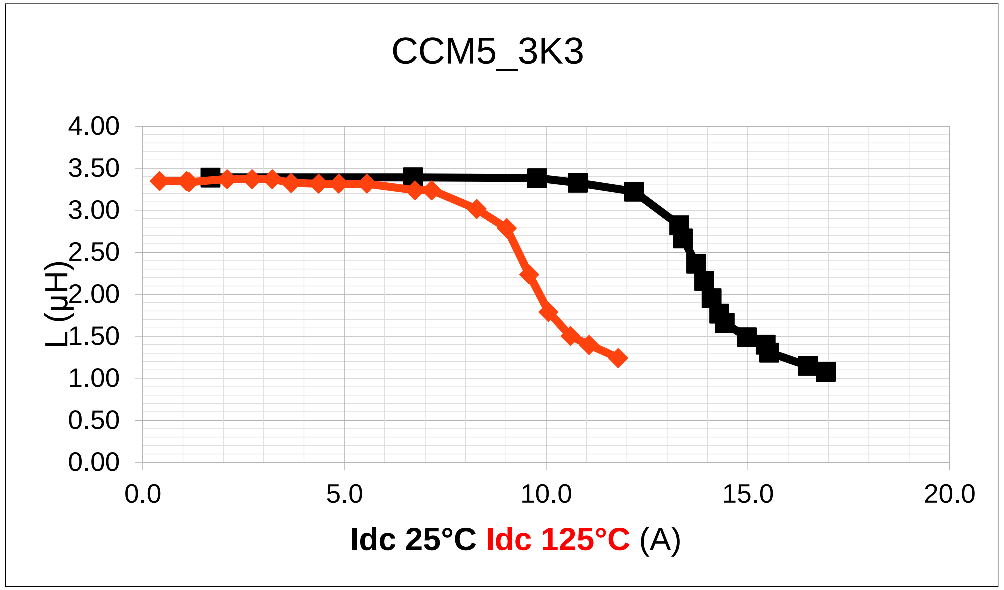
With saturation

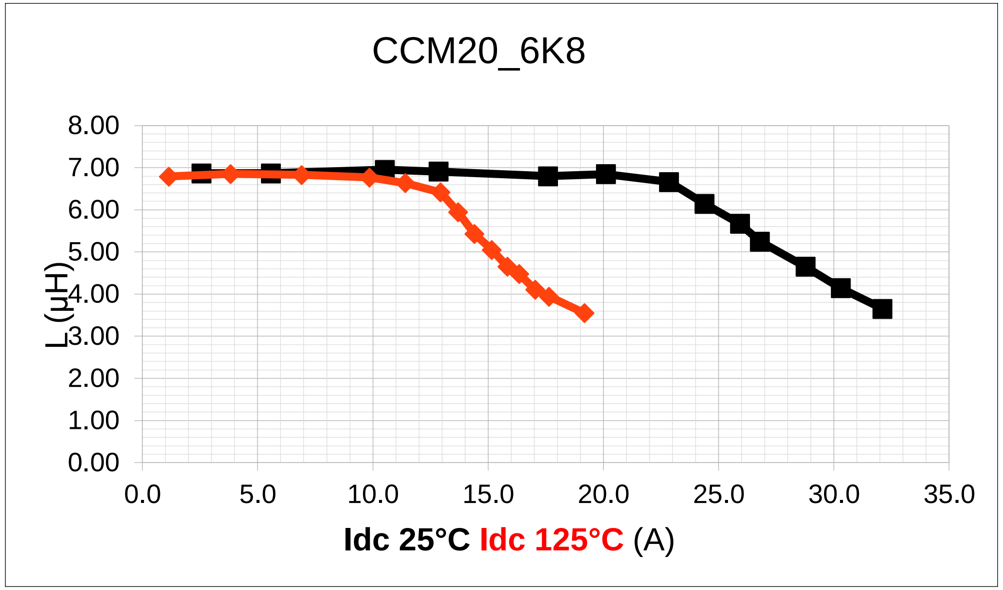


Part 2 : CCM technology performances 7/7

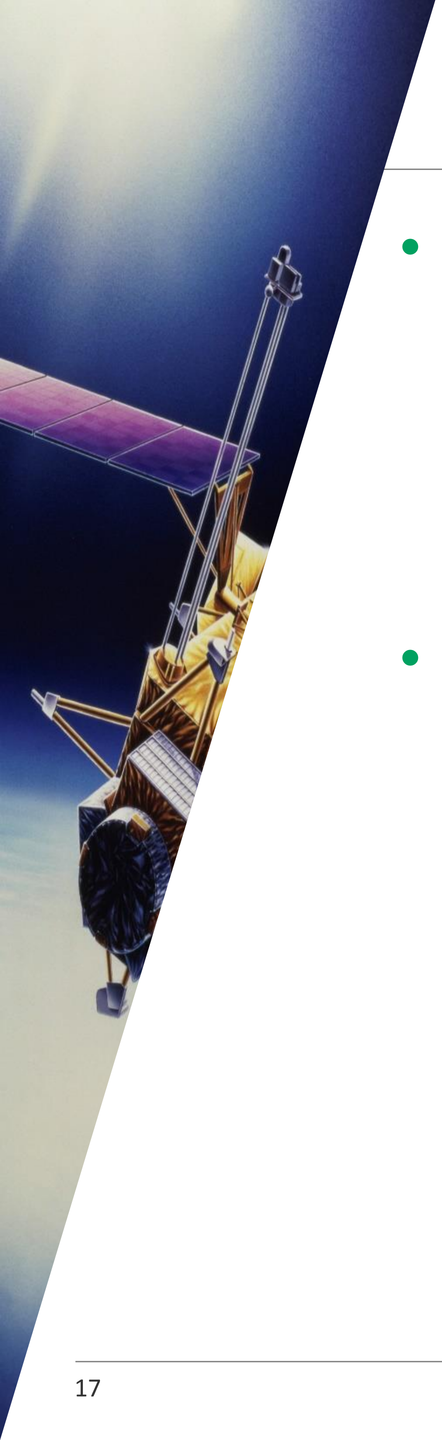
- Measurements realised for each of 5 shapes
  - 2 L values / 2 Tenv, ambiant and 125°C / up to 15 meas. points for each Tenv
  - 2 types of curves L function of Idc or Imax (Idc+ΔI/2)







- Result overview
  - Big ≠ between 25 and 125°C : taking account of thermal behavior of Ferrite is mandatory
  - Main interest : to detect the beginning of saturation



Part 3 : multi Flyback optimization 1/4

