

600W halfbridge LLC evaluation board

EVAL-600W-12V-LLC-A	Analog
EVAL-600W-12V-LLC-D	Digital

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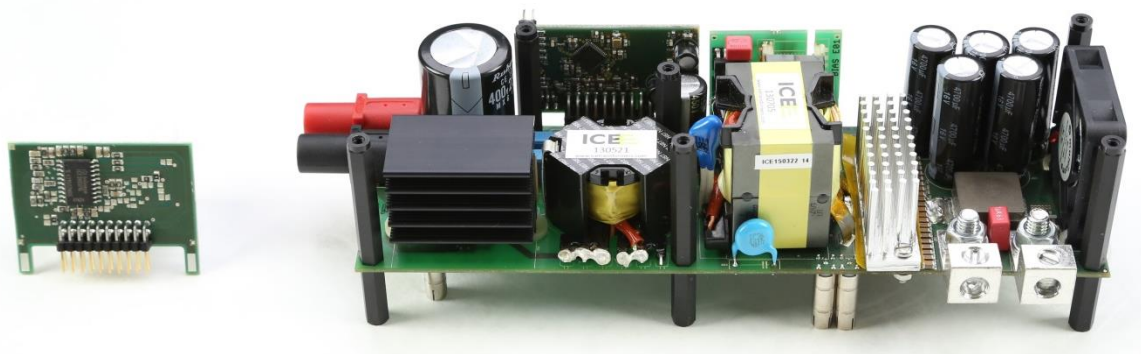
General

Description:

The **"EVAL-600W-12V-LLC-x"** - Evaluation board in the Analog version "-A" or digital controlled "-D" shows how to design a Half-Bridge LLC stage of a server SMPS with the target to meet **80+ Titanium standard** efficiency requirements. On this purpose there has been applied CoolMOS™ P6 technology [IPP60R190P6](#) 600V Power MOSFET on the primary side and OptiMOS™ low voltage Power MOSFET in SuperSO8 [BSC010N04LS](#) in the synchronous rectification secondary stage, in combination with QR CoolSET™ [ICE2QR2280Z](#), Hi-Low Side Driver [2EDL05N06PF](#), in the newest version a Low Side Gate Driver [2EDN7524F](#). The system is controlled by a LLC Controller [ICE2HS01G](#) for the analog or [XMC4200](#) in the digital version.

Summary of features:

- › Output voltage: 12 V
- › Output current: 50 A
- › Peak efficiency @ 50% load > 97,8%
- › Efficiency @ 10% load > 95%



The following variants are available:

- › 600W 12 V LLC **analog** version with CoolMOS™ P6, [IPP60R190P6](#), EVAL-600W-12V-LLC-A
- › 600W 12 V LLC **digital** version with CoolMOS™ P6, [IPP60R190P6](#), EVAL-600W-12V-LLC-D

Example of system understanding: Infineon demo solution for Titanium HV DC/DC stage

Half Bridge LLC with synchronous rectification in center tap configuration

V_{in}	350-410 V _{DC}
V_{in_nom}	380 V _{DC}
V_{out_nom}	12 V _{DC}
I_{out}	50 A
P_o	600 W
$f_{res}=f_0$	157 kHz
f_{min}	90 kHz
f_{max}	210 kHz
Transformer turns ratio	16:1
C_r	66 nF
L_r	15.5 μ H
L_m	195 μ H

Primary HV MOSFETs
CoolMOS™ IPP60R190P6
 Reduced gate charge (Q_g)

- › Reduced E_{off}
- › High body diode ruggedness

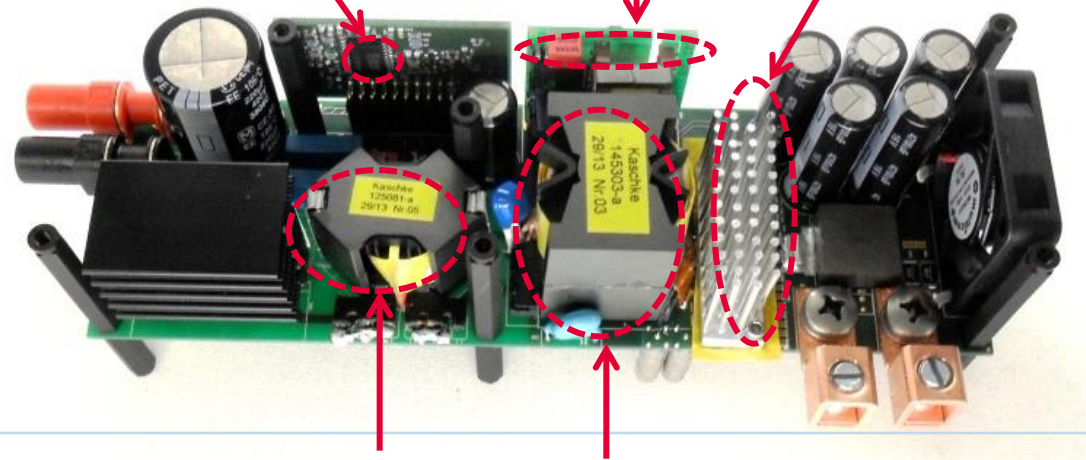
SR MOSFETs
OptiMOS™ BSC010N04LS
 New generation

- › Best FOM $R_{DS(on)} \times Q_g$
- › Best FOM $R_{DS(on)} \times Q_{oss}$

HB Gate Drive IC
 2EDL05N06PF
Non isolated LS Gate Drive
 2EDN7524F
LLC controller
 Digital XMC4200 / Analog ICE2HS01G

Bias QR Flyback controller
 ICE2QR2280Z

SR MOSFETs
 BSC010N04LS



Resonant inductor
 RM12 core

Transformer
 PQ35/35 core

Control board analog & digital

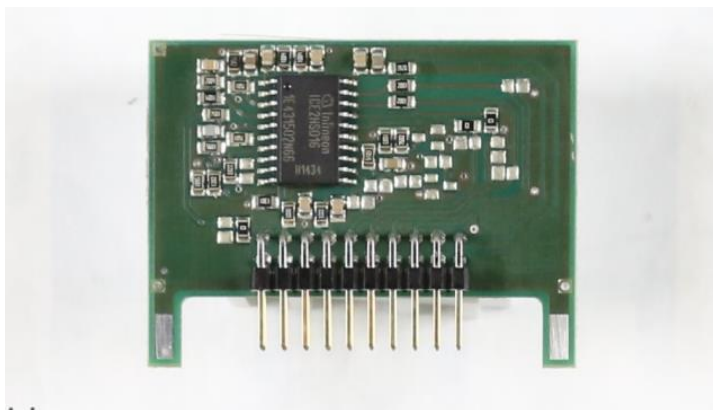
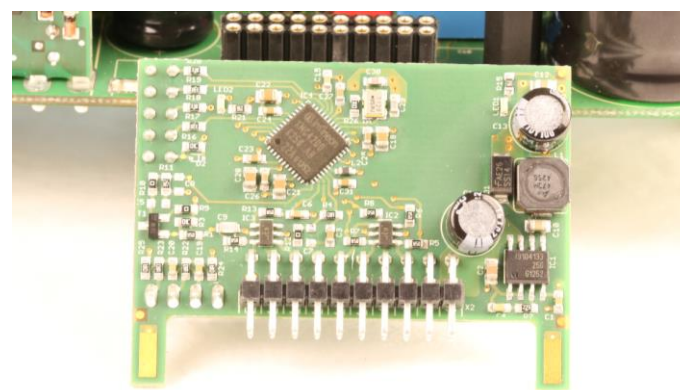
Two possible solution to control Infineon`s 600 W LLC evaluation board

