
Manufacturing of Unique Winding Geometries

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James Lau obtained his Bachelor of Science in Electrical Engineering from Texas Tech University, Lubbock, Tx in 1986, and Master of Science in Electrical Engineering from University of California, Los Angeles (UCLA), Ca in 1988.

James co-founded Broadband Telcom Power Inc (BTC Power) in 1998 with venture capital funding. The company was sold in 2004. It then evolved into a manufacturer of fast charger for EV.

In 2006, Coil Winding Specialist Inc (CWS) was started to design and manufacture transformers, inductors and coils and energy savings products.



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Unique Winding Geometries

Why is Unique Winding Geometry important ?



- High Frequency operation : less turns reduce proximity effect
- Thermal Management : more exposed surface area for heat to be dissipated
- Lower DCR : Less turns = Lower Copper Losses
- Density : More copper and minimize space wastage between windings

Current Status

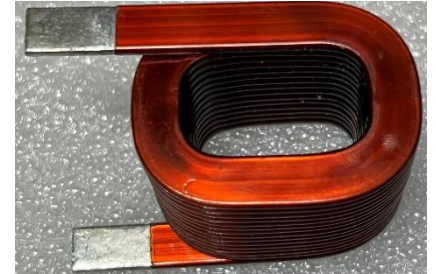
- Most Inductors and Transformers are wound using round wires or Litz wire.
- Square or rectangular wires on a single core structure is also quite common.
- Recently, helical or edge wound inductors are gaining popularity as well
- Conventional winding is not efficient in high frequency application and thermal management.



Unique Winding Geometries

Helical / Edge Winding Coils and Inductor

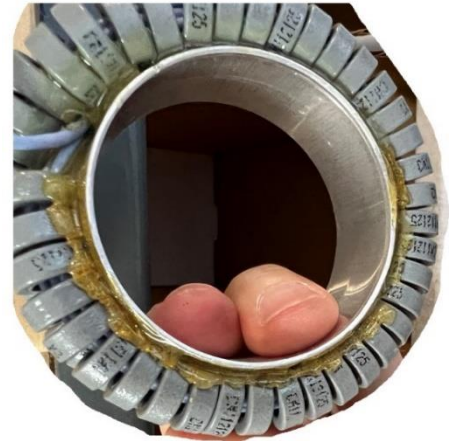
- Helical Coil has higher copper density, better thermal efficiency and good winding consistency.
- Helical winding can increase the current handling capacity of an inductor over the round wire windings.
- Mainly use for high current application
- Not suitable for high frequency operation



Unique Winding Geometries

Matrix Winding Inductor

- Matrix inductors are high frequency inductor with reduced number of turns.
- The winding is done on multiple cores
- It has good better thermal efficiency, lower skin and proximity losses.
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- Suitable for very high current application by using a single turn
- Optimize for high frequency operation



Unique Winding Geometries

Analysis/Approach

- Converting one core to many cores. Matrix Inductor.
- Example: Convert a 5-turn inductor to a 1 turn inductor:

$\hat{H} = \frac{N \cdot I}{l_e} * \sqrt{2}$; To have the same \hat{H} with one turn, I_e must be 1/5th.

$L = N^2 * \mu_0 * \mu_e * \frac{A_e}{l_e}$; To have the same L with $N^2 = 1$ and $I_e = 1/5^{\text{th}}$, A_e must be 5 times.

If the $\frac{ID}{OD}$ ratio is kept the same, with $I_e = 1/5^{\text{th}}$ and $A_e = 5$ times, the core height ht must be 25 times.

- THE CORE VOLUME V_e is UNCHANGED !!!



Unique Winding Geometries

Solution for High Frequency Inductor

5 turn inductor. Conventional winding

$$L = 1.81\mu\text{H}$$

$$Q = 3.29$$

$$\text{Weight} = 196 \text{ grams}$$



U-Turn equivalent Inductor

$$L = 1.82\mu\text{H}$$

$$Q = 3.27$$

$$\text{Weight} = 156 \text{ grams}$$



Spiral equivalent Inductor

$$L = 1.79 \mu\text{H}$$

$$Q = 3.54$$

$$\text{Weight} = 156 \text{ grams}$$



Unique Winding Geometries

20-turn inductor can convert to a 4-turn inductor

20-Turn inductor. Conventional winding

$$L = 59.2\mu\text{H}$$

$$Q = 7.83$$

Weight = 185 grams

Single core with 20 turns of Litz wire



4-Turn equivalent Spiral Inductor

$$L = 63.3\ \mu\text{H}$$

$$Q = 7.29$$

Weight = 196 grams

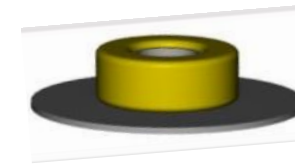
Multiple cores with 4 turns of same Litz wire



Unique Winding Geometries

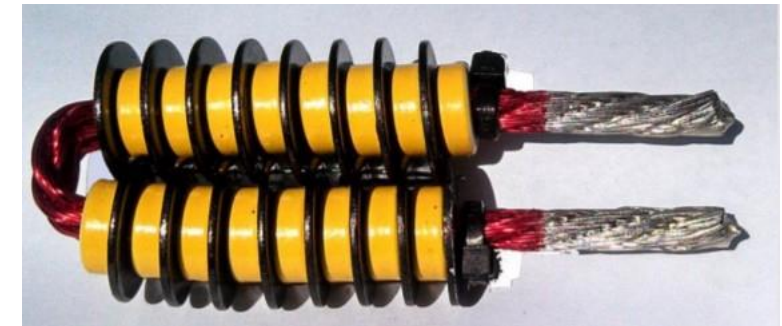
Thermal Management. Heat Sinking can be added

Heat Sink attached to core for better heat dissipation.



U-Turn Inductor with Heat Sink discs

Heat removal using heat sink disc bonded to the cores. Increase surface area and heat conduction out



Unique Winding Geometries

Summary of Findings

- **Helical Wound inductor** :-
- Superior thermal characteristics especially for high current application.
- **For Matrix inductor**: -
- Conversion of conventional inductors to matrix style multiple core inductors can achieve higher frequency of operation for the same current and voltage
- NI will be the same, but L can decrease, and fewer cores are needed.
- If losses can be held constant, then power density will increase
- Better thermal management and removal of heat can easily be accomplished by using multiple heat sink discs.



Thank you for your interest.

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