600W Halfbridge LLC Evaluation Board

EVAL 12V 600W LLC analog
EVAL 12V 600W LLC digital

Table of Contents

- General Description
- Efficiency Results
- Design Concept

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

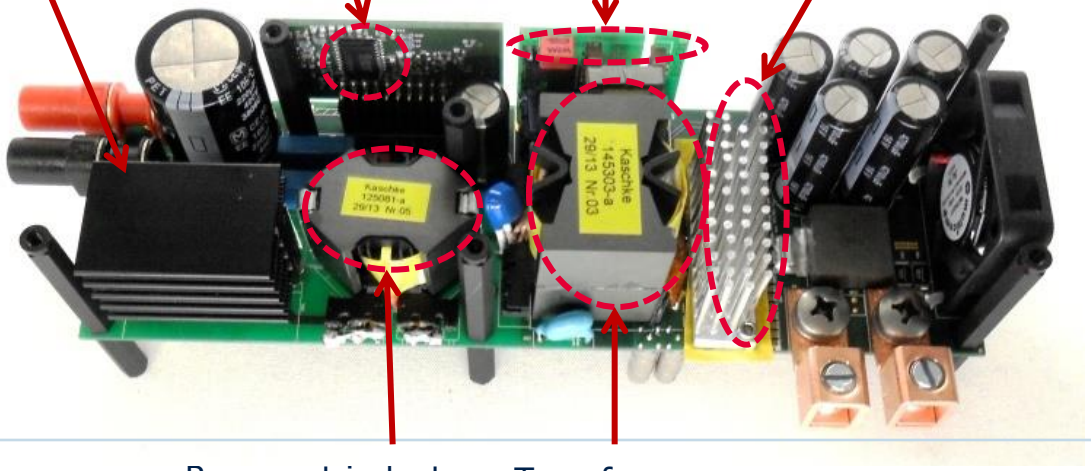
Primary HV MOSFETs
- **CoolMOS™ IPP60R190P6**
- Reduced Gate Charge (Q_g)
- Reduced E_{off}
- High body diode ruggedness

SR MOSFETs
- **OptiMOS™ BSC010N04LS**
- New generation
- Best FOM $R_{DS(on)}$ x Q_g
- Best FOM $R_{DS(on)}$ x Q_{oss}

LLC analog controller
ICE2HS01G
or digital controller
XMC4200
HB Gate Drive IC
2EDL05N06PF

