Considerations for Reliable Magnetics

A non-exhaustive reference

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Power Magnetics @ High Frequency Workshop 2022

BH Electronics
INNOVATIVE MINDS…EXCEPTIONAL QUALITY

Matt Dvorak

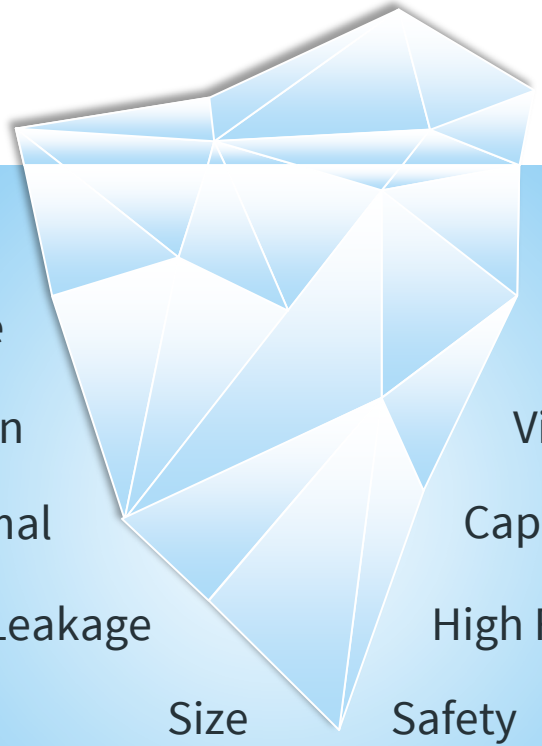
Matt is an experienced Magnetics Design Engineer with BH Electronics, having US manufacturing based in Marshall, Minnesota. Matt began his career at BH Electronics after graduating from Minnesota State University with a Bachelor of Science in Electrical Engineering in 2010.

Matt's expertise is in creating high reliability and safety critical transformer designs, most having high voltage and isolation requirements, regulatory compliance requirements, and space constraints – often incompatible design goals without careful and creative design effort. End use applications range from medical products and explosive environments to laboratory equipment and automotive power delivery.

Magnetic Devices

A bit of copper and some rust…

Magnetic Devices



High voltage

Creepage

Insulation

Thermal

Leakage

Size

SMD

Clearance

Vibration

Capacitance

High Frequency

Safety

Engineers like to solve problems.

If there are no problems handily available, they will create their own problems.

-Scott Adams

Don’t create problems!

- Be aware of simple, but common pitfalls
- Work with your magnetics vendor on the details
- Insulations, voltages, wire configurations, mechanicals all critical
- Keep the end application in mind

Identify potential issues early in the design process

Saves resources and headaches later

Insulation

Datasheets matter – But results top

“It works on paper”

Insulation – Magnet Wire Example, MW 80C

NEMA 1000:

- Twisted Pair Method
- 26 AWG MW80C
- 4,620 VAC MIN breakdown

In practice:

- 500 VAC
- Turn to turn
- No safety rating

NEMA standard - A metric to verify conformance
Do not rely on for isolation ratings in circuit

Insulation – Magnet Wire, continued

Reliable approach:

- Layer tape
- Sleeving where required
- Avoid perpendicular crossovers
- Extruded insulations

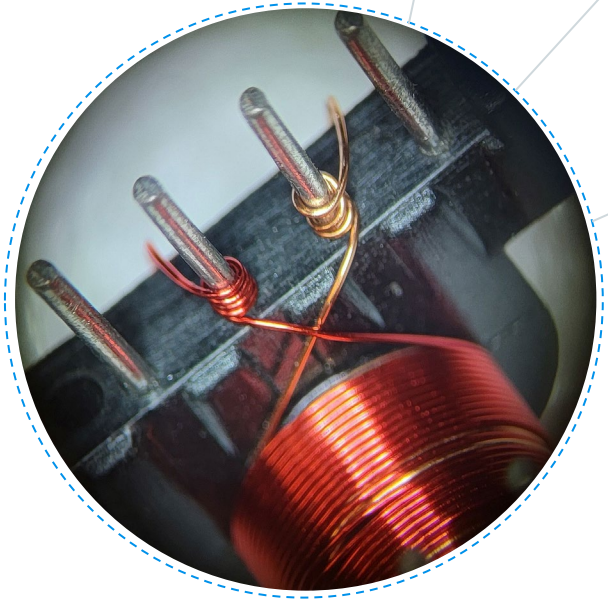
Insulation – Example, Perpendicular crossovers