Analog - ICE2HS01G

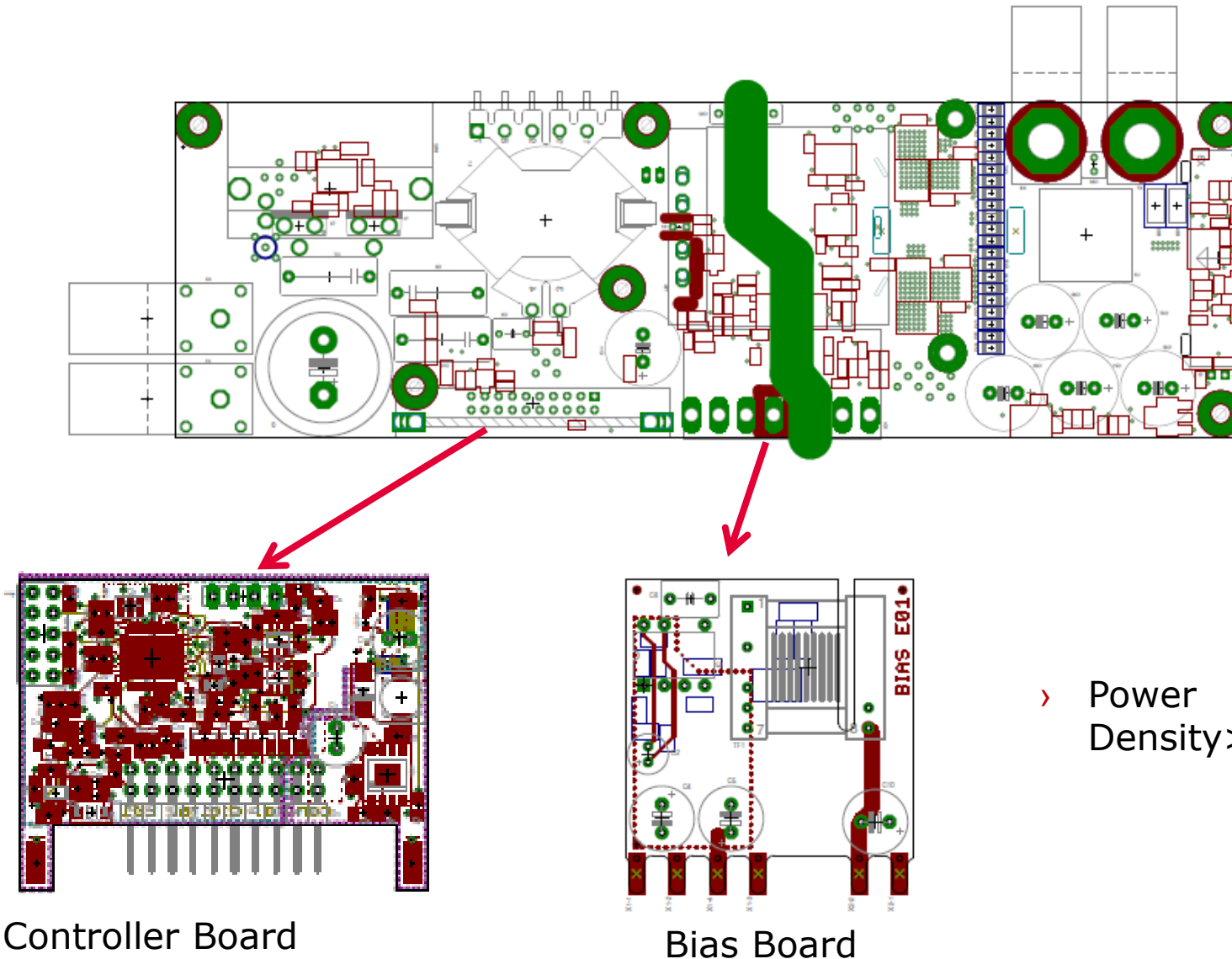
- › Resonant mode controller for Half-Bridge LLC resonant converter with synchronous rectification drives
- › Driving signal for synchronous rectification which support full operation of Half-Bridge LLC resonant converter
- › 20-pin DSO package
- › 30 kHz to 1MHz switching frequency
- › 50% duty cycle for both primary and secondary gate drives
- › Adjustable dead time with high accuracy

Digital - XMC4200-Q48K256 AB

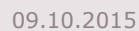
- › ARM® Cortex®-M4, 80 MHz, incl. single cycle DSP MAC and floating point unit (FPU)
- › 8-channel DMA + dedicated DMA for USB
- › USB 2.0 full-speed device
- › CPU Frequency: 80 MHz
- › eFlash: 256 kB including hardware ECC
- › 40 kB SRAM
- › Package: PG-LQFP-48