Bias QR Flyback controller
ICE2QR2280Z

SR MOSFETs
BSC010N04LS



Resonant inductor
RM12 core

Transformer
PQ35/35 core

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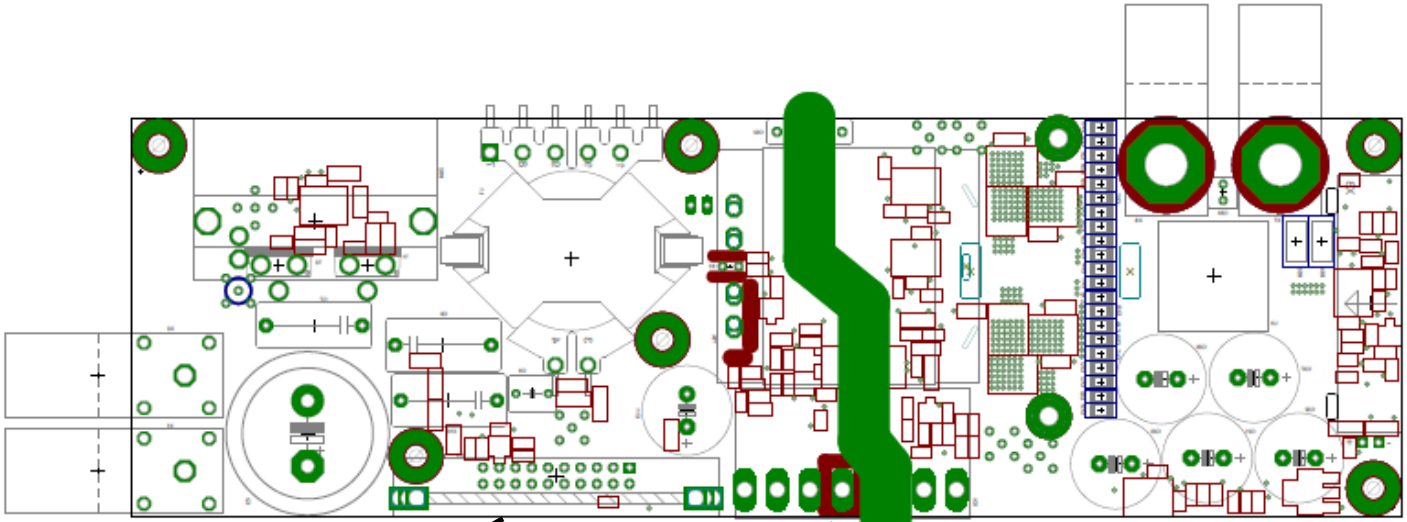
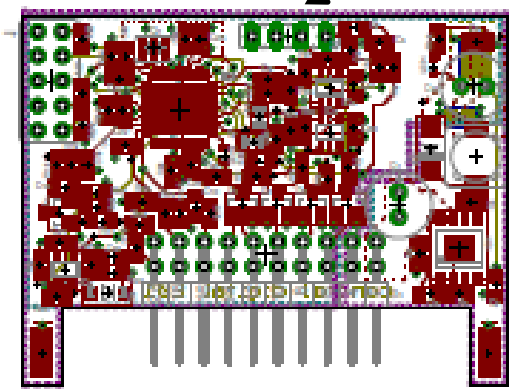
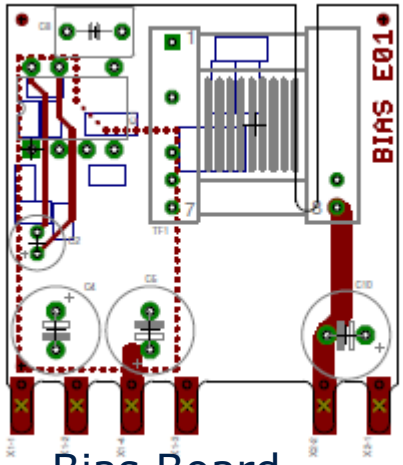
PCB Boards Layout: Main Power Board and Control and Bias Daughter Boards