26 AWG ‘heavy’ enamel (MW80C):

~0.0005” insulation thickness

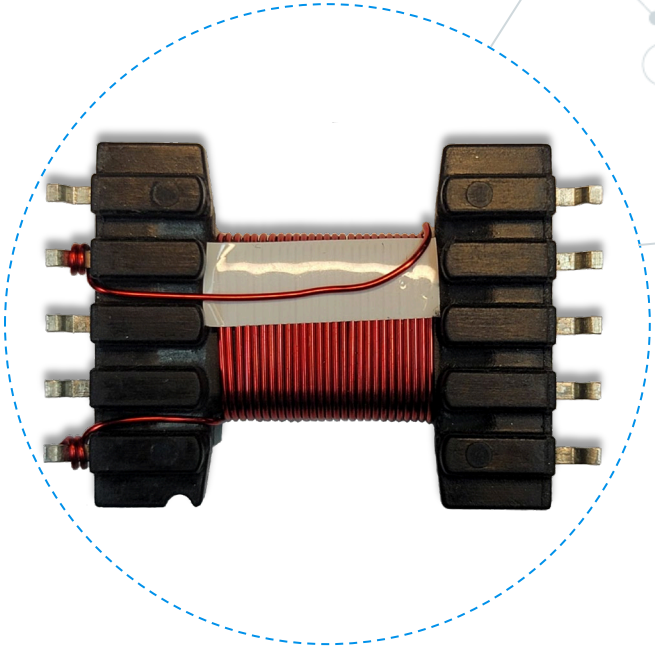
Minimal strain before cut-through:

- Thermal shock
- Burn in
- Reflow soldering profiles



Insulation – Crossover tape

- Reconfigure pinout
- Full layer if space allows
- Additional layer(s) prior to additional windings



A small piece of tape can have a large impact

Insulation – Safety Agency (UL, IEC, etc.)

Creepage/Clearance:

- Reference standard
- Operating point
- Environmental

Enamel coatings:

- Not sufficient
- C/C effectively zero
- FIW some standards

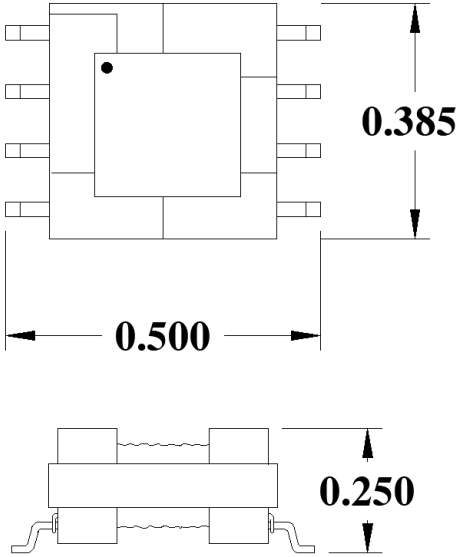
Methods:

- Layer/margin tape
- Sleeving
- Extruded insulation
- Bobbin features

Relay requirements to your manufacturer

Insulation – Safety Agency - Continued

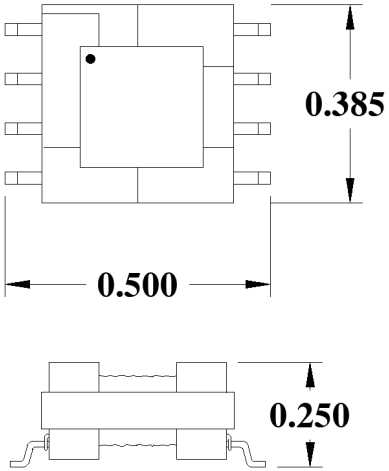
- Insulation requires space
- Likely increasing component size
- Better to account for this early
- Usually space restricted
- At times performance compromises

