Planar Magnetics: A Case Study Showcasing Software Design Tools That Provide Real-Time Relative Performance Analysis

Industry Session Presenter

Vladimir Alexiev

power integrations™

Objectives

- Review challenges associated with design of planar magnetics
  - Complexity of calculations
- Critical need for a tool that enables design in

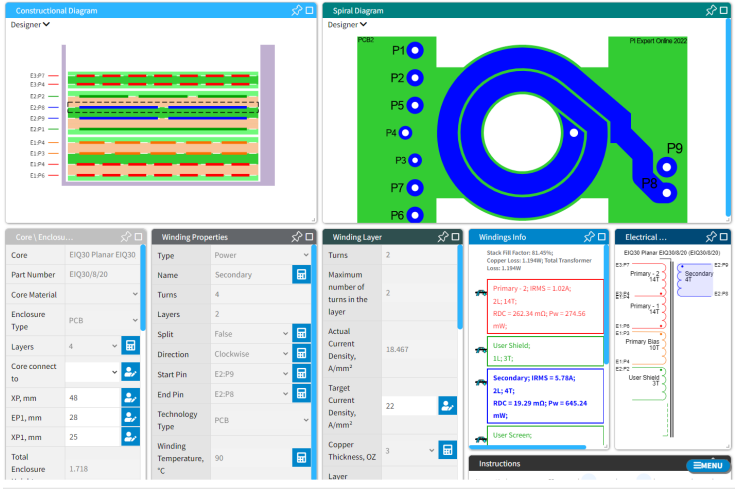
- Review of tools and correlation of results
  - PI Expert Planar Magnetics design tool and Ansys
  - Key design parameters – mechanical construction, electrical and parasitic elements, safety standards
  - Ease of design with convenient visualization of planar magnetics structure
  - Documentation and manufacturing files – generation of Gerber files
- Important considerations for design of planar magnetics for USB PD power adapters

Planar Magnetics – Design Challenges

- Expensive to prototype – design has to be right first time
- Design process of PCB spiral not as straightforward as wire-wound alternative
  - Mechanical difficulties: PCB size, copper-to-core distances, pin position, vertical and horizontal fit
  - Electrical challenges: internal connections (vias), calculation of parasitics
  - Calculation of winding resistance
    - Unlike wire wound construction, simple calculation needs software tools
    - Winding resistance changes for each turn in a spiral
- Knowledge of PCB CAD tools, safety and manufacturability requirements
  - Prototyping requires translation of calculations to CAD and Gerber files

Design Challenges and Capabilities of PIExpert

- Mechanical difficulties:
  - PCB size, safety and functional distances
  - Pin position – dynamic adjustment support
  - Vertical and horizontal fit of the stack
- Electrical Challenges:
  - Internal connections (vias)
  - Parametric values and dynamic calculations for parasitics



- Visualization is key to achieving a design quickly and efficiently
  - “What-if?” analysis important to optimize design expeditiously
- Automatic generation of ‘manufacturable’ solution
  - Providing Gerber files for manufacturing speeds up design process

Design Tool - Safety Implementation

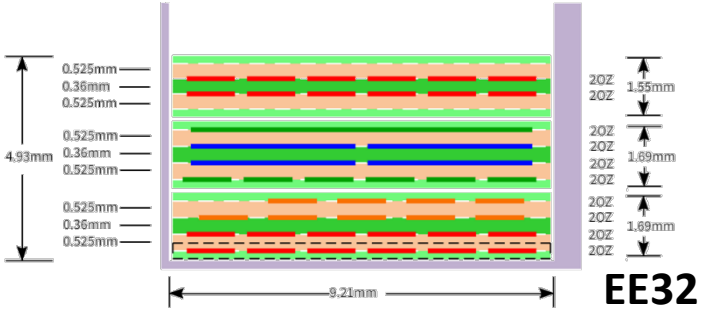
- Reinforced isolation
  - Distance to Insulator (DTI) = 0.4mm required as internal clearance
  - Distance to Air (DTA) = 6.4mm creepage and clearance for external parts (Pins)
- Automatic implementation
  - Set vertical & horizontal isolation during design