Controller Board



Bias Board

- Power Density>20W/inch^3

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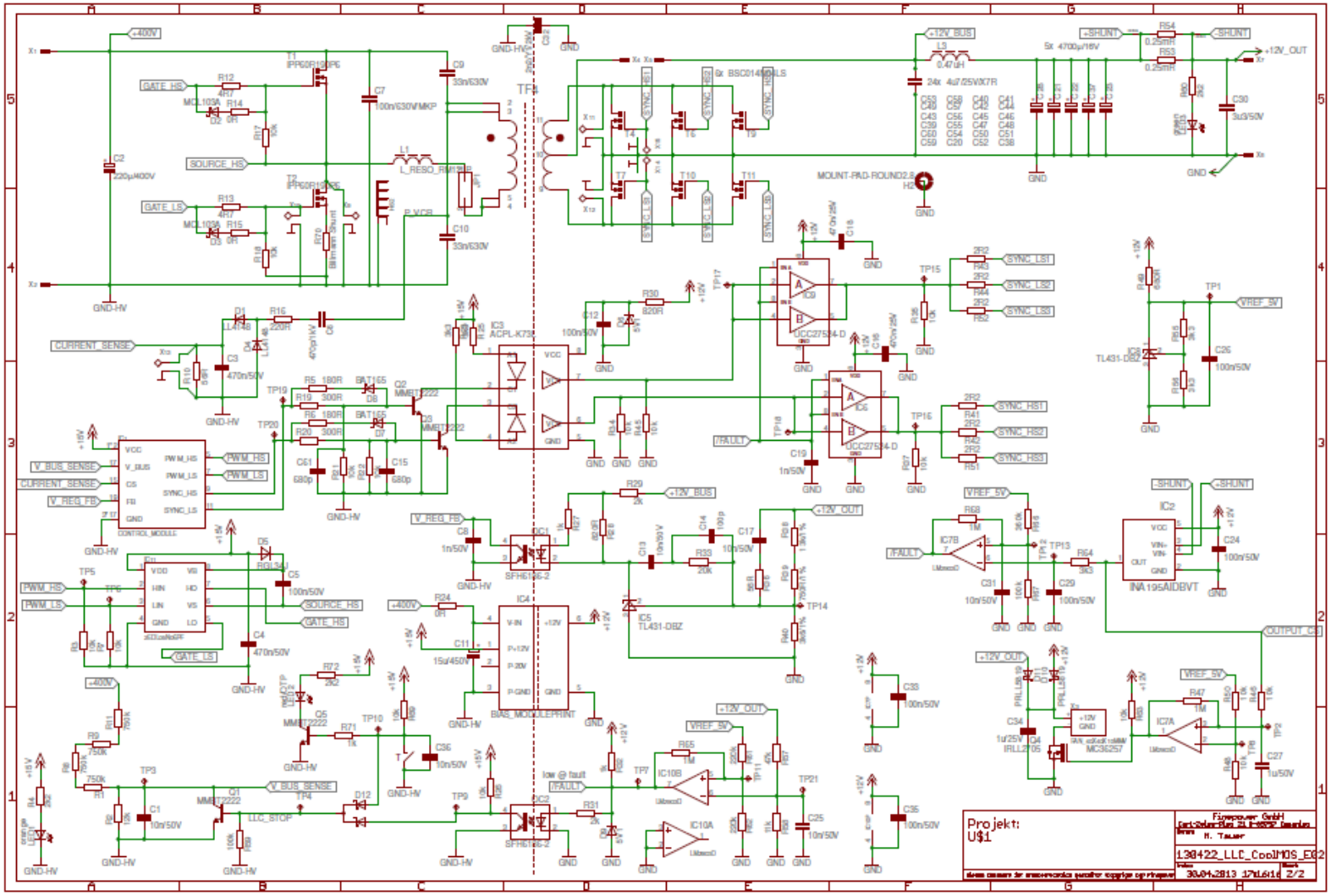
Main Power Board Schematic