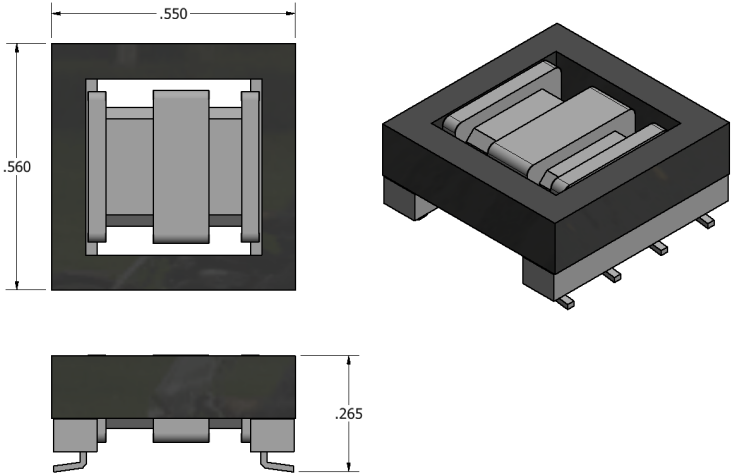


Design, pre-agency requirements

Insulation – Safety Agency - Continued

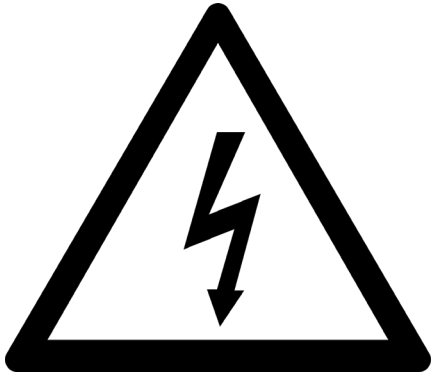
Filling in those details





68% increase in component area

Voltage Considerations



Voltage buildup and Hipot

Voltage – Areas of concern, isolation requirements

Primary to Secondary:

- Low isolation (functional)
- 300 VAC – 500 VAC

Primary to Secondary:

- High isolation, no agency standard
- 1,000 VAC and up (1,500 VAC common)

Turn to Turn:

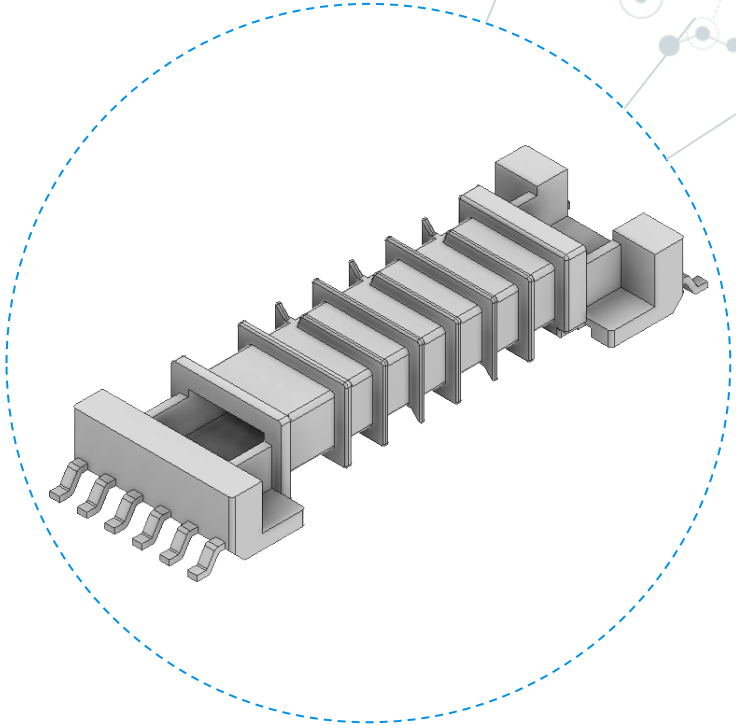
- Within a winding
- Particularly with high output secondaries

Safety Applications:

- Medical, Industrial (basic, double, reinforced)
- 1,500 VAC and up (4,000 VAC typical)
- Creepage/Clearance

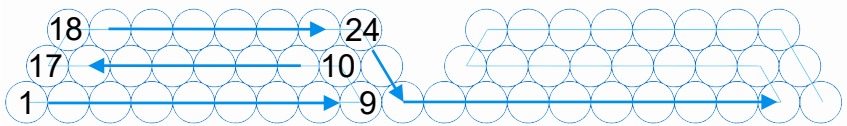
Voltage – Example, high output transformer

- Split the high voltage winding
- Multi-section bobbin
- Check volts per turn
- Adjust according to insulation



Voltage – Example, toroids

- Turn to turn voltage
- Start and finish
- Capacitance and leakage current
- Automated process



