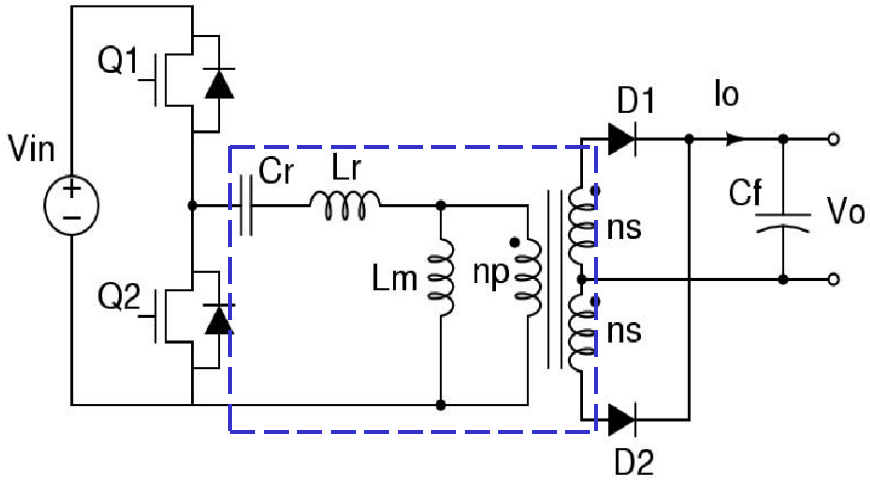
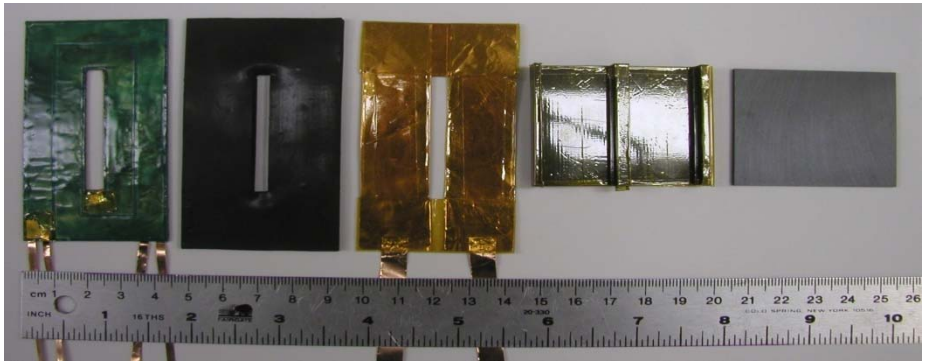
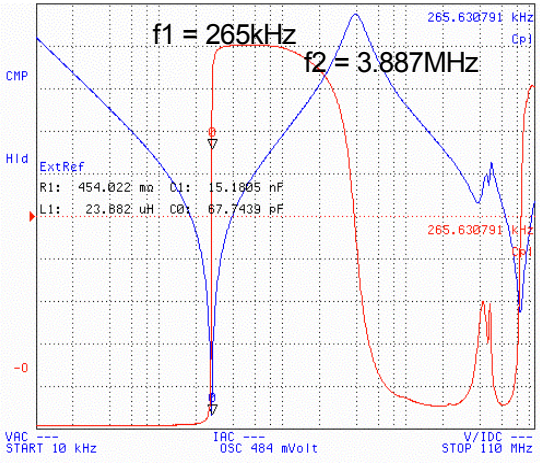
Integrated L-L-C-T Design for a 1MHz 1kW LLC Resonant Converter



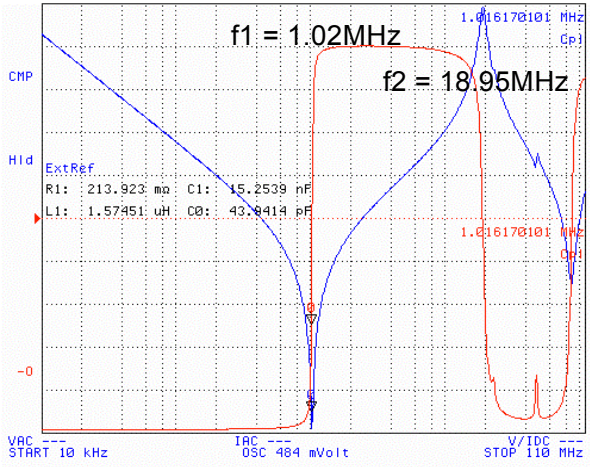
Schematic of half-bridge LLC resonant converter



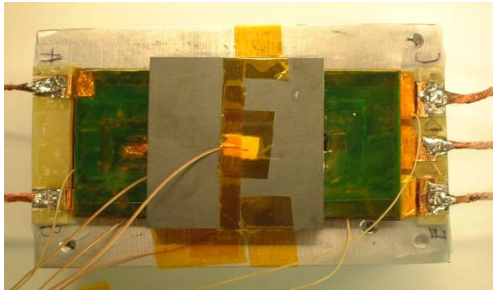
Primary winding | Leakage layer | Secondary winding | Magnetic core



Impedance and phase graph with CE open circuit



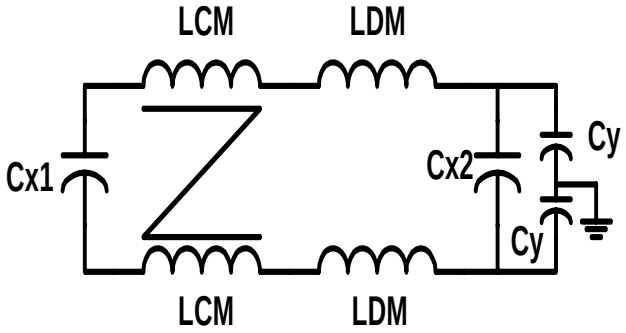
Impedance and phase graph with CE short circuit



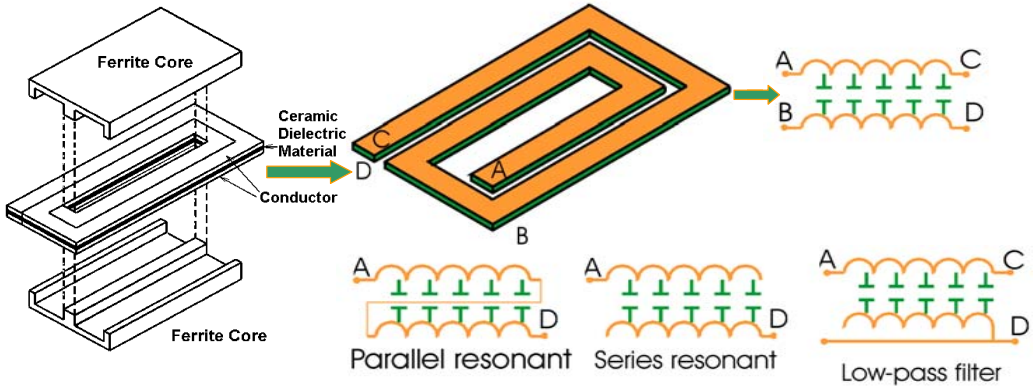
Integrated component

Planar Electromagnetic Integration Technologies for Integrated EMI Filters

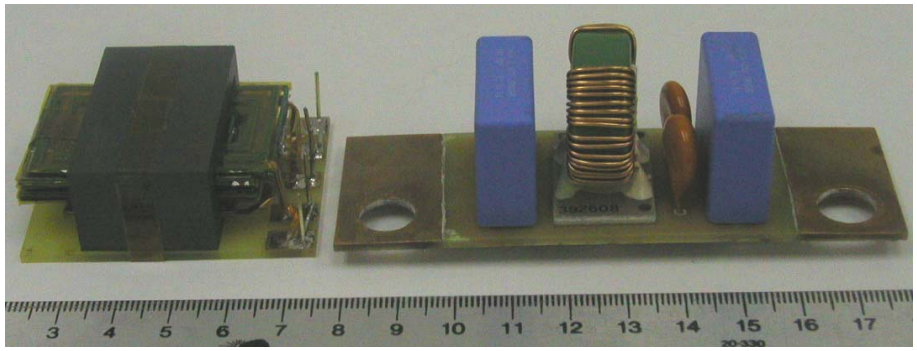
Schematic of EMI filter



Planar Electromagnetic Integration Technology – Integrated L-C

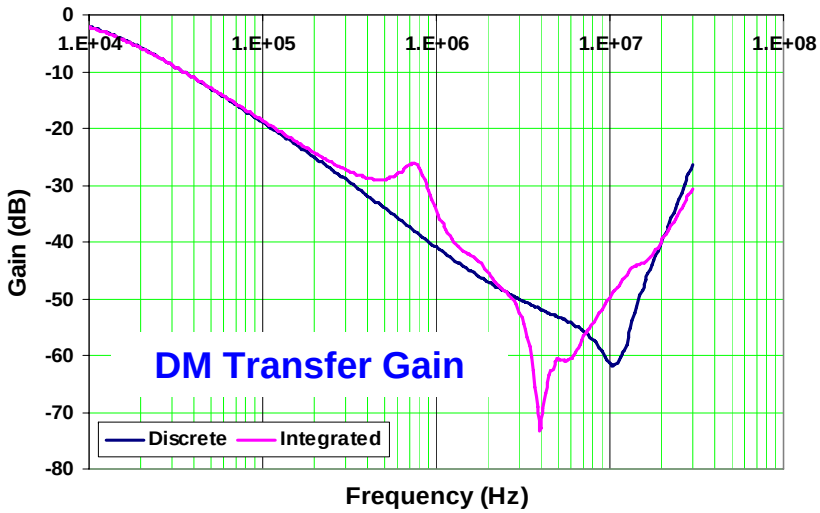


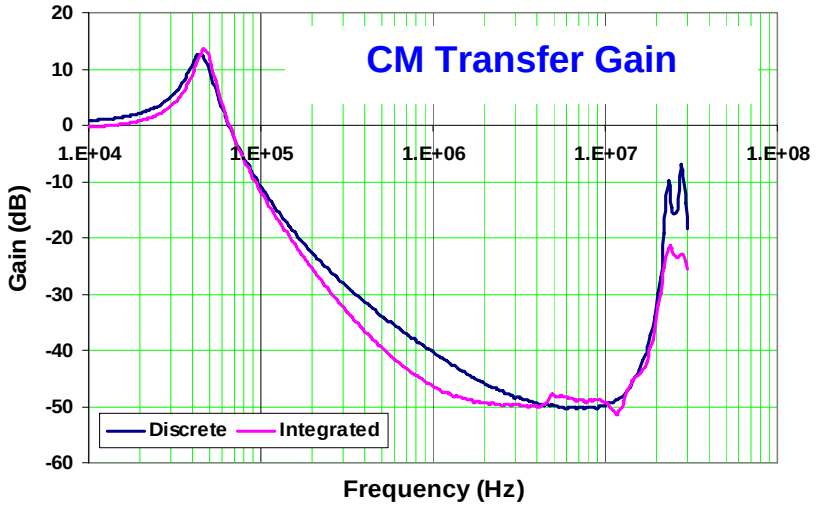
Comparison with Discrete EMI filter



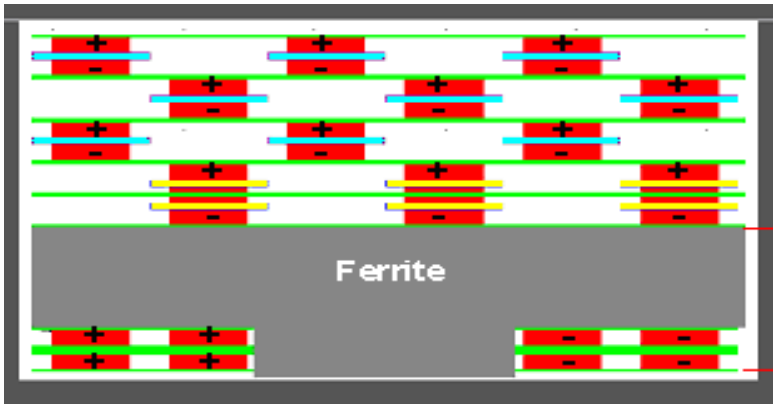
Parameters	Discrete	Integrated
L_{CM} (mH)	3.3	3.0
L_{DM} (μH)	17	20
C_{CM} (nF)	3.3	3.2
C_{DM} (μF)	0.56	0.6
EPC (pF)	12	6

Planar Electromagnetic Integration Technologies for Integrated EMI Filters





Cross-section View of Half Winding Window

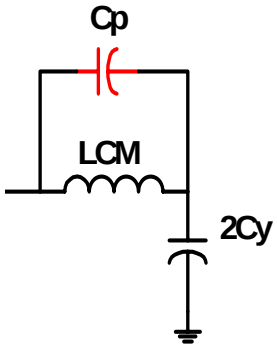


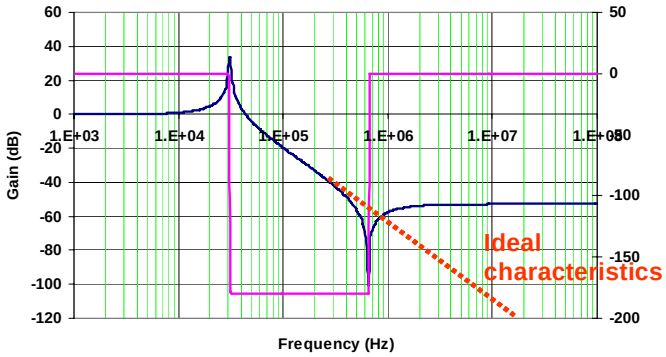
– Conductor
– Y5V ceramic
– N1250 ceramic
– Kapton
– Ferrite

Embedded Conductive Layers to Improve Characteristics of Integrated EMI Filters

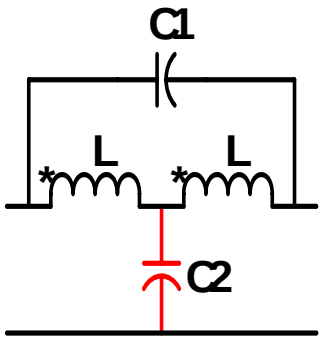
Structural Winding Capacitance Cancellation