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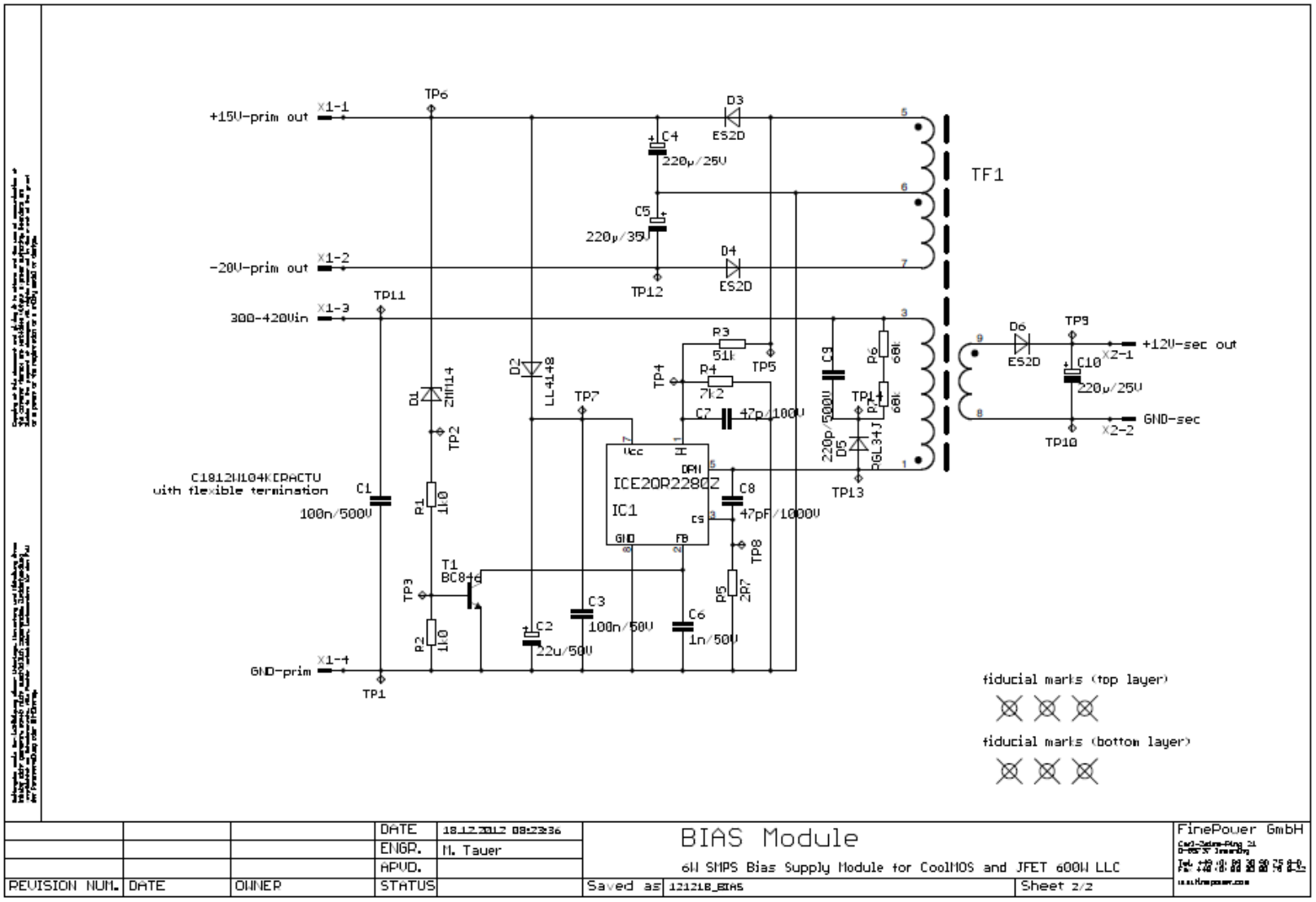
Bias Board Schematic



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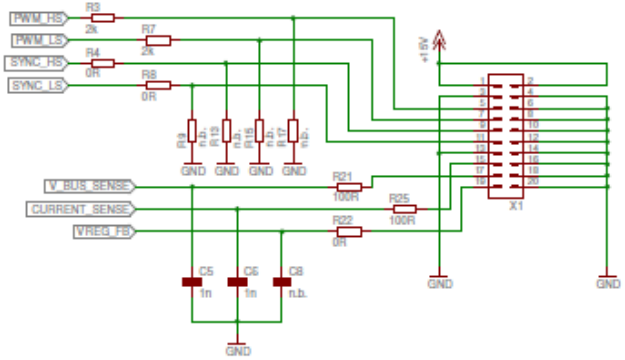
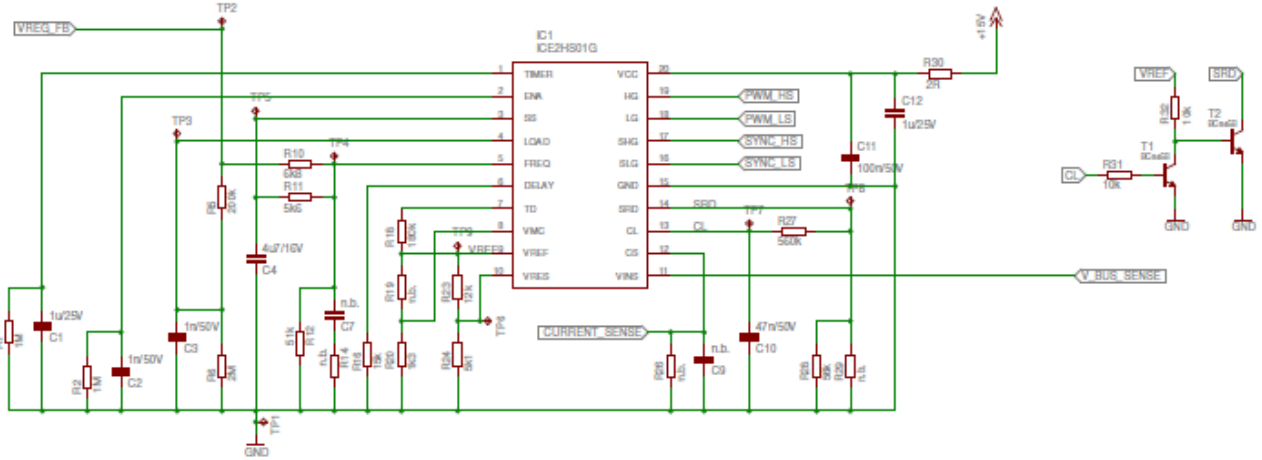
Analog Control Board Schematic





