EMI Filter Optimization Report

Global Parameters

Number of stages considered: 1

Ambient temperature: 25°C

Converter switching frequency: 36 kHz

Resulting design frequency: 180 kHz

Desired DM attenuation: 78 dB

CM attenuation: 88 dB

Mains voltage: 230.0 V (RMS)

Mains frequency: 50 Hz

Scaled converter inductance: 152.5 uH

Parasitics and Additional Components

Lumped stray capacitance Ceq: 600 pF

Lumped stray capacitance Cg: 2000 pF

Total volume is increased by 10% to account for the PCB.

Total volume is increased by 0% and total losses are increased by 0% to account for additional components.

Additional components (max. 10 displayed per category):

Single DM Additional Components			
Name (Unit)	*Min*	*Max*	*Increment*

Per-Stage DM Additional Components			
Name (Unit)	*Min*	*Max*	*Increment*

Single CM Additional Components			
Name (Unit)	*Min*	*Max*	*Increment*

Per-Stage CM Additional Components			
Name (Unit)	*Min*	*Max*	*Increment*

DM Filter Parameters

Maximum total DM capacitance per phase: 13 uF

DM attenuation is not equally distributed amongst the filter stages and per-stage attenuation is varied by 0.1 of the total.

All filter stages are set to have the same range of inductance values.

All filter stages are set to use the same inductor and capacitor design space.

DM Stage 1

CDM1 is not fixed to a constant value.

Attenuation of the first stage is not fixed to a separate constant value.

LDM range: 50 to 350 by 50 uH (applies to ALL filter stages)

Inductor design space single constraints	
Max. volume	1.0 L
Max. temperature	150.0 C
Core material	Micrometals -14
Core type	R (toroidal)
Wire material	Annealed Copper
Wire type	Round litz wire
Custom core	no
Custom wire	yes
Design approach	Parameter Variation
Ignore high freq. effects	yes
Ignore proximity effect	yes
Ignore leakage inductance	N/A

Core Parameters			
Name (Unit)	*Min*	*Max*	*Increment*
Number of Stacked Inductor Cores	1.0	3.0	1.0

Cores (max. 40 shown)			
T106	T124	T131	T14
T150	T16	T184	T20
T22	T32	T38	T60-D

Wire Parameters			
Name (Unit)	*Min*	*Max*	*Increment*
Inductor fill factor	0.5	0.5	0.1
Strand diameter (bare) di (m)	0.0002	0.0002	1.0E-5

Extra Wire Parameters	
Compact factor	1.3

Thermal Properties	
Core orientation	VERTICAL
Non-exposed sides	None

Capacitor Series (max. 40 shown)			
X1 B32911-6	X2 B32921-8	X2 B81130	

Above design space applies to ALL DM filter stages.

CM Filter Parameters

Maximum leakage current to earth: 3.5 mA Resulting maximum total CM capacitance: 35.228 nF

CM attenuation is not equally distributed amongst the filter stages and per-stage attenuation is varied by 0.1 of the total.

All filter stages are set to have the same range of inductance values.

All filter stages are set to use the same inductor and capacitor design space.

CM Stage 1

CCM1 is not fixed to a constant value.

CCM1 is in series with CDM1.

LCM range: 1000 to 2000 by 500 uH (applies to ALL filter stages)

Inductor design space single constraints	
Max. volume	1.0 L
Max. temperature	150.0 C
Core material	Vitroperm 500F-18k
Core type	R (toroidal)
Wire material	Annealed Copper
Wire type	Round solid wire
Custom core	no
Custom wire	yes
Design approach	Parameter Variation
Ignore high freq. effects	yes
Ignore proximity effect	yes
Ignore leakage inductance	yes

Core Parameters			
Name (Unit)	*Min*	*Max*	*Increment*
Number of Stacked Inductor Cores	1.0	3.0	1.0

Cores (max. 40 shown)			
T60006-L2020-W450+	T60006-L2025-W451+	T60006-L2040-W452+	T60006-L2040-W453+
T60006-L2045-V101#	T60006-L2050-W565#	T60006-L2063-V110#	T60006-L2160-V066#

Wire Parameters			
Name (Unit)	*Min*	*Max*	*Increment*
Inductor fill factor	0.4	0.4	0.1

Extra Wire Parameters	
s as % of d	0.05
Minimum s (mm)	0.001

Thermal Properties	
Core orientation	VERTICAL
Non-exposed sides	None

Capacitor Series (max. 40 shown)			
Y1 B81123	Y2 B32021-6		

Above design space applies to ALL CM filter stages.