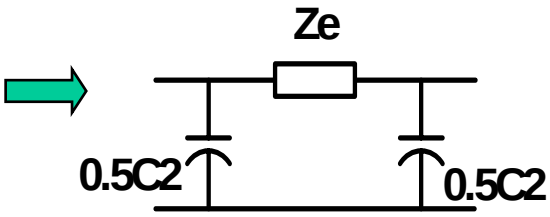
Problem: structural winding capacitance





Canceling EPC



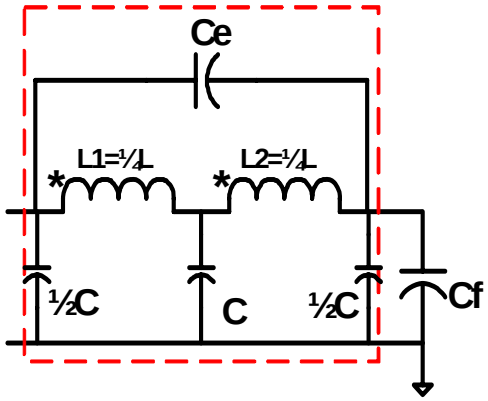


$$Z_e = \frac{4j\omega L}{1+\omega^2 LC_2 - \omega^2 4LC_1}$$

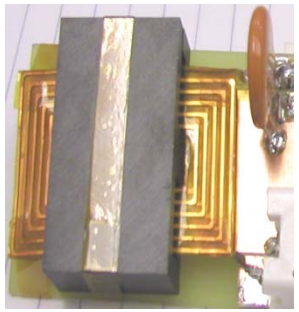
When $C_2 = 4C_1$, $Ze = 4j\omega L$

Implementation: Embedded Conductive Layers

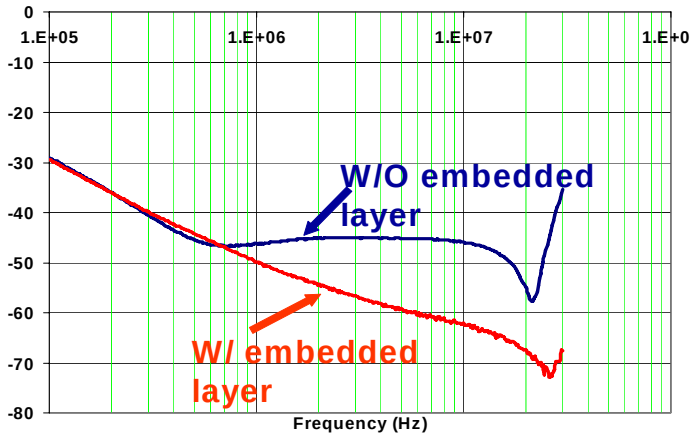
Equivalent Circuit



Prototype

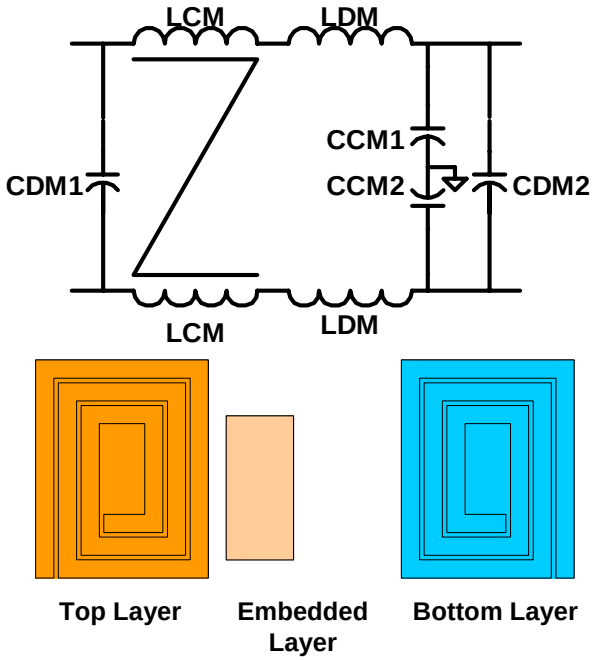


Results

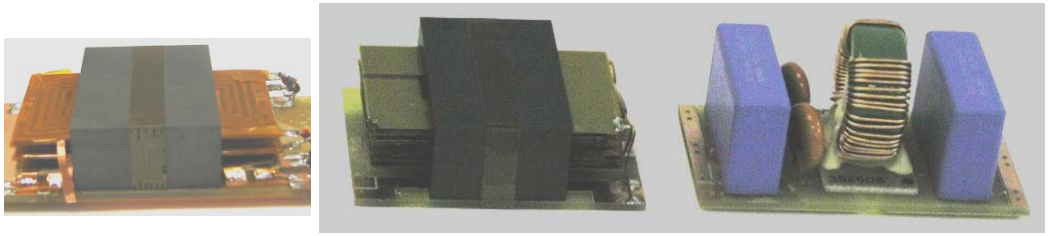


Embedded Conductive Layers to Improve Characteristics of Integrated EMI Filters

MODULE 23



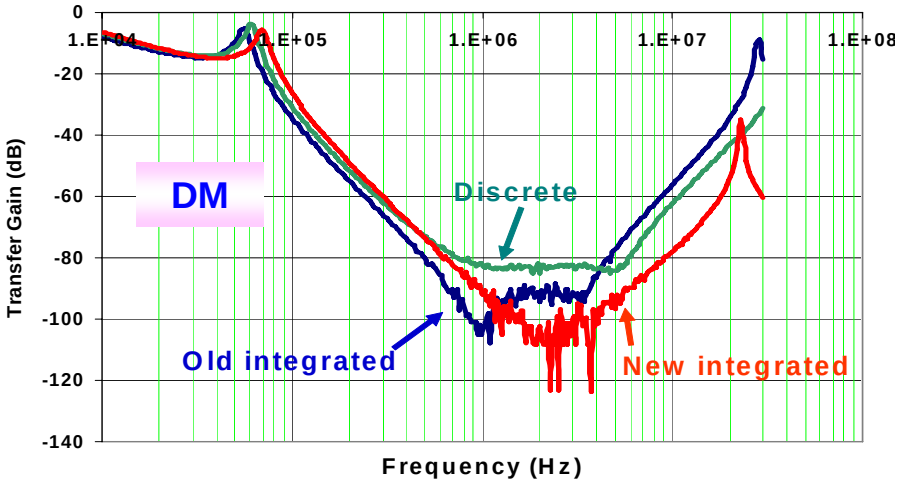
Prototypes

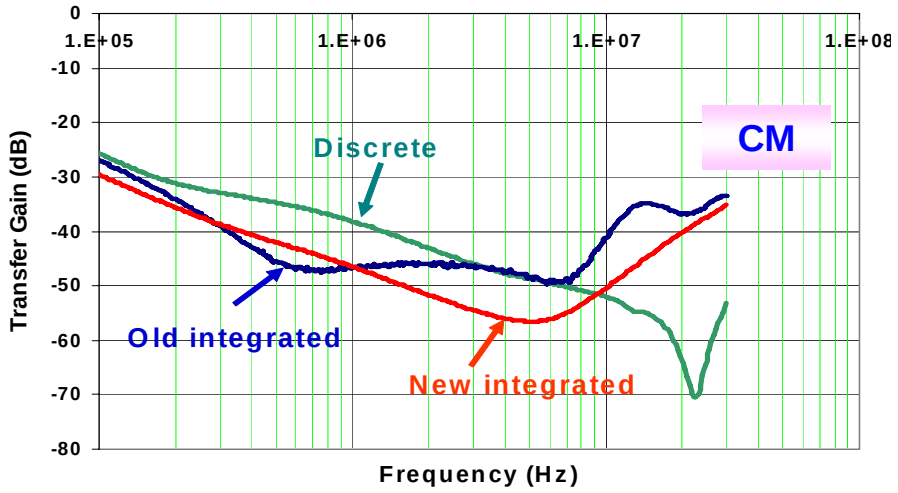


Improved Old Discrete

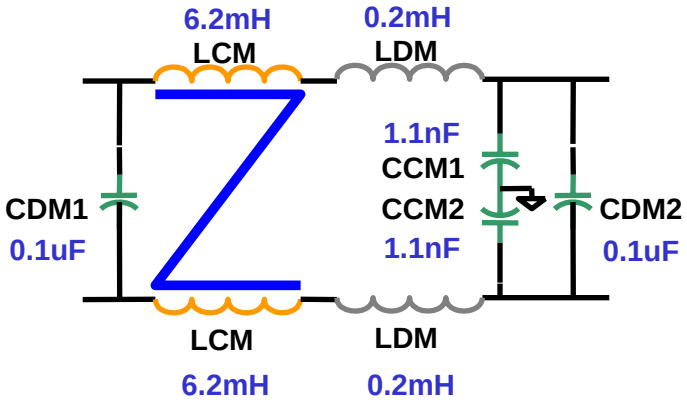
Size Comparison

	Improved Integrated	Old Integrated	Discrete
Profile (cm)	1.2	1.6	2.6
Volume (cm^3)	20	27.4	39.8

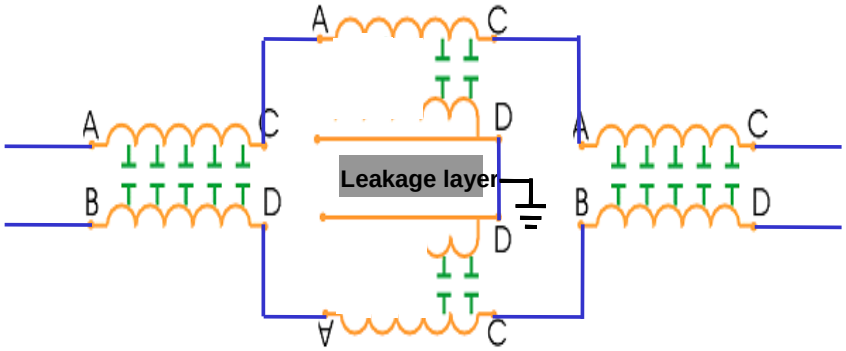




Integrated EMI filter for Low Wattage HID Ballast

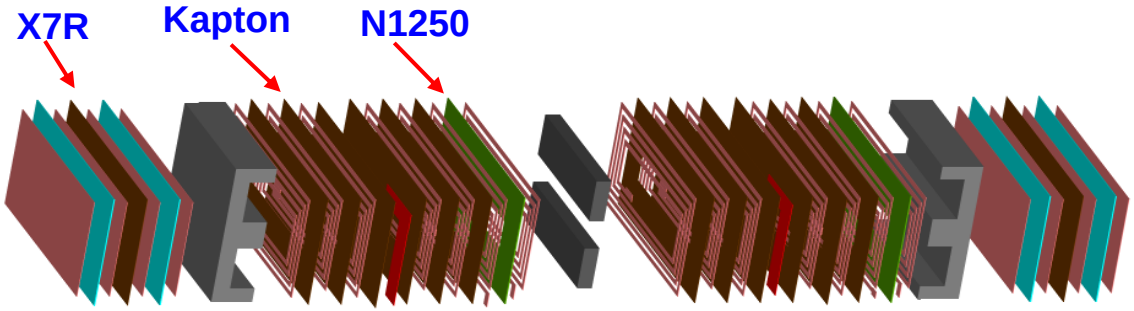


Schematic of EMI Filter



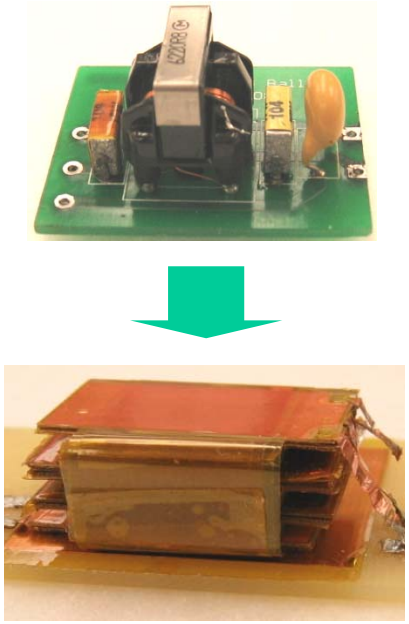
Integrated EMI filter composition

Physical Structure of the integrated EMI filter



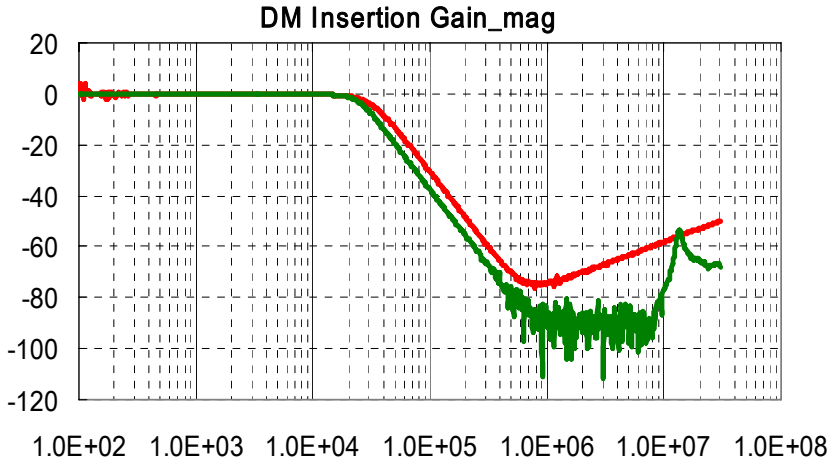
C_{DM} L_{CM} +C_{CM} Leakage layer L_{CM} +C_{CM} C_{DM}

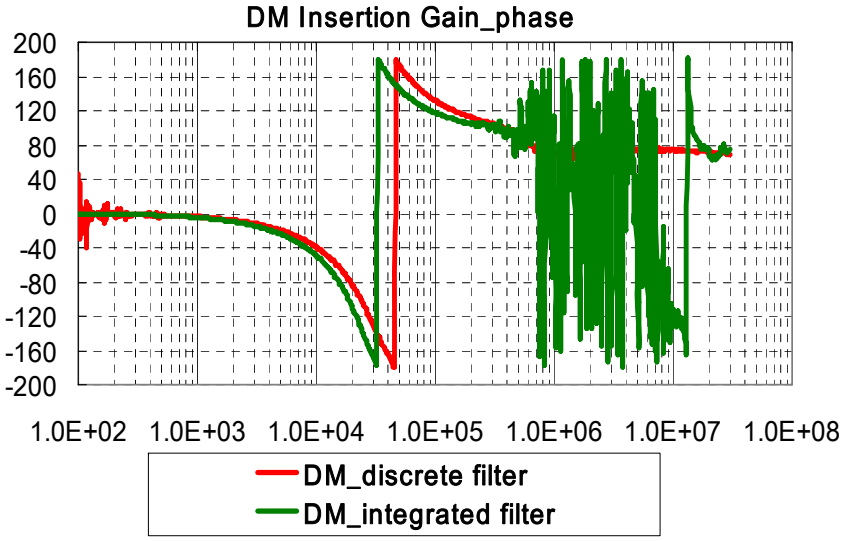
Prototypes and Results



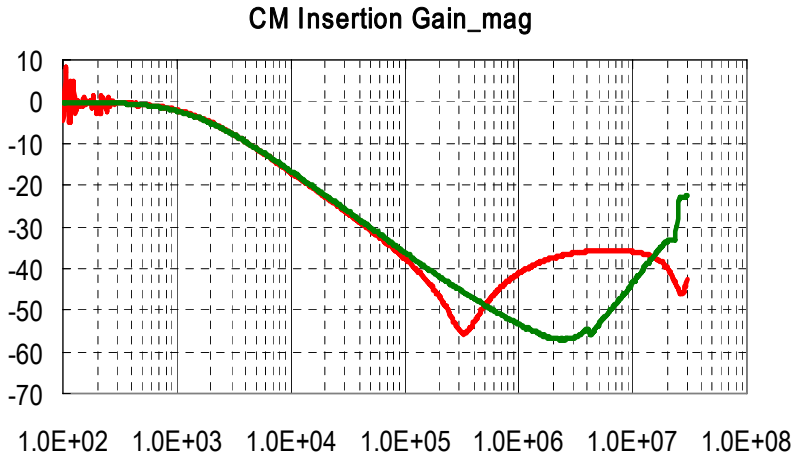
Integrated EMI filter for Low Wattage HID Ballast