Wire – Size and Termination

Multi-filar winding and Skeining

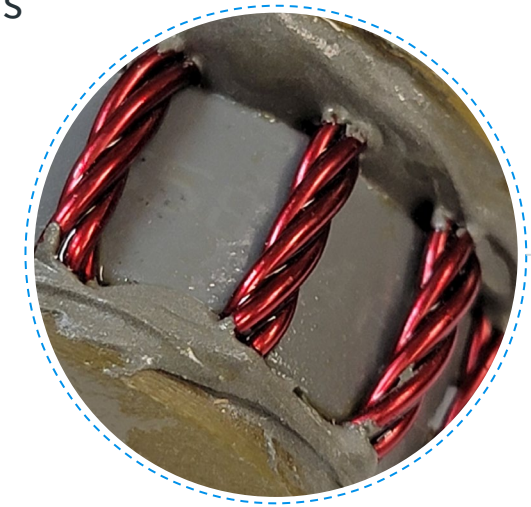
Multi -filar Windings

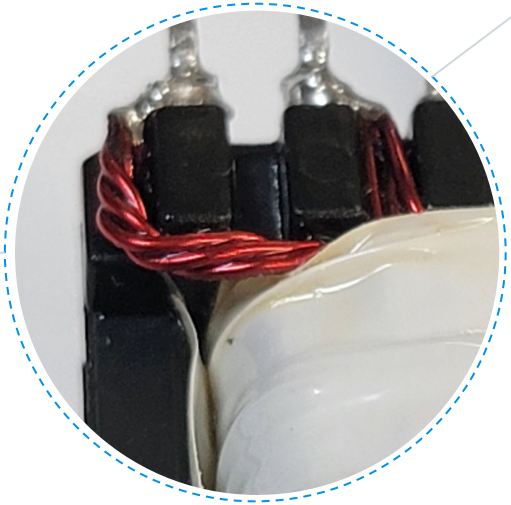
Benefits:

- Reduce DCR
- Winding ease
- Terminations

Test for:

- Wire breakage
- Shorts within a winding





Multi -filar windings – Continued, Litz

Litz bundle:

- 165/36
- 4,125 circular mils
- 14 AWG equivalent
- Electrical benefits
- Mechanically easier to wind

Skeined leads – A chord of 3 strands...

Technique:

- Typically 38AWG or smaller
- Odd number integers
- 3 and 5 strands common
- Embedded in final turn(s)

Benefits:

- Exit lead strength
- Routing to pin(s)
- Soldering

Opportunities for automating skeining process

Skeined leads . . . is not easily broken

Start and finish leads:

- 43 AWG
- 5 strand skein
- Terminated to hook-up leads
- 36 AWG equivalent in cross-section

Significantly stronger lead

Mechanical Concerns

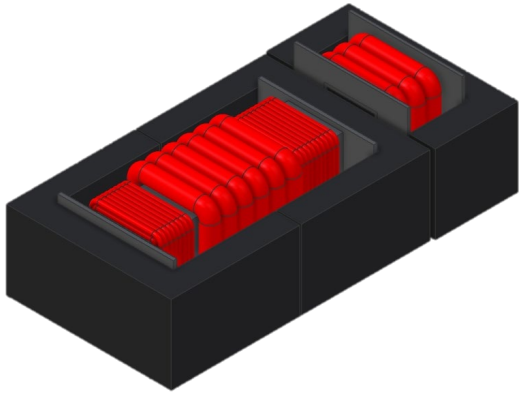
Design for the end application

Mechanical – Surviving the final application

- Electrical parameters are important
- Surviving the environment is critical
- Orientation can be critical for
  - Shock
  - Vibration

Mechanical – Example – Surviving the application

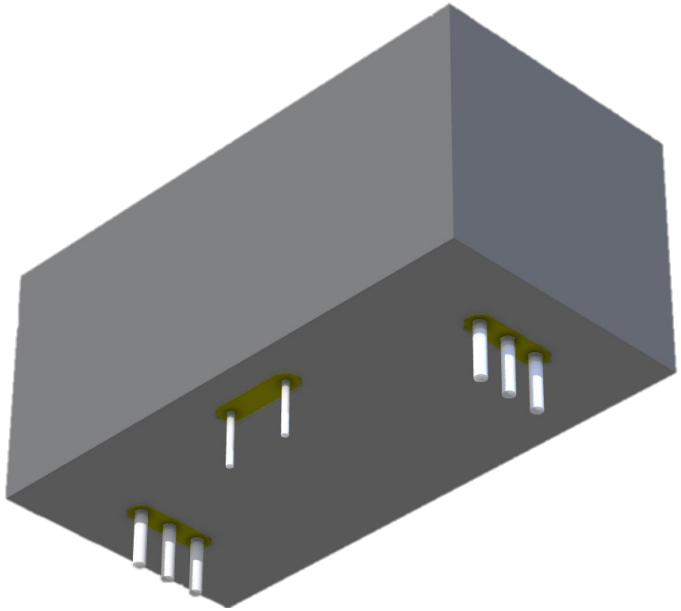
- Shock and vibration expectations
  - Launch environment
- Original design overlooked structural deficiencies
- Flying leads
- Thermal transfer critical



Be open to design adjustments

Mechanical – Example – continued

- Reconfigured magnetic structure
- Proposed package changes
- Mounting options
- Added thermal epoxy



In Summary

Don’t create problems!

- Watch for common design pitfalls
- Work with your magnetics vendor early on
- Insulations, ratings, and operating points are critical
- Wire and lead placements can pose risks
- Safety standards change design strategies
- Mechanical constraints should shape the design

Thank You!

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