Optimization Parameters

Optimization Goal: 0.5

Optimization type: Exhaustive (brute force)

Converter output power: 7.5 kW

Converter switching frequency: 36 kHz

Optimization Results

Overall Best Filter Design: 1-Stage Filter

(See the pages for the best 1-stage filter for details)

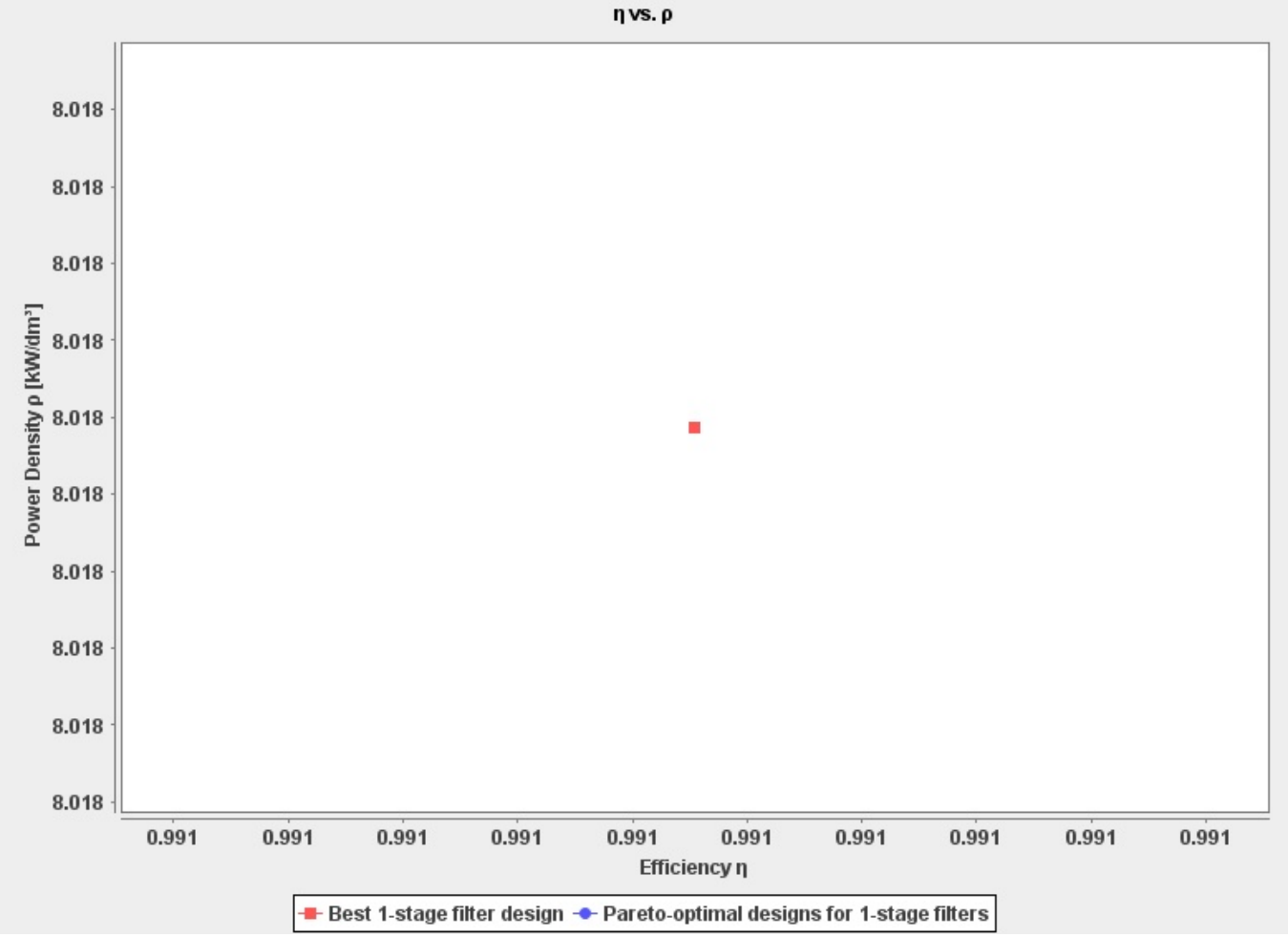
Total Losses: 68.091 W

Efficiency: 99.1%

Total Volume: 0.935 L

Power Density: 8.018 kW/L

EMI Filter Pareto-Optimal Designs:



