

**Special Features in Space Magnetics
to support Insulation Requirements in High Voltage Applications
and to improve Power Dissipation as well as assembly time.**

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INTRODUCTION

This paper trades with two types of parts which are significant for the design of analogue electronics. Especially for electrical power supplies transformers and inductors are applied, whereby individual solutions support the designer to meet cutting edge requirements for weight, size, efficiency and thermal behavior. On the other hand side ESA standards need careful attention and proven experience in the production of electronic space components.

For several applications electronic engineers face difficulties in finding a catalogue-product magnetic that would help the end-product to provide outstanding performance. Customized magnetics cannot be found as “off the shelf products” directly on the market.

Advanced Space Power Equipment GmbH (ASP) has developed processes to produce magnetics according to individual product requirements in accordance to MIL- and ESA standards. In addition the experts at ASP provide advanced solutions for critical design challenges like the thermal connectivity of a magnetic to the structure. Also special solutions are provided for the insulation of magnetics in high-voltage application in the range of approximately 500V – 30.000V.

ASP is certified according to EN9100:2009 and a Quality Management System for the Development, Analysis, Manufacturing and Test of Space Power Components is established.



Figure 1: Samples of ASP Magnetics

CUSTOMIZED MAGNETICS

In the context of this paper a **magnetic device** shall be understood as an **inductor** or **transformer**. In most cases ASP magnetics are applied in power electronics in the power range of 1 Watt to 20 Kilowatt.

The basic ingredients of a magnetic device are a carefully chosen **core** and **insulated copper wire**.

For standard applications (no high voltage applications) a variety of standard cores in different materials, shape and size can be used. As examples these could be (but are not limited to):

Core Geometry

- RM Cores
- Toroids
- Pot-Cores
- and others...

Core Materials and size

- Molypermalloy Powder (Toroids \varnothing 7,0 – 41 mm)
- Hi Flux (Toroids OD \varnothing 7,0 – 41 mm)
- Ferrite (Toroids OD \varnothing 6,3 – 17,2 mm)
- Ferrite (pot-core OD \varnothing 20,3 – 42,2 mm)
- Vitroperm (Toroids OD \varnothing 11,6 – 27,8 mm)
- and others...

With respect to shaped enamelled wires ASP uses products with excellent thermal capabilities, outstanding chemical resistance and very good resistance to abrasion. Usually “Grade 2” wires are used which means that there is a double wire insulation foreseen. For protection purposes magnetics can be dipped additionally in a space-proof insulation coating material.

ASP is highly flexible in the setup of magnetics. They are built purely to customer specific requirements. Since there is a high level of competence for power electronics in ASP available, engineers are skilled to provide design features to challenging product requirements. As a consequence design support for magnetics can be provided to customers.

Lot sizes vary from 1 to up to several hundred pieces of a particular design. There is dedicated production competence with almost 10 years of experience available which ensure compliance to space requirements.

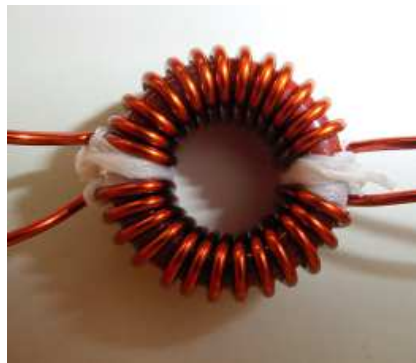
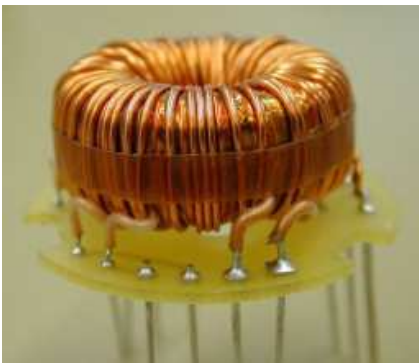


Figure 2: Inductor on carrier PCB **Figure 3: Differential Mode Inductor** **Figure 4: Common Mode Inductor**

POTTING MATERIAL AND PROCESS TECHNOLOGY



For high voltage designs (high voltage in the region of approximately 500V – 30.000V), the use of potting is typical to provide safe insulation between two different potentials.