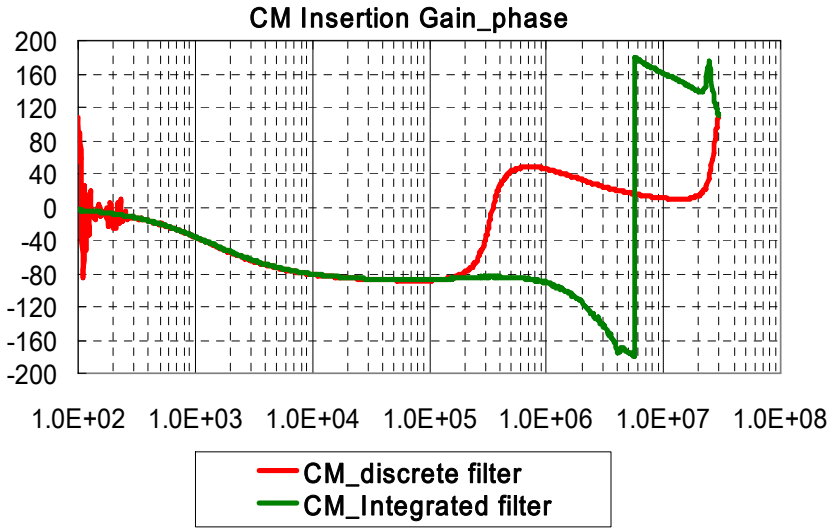
DM Insertion Gain



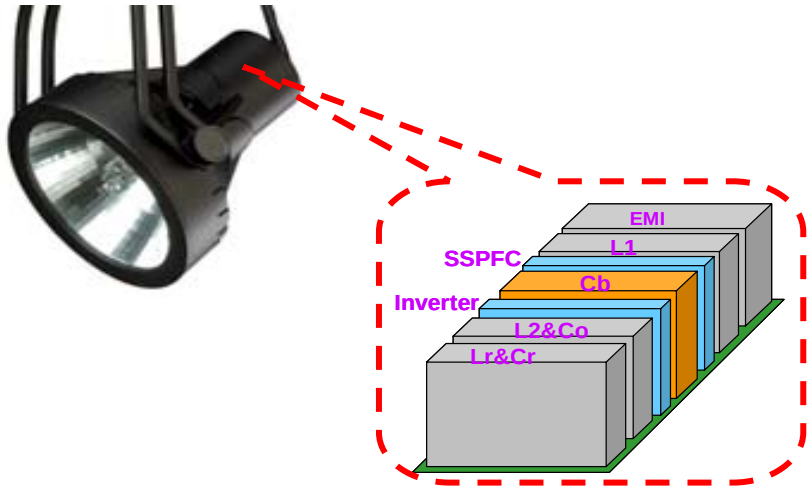


CM Insertion Gain



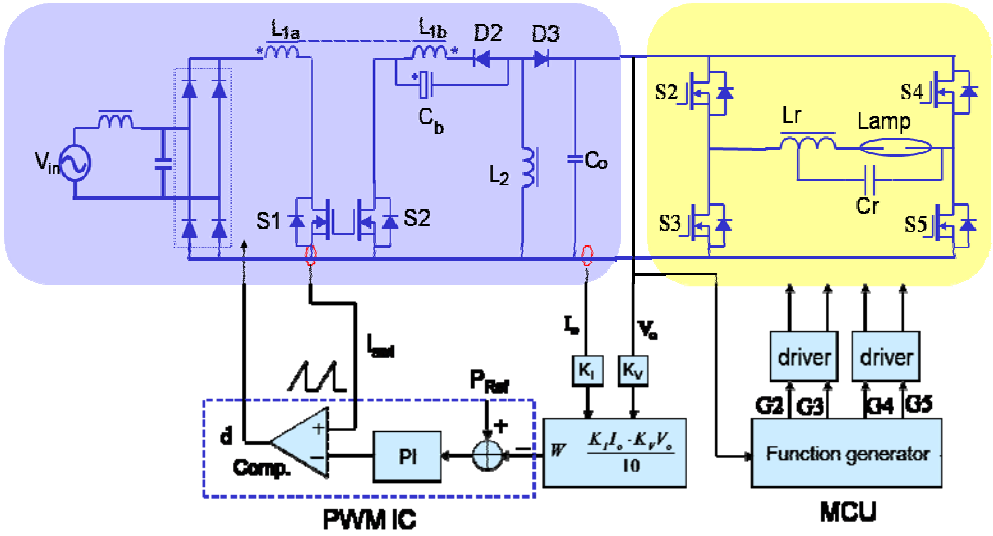


A High-Power-Density Integrated Electronic ballast for Low Wattage HID lamps



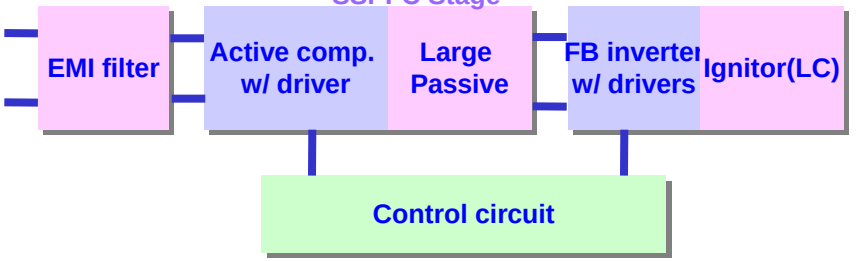
Single stage PFC stage

Inverter/Ignitor stage



System structure of the HID ballast

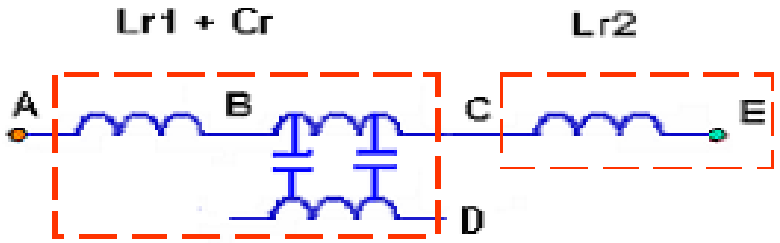
SSPFC Stage



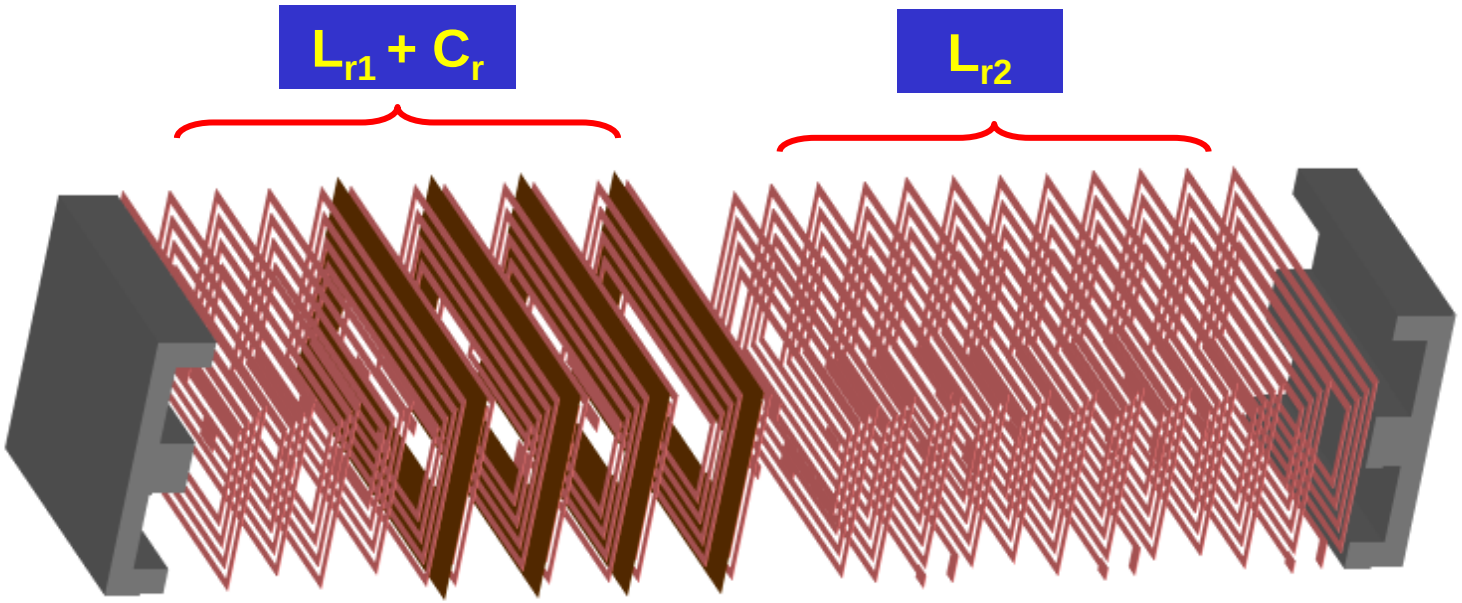
Circuit partitioning for integration

A High-Power-Density Integrated Electronic ballast for Low Wattage HID lamps

Passive Integrated Components



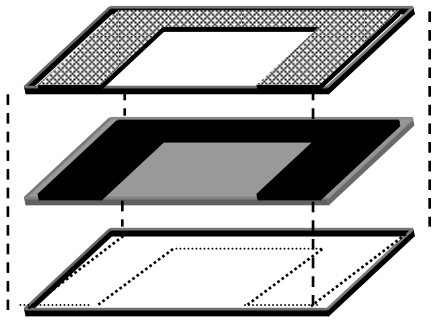
- Integrated ignitor

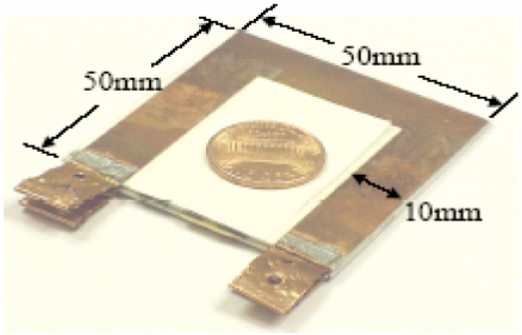


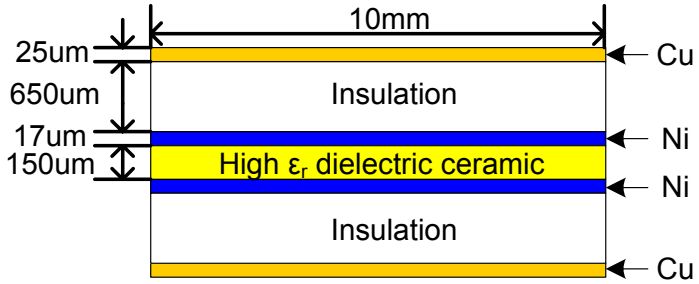
Implemented by Pyralux

Implemented by PCB

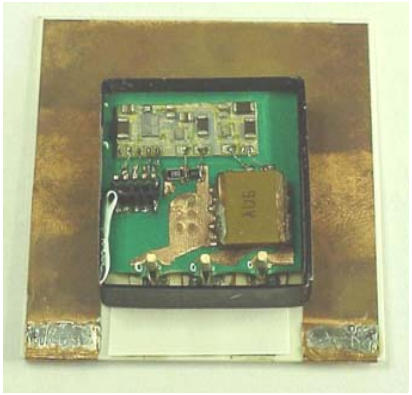
Integrated RF-EMI transmission line filters for IPEMS



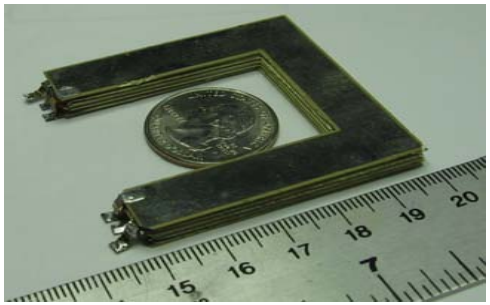


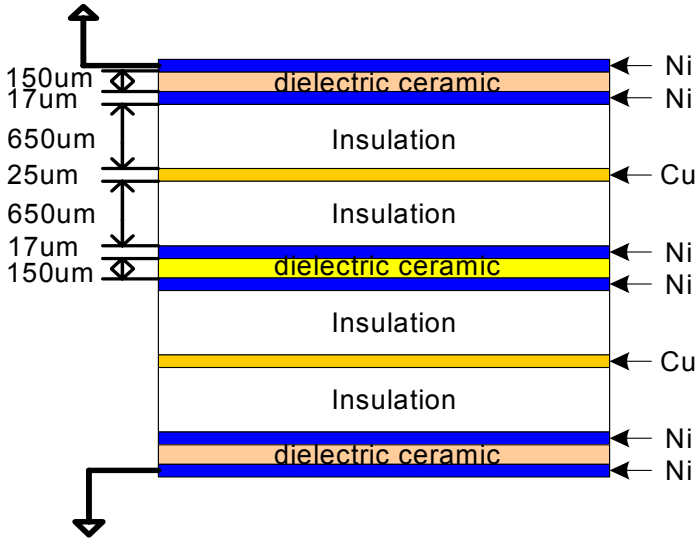


Prototype of DM TL EMI filter



Filter shown with IPEM module

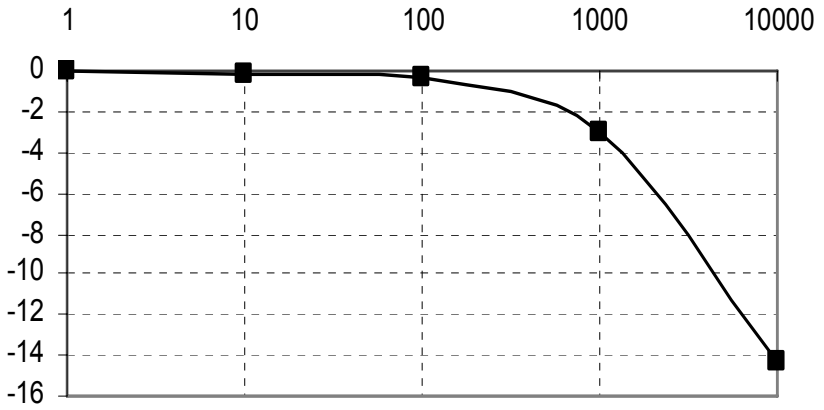




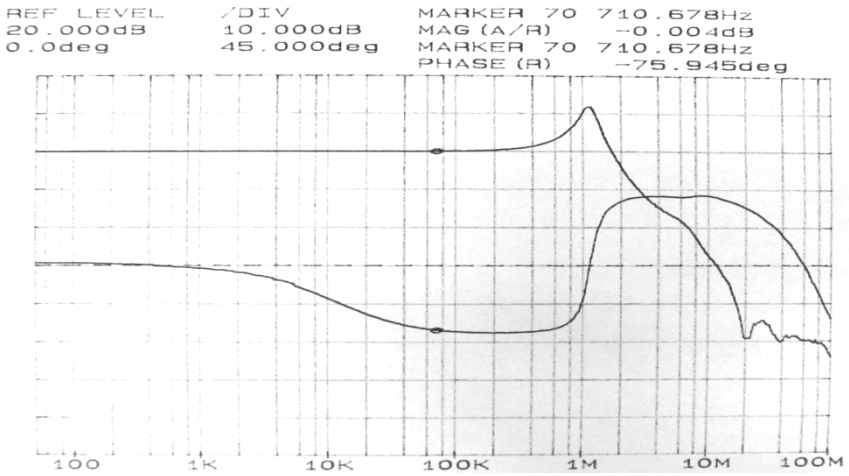
Prototype of CM & DM TL EMI filter

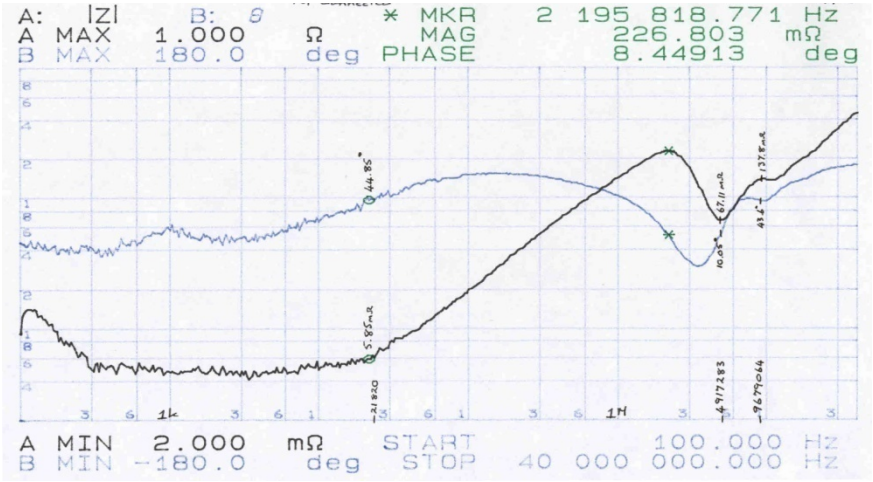
Integrated RF-EMI transmission line filters for IPEMS

Simulated Results

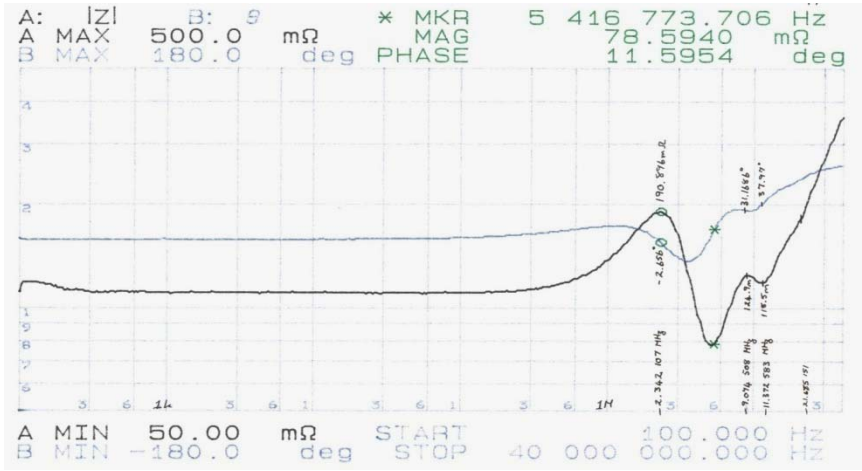


Measured Results



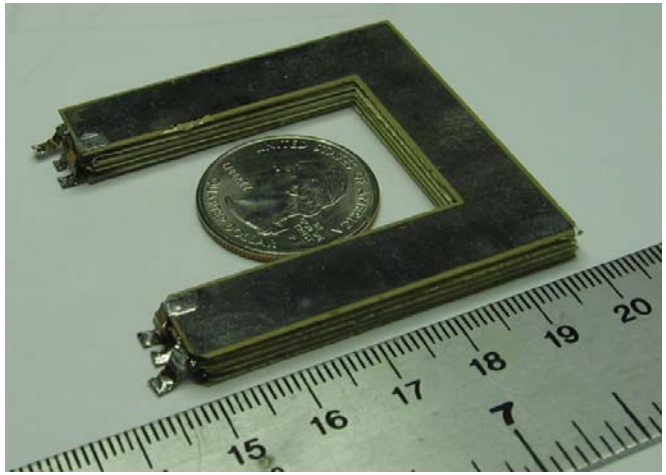


Short Circuit Impedance – Filter structure

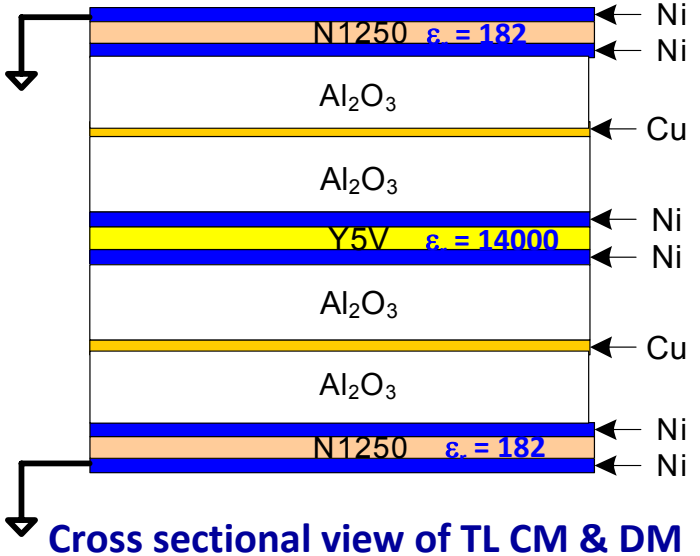


Short Circuit Impedance – Inside transmission line

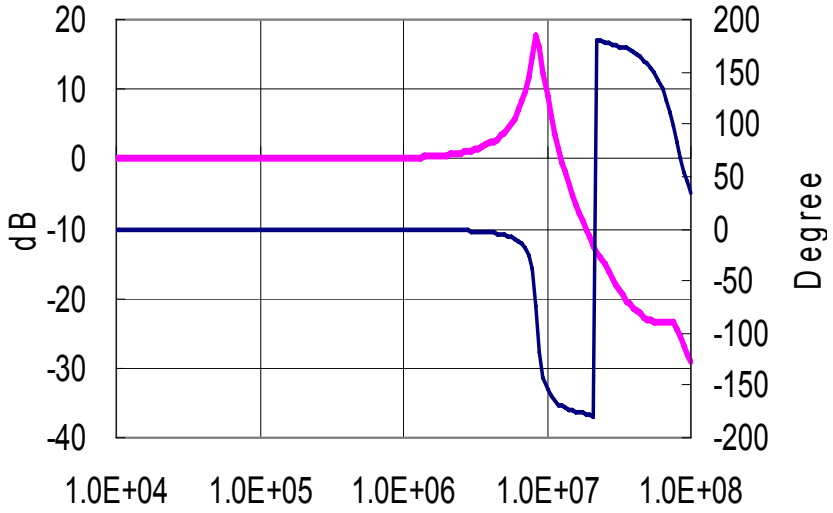
Absorptive Frequency-Selective Transmission Line EMI Filter