USB PD Chargers with Planar Magnetics Evaluation

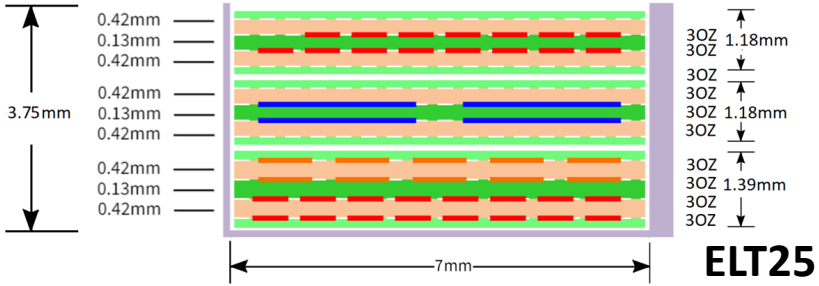
- Different power range solutions targeted for planar magnetics assessment
  - Prototype P1 – 45 W Low Range
  - Prototype P3 – 100 W High Range
- Design Tools Used
  - PI Expert Online to design the USB-PD power supply
  - PI Expert Magnetics Designer to design and optimize planar transformer (stack variations, connection pins, core selection, PCB shape adjustments)
  - Ansys to compare results with Finite Element Analysis (FEA)

Prototype Design Information Summary

P_{OUT} W	Controller (InSOP-24D)	$I_{P(RMS)}$ A	$I_{S(RMS)}$ A	KP	B_m T	C_{BULK} µF	F_{SW} kHz	L_m mH
45	InnoSwitch3-Pro	0.88	5.1	0.7	0.27	100	90	0.408
100	InnoSwitch4-Pro	0.74	8.94	1.2	0.35	-	110	0.351