ASP uses a hard potting (ASP-Epoxy) based on various resins and quartz flour as filler. A special machinery (see figure 5) is used to dry the ingredients and mix them to a potting fluid. The PCB circuitries are integrated in casting moulds. Under application of vacuum the potting fluid gets filled into the casting moulds. A next process step treats the potting under temperature and overpressure in an autoclave and will result into a solid material block. The process provides a guaranteed air-bubble free material.

The potting process has been verified by ESA. A Process Identification Document (PID with the ASP Number PR0000-0000 ASP/37) with ESA approval is available.

This potting process was used in several space products like *EPC for Ka-Band TWT* and *High Voltage Power Supply for Electric-Propulsion*. It is also used for encapsulation of high voltage modules for ground station EPCs. But not only encapsulation of circuitries is possible. ASP-Epoxy is also used as raw material for High-Voltage Transformers and as Thermal interface for Inductors.

It is of importance that the process parameters will never change. A continuous operation of machines and excellent trained personnel is supporting high quality standards.

Figure 5: Potting Facilities

The physical properties of ASP-potting are

- Colour: Olive
- Density: 1.9g/cm³
- Heat Conductance: 0.91W/m * K
- Thermal Expansion Coefficient: 40*10⁻⁶ /K
- Hardness: (DIN 53 505): 93
- Compression Strength: 166N/mm²
- Tensile Strength: 35N/mm²
- Out gassing: TML: 0.25%
VCM: 0.01%
- Temperature Range: -40°C to 130°C

Besides the excellent insulation capabilities there are two other important aspects to ASP-epoxy: Because of the quartz-flour in the potting the thermal conductivity is high and allows heat to be transported in an efficient way. Then the thermal expansion is in a region where mechanical stress between an electronic circuitry and the potting material is uncritical over the defined temperature range.

It is of importance that the process is in continuous operation and its parameters will not change. ASP in-house procedures and the knowledge of experts with more than 20 years of experience in space potting technology ensure very good production quality.

The potting-material is very useful as an ingredient to space magnetics.

For high voltage transformers the potting material is very helpful to provide adequate protection (insulation of high voltages) in satellites. Also in low voltage applications the potting material is used to provide mechanical fixation and to apply an easy to assemble and reliable thermal connectivity between magnetic and the PCB structure at the same time.