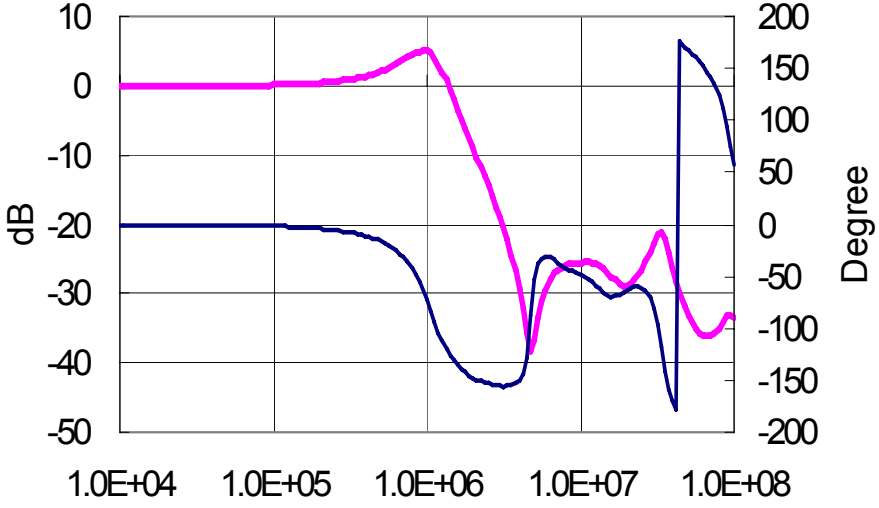
TL CM & DM EMI Filter



Cross sectional view of TL CM & DM EMI Filter



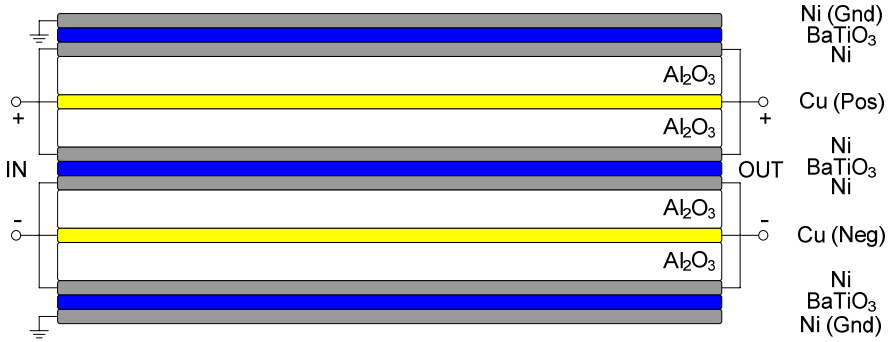
Measured CM Transfer Function

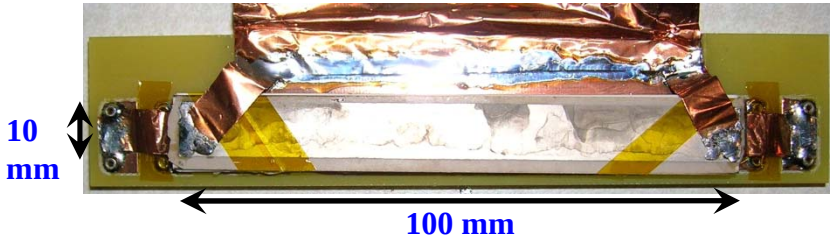


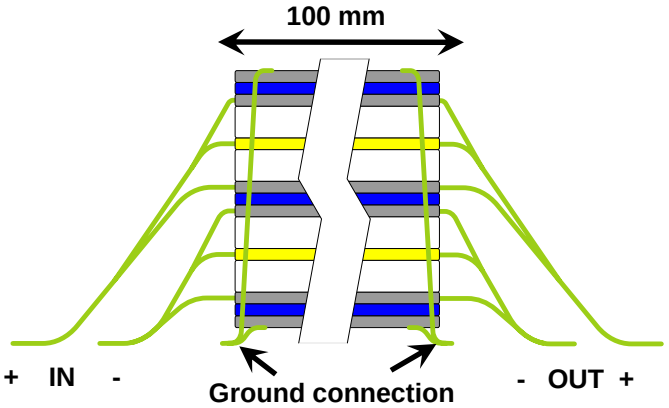
Measured DM Transfer Function

Enhanced Design of an Integrated Transmission-Line Bus Filter

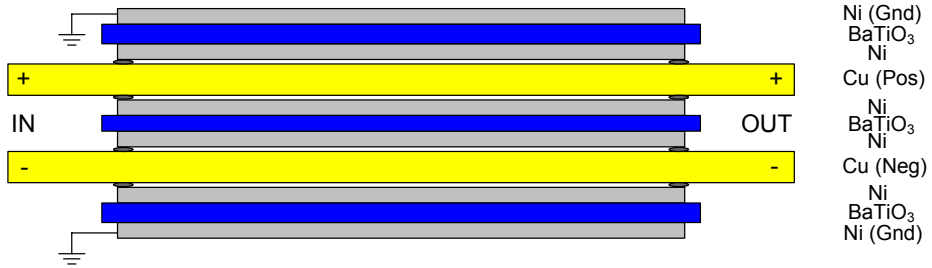
Original Design

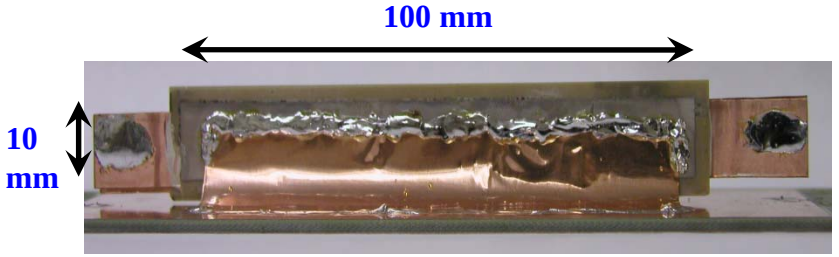


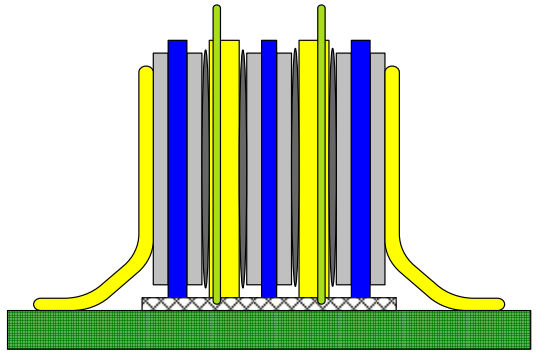




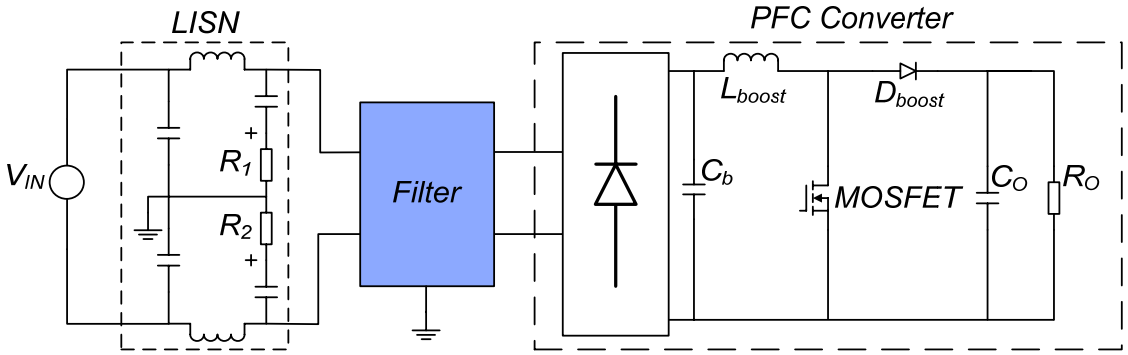
Modified Design

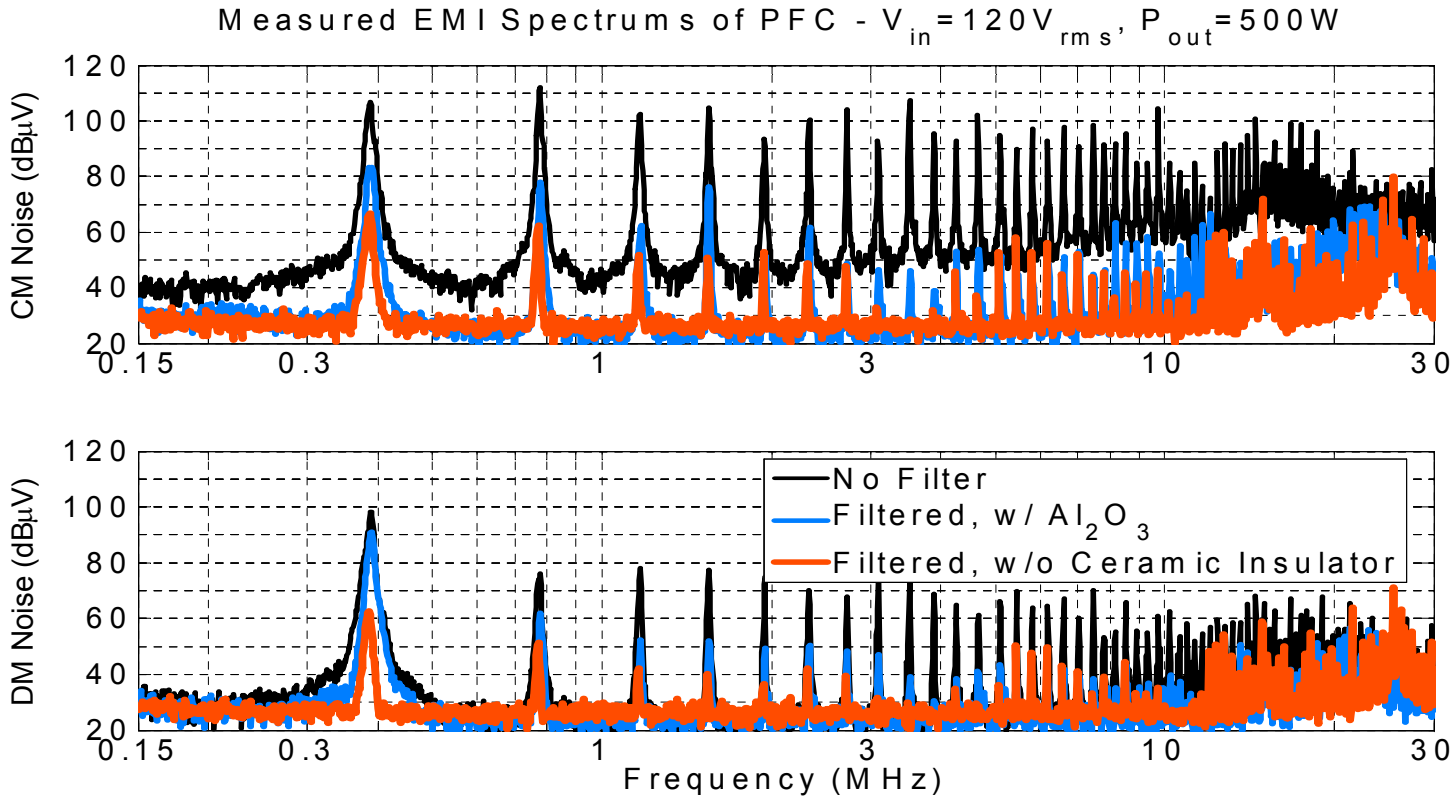




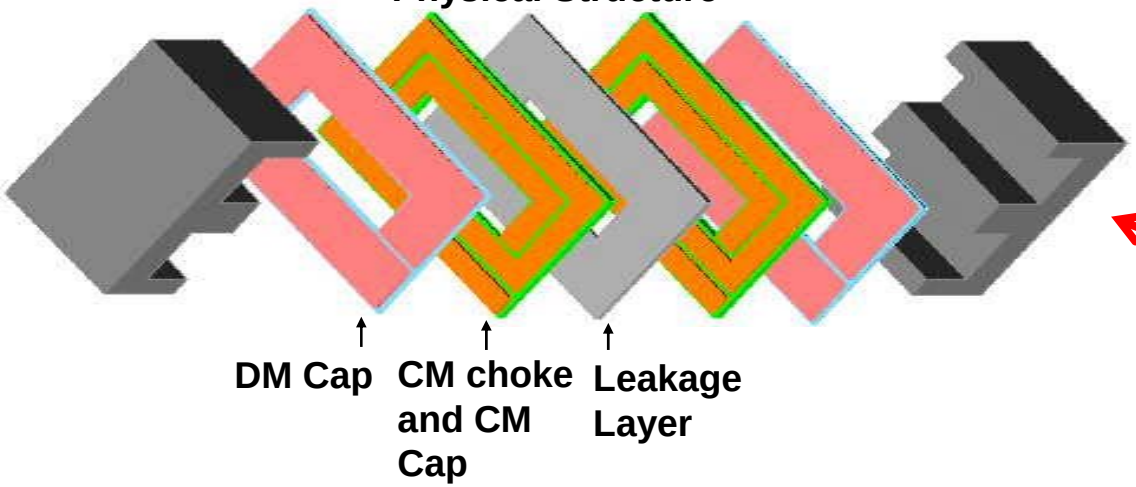


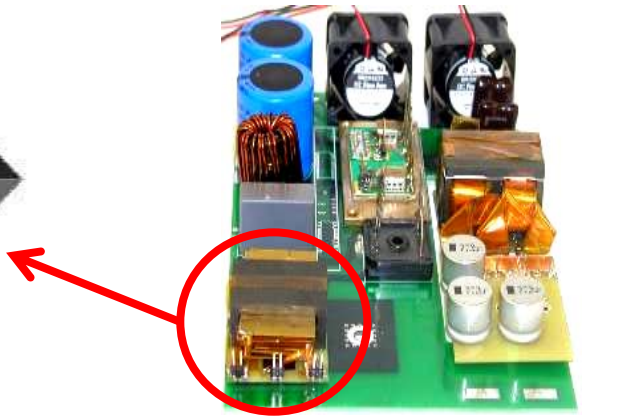
Enhanced Design of an Integrated Transmission-Line Bus Filter





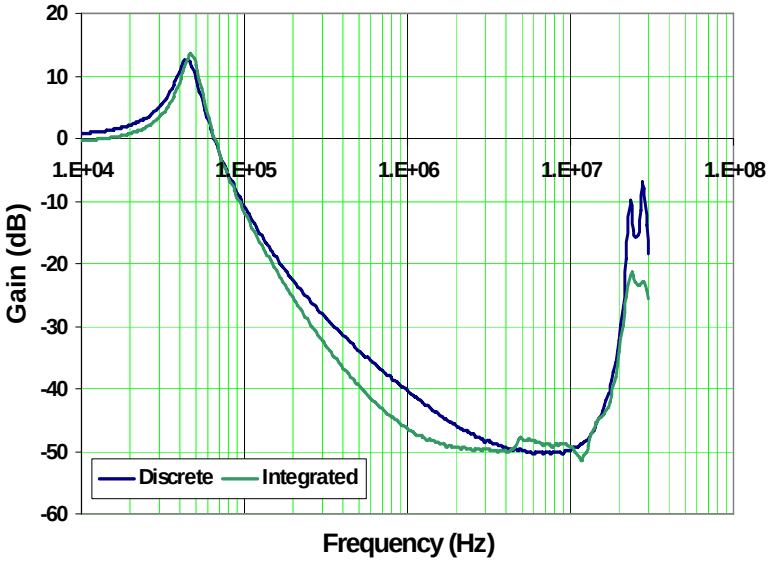
Integrated CM&DM EMI Filter for 1MHz Interleaved PFC



