Component Design Challenges
Part 2

Introduction

Electronic component designs are driven by customer requirements and preferences. Reliability and manufacturability are additional factors that should be included in the design process. Following these fundamentals and maintaining balance with trade-offs delivers the optimum design solution.

Component Design Challenges Part 1 considered customer requirements versus preferences and used that evaluation to define a prioritized list of characteristics. That priority list guided a review of possible design trade-offs. Manufacturability and reliability were incorporated as core elements of the design process. These principles were then put into practice for development of a custom autotransformer design. The focus in Part 1 was on the electrical characteristics of the autotransformer. Here in Part 2 the focus is on the mechanical aspects of the design since such aspects can provide their own challenges for which there are often multiple solutions.

Design Options for Mechanical Assembly

Using the example from Component Design Challenges Part 1 we will now explore two design options for the mechanical assembly. The first option will use commercially available materials. This approach has a lower initial cost but will have higher labor costs and increased opportunities for manufacturing error. The second option will rely on custom-designed materials with a focus on manufacturability and reliability. There may be a higher upfront cost to develop and create tooling for the custom materials, but several process steps will be eliminated thereby reducing labor costs and minimizing the risk of manufacturing errors.

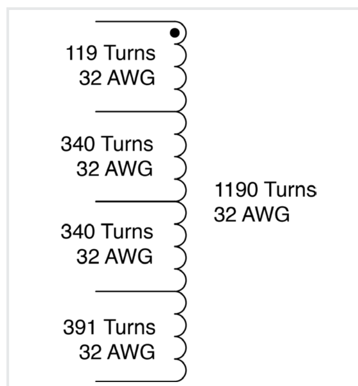
As in Part 1, the following requirements were provided for an autotransformer in order of design priority:

1. Inductance: L (1-5) = 180 mH ± 10% @ 1 kHz, 1 V_{rms}
2. Voltage Ratios: (1-5 to 1-2) 1:10
(1-5 to 2-3) 1:3.5
(1-5 to 3-4) 1:3.5
(1-5 to 4-5) 1:3
3. DCR: (1-5) 90 Ω Maximum @ 20°C
4. Size: 2.25”L X 2.25”W – reduce by 50% if possible
5. Height: 0.75” Maximum
6. Configuration: Thru-Hole, 0.025” to 0.028” leads
7. Fastening: Mechanical Fastening to PCB Required
8. Environmental: Environmental Seal Required

From Part 1 the resulting design was: Magnetics Inc. toroid 0077548-A7 with 1190 turns total, with electrical taps at turn 119, turn 459 (119 + 340) and turn 799 (459 + 340), using #32 AWG. See schematic to the right.

For both mechanical assembly options to fulfill the remaining requirements, several concepts will be utilized. The wound toroid will be epoxy potted in a thermoset epoxy housing to meet the Environmental Seal Requirement. Terminals will be assembled to the potting box. The toroid magnet wires will be solder connected to the terminals. For mechanical fastening a blind threaded insert will be placed in the center of the box and sit within the inside diameter of the wound toroid.

Part 1 Schematic



Mechanical Assembly Option A

An off-the-shelf potting box is available with the following dimensions: 1.50”L X 1.50”W X 0.75”H. Holes will need to be drilled in the bottom of the case to allow for the terminals and the threaded insert. To ensure the correct placement of the holes it is wise to create fixturing (that sits over the case) with predetermined holes to guide the drill press.

The height of this off-the-shelf case is equal to the customer’s maximum height specification. In order to add spacing below the case for solder joints and their maintenance, the case will need to be cut down to allow room for the standoff. This design will use a 0.025” maximum thickness G10 standoff. Considering that it will be epoxied in place, an additional 0.015” will be cut off to allow for the thickness of the epoxy. Therefore, the box will be cut to a total height of 0.71”. Once cut to size the standoff can be epoxied to the bottom of the case. The standoff must not cover the terminal holes or insert holes. There should also be clearance around the terminal holes to allow for proper solder fillets when the component is later mounted to a PCB.

> *Tip: Potting cases can have a slick interior surface that does not promote maximum adhesion to potting epoxies; creating a rough surface with sandpaper or other media will ensure good adhesion between the two materials.*

Terminals will be placed into the drilled holes and epoxied into place. The threaded insert will also be epoxied into place. Using a bolt and washer to secure the insert while the epoxy cures will help to assure that the insert is positioned correctly and remains straight.

The case is now prepared for the wound autotransformer. The magnet wire leads of the transformer must be solder connected to each of the terminals that were epoxied into place. Connections should have enough space between the body of the transformer and the terminal to form a stress relief in the wire, but not so far away that there is excessive (wayward) wire; correct spacing will also enable the soldering of final connections (as available work space becomes more and more limited). It is good practice to use high temperature solder alloys for internal connections to avoid reflow problems when the component is later mounted to a PCB.