Best 1-Stage Filter Design

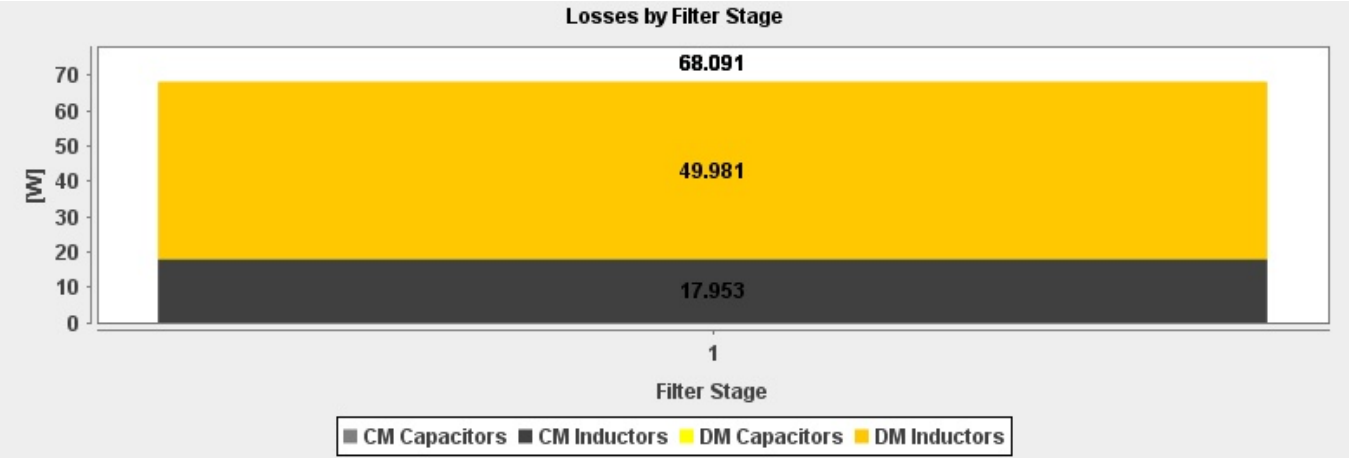
Total Losses: 68.091 W

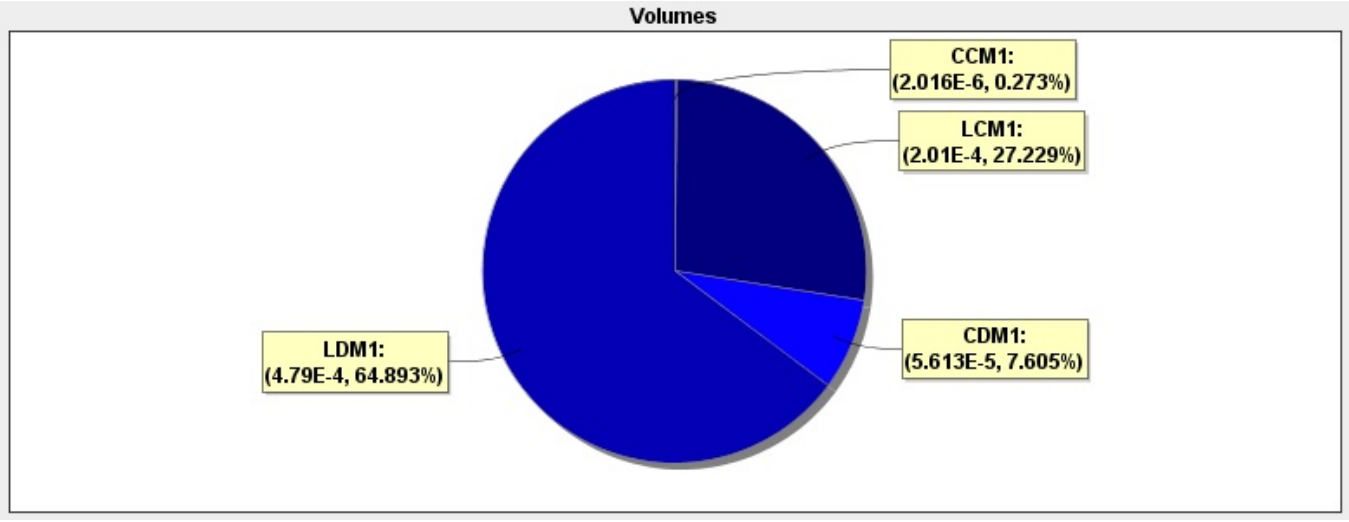
Efficiency: 99.1%

Total Volume: 0.935 L

Power Density: 8.018 kW/L

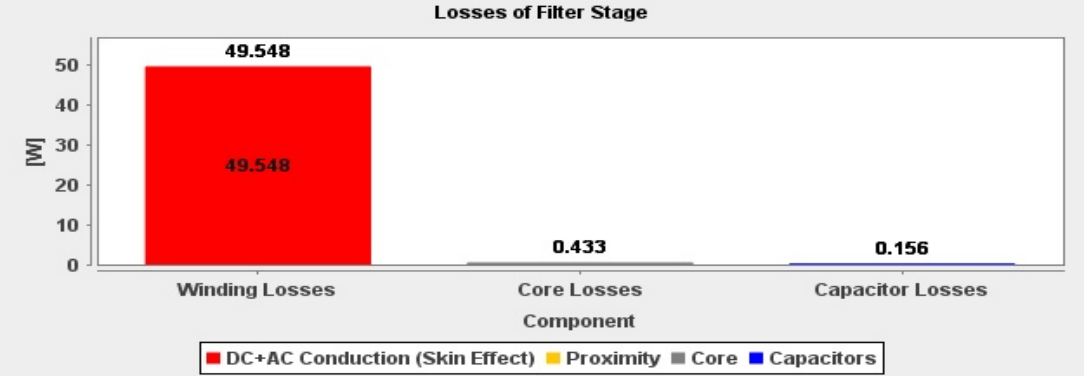
Stage 1	
LDM1	440.43 uH
CDM1	14.1 uF
LCM1	51.36 mH
CCM1	33 nF