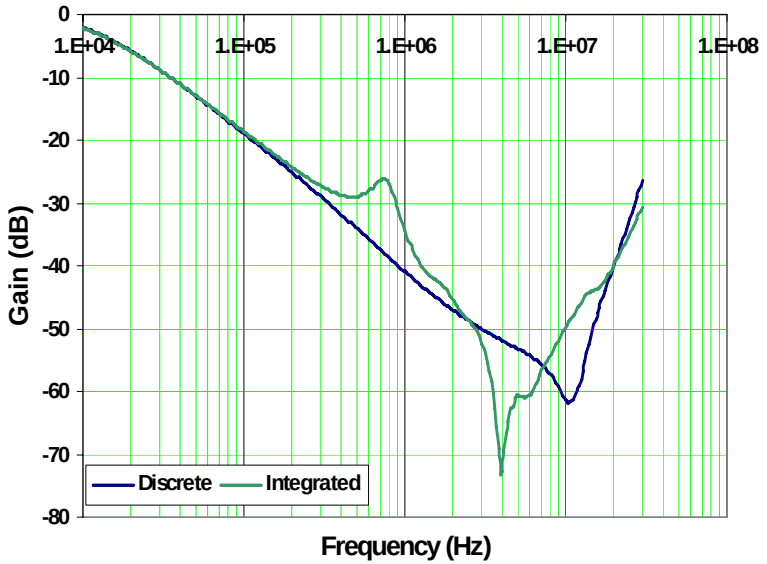


3Phase PFC **1 MHz LLC**

CM Transfer Gain

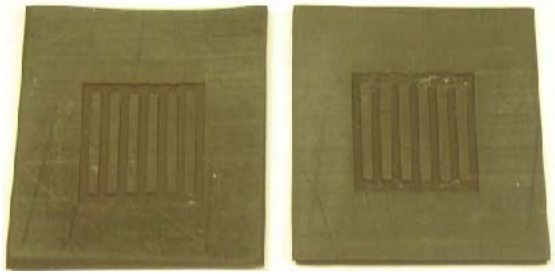


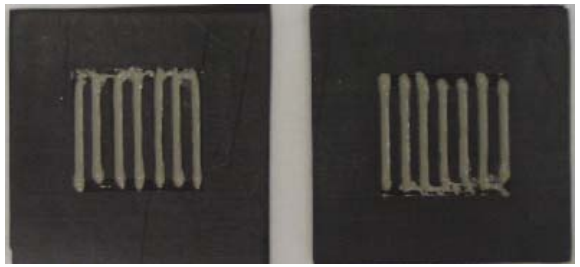
DM Transfer Gain

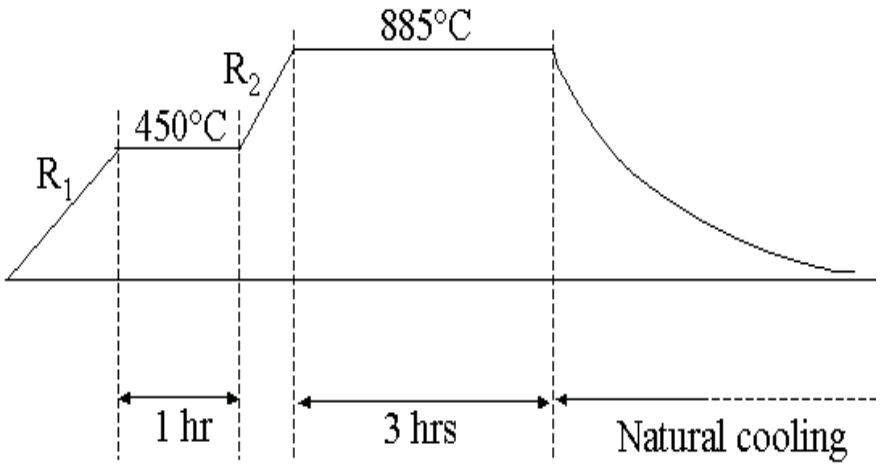


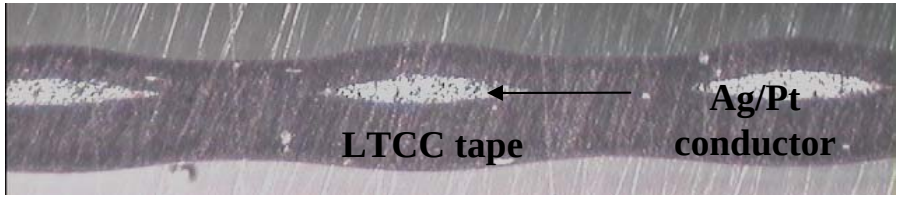
Processing and Design of Lateral Embedded Chip Inductor

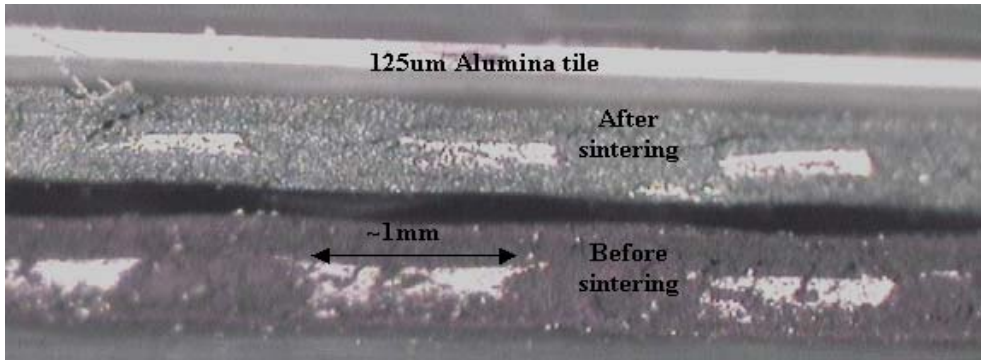
Fabrication procedure







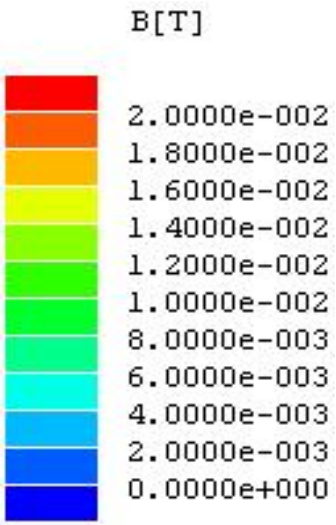


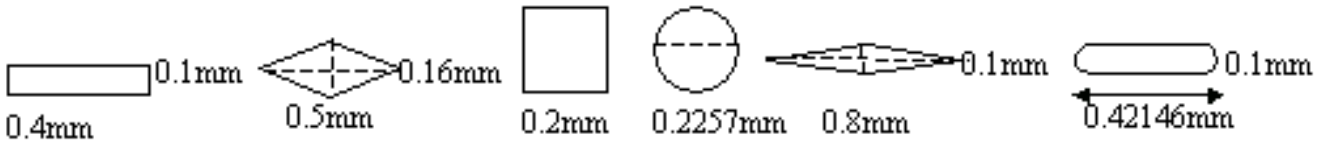


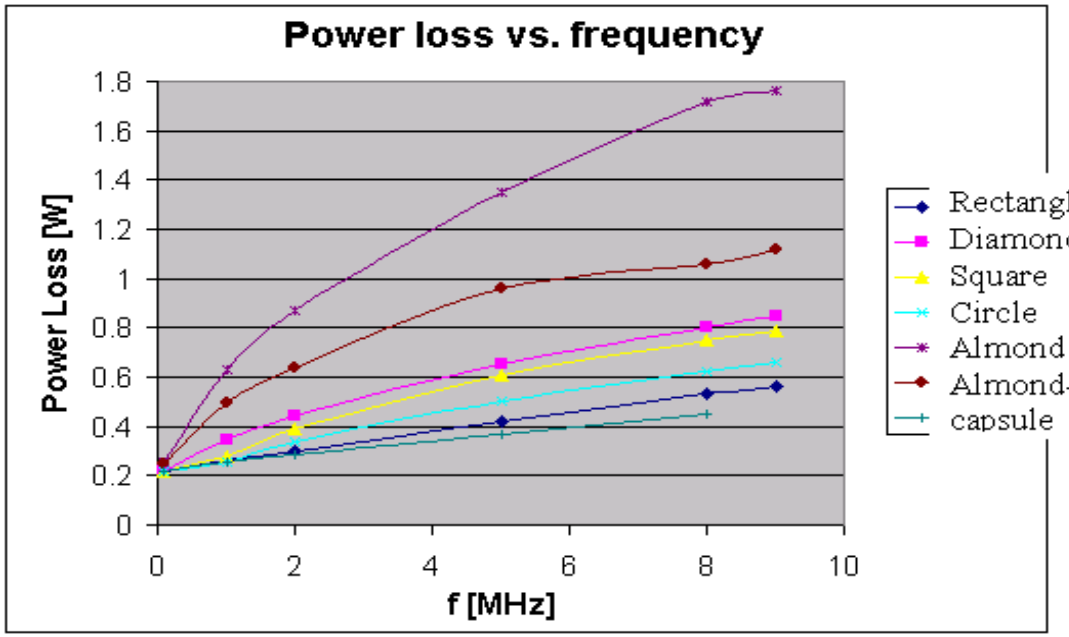
Processing and Design of Lateral Embedded Chip Inductor

Single conductor (L=22.7nH/10mm)

7 parallel conductors (L=25.7nH/10mm)







Design and fabrication of LTCC inductor

MODULE
31a


(A) Bottom layer (6 sheets of ferrite tape)

+


(B) Middle layer (8 sheets of ferrite tape

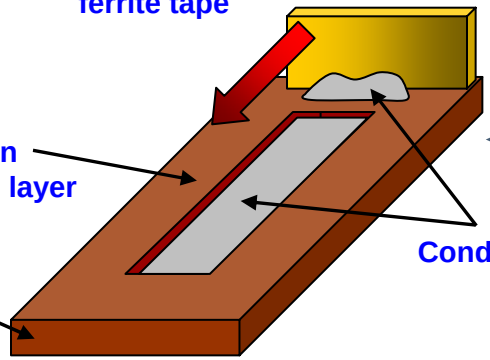

Lab press


(C) Laminate Bottom and Middle layers


(D) Dispense conductor paste into slot


(E) Dry conductor paste at 80ºC

Repeat (D) and (E) for 4 to 5 times till dried conductor is leveled with surrounding LTCC laminated green tape




(E) Conductor filled slot

+


(F) Top layer (6 sheets of ferrite tape)

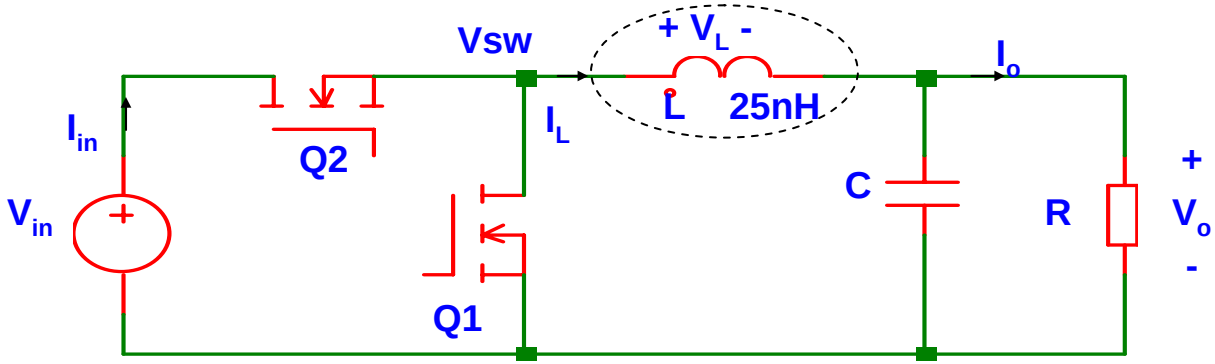

(G) Laminate (E) and (F), fill exposed area with conductor paste, dry at 80 ºC. Laser cut to desired size