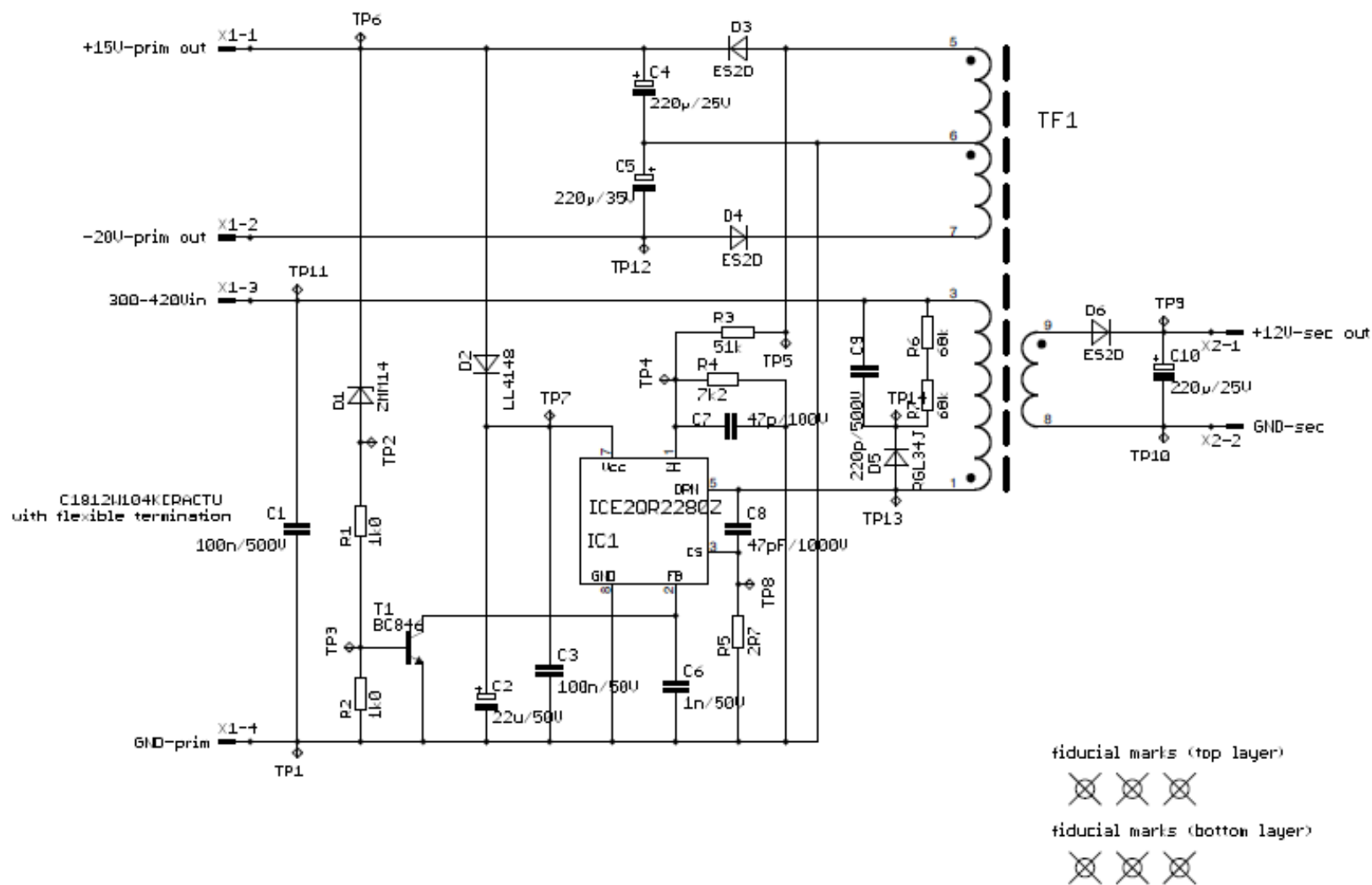
PCB boards layout: main power board and control and bias daughter boards