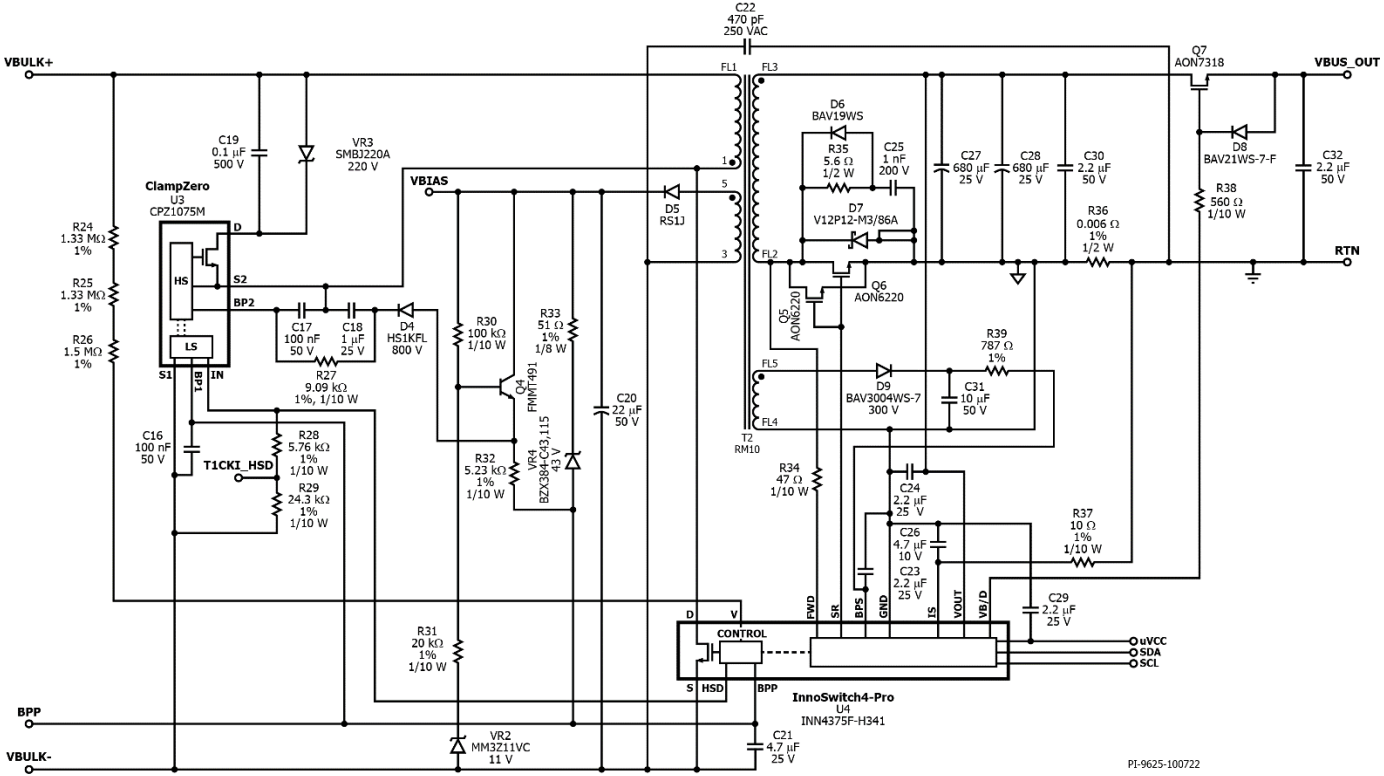
EE32



ELT25

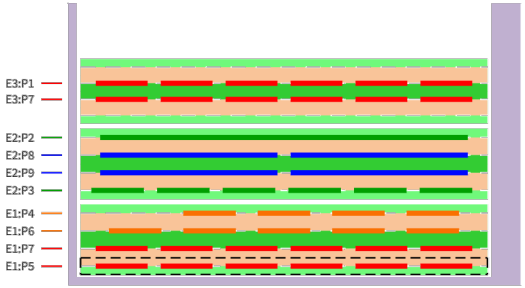
- $I_{P(RMS)}$ $I_{S(RMS)}$: primary and secondary RMS currents
- KP: current continuity factor
- C_{BULK} : Input bulk capacitor

100 W Power Conversion Stage with Active Clamp Flyback

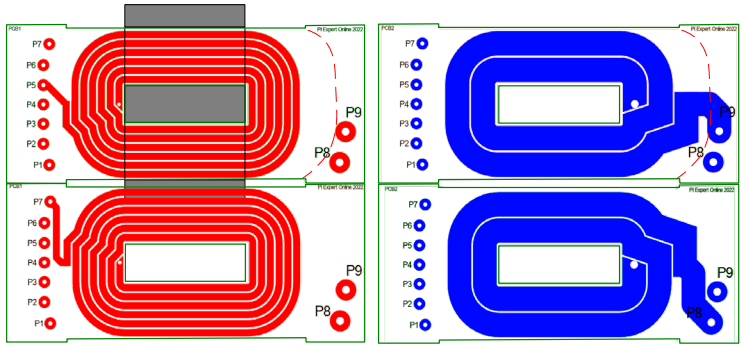


Prototype Transformer Construction PIE

- EE32/6/20/R-3C90

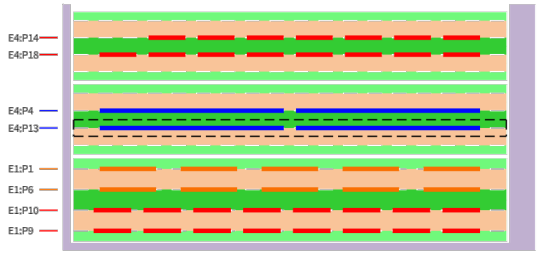


2 oz copper, same isolation thickness

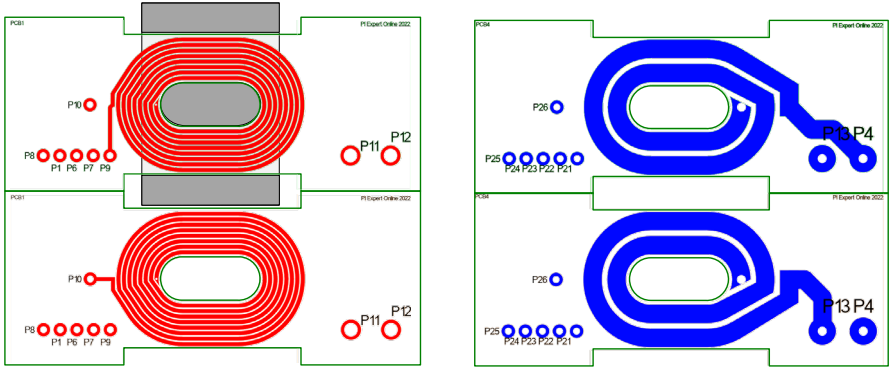


- ELT25X8.6-Z – PC95

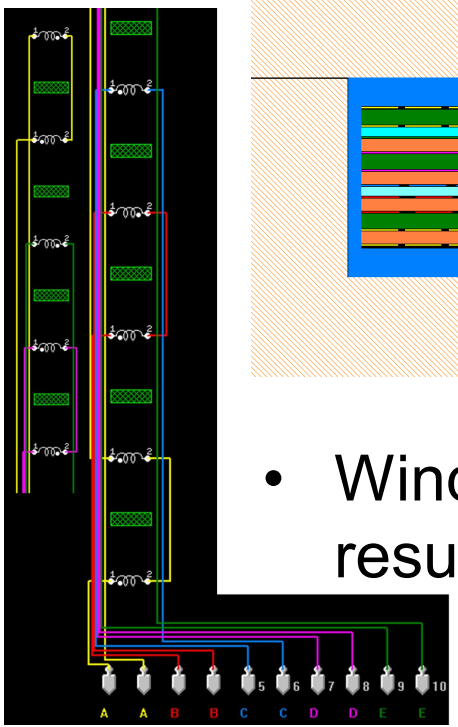
(Transformer oriented vertically on power supply PCB)