- What are voltage deviations also named cross regulation problem?

  1 At nominal point of load, some output voltages are different from theoretical values

  2 If power level at regulated output varies, some non regulated output voltages values vary

  3 Current waveform on some auxiliary outputs is very different from theoretical triangle shape

- Observation :

  The more different output / voltage levels / power levels …

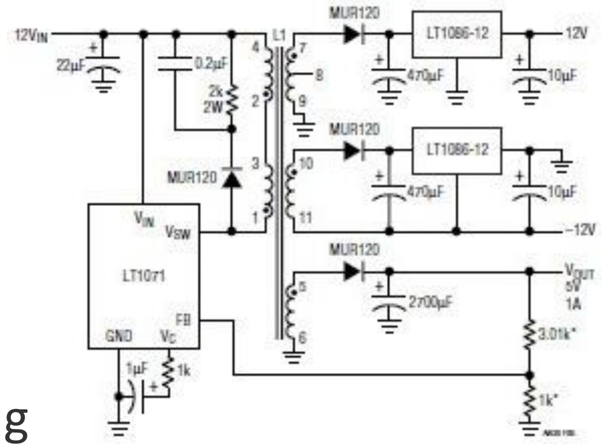
  … The greater the probability to have voltage deviations

  On which output(s) : ???

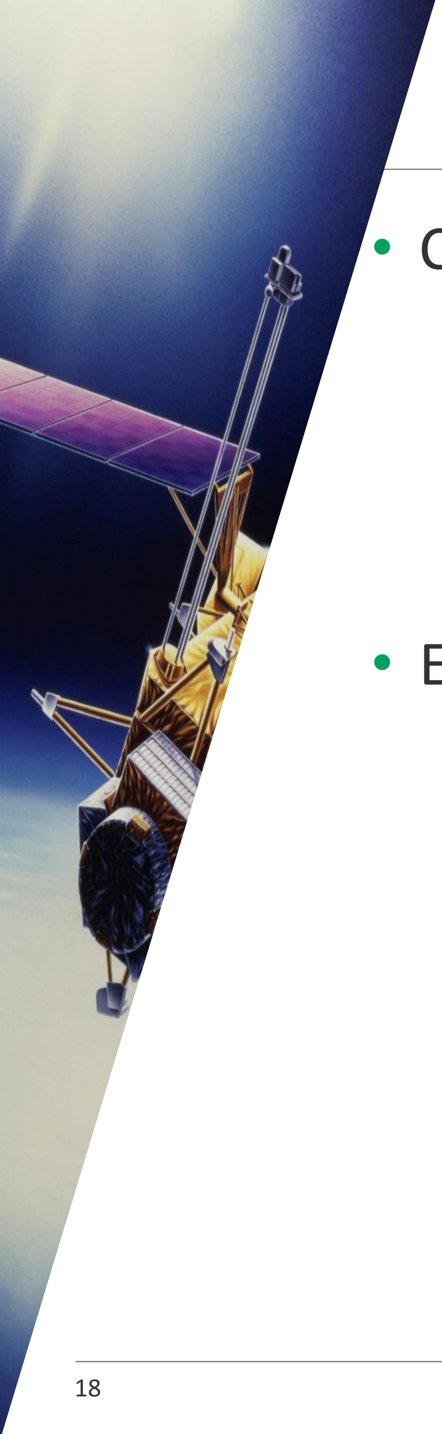
  Of which value : ??? some % up to x2!