HIGH VOLTAGE DESIGNS

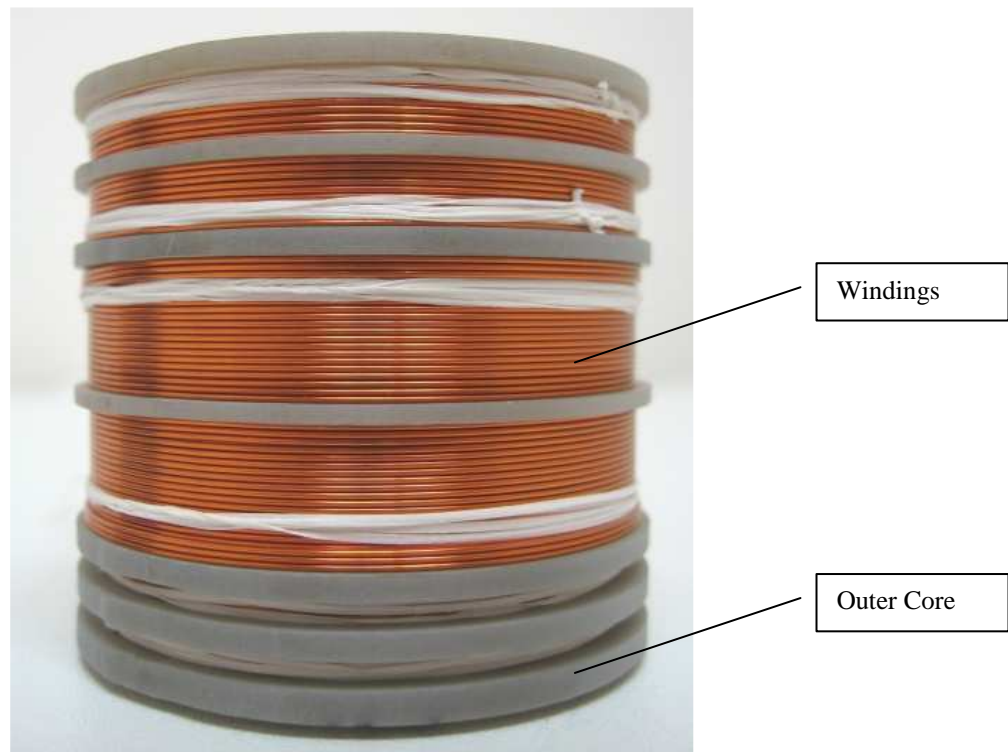


Figure 6: High Voltage Transformer windings on an Outer Core

Figure 6 shows a transformer for a high voltage application with several different windings. The outer core is potted with ASP-Epoxy, using a specific customized casting mould. The purpose of that outer core is to provide insulation between primary and various secondary windings. The inner section is hollow and allows the assembly of a ferrite as inner core. The product shown is suitable for a rated voltage of 13.000V, whereby ASP-Epoxy is feasible to insulate up to 30.000V. In a following step the outer core with the wire-windings will be potted again with ASP-Epoxy. This creates a solid component that provides insulation according to space requirements. Finally the ferrite core is assembled into the outer core in order to enable the magnetic coupling between primary and secondary side.

LOW VOLTAGE DESIGNS

The occurrence of thermal energy in magnetics can become an issue in certain cases with the result that thermal limits can become critical. ASP-Epoxy can then be used to install an excellent thermal path between the copper winding and the structure underneath the magnetic. At the same time a metallic insert can be potted in the center of the magnetic to allow very efficient mechanical assembly on the PCB. One screw is enough to provide an appropriate mechanical fixation and very good thermal connectivity at the same time.

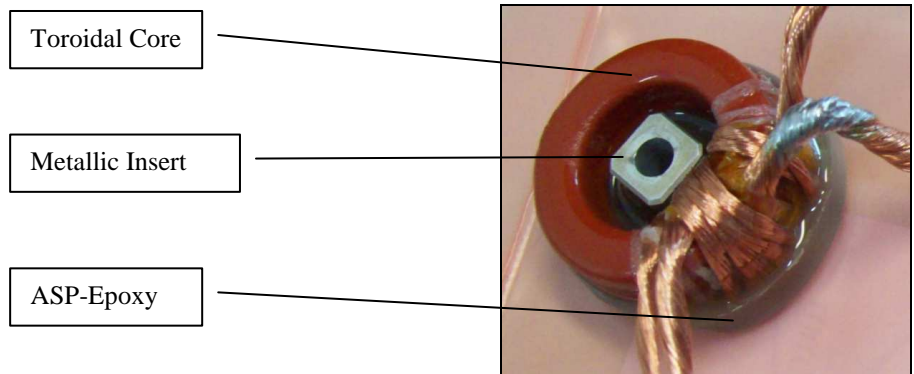


Figure 7: Coil

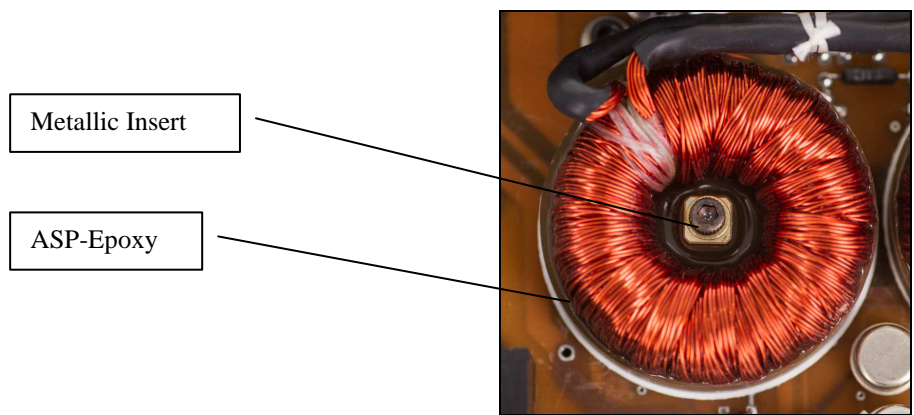


Figure 8: Power Inductor

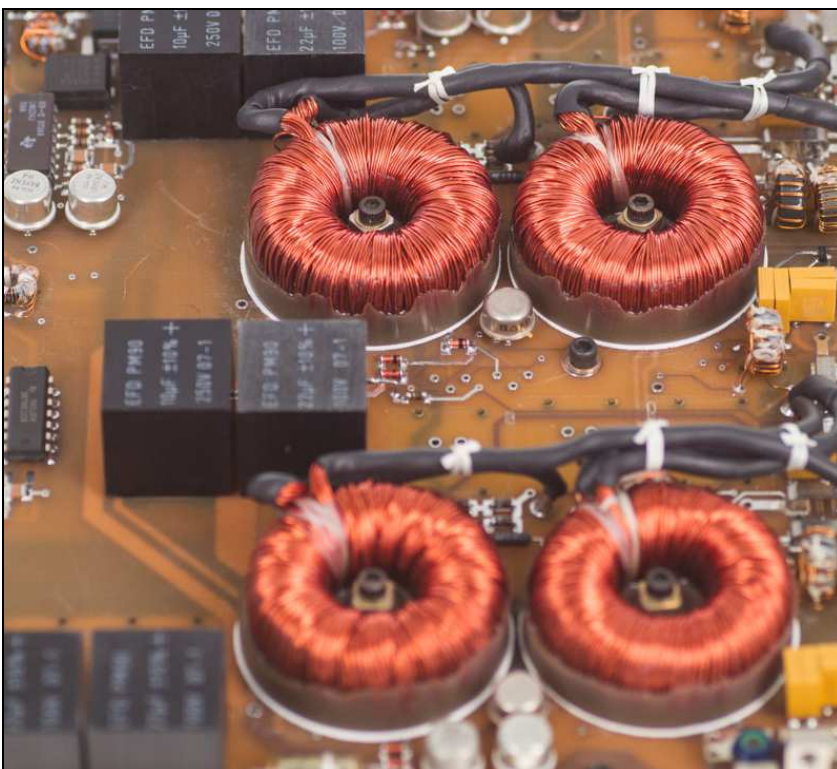


Figure 9: Power Inductors assembled on a PCB

QUALITY ASSURANCE ASPECTS

Worldwide customers require different approaches to ensure product quality. Generally it should be stated that ASP provides product heritage of almost 10 years with a quantity of approximately 4000 space magnetics per year. A lot of ASP magnetics show good space heritage, since they fly in space.

For space products ASP uses a process for 100% product screening which is documented in the in-house QA Handbook. This process is composed of test steps like (incomplete listing):

1. Electrical Tests for all transformers / inductors
2. Thermal Shock acc MIL-STD-981 Class S)
3. Visual Inspection as per MIL-STD-981 Class C
4. Burn-In as per MIL-STD-981 Class S /MIL-PRF-27 (if required):

As an option Lot Acceptance Tests (LAT) can be performed. In a customer project various magnetic types are put together under aspects of similarity in order to perform LAT. A representative number of parts will be subject to various tests steps including a Destructive Part Analysis (DPA). The test steps are (incomplete listing):

- Life test acc. to MIL-STD-202
- Electrical Tests
- Visual Inspection acc. to MIL-STD-1580B,
- Mechanical Shock according to MIL-STD-202
- Radiographic Inspection acc. to MIL-STD-981,
- Micro sectioning acc. to MIL-STD-1580B

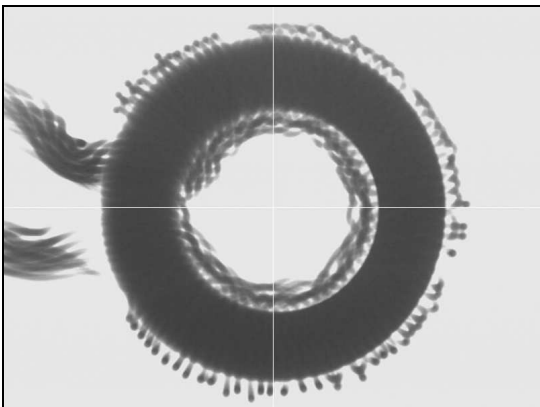


Figure 10, Radiographic Analysis



Figure 11, Destructive Part Analysis (Microsectioning)

As result from 100% screening and LAT activities ASP is in the position to issue PAD sheets, which is an official and formal documentation of product quality.

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