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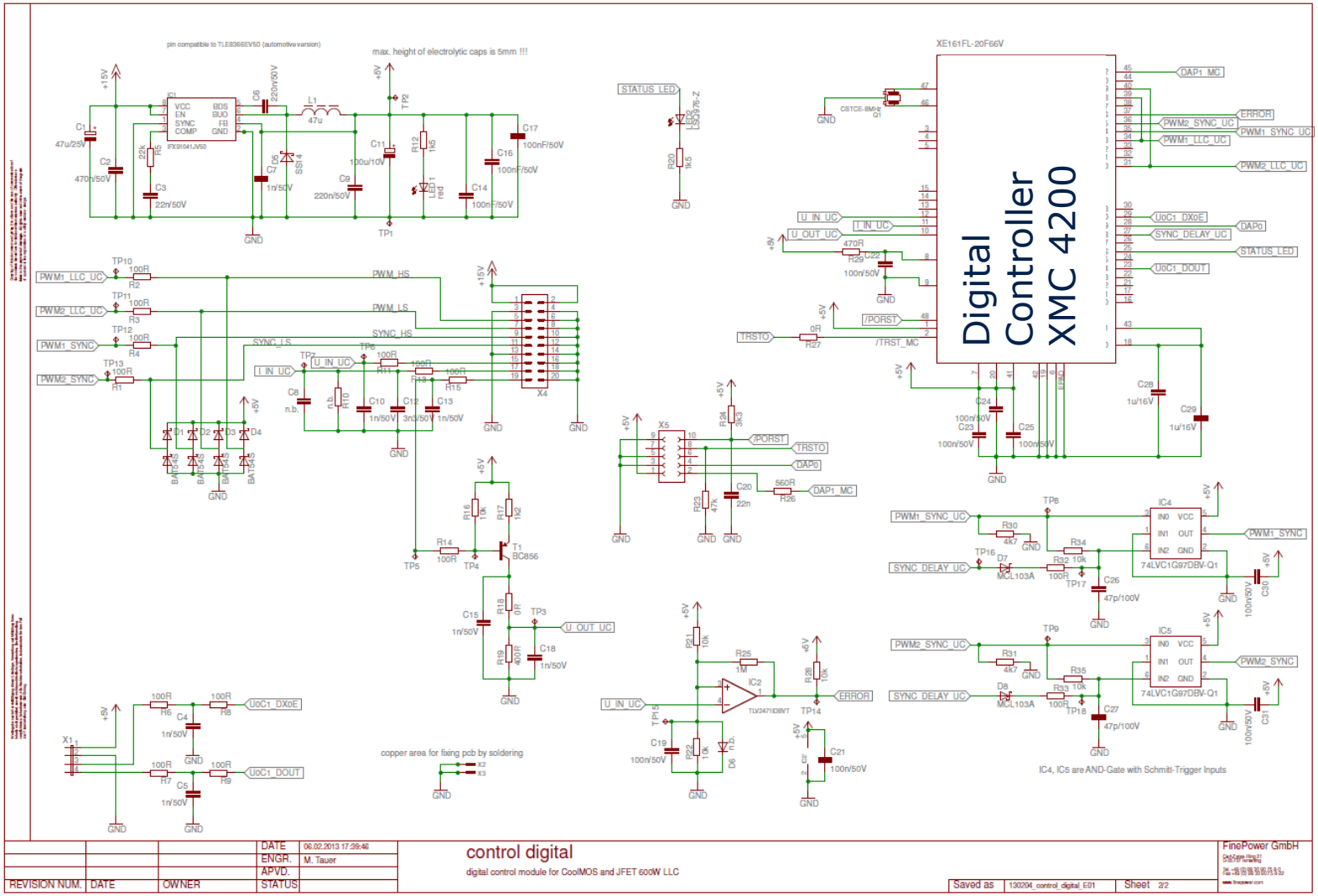
Digital Control Daughter Board Schematic