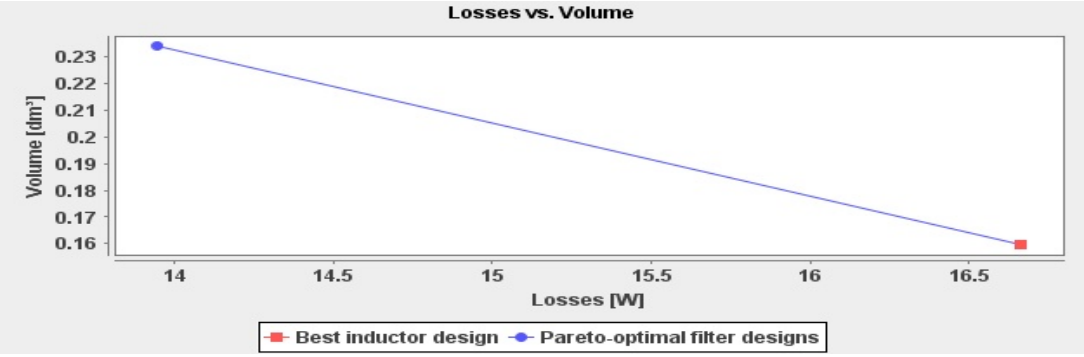




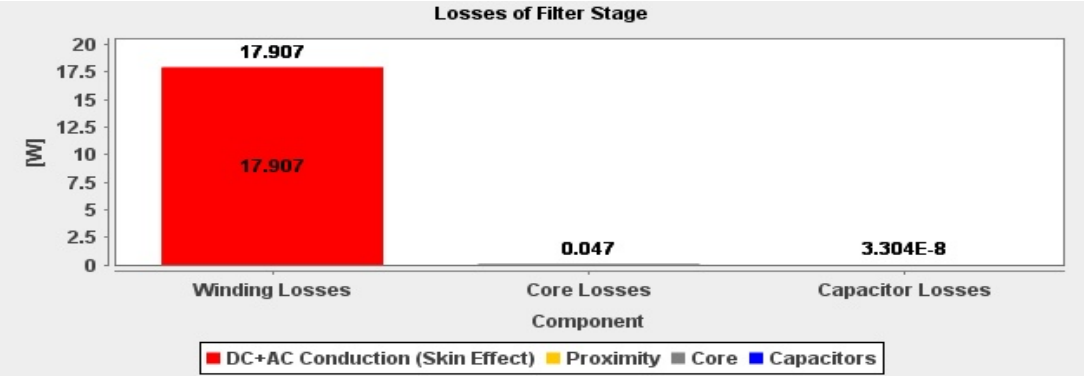
Filter Stage 1

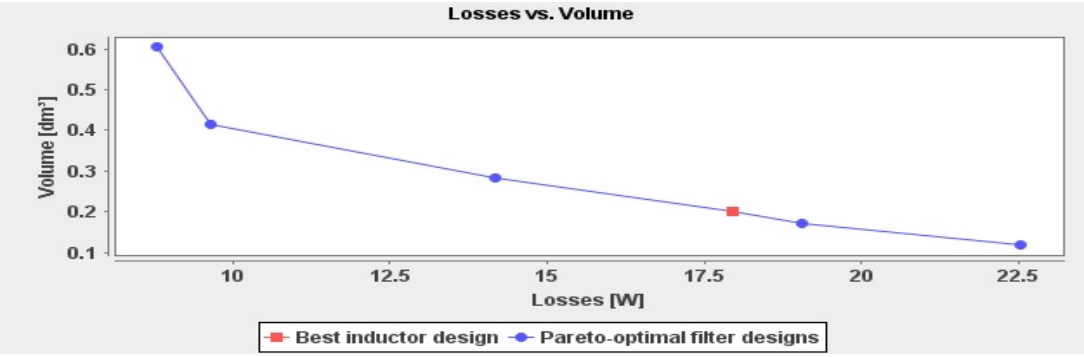
Differential mode:





Common mode:





DM Capacitor and Inductor Design For Stage 1

```
Capacitor:                          3 x EPCOS B32924C3475M
 Capacitance:                C = 14.1 µF
 Rated Voltage:             Vr = 305 V
 Losses:                         0.05 W
 Volume:                         56.133 cm^3
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Toroid-Inductor:              L = 437.5036 µH

Core:                               T184
Type:                               R (toroidal)
Core Material:                      Micrometals -14
Number stacked:                     2

Dimensions (mm):
 Outer Diameter:             do = 46.7
 Inner Diameter:             di = 24.1
 Thickness:                   t = 36.0

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Winding:                            Custom Litz (fill factor)
Type:                               Round litz wire
Material:                           Annealed Copper
Number of turns:              N = 81

Dimensions (mm):
 Total diameter:              d = 1.893
 Strand diameter:            di = 0.25
 Number of strands:           n = 34
 Wire spacing:               yd = 0.0

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Losses (W):
 Core Losses:                       0.14
 Winding losses DC:                 4.750999553154194E-10
 Winding losses skin effect:        16.52
 Winding losses prox. effect:       0.0
 TOTAL:                             16.66

Winding temperature:                91.02 C
Core Temperature:                   91.3 C
Inductor Orientation:               VERTICAL
Convection:                         NATURAL