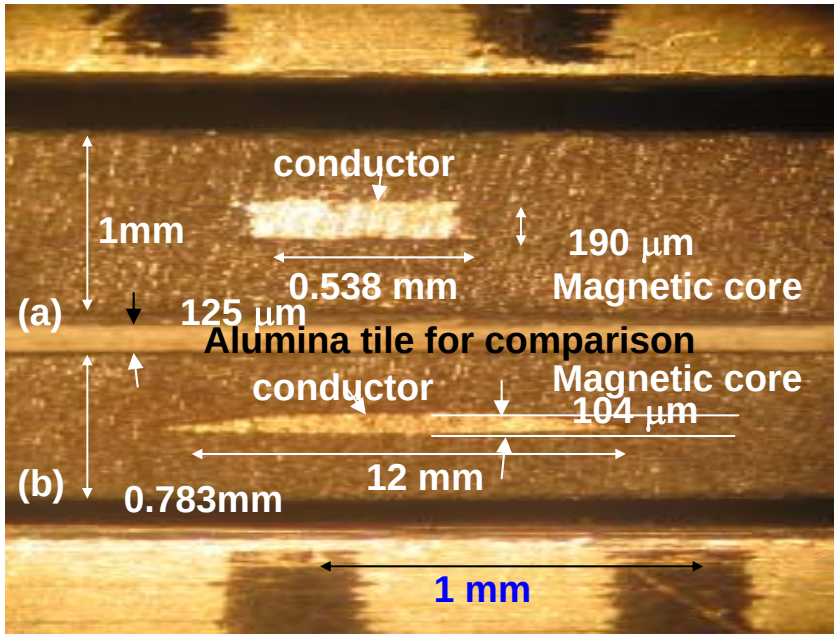

Sintering oven

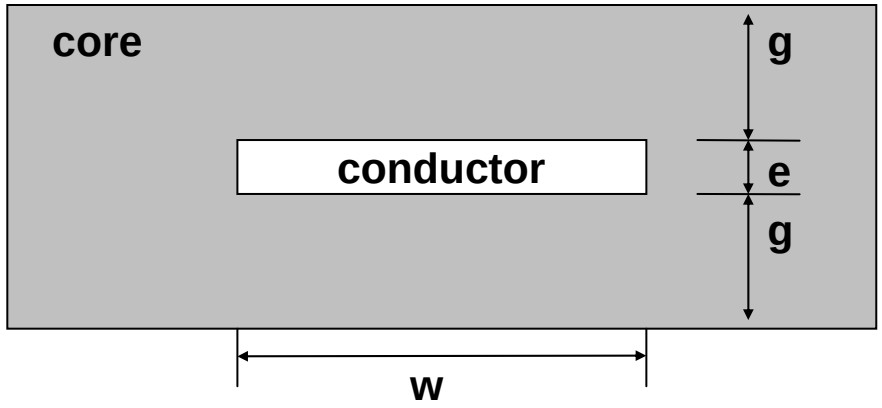

(H) Sinter

LTCC Technology for Power Electronic Integration

Test Conditions:
Vin = 5 V
Vo = 1.1 V
Fs = 4 MHz
Io = 12.5 A

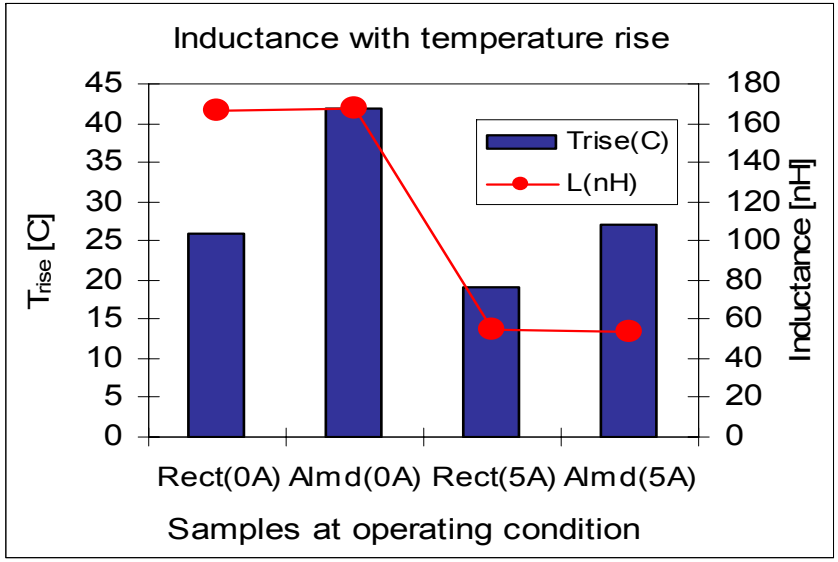


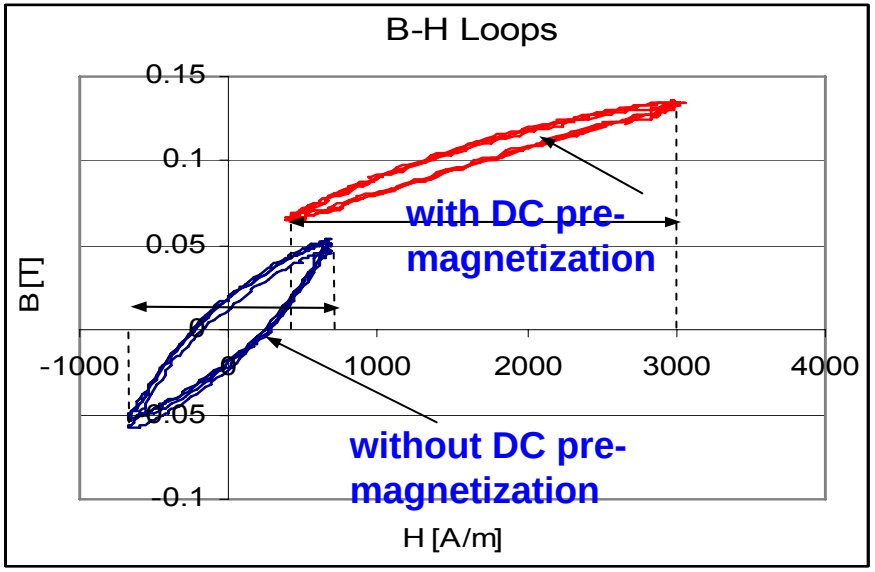


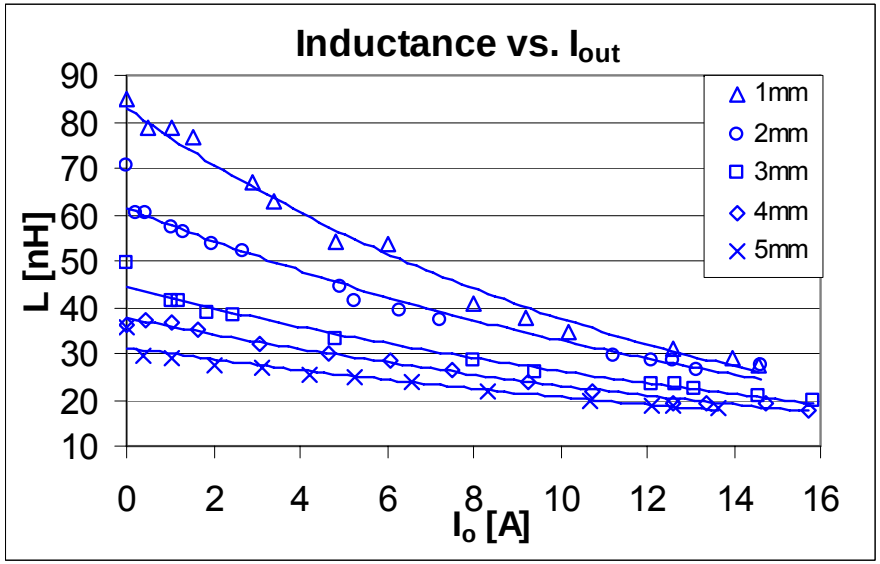


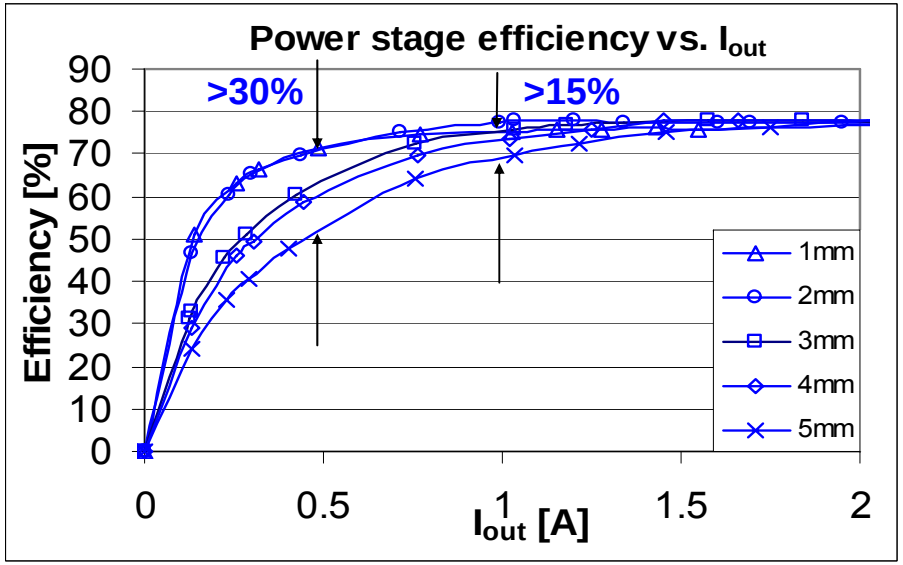
Cross-sectional view of inductor with (a) rectangular and (b) almond cross-sectional shape

LTCC Technology for Power Electronic Integration

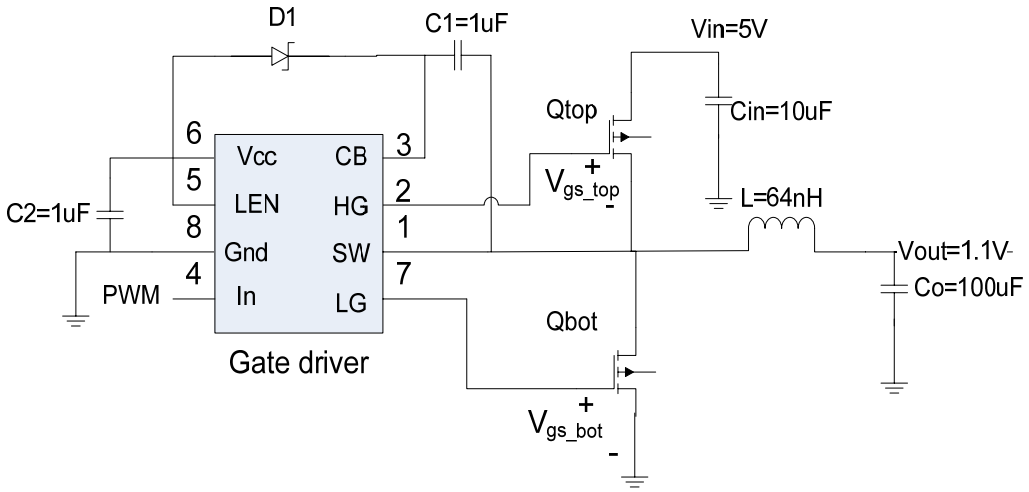


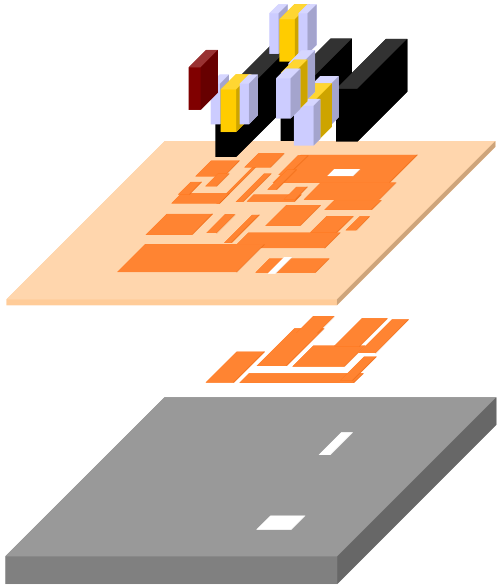


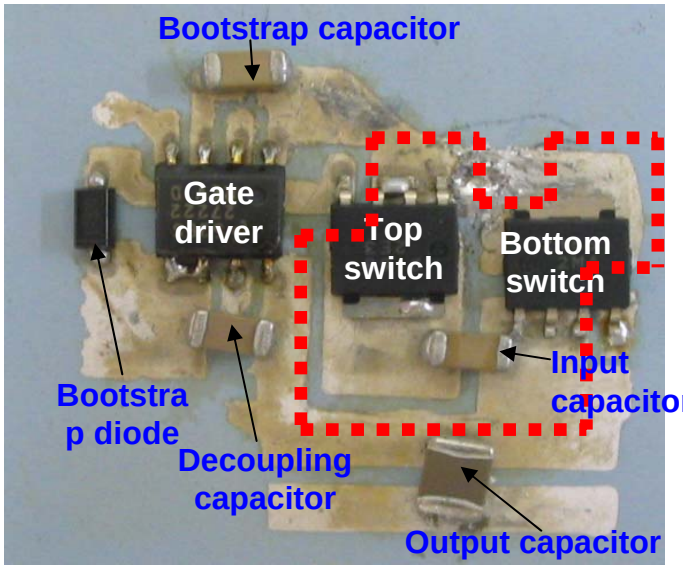


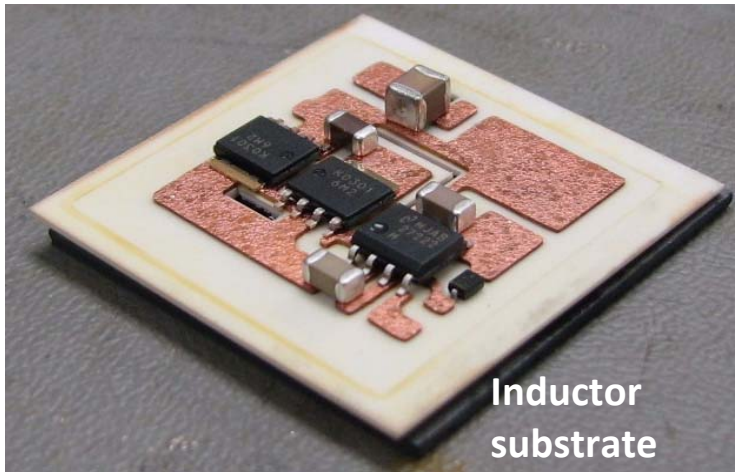


Shielded LTCC Inductor as Substrate for Power Converter

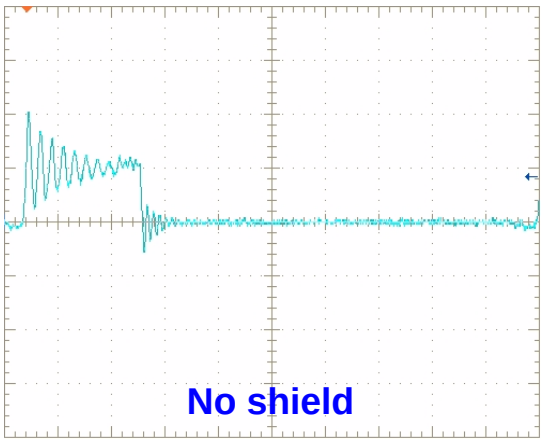


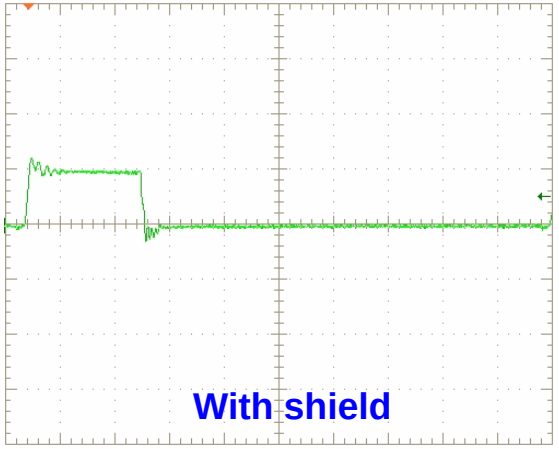




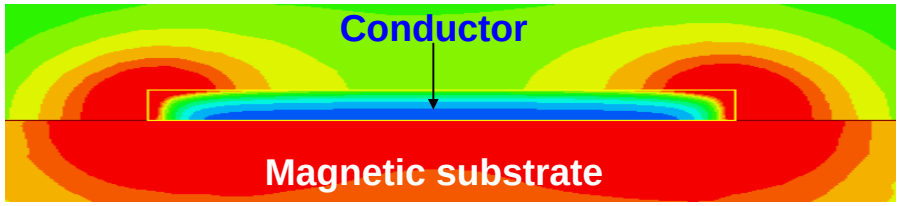


Shielded LTCC Inductor as Substrate for Power Converter

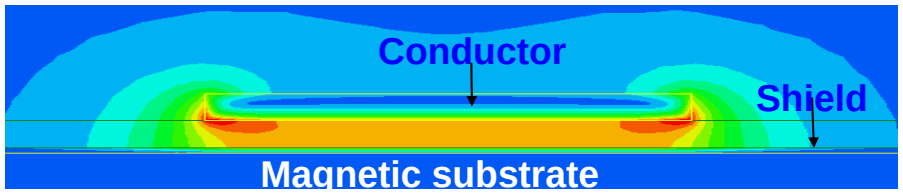




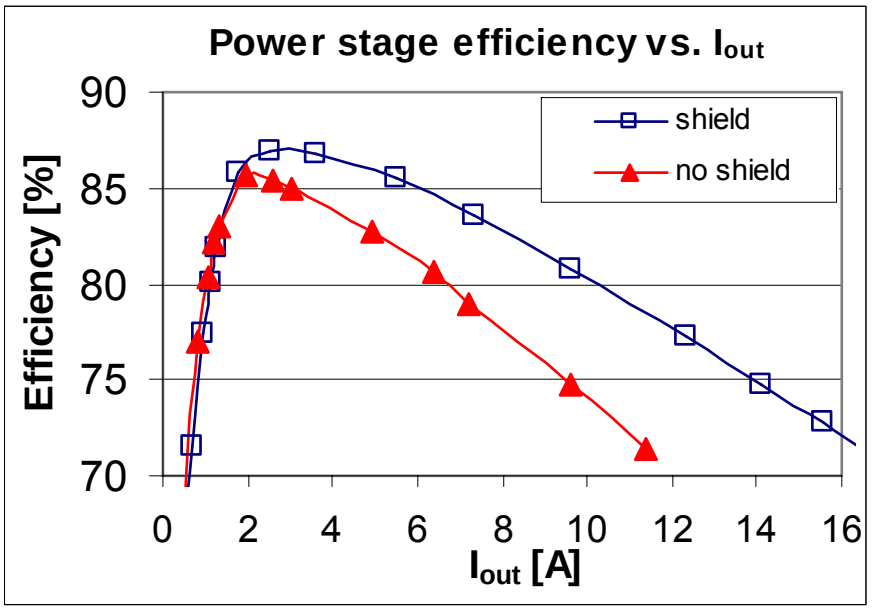
Voltage waveform at switching point of Buck converter



Conductor on Magnetic Substrate

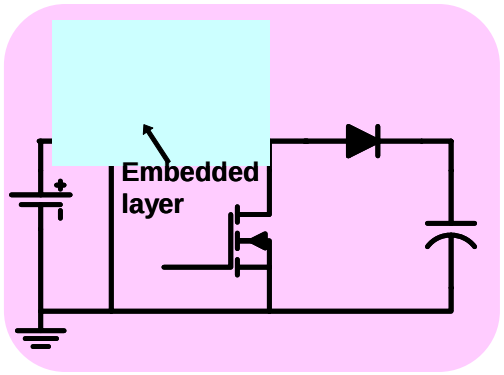


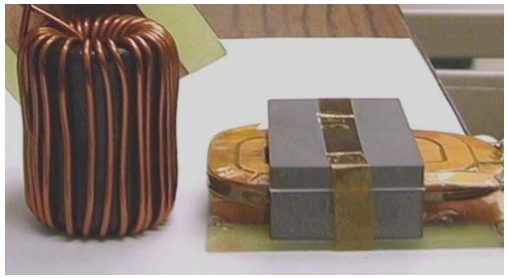
Metal Shield Between Conductor and Magnetic Substrate

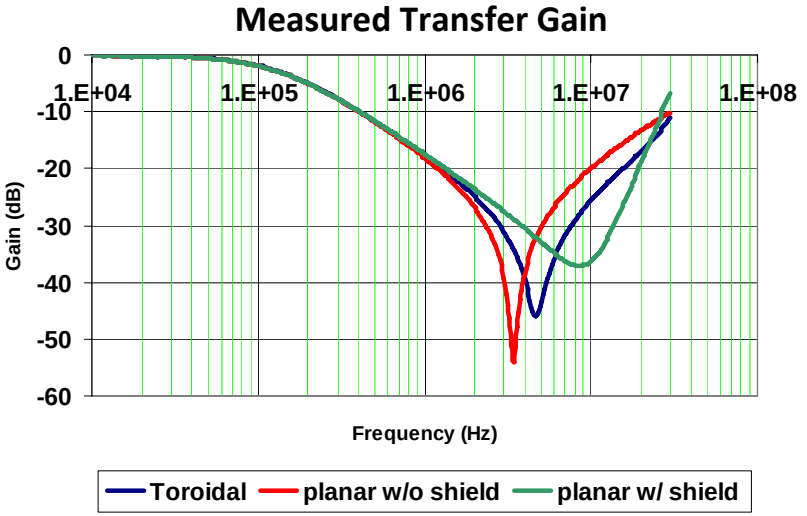


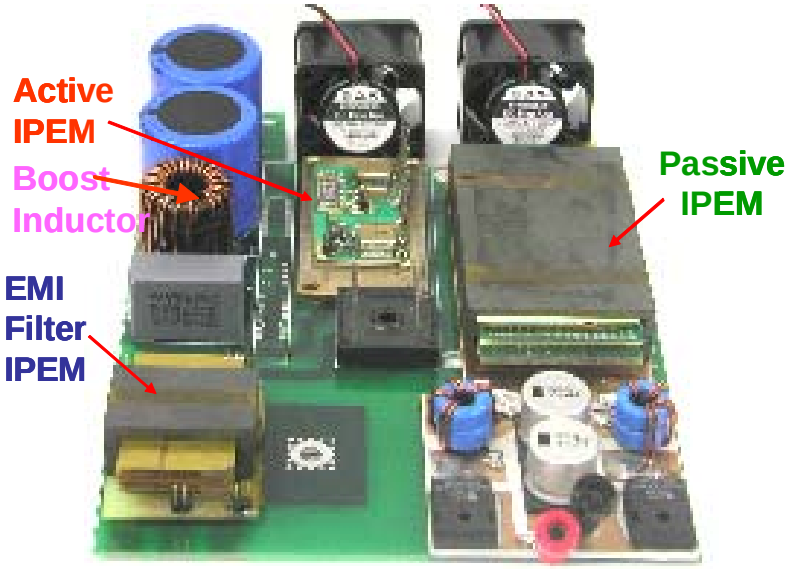
Planar Inductor with Structural Winding Capacitance Cancellation for PFC Boost Converters

