Transformer Design Guidelines To Meet RoHS and Hi-Temp SMD Soldering Requirements

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Introduction

Transformer manufacturers and the designers of electronic equipment continue to face technology and manufacturing challenges in the design of their respective products to meet the European Union's (EU) Directive 2002/95 entitled, "Restrictions On The Use of Hazardous Substances (RoHS).

The EU's RoHS directive restricts the use of mercury, lead, hexavalent chromium, cadmium and a range of flame retardants, notably polybrominated biphenyls and polybrominated diphenyl ethers. While there are a number of exemptions to RoHS requirements, the directive applies to the producers and importers of electrical and electronic equipment in Europe. The involvement of the EU has made RoHS a defacto global standard for nearly all transformer manufacturers.

RoHS requires that products placed on the market must not contain the restricted hazardous substances at levels above the maximum concentration limit. Manufacturers must prepare documentation to show their products are compliant and make themselves available for audit if requested. The documentation also must be maintained for four years after the product is no longer sold in the marketplace.

RoHS Effects On Transformer Design & Construction

For the manufacturers of transformers, the solution to the RoHS dilemma is to control the materials used to only those that meet the RoHS specification. For a transformer manufacturer, controlling the material list, required certifications, material trace identification and any material test confirmation is full of detail work, but has been relatively simple to implement. See Fig 1: *Examples of RoHS Compliant Transformers.*

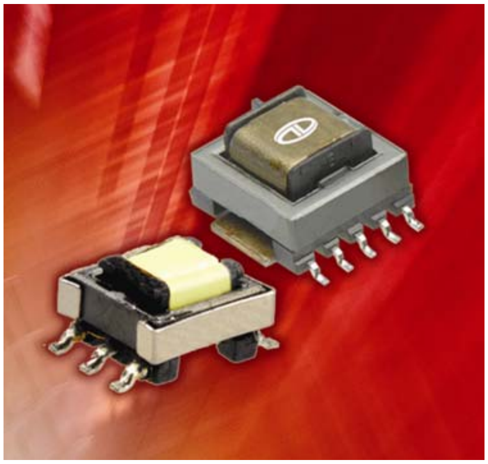

Fig. 1 RoHS Compliant SMD Transformers

Problems begin to occur, however, in transformer design when RoHS material compliant transformers are packaged as surface mount device (SMD's) for high volume and/or automated production environments. The demands of high-temperature vapor phase soldering on packaging materials in particular can affect the performance of the transformer due to a mismatch of materials and the soldering process.

<u>The Effects of SMD Technology & High Temperature Soldering</u>

Surface mount transformer design, packaging, soldering and RoHS compliance can all quickly come into conflict during the manufacturing process. The soldering process for SMD's was largely developed prior to RoHS regulations and originally depended heavily on the use of lead in leadframe and other component materials.

Attaching SMD transformers to print circuit boards (PCB's) using hand soldering techniques does not pose excessive thermal stress to the transformer. Tests for "Resistance to Soldering Heat" can be found in MIL-STD-202, Method 210. This standard includes tests for hand, wave and reflow soldering.

Hand soldering, however, does not support the high-volume electronic equipment market, which is most of the market today. Most circuit designers need to be careful in specifying RoHS compliant SMD transformers that their packaging will withstand harsh surface mount assembly environments.

High Temperature Vapor Phase Soldering

To eliminate the need for a separate hand soldering operation, nearly all major electronic equipment manufacturers have been specifying vapor phase or IR/convection reflow soldering as part of the transformer specification for many years. The RoHS requirement eliminates the possibility of using low temperature lead bearing solders. This drives up the soldering temperature.

Every manufacturer has its own reflow solder profile to support the unique requirements of its end product and manufacturing process. The maximum temperature of these profiles has now exceeded 260ºC and pose potential problems.

Providing the reflow solder profile maximum temperature and exposure time at the maximum temperature to transformer design and application engineers early in the transformer and end-product design cycle is important to prevent delays in the successful completion of a design. This is especially in the development of custom design transformers.