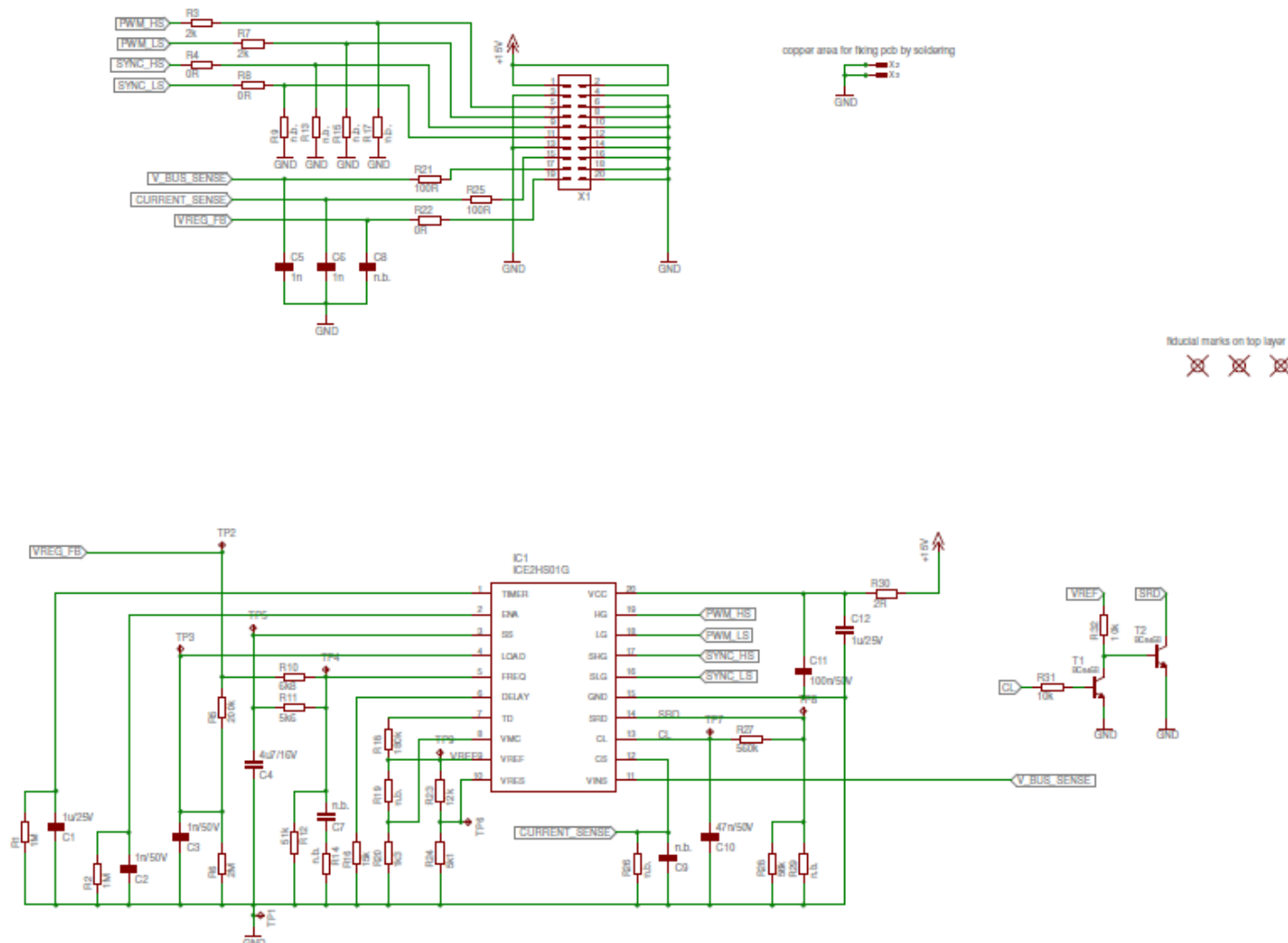
> Power Density > 20W/inch³

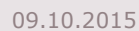


Bias board schematic



Analog control board schematic

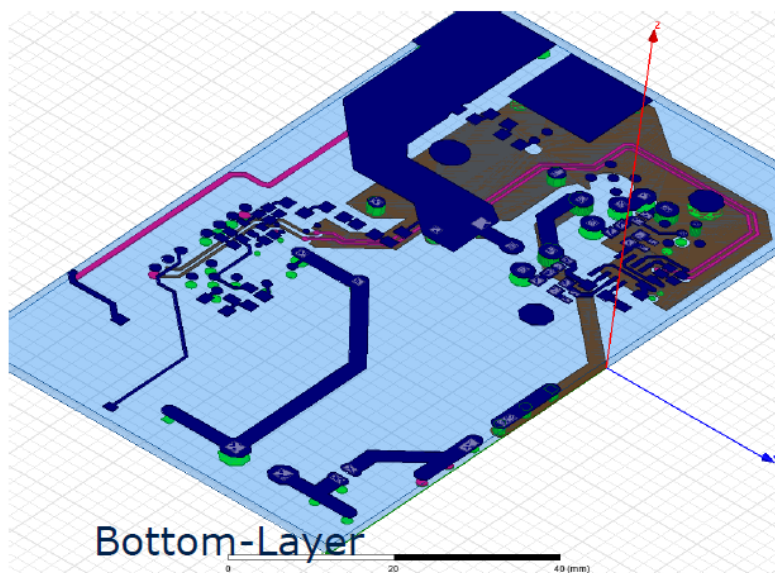
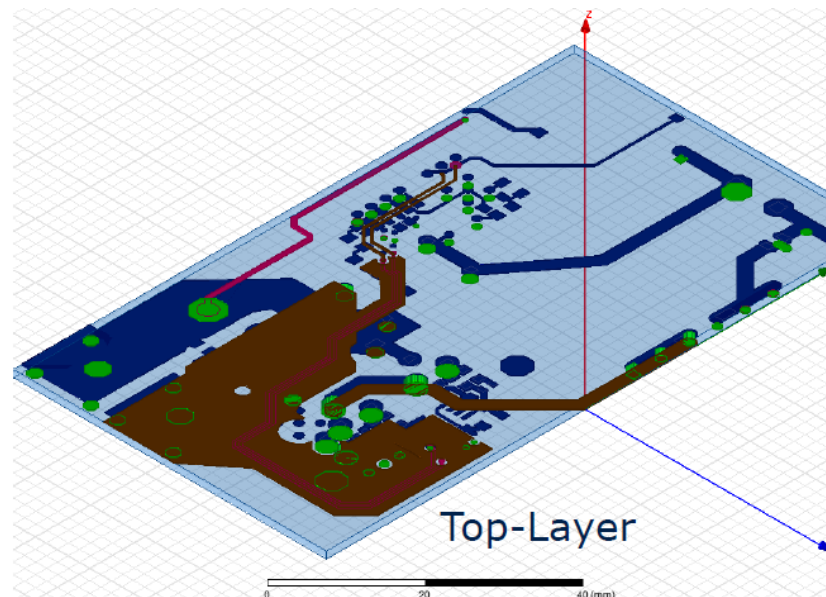




BOM (rework from analog to digital)

Part	Value	Pcs	Tolerance	Device	Package	Description	Assembling info	Supplier
C3	10 n/50 V	1		C-EU_C0805	C0805	CAPACITOR,	Replace 470 n/50 V with 10 n/50 V	
R19	330R	1	±1%	R-EU_R0805	R0805	RESISTOR	Replace 4K3 with 330R	
R20	330R	1	±1%	R-EU_R0805	R0805	RESISTOR	Replace 4K3 with 330R	
n.a.	n.a.	1	±1%	R-EU_R0805	R0805	RESISTOR	Assemble 56R with n.a.	
IC1	Board	1		Board	PCB	Digital_Controlcard		IFX

PCB structure



PCB-Stackup

Nr	Copper		Isolation	
1	0.07mm		0.15mm	
2	0.07mm		0.93mm	
15	0.07mm		0.15mm	
16	0.07mm			
Gesamt: 1.51mm				

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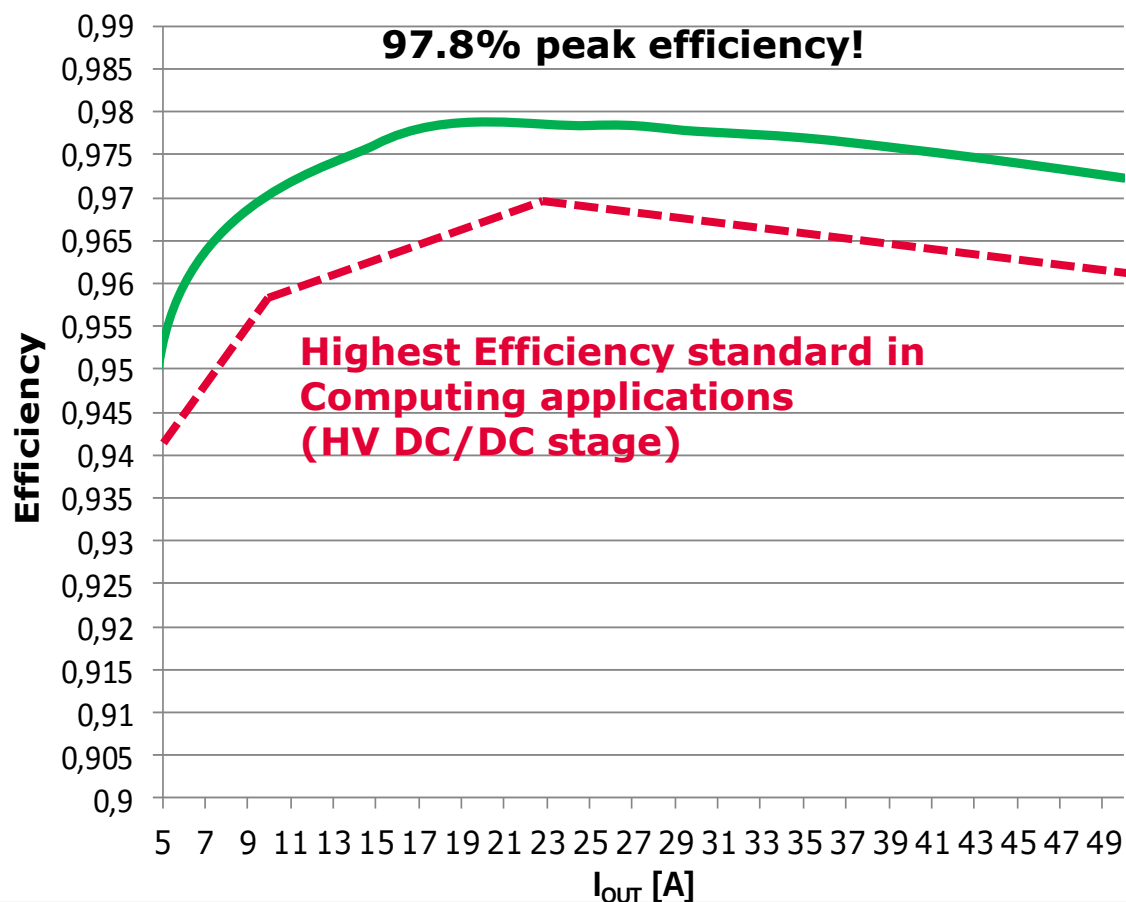
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Design concept