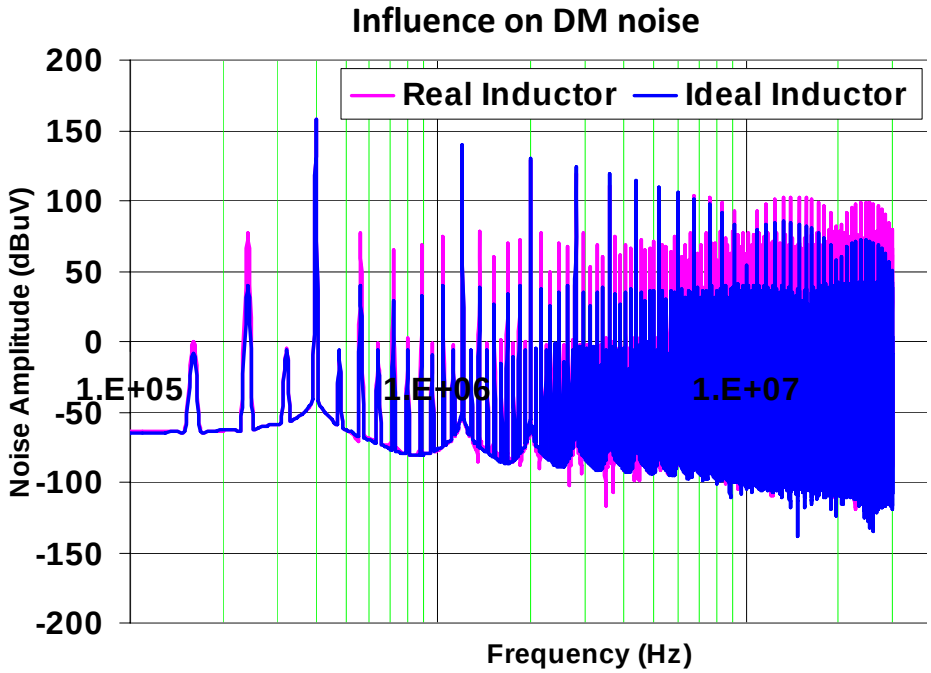
Structural winding capacitance of boost inductor



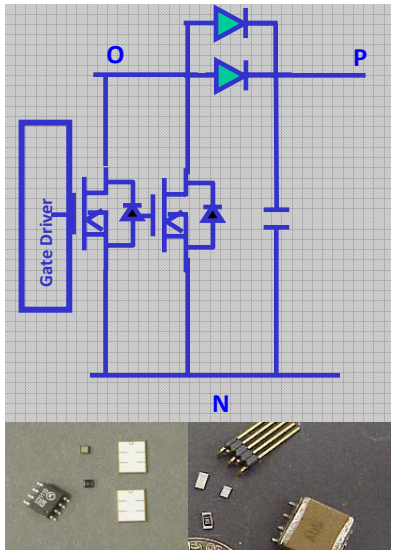


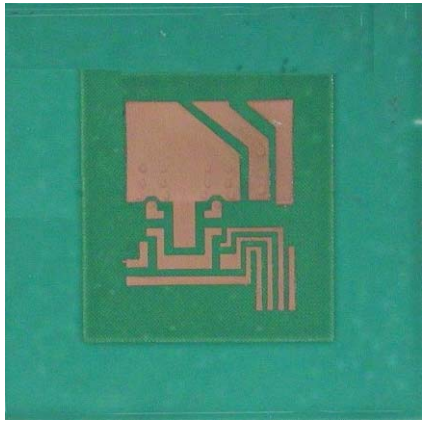


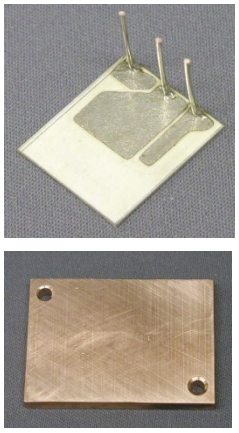


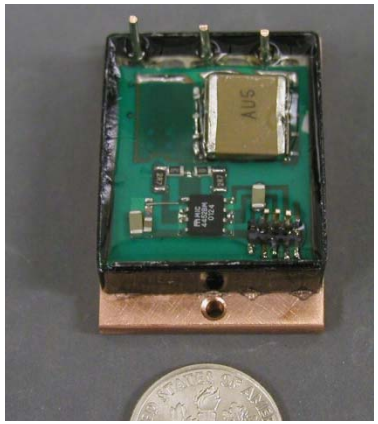


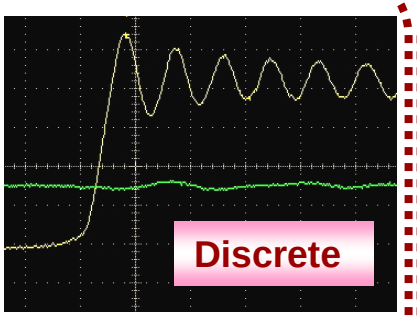
PFC Active IPEM Packaging







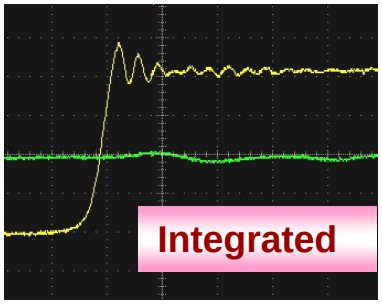




Overshoot:

106V@7A

54MHz

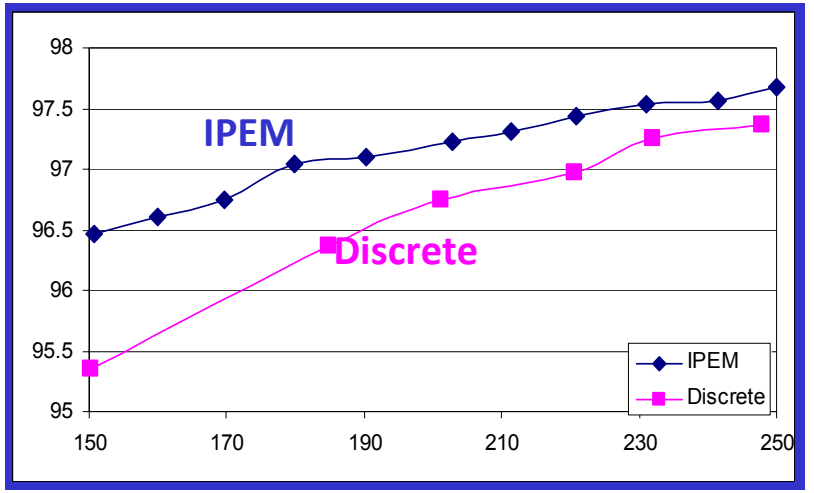


Overshoot:

70V@10A

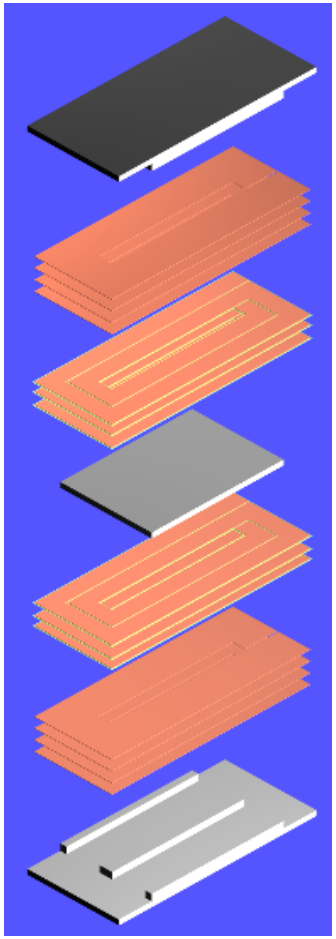
150MHz

Performance



Integrated Power Passive Module for DPS (non-resonant)

Exploded View



Ferrite

Secondary windings

Primary windings

Ferrite

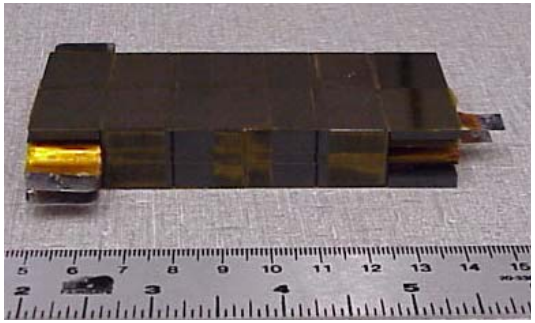
Primary windings

Secondary windings

Ferrite

Exploded view of half-module

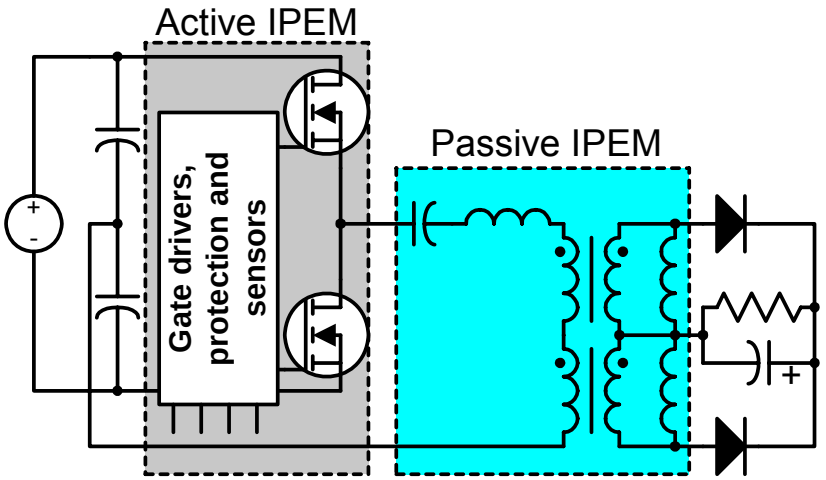
Overview

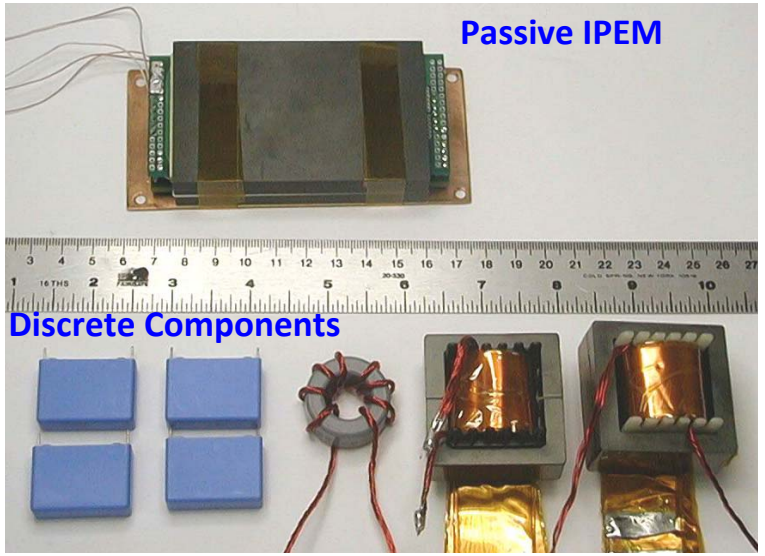


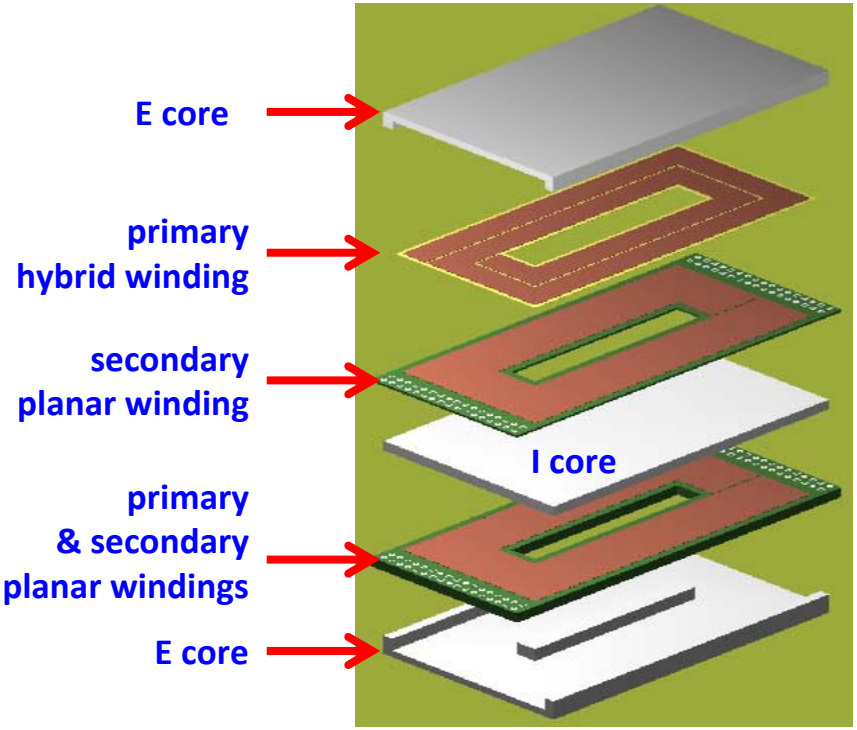
Comparison

	Integrated	Discrete
Power rating (kVA)	1.5	1.5
$L_{magnetizing}$ (uH)	40 x 2	40 x 2
$L_{leakage}$ (uH)	4	4
Capacitance (uF)	2	2
Fs (kHz)	200	200
Total Volume (cm^3)	**60**	245

Design of Integrated Passive Module for 1 kW Asymmetrical Half-Bridge ZVS PWM Converter





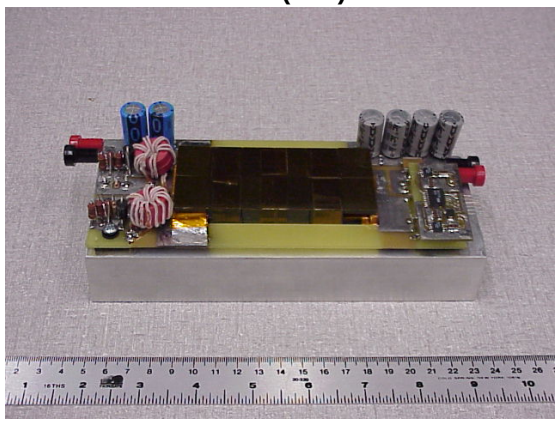


Comparison

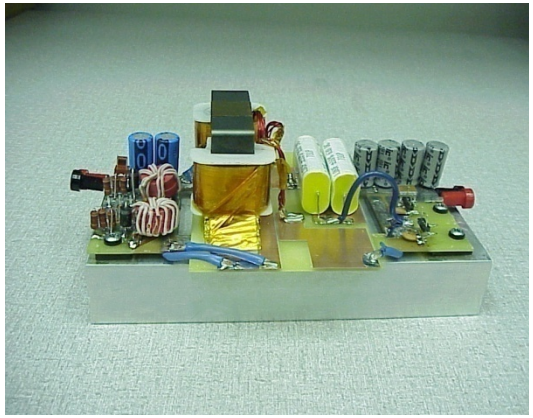
Parameter	Discrete	Passive IPEM
Power (kVA)	1.0	1.0
$L_{m1,2}$ (uH)	45	45
L_s (uH)	2	1.8
C (uF)	2.3	2.5
No. of Components	7	1
Profile (mm)	42	16
Total Volume (cm^3)	168	82