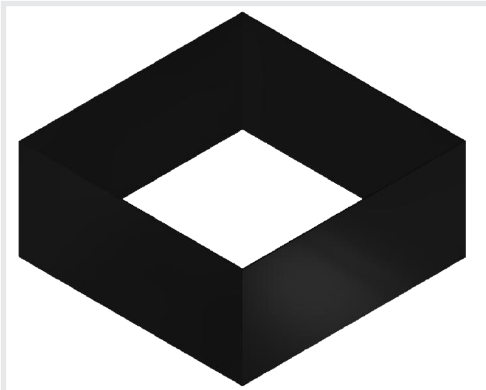
With the transformer assembled in the case and solder connections completed, the component is ready to be epoxy potted. There are a wide variety of epoxies available for component encapsulation. Many factors need to be considered when choosing an epoxy. See page 6 for helpful information regarding epoxy properties and considerations.

For this design the requirements of the epoxy are minimal so a general encapsulating epoxy will be used. It is good practice to subject a finished component to an elevated temperature or maximum operating temperature to evaluate the effects this can have on the component as a whole and on each material in its composition.

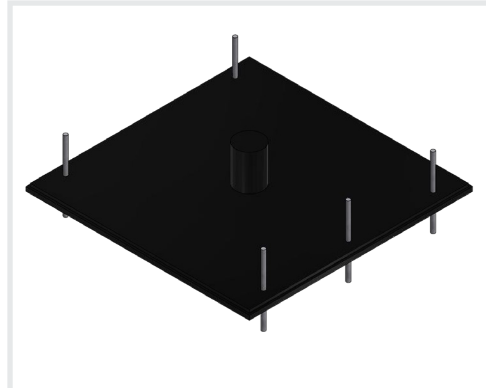
Mechanical Assembly Option B

The second design option (Option B) will take a slightly different approach by utilizing a custom molded case. One of the biggest advantages of a custom tooled case is that dimensions can be defined to meet the exact requirements. In addition, many features can be designed in as part of the raw material rather than added on via additional process steps (as in Option A).

Option B will use a two-piece design. There will be a mounting base and a 4-walled encapsulation sleeve. The advantage to this approach is that there will be plenty of room to make the solder connections from the toroid to the terminals (on the base) before the walls are put in place. The mounting base will have the terminals and the insert molded in place; this provides strength and durability and also ensures their placement and straightness will always meet the requirements. Because the dimensions are defined by the custom designer, a standoff can be included to allow for cleaning and inspection of the solder joints. The base will also have a seating ledge around the outside so that the encapsulation sleeve can seat correctly each and every time. The encapsulation sleeve consists of four walls with an open top and bottom. This sleeve will be seated on the base to provide a shell into which the potting compound can later be poured. Refer to the images and descriptions below.

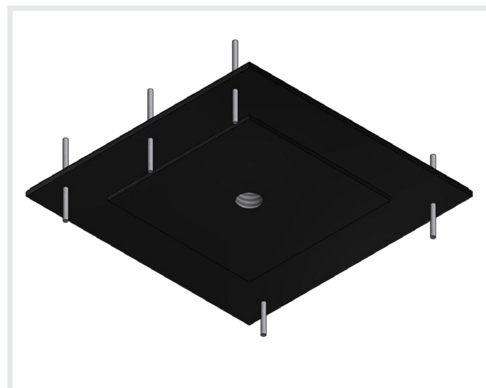


This is the sleeve; this is used as a container to shape and hold the epoxy encapsulant



This is the base or mount (top view) and shows molded-in terminals and threaded insert; the lip or ledge around the outside is where the sleeve will rest, ensuring proper mating between sleeve and base

This is the base or mount (side view) and shows the standoff designed-in as part of the molded configuration.



This is the base or mount (bottom view) and shows the integrated standoff

To complete the assembly, the wound toroid will be seated on the base and tied off to the molded-in terminals. The solder connections will be made using a high temperature solder. The sleeve will be seated on the ledge of the base; it will then be epoxied along the inside seam to form a seal. Once the epoxy seal is cured the component is ready to be potted. A photo of the actual assembly is provided below.

Actual completed assembly

Comparison

The custom molded case (Option B) eliminates many build steps that are required when using a traditional assembly (Option A). Refer to the table below. Option B also significantly decreases the amount of time it takes to actually build the case. While it may take several days to prepare the traditional case, the custom molded case can be prepared in minutes. The custom molded case also eliminates the G10 standoff by incorporating the standoff as a feature within the base itself. Other benefits of the custom molded design include consistency in terminal and insert placement as well as superior holding strength, eliminating concerns about twists or pulling out.