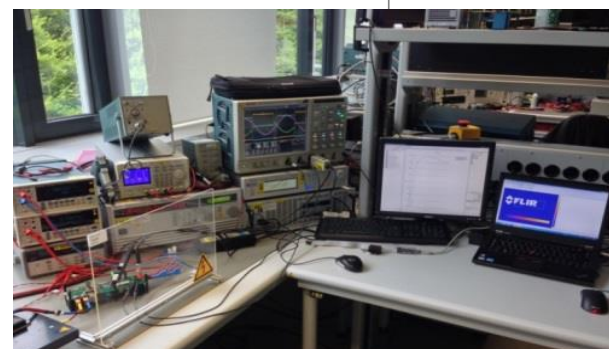
Automated efficiency measurement

Combination of converter design
(resonant tank, transformer) and
proper HV device election

Proper selection of SR LV device and
secondary side

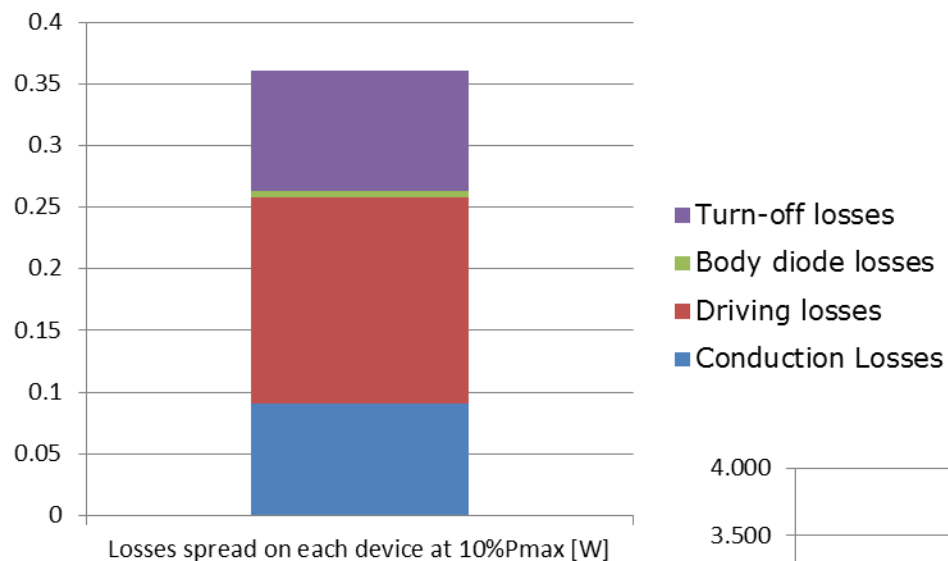
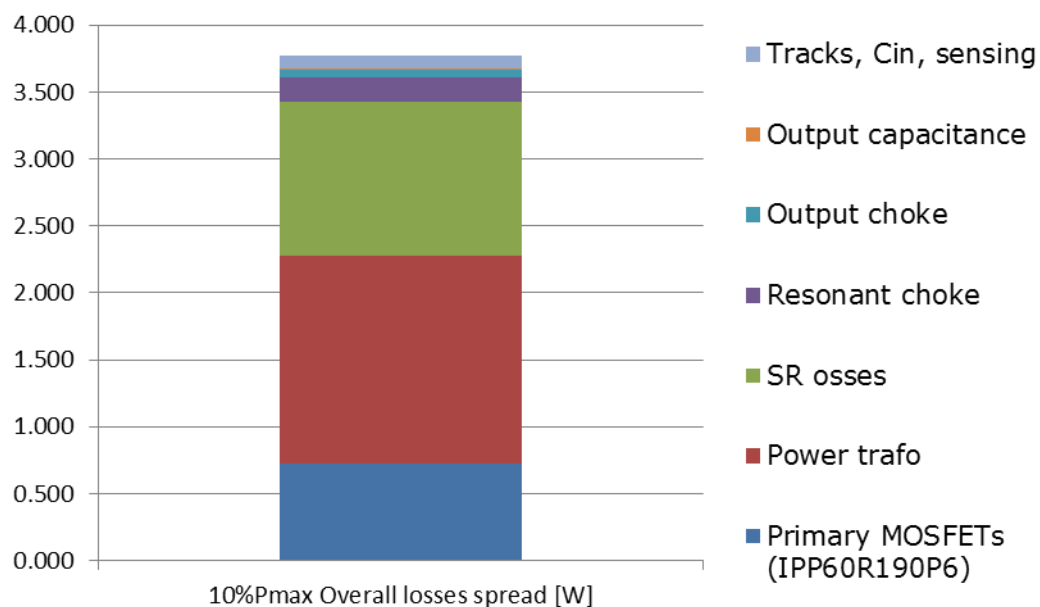


- > Output voltage: 12 V_{DC}
- > Output current: 50 A
- > Efficiency: > 95% @ 10% load, $V_{in} = 380$ V_{DC}
- > Efficiency max: 97.8%, $V_{in} = 380$ V_{DC}