  Actual solution : linear regulators

  ==> more volume/weight, less efficiency, more heating



Aim : **Is it possible to remove (some!) linear regulators?**



Part 3 : multi Flyback optimization 2/4

- Charge : Transformer is mostly **responsible**

  Is the customer able to define a technical constraint to respect for the supplier? **No**

  Problem seriousness depends on application and even on piece inside a manufacturing batch

  Magnetic root cause (transformer), but power electronics consequence (converter)

  ==> need to work in **both electromagnetism and power electronics**

- EXXELIA decided to manage a **PhD thesis** on this subject

  Aims :

  1 Understand scientific problem, Identify root causes (transformer, other components?),

  2 Find solutions, Take account of voltage deviations in design and manufacturing process

  Partners : G2Elab laboratory, D. Motte Michellon student, CNES, Steel Electronique

G2E Lab Grenoble Génie Electrique Grenoble Electrical Engineering

cnes CENTRE NATIONAL D'ÉTUDES SPATIALES

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Part 3 : multi Flyback optimization 3/4

- **PhD step 1 :** Understanding the scientific problem, identify root causes

  Study of magnetic behavior of several transformers

  ==> use of **FLUX** finite element simulation software

  Identification of a circuit model compliant with several softwares (Psim, Spice, other)

  ==> extended **Cantilever** magnetostatic model

  Calculation of all output voltages for different transformers/converters

  ==> use of **Psim** circuit software

- **Result of analysis :**

  75% of the problem comes from the transformer : magnetic coupling between all secondaries

  25% of the problem comes from drawbacks of some other components of the converter

- **Actions :**

  1 creating an analytical model to take account of leakage inductances between secondaries

  2 use this model to quickly calculate all output voltages

Part 3 : multi Flyback optimization 4/4

- **PhD step 2 :** Finding theoretical and industrial solutions

We identified relationship between CCM winding process,
couplings between secondaries
and voltage deviations

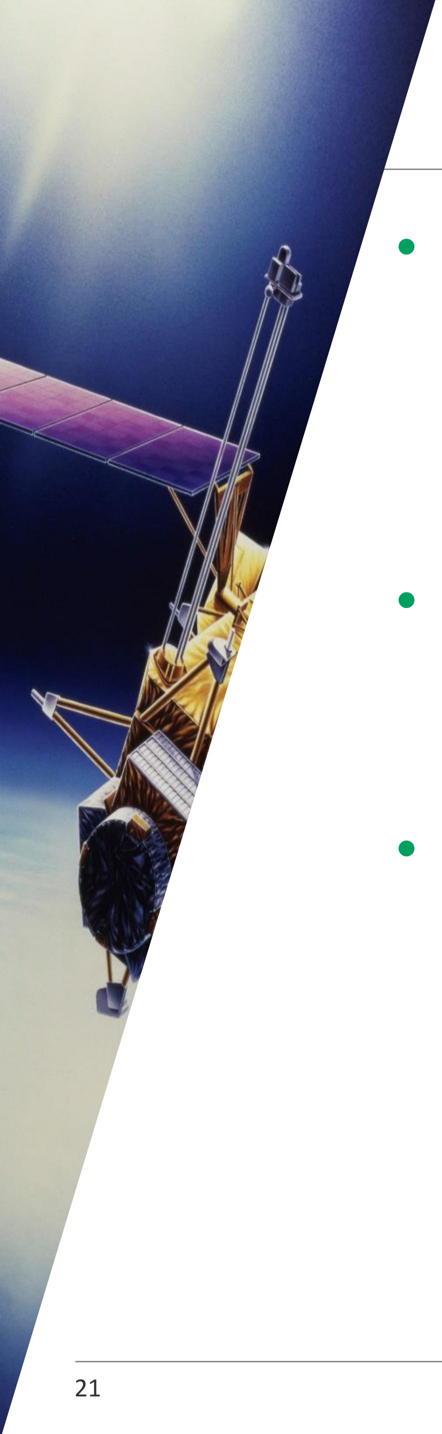
We identified which other components and which drawbacks are concerned

For the moment, one method of winding CCM to avoid worst cases of voltage deviations
and to minimize variations from one piece to another

applied since 01/01/2022 for all designed Flyback in CCM

In progress a software to optimize (minimize) voltage deviations
and to identify best cases of CCM winding processes

➔ **Increase of know-how for the customers' benefit**



CCM family : CONCLUSION

- Whatever the function you need

  Component is already qualified ==> Reliability / Security / Money saving

  Many pins ==> many input/output possibilities

  You know its thermal behavior ==> have a good idear of its energy/power limit

- For inductor applications

  You can have standard or custom components

  You know frequency and current saturation responses

- For multi output Flyback transformers

  Design method focused on 1 meeting customer's need as close as possible

  2 volume and weight reductions

  Understanding voltage deviations → problem minimization + ability to assist customer

==> **CCM technology is well adapted for space**

… and we continue to improve it

Thank you for your attention

Questions?

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