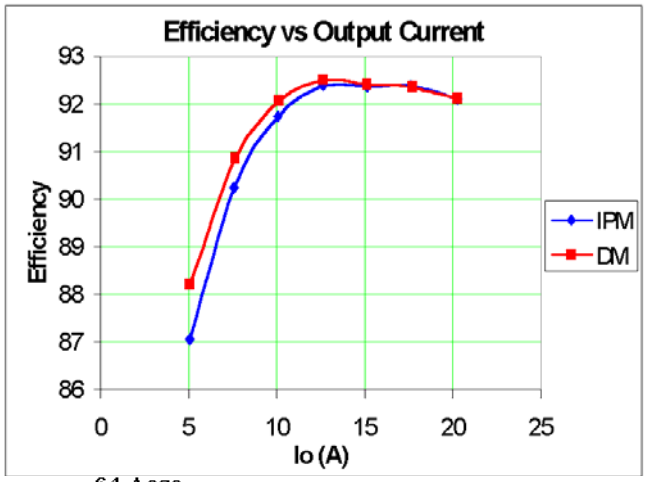
Design of Integrated Passive Module for 1 kW Asymmetrical Half-Bridge ZVS PWM Converter

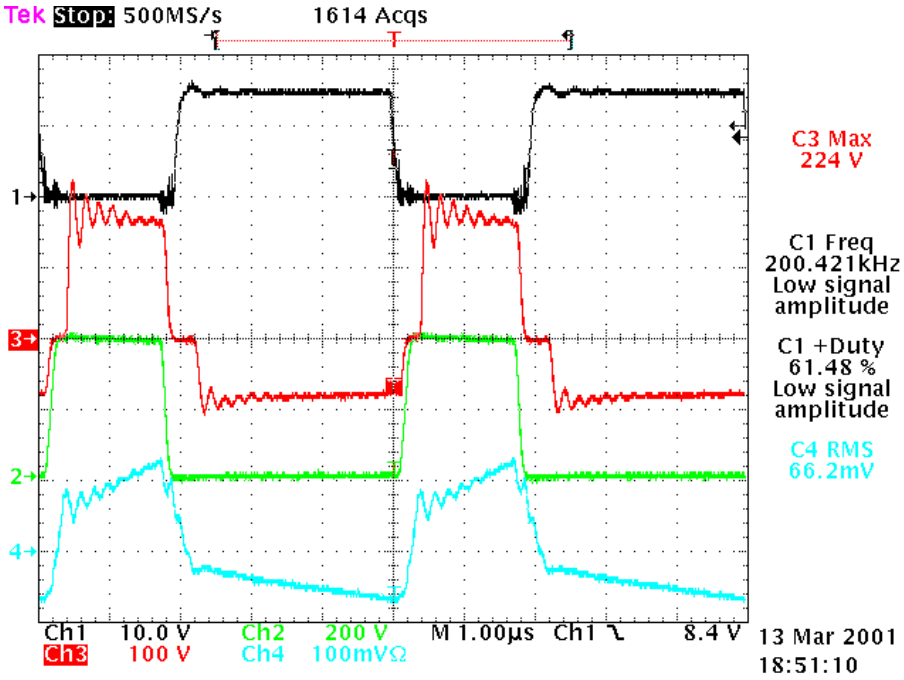
Employing Integrated Passive Module (IPM)

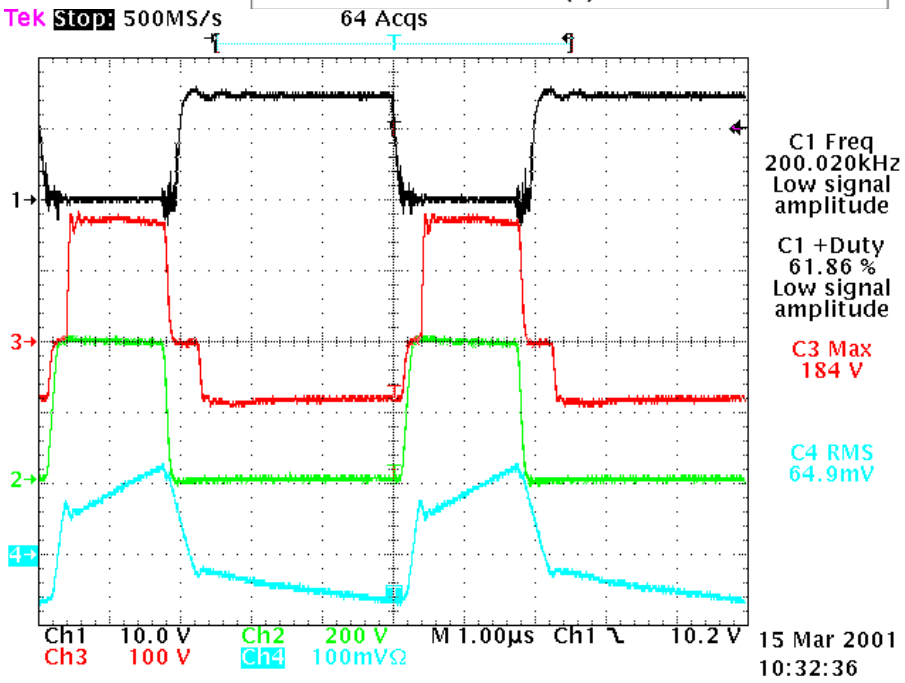


Employing Discrete Module (DM)

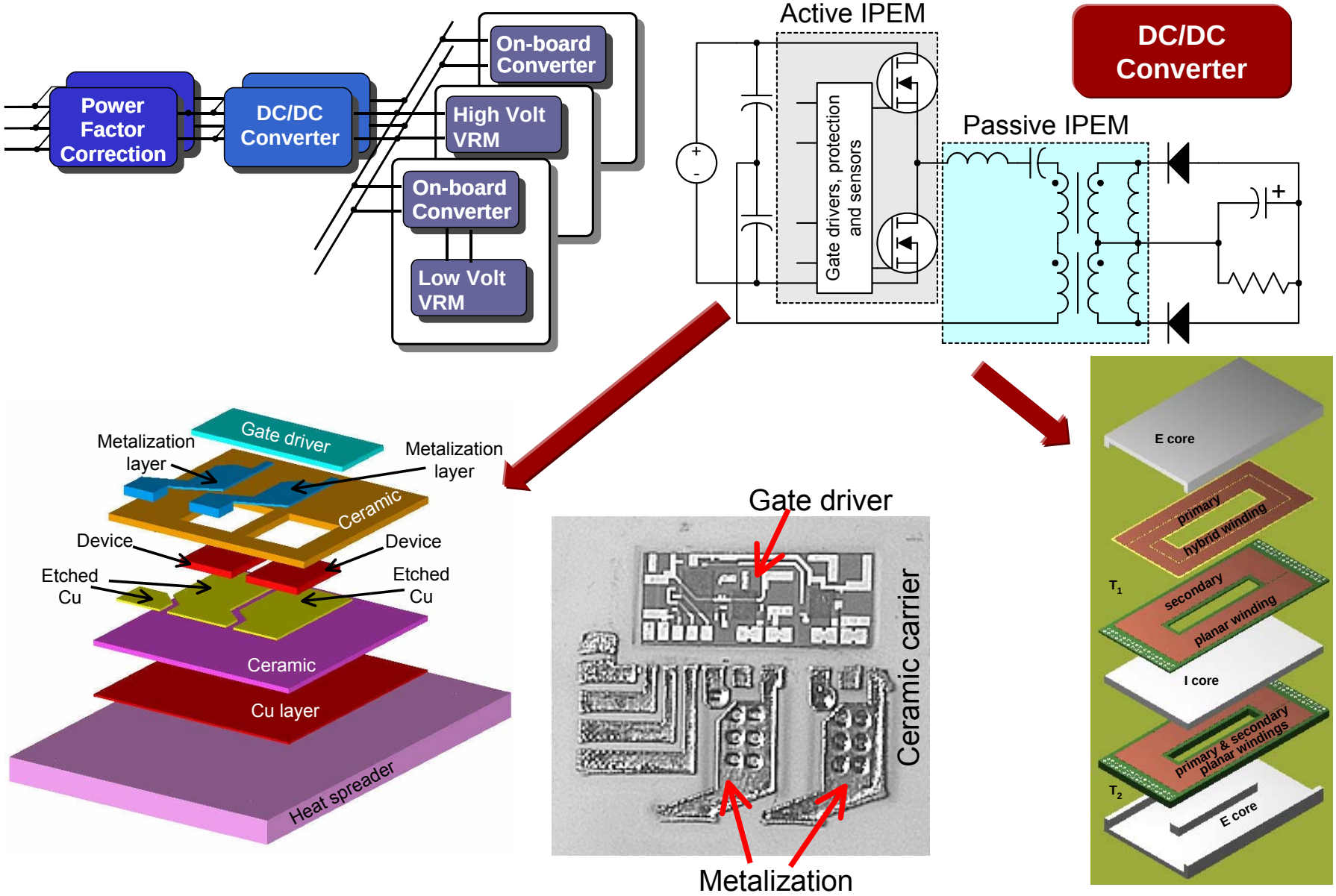




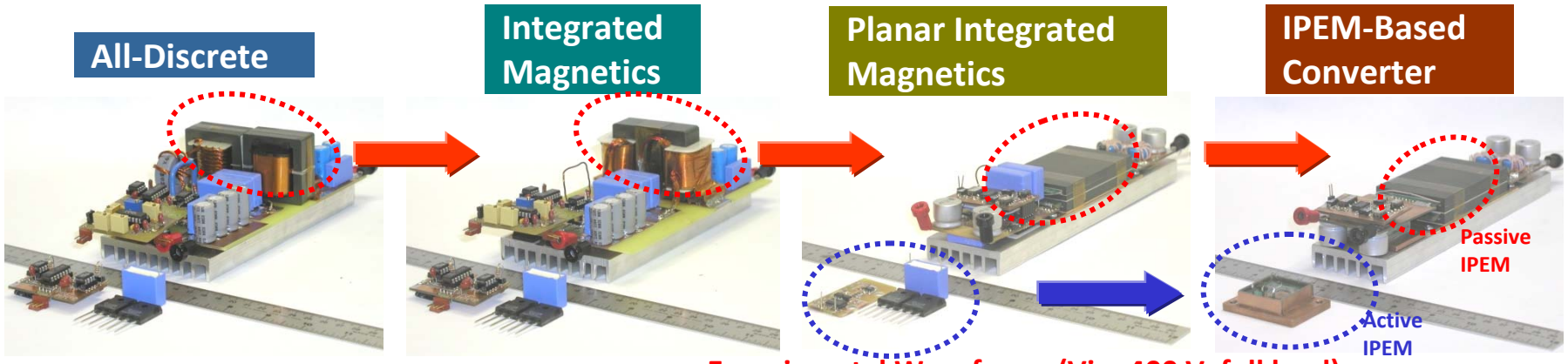




An Overview of the IPEM-Based Modular Implementation for DPS



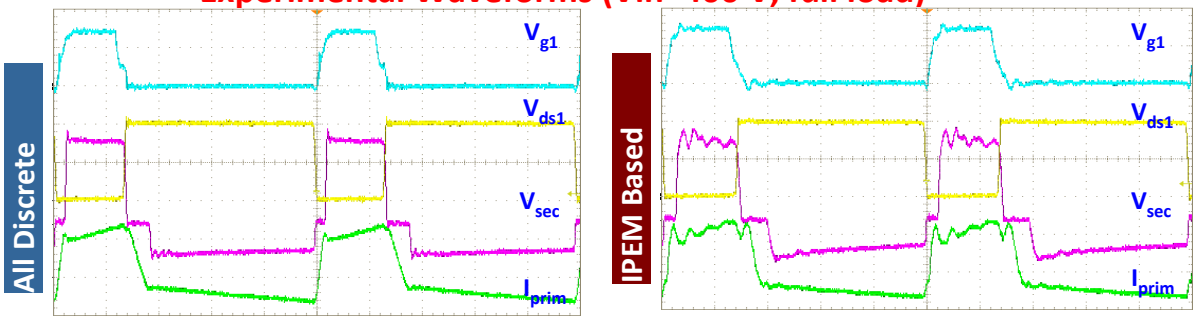
Development of Integrated DC/DC Converter Using IPEMs



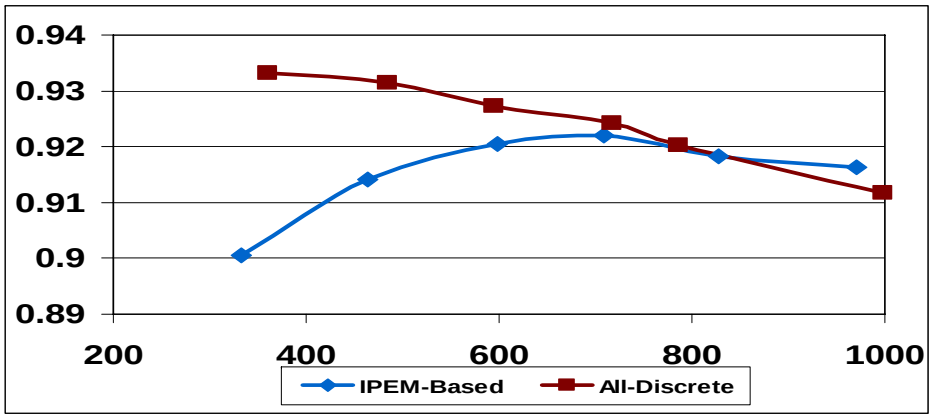
Comparison

Improvements	All-Discrete	IPEM-Based
No. of Main Components	11	5
Profile (cm) (1U=4.45cm)	6.6 (1.5 U)	3.8 (0.85U)
Footprint (cm^2)	202	120
Power density (W/in^3)	12	34

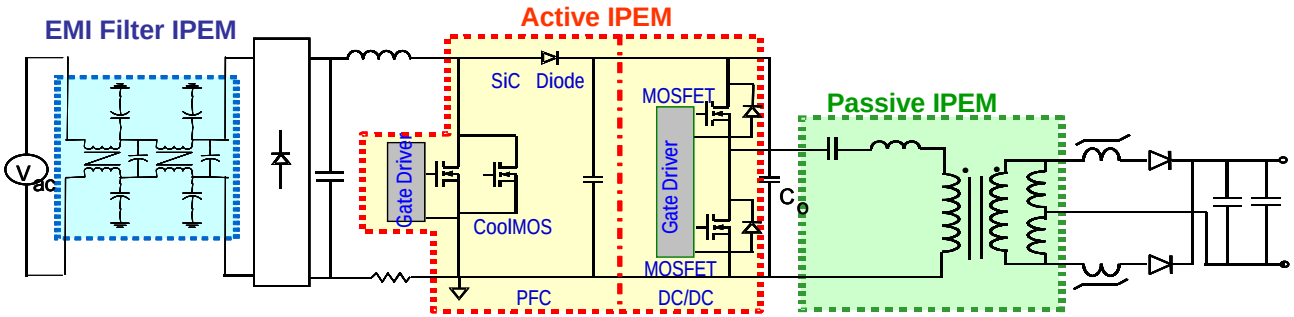
Experimental Waveforms (Vin=400 V, full load)

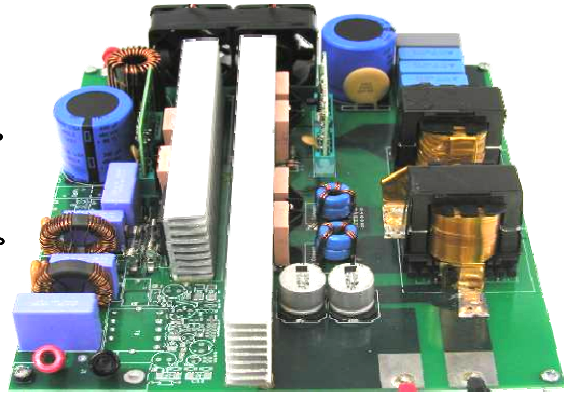


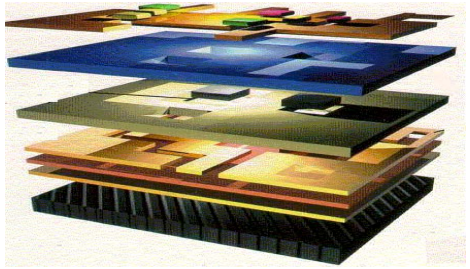
Efficiency Comparison

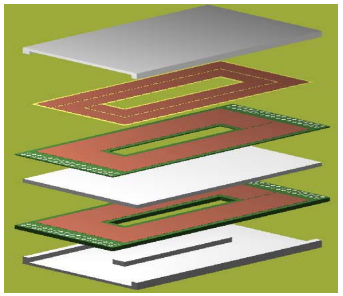


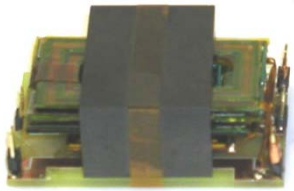
An Overview of the IPEM-Based Modular Implementation for DPS

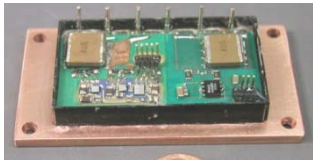




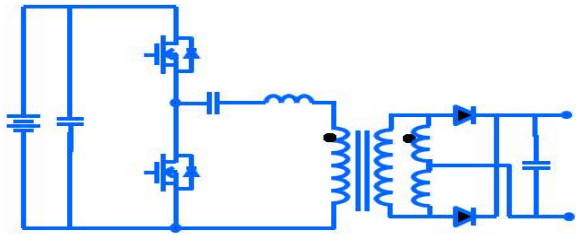








1998 1999 2000 2001 2002 2008



LLC Resonant