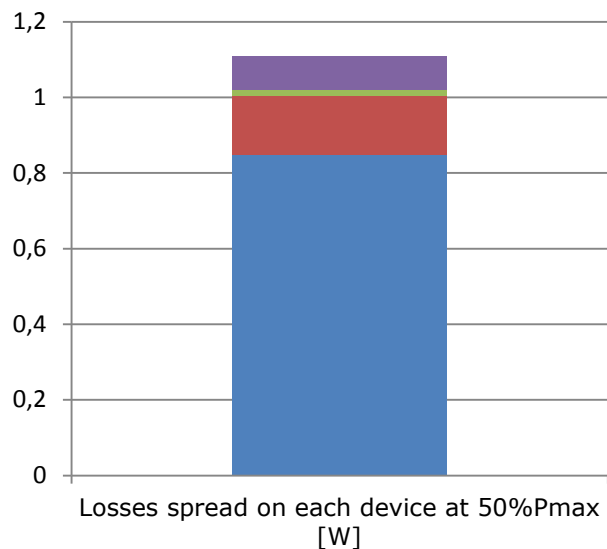


0.1% Total accuracy

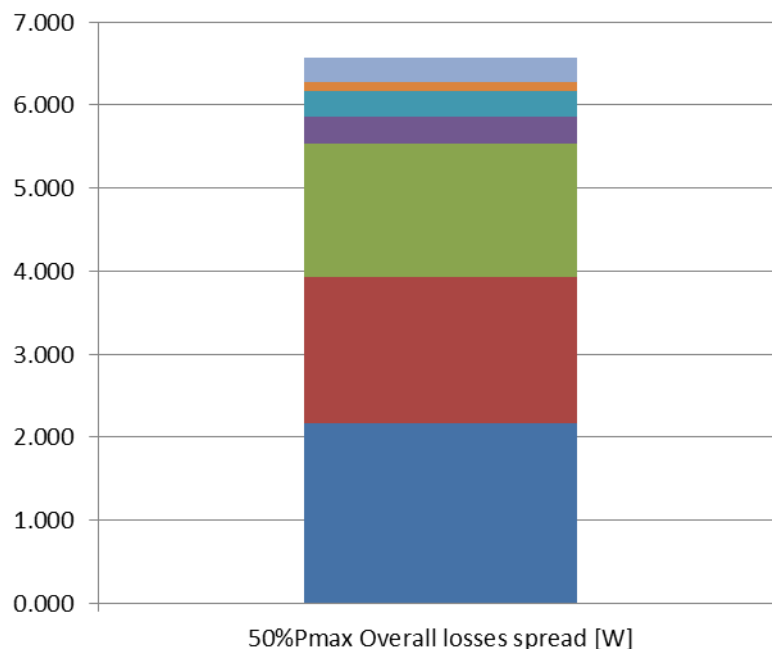
10% $P_{\max}$ $V_{\text{in}} = 380$ V_{dc}



50% $P_{\max}$ $V_{\text{in}} = 380$ V_{dc}

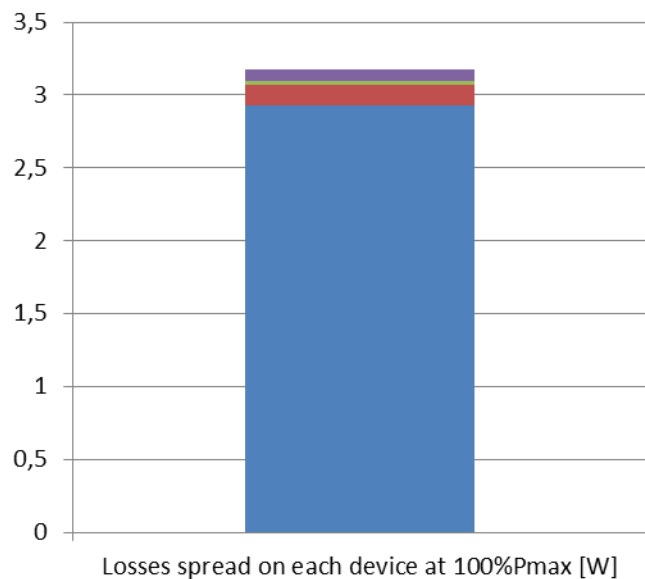


- Turn-off losses
- Body diode losses
- Driving losses
- Conduction Losses



- Tracks, Cin, sensing
- Output capacitance
- Output choke
- Resonant choke
- SR losses
- Power trafo
- Primary MOSFETs (IPP60R190P6)

100% $P_{\max}$ $V_{\text{in}} = 380 \text{ V}_{\text{dc}}$



- Turn-off losses
- Body diode losses
- Driving losses
- Conduction Losses

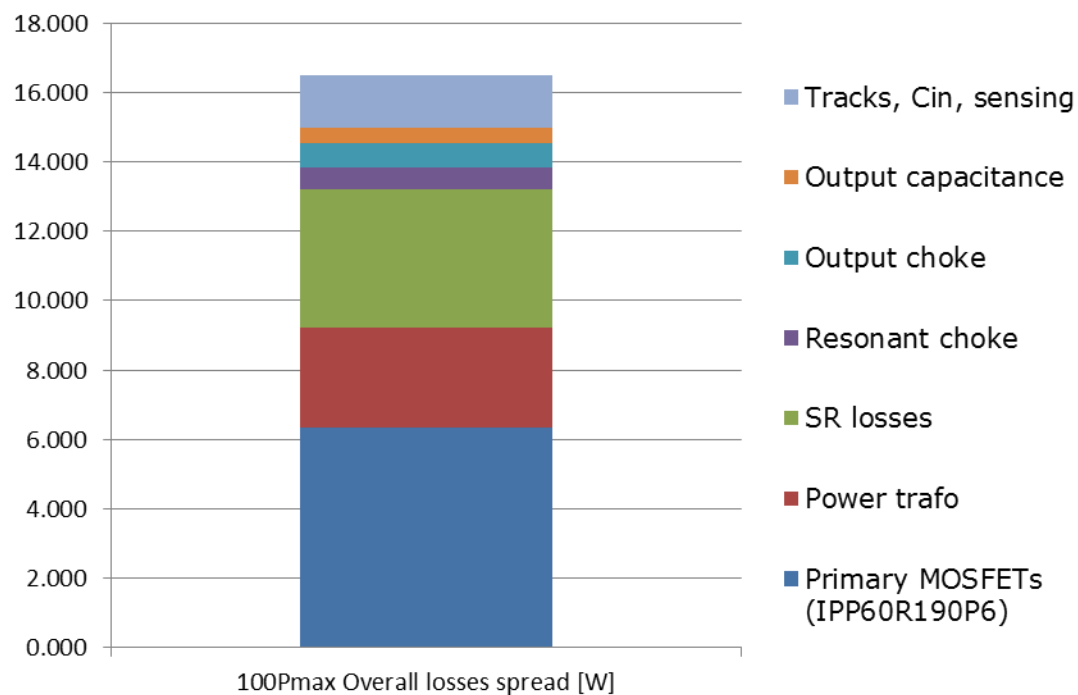


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Design procedure: input data

$$n = \frac{V_{in\_nom}}{2 \cdot V_{out\_nom}}$$

$$M_{min} \equiv K_{min}(Q, m, F_x) = \frac{n \cdot V_{o\_min}}{V_{in\_max} / 2}$$

$$M_{max} \equiv K_{max}(Q, m, F_x) = \frac{n \cdot V_{o\_max}}{V_{in\_min} / 2}$$