Comparison of Mechanical Assembly Options

Build Steps - Option A **Traditional Case**	**Build Steps - Option B** **Custom Molded Case**
• Create Hole Placement Fixture	• Seat Transformer and Make Solder Connections
• Drill Terminal Holes	• Assemble Sleeve and Seal
• Drill Insert Hole	• Encapsulate
• Cut Box Down to Height of 0.71”	
• Assemble and Epoxy Standoff in Place	
• Assemble and Epoxy Terminals in Place	
• Assemble and Epoxy Insert in Place	
• Make Solder Connections and Seat Transformer in Case	
• Encapsulate	
Total of 9 Steps	**Total of 3 Steps**

While a custom molded case has upfront development time the use of 3D printers have allowed development times to decrease dramatically; concept ideas can be converted to physical prototypes in as little as one day. For creation of thermoset epoxy molded prototypes, prototype tooling can be achieved in a matter of days; from concept to prototype is typically four weeks (at GCG).

The upfront cost of custom molded cases has often deterred their use. This is especially true for low volume components; the investment is not justified for a single application component. These initial costs can be offset by the decreased labor, elimination of epoxies, prevention of quality issues and higher production yields. By using extensive in-house tooling capabilities, GCG is able to offer a much lower upfront cost for custom molded cases. Tooling ranges from prototype tooling to high volume hardened steel molds. GCG’s custom molding department is set up to handle anything from tens – to tens of thousands – of pieces. This makes custom tooling a reliable and affordable option for just about any custom component, regardless of volume.

Some examples of GCG’s custom design equipment are shown below. The first two pieces of equipment (HAAS and DEM) are utilized to cut the tooling that is then used to mold the custom case. The equipment features excellent CNC control enabling complex shapes, small dimensions, close tolerance even on very hard materials and part-to-part repeatability. The Stratasys 3D printer enables quick production of prototypes and parts for concept development, design validation and functional performance evaluation. Additionally, GCG’s unique support material can be readily dissolved thereby providing a clean finish and hands-off removal.

HAAS VF2SS – Vertical Machining Center

DEM 320A - CNC Electric Discharge Machine

Stratasys F170 - 3D Printer

IN CONCLUSION

At each step of component design there can be challenges that may be resolved in a variety of ways. Here in Part 2 of our example we showed the difference between using off-the-shelf materials and modifying them to the requirements versus tooling a custom molded case tailored to the requirements. By utilizing GCG's in-house molding equipment and expertise the custom approach is not only more reliable but also financially viable for just about any component, regardless of volume.

HELPFUL INFORMATION

GCG and its affiliate Gowanda Electronics provide additional information on related topics:

- Custom Products Overview: https://www.gowanda.com/custom-products/
- Custom Inductors: https://www.gowanda.com/custom-products/custom-inductors/
- Custom Transformers: https://www.gowanda.com/custom-products/custom-transformers/
- Custom Molding: https://www.gowanda.com/capabilities/custom-molding/
- GCG Technology Center: https://www.gowandacomponentsgroup.com/gcg-technology-center/

Information about epoxy properties and considerations appears in the Addendum on the next page.

To access downloadable versions of this and prior technical tips please **click here**.

If you have any questions about this Technical Tip, suggestions for future Technical Tips, or need assistance with our standard or custom products, please contact us.

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ADDENDUM

Epoxy Properties & Considerations

Viscosity: Epoxies can vary significantly in viscosity. Thinner materials may be more appropriate when small crevices and nooks need to be filled and the material may need to readily flow to reach these areas. Thicker materials such as a non-sag materials can be optimal if the lack of flow is preferred, perhaps to prevent epoxy from getting into an area that should be epoxy free.

Thermal Properties: Thermal expansion coefficients define the amount of expansion a material will experience over a range of temperatures. Having a system of materials that have similar or matching expansion rates will help to avoid cracks, voids and breaks where two materials meet. Operational temperatures of epoxies are vital. The operational temperature of the epoxy should meet or exceed the expected operating temperature range of the component.

Pot Life: This is defined as the working life or length of time a material is suitable for its intended application once mixed (in the case of a two-part epoxy) or exposed to air (in the case of an air cure RTV). A short pot life can be advantageous. For example, an air cure epoxy can be handled much sooner if the epoxy sets in a shorter time, thereby increasing throughput. A short pot life also poses some disadvantages. Several small batches of epoxy may need to be mixed to avoid material degradation while processing larger volumes of components.

Insulation/Conduction Characteristics: This applies to both thermal and electrical transference. If a component dissipates a high amount of heat, a thermally conductive material would help to transfer the heat into the air. A high voltage application would benefit from an electrically resistive material that acts as an electrical insulator.

Environmental Durability: Environmental durability covers many aspects. Components may need to be capable of withstanding thermal shock testing or very fast changes from high to low temperatures, sometimes as much as 190°C difference. Resistance to solvents and moisture can be important as well if the component will be exposed to a cleaning agent, washing process or operated in a moist environment.

Specific Requirements: Some components carry specific requirements. One example is low outgassing. In such cases an epoxy needs to be selected that will meet the outgassing requirements. Another condition could be a limitation on specific materials, such as silicon. The epoxy would then need to be evaluated for its material composition to ensure such a requirement is met.

Ease of Use: An epoxy that is difficult to work with can cause an array of problems. Additional labor time, costs, rework and quality issues can all be a result of an epoxy that is difficult to use.