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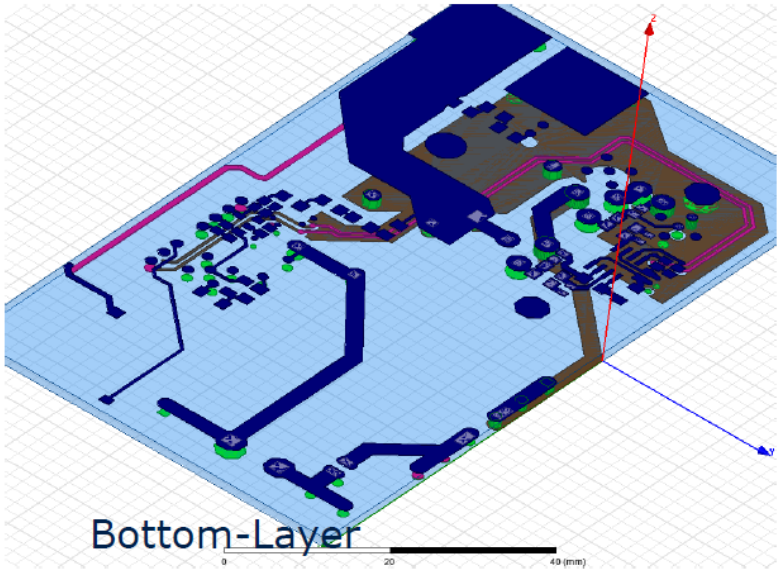
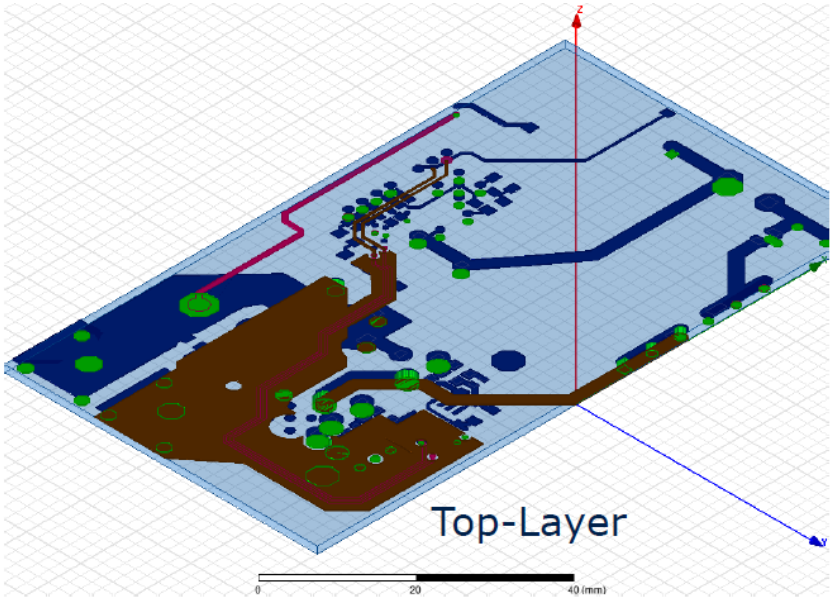