Resonant tank components and related resonant frequencies

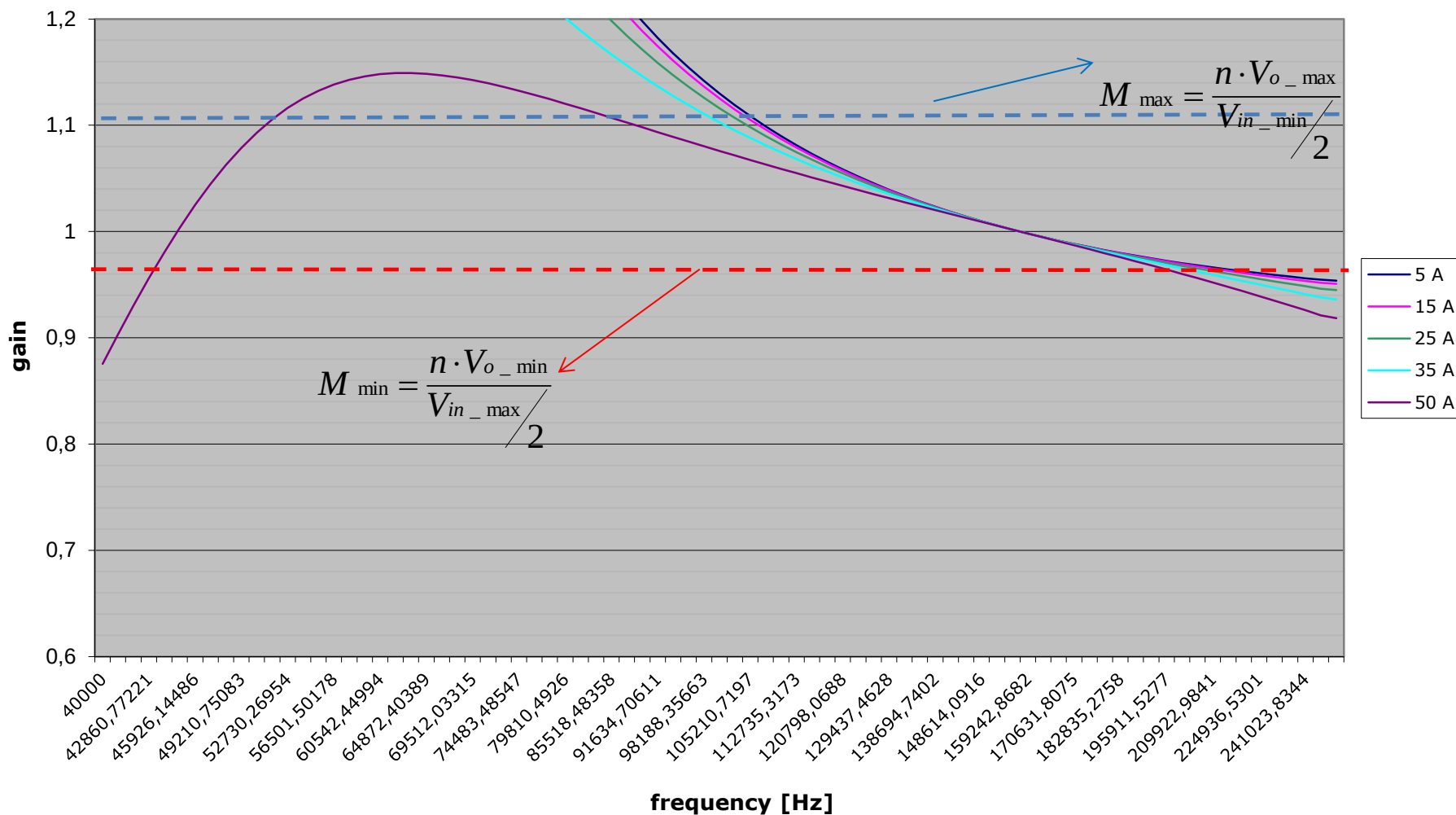
- › $n = V_{in\_nom} / (2 \times V_o) = 380 / (2 \times 12) \approx 16$
- › $L_m = 195 \mu H$
- › $L_r = 15.5 \mu H$
- › $L_n = L_m / L_r = 12.5$
- › $C_r = 66 nF$

$$f_o = \frac{1}{2\pi \cdot \sqrt{L_r \cdot C_r}} = 157 kHz$$

$$f_p = \frac{1}{2\pi \cdot \sqrt{(L_r + L_m) \cdot C_r}} = 42.7 kHz$$

Gain curves

DC - gain curve (600 W LLC hardware revision P6)



Energy related calculations (Ref. IPP60R190P6 device parameters)

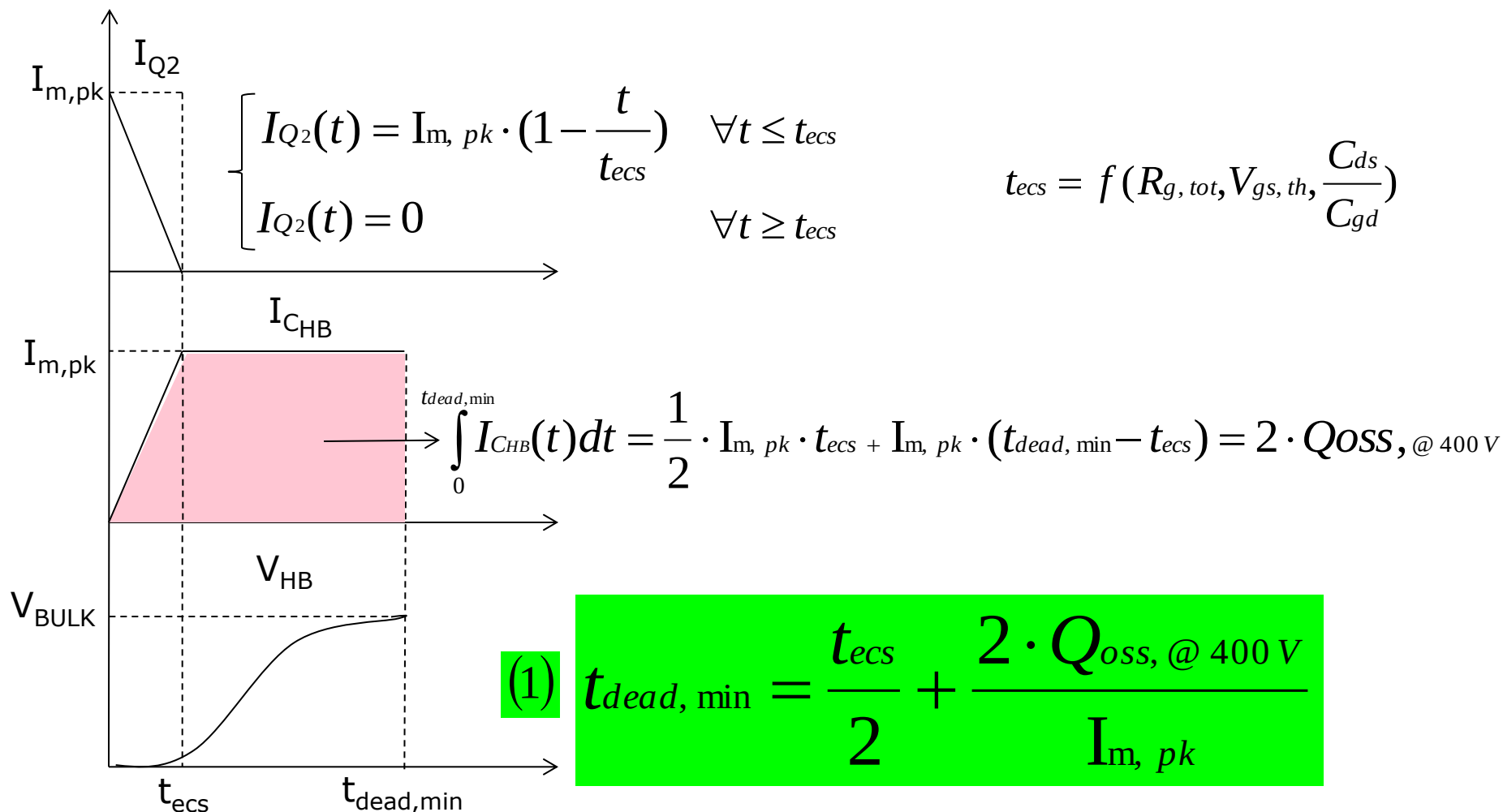
$$I_{mag\_min} = \frac{2 \cdot \sqrt{2}}{\pi} \cdot \frac{n \cdot V_o}{2\pi \cdot f_{sw\_max} \cdot L_m} = 0.672 \text{ A}$$