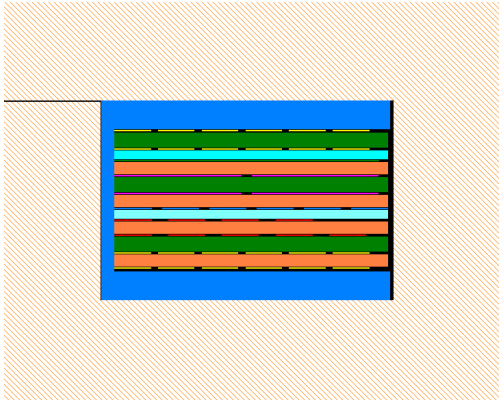


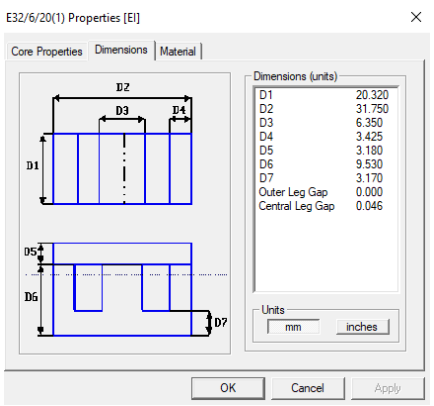
3 oz copper, same isolation thickness

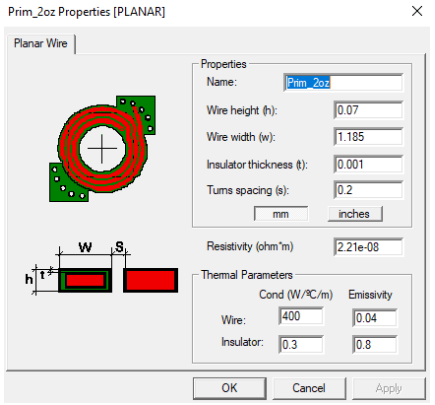


EE32/6/20 Transformer Construction - Ansys

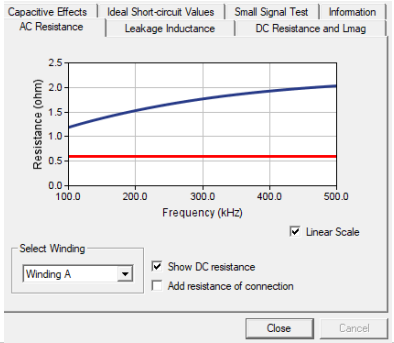








- Winding, core information and results windows



Transformer Parameter Summary

Core	BM, T	Turns Ratio	Cu. Oz	$R_{DC(P)}$, mΩ PIE - Ansys - Bench			$R_{DC(S)}$,mΩ PIE - Ansys - Bench			TW(P) um	TW(S) um	Stack FF (%)
EE32	0.27	6	2	564	597	515	30.4	29.5	26	1.19	4.1	80.8
ELT25	0.29	7.8	3	729	750	712	22.5	20.8	20	0.61	2.7	98.6

Core	$L_{lk(P)}$, uH PIE - Ansys – Bench			$C_{IntraWdg(P)}$,pF PIE - Ansys – Bench		
EE32	-	2.27	3.15	-	27.36	56.84
ELT25	-	4.67	4.9	-	21.6	32

- $R_{DC(P)}$, $R_{DC(S)}$ – primary and secondary DC winding resistance
- TW(P),TW(S) – primary and secondary track width
- Stack FF – Stack Fill Factor as percentage of total window height

Summary

- Cost optimized PCB solution (fixing layer number and limiting copper to 3 oz max.)
  - Price and turnaround time reduced
  - Efficiency however impacted by DC loss
  - Size of magnetics pushed by reduced copper thickness
  - AC loss contribution relatively low
    - Gap fringing-effect losses not included in analysis
    - Planar structure allows fringing area to be constructed ‘free of copper’
  - Limits secondary turns options in safety compliant applications
  - Interleaving opportunities significantly limited in safety compliant applications
  - Temperature conduction reduced (heat distribution)
  - EMI reduction through compensation windings and shields
    - Affected by limited availability of copper layers

- Employing design and simulation tools in the early stages of development helps find design flaws and potential issues