Total Boxed Volume:                 159.6564 cm^3
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CM Capacitor and Inductor Design For Stage 1

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Capacitor:                          1 x EPCOS B32022A3333
 Capacitance:                C = 33.0 nF
 Rated Voltage:             Vr = 300 V
 Losses:                         3.304496127659499E-8 W
 Volume:                         2.016 cm^3
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Toroid CM 3ph-Inductor:       L = 51.524 mH
                             Ls = 38.2144 mH

Core:                           T60006-L2050-W565#
Type:                           R (toroidal)
Core Material:                  Vitroperm 500F-18k
Number stacked:                 2

Dimensions (mm):
 Outer Diameter:             do = 50.0
 Inner Diameter:             di = 40.0
 Thickness:                   t = 40.0

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Winding:                        Custom SR (fill factor)
Type:                           Round solid wire
Material:                       Annealed Copper
Number of turns:         3 x  N = 40

Dimensions (mm):
 Conductor diameter:          d = 1.834
 Isolation thickness:         s = 0.0917
 Wire spacing:               yd = 0.0

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Losses (W):
 Core Losses:                   0.05
 Winding losses DC:             4.093933540197082E-15
 Winding losses skin effect:    17.91
 Winding losses prox. effect:   0.0
 TOTAL:                         17.95

Winding temperature:            93.68 C
Core Temperature:               93.88 C
Inductor Orientation:           VERTICAL
Convection:                     NATURAL

Total Boxed Volume:             200.9776 cm^3
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