$$En_{res\_min} = \frac{1}{2} \cdot (L_m + L_r) \cdot I_{mag\_min}^2 = 95.1 \mu J$$

$$En_{cap\_max} = \frac{1}{2} \cdot (2Co(er)) \cdot V_{DS\_max}^2 \approx 9 \mu J$$

$$\Rightarrow En_{res\_min} > En_{cap\_max}$$

$Q_{oss}, I_{mag}, p_k, t_{dead,min}, t_{ecs}$ relationship



Time related calculations

(Ref. IPP60R190P6 device parameters)

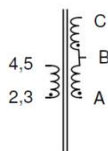
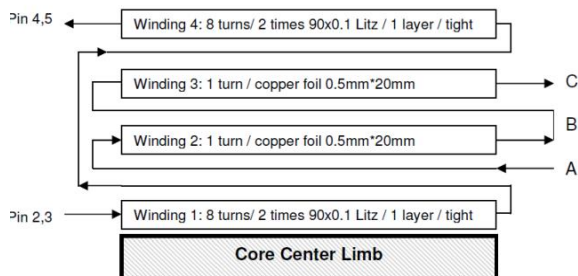
$$I_{mag\_min} = \frac{2 \cdot \sqrt{2}}{\pi} \cdot \frac{n \cdot V_o}{2\pi \cdot f_{sw\_max} \cdot L_m} = 0.672 \text{ A}$$

$$I_{mag\_max} = \frac{2 \cdot \sqrt{2}}{\pi} \cdot \frac{n \cdot V_o}{2\pi \cdot f_{sw\_min} \cdot L_m} = 1.66 \text{ A}$$

$$t_{dead, min} = \frac{t_{ecs}}{2} + \frac{2 \cdot Q_{oss, @ 400V}}{I_{mag, max}} \approx 130 \text{ nsec}$$

$$t_{dead, max} = \frac{t_{ecs}}{2} + \frac{2 \cdot Q_{oss, @ 400V}}{I_{mag, min}} \approx 311 \text{ nsec}$$

Core form and material	PQ35/35, PC95 (TDK)
Bobbin	Epcos, B65882E0012T001
Primary inductance L_p	195uH, measured between 2,3 and 4,5, other pins open
Leakage inductance L_k	1.5uH, measured between 2,3 and 4,5, other pins shorted
Isolation voltage V_{iso}	2500V _{rms} / 50Hz, 1min (between 2,3,4,5 and A,B,C)



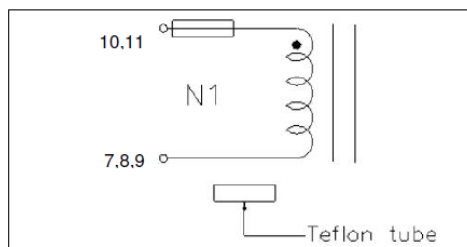
Windings	Start	End	Wire	Turns	Layers	Method
1	2,3	Float	2 times 90x0.1mm Litz	8	1	Tight
2	A	B	0.5mm*20mm copper foil	1	1	Tight
3	B	C	0.5mm*20mm copper foil	1	1	Tight
4	Float	4,5	2 times 90x0.1mm Litz	8	1	Tight

Customer : Infineon Technologies	Part designation : SP-PQ 35/35	Customer part number :
Core / material / air gap		PQ35/35 / K2008 or equiv. / 0,25
Nominal inductance		LI+LVI = 195µH ± 15%
Ratio of transformation		8 : 1 : 1 : 8
Dielectric strength (50Hz/1s)		2,5kV (prim - sec)
Leakage inductance		max. 3µH
Operating temperature		-25°C - +125°C
Storage temperature		-25°C - +85°C
Humidity- / application class		F (DIN 40040)

Resonant choke: RM12 core, material N87

LLC resonant choke

Core form and material	RM12, N87 (Epcos)
Bobbin	Epcos, B65816C1512T001
Inductance L	14uH



Windings	Start	End	Wire	Turns	Layers	Method
N1	7,8,9	10,11	120x0.1mm Litz	9	1	Tight

Technical Data Sheet		
Customer : Infineon Technologies	Part designation : SP-RM 12	Customer part number :
	Core / material / air gap	RM12 / K2008 or equiv. / 1,1
	Nominal inductance	L = 14μH ± 15%
	Operating temperature	-25°C - +125°C
	Storage temperature	-25°C - +85°C
	Humidity- / application class	F (DIN 40040)

Support slides 600 W LLC evaluation board

Evaluation board page

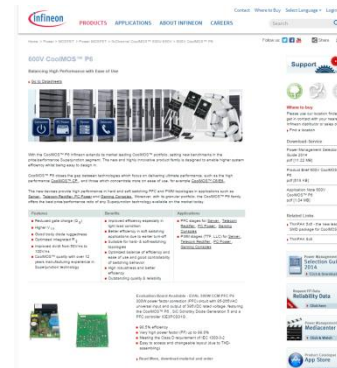
- Technical description
- Datasheets
- Parameters
- Related material
- Videos



- www.infineon.com/600w-llc-evaluationboard-a
- www.infineon.com/600w-llc-evaluationboard-d

Product family pages

- Product brief
- Application notes
- Selection guides
- Datasheets and portfolio
- Videos
- Simulation models



- www.infineon.com/p6
- www.infineon.com/xmc
- [Resonant Mode Controller](http://www.infineon.com/Resonant Mode Controller)
- www.infineon.com/optimos5-40v60v



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