Rapid Temperature Rise Thermal Shock

The rapid temperature changes required by reflow soldering are potentially problematic for transformers. The temperature profile that will be used to solder the transformer to the PCB must be considered early in the design process. Knowing the reflow solder temperature profile is critically important to the designer when selecting the type of magnetic core to be used in the transformer. How quickly will the temperature rise peak, and how quickly will the temperature dissipate?

Test profiles specify the temperature transition of up to 4ºC per second. Transformers made of steel laminated cores or toroid cores made of pressed powders (iron, MPP, Hi-Flux and Sendust) have few problems. When encapsulated, the largest problem is surface cracks in the epoxy.

Soldering Open-Frame Ferrite Core Transformers

Transformers designed with an open-frame construction (as opposed to an encapsulated design) generally have few problems. Any problems that do occur are easily identified in the initial design tests.

The exception to this rule is ferrite cores. Ferrites are very hard and inflexible much like glass. We have seen failures due to uneven mounting clamp pressure, bobbin interference and the inability of the ferrite to withstand very rapid temperature changes.

Each ferrite shape has its weak points. For example, the long unsupported legs of the EFD cores are subject to breakage with shock and vibration. Our experience shows the most fragile shape is the pot core.

The worst case occurs in a transformer design where frequency requirements make a ferrite core the best choice. This type of application requires a full encapsulation and surface mount with RoHS compliance. The easy answer to this problem is to use some other core and suffer degraded performance.

Ferrite cores offer a wide variety shapes and sizes, low loss at high frequency, wide selection of materials and low cost. Even the fragile pot core offers excellent use of space and good self-shielding. For more detail on the pot core problems and one approach to overcome the fragility, see Ref 1.

Encapsulating Ferrite Cores—Problems & Solutions

There are three major problems with encapsulating ferrite cores. The following is a discussion of each. For more detail see Ref 2.

1) Epoxy resins shrink as they cure. The shrinkage may cause changes in the electrical characteristics. Some of the problems can be helped by using less rigid epoxies. In general, less rigid epoxies have greater cure shrinkage rates. Adding fillers helps the shrinkage but causes the epoxy to become harder. The epoxy selection must be balanced to provide sufficient mechanical strength and have the ability to adhere to surfaces. Good adhesion provides a barrier to water vapor.

2) If epoxy fills the space between the bobbin and the core, exposure to temperature greater than the cure temperature will cause bursting stress on the core. Large voids invite vibration problems and thermal stress at wire/epoxy interface. Trapped air may help create unwanted corrosion products. Various foams have been used to fill the open space. Great care must be taken to select an appropriate system.

3) Epoxies with good adhesion will also bond to the ferrite core. During thermal cycling shear stresses are set up on the core. Stress factors depend on the amount of epoxy, epoxy type, bonded surfaces and core shape. One approach is to use a release agent to prevent bonding to the core. The approach is very difficult to control. Should the release agent migrate to other surfaces, removal is extremely difficult.

All of the problems encountered with encapsulating ferrite cores can be overcome. Reviewing potential Solutions 1-3, as discussed previously, will show overlapping and conflicting requirements. The problem is complex but not impossible.

One last item should be mentioned. The magnet wire insulation must be rated high enough to pass the reflow profile without degradation. Often this requires wire that has to have the insulation removed by special processes which adds even more cost. Careful consideration at the specification step can significantly reduce the component cost.

Conclusions

Circuit designers specifying RoHS compliant transformers for high volume assembly environments that utilize vapor phase and IR soldering equipment need to be concerned about rapid temperature rise and shock. They need to provide transformer suppliers with their soldering process profile prior to specifying products to the manufacturer. Working closely with the applications engineering team at your transformer supplier will prevent many problems and avoid potential quality issues or failure. Transformer manufacturer specifications include thermal shock testing data, which needs to be consulted before specifying your transformer.

References

1) R.O. Sanchez, "A Method For Reducing Encapsulation Stress To Ferrite Pot Cores", Wound Magnetics Journal, July-Sept. 1996, pp. 13-22
2) E.C. Snelling, Soft Ferrites, 2nd ed., (London: Butterworths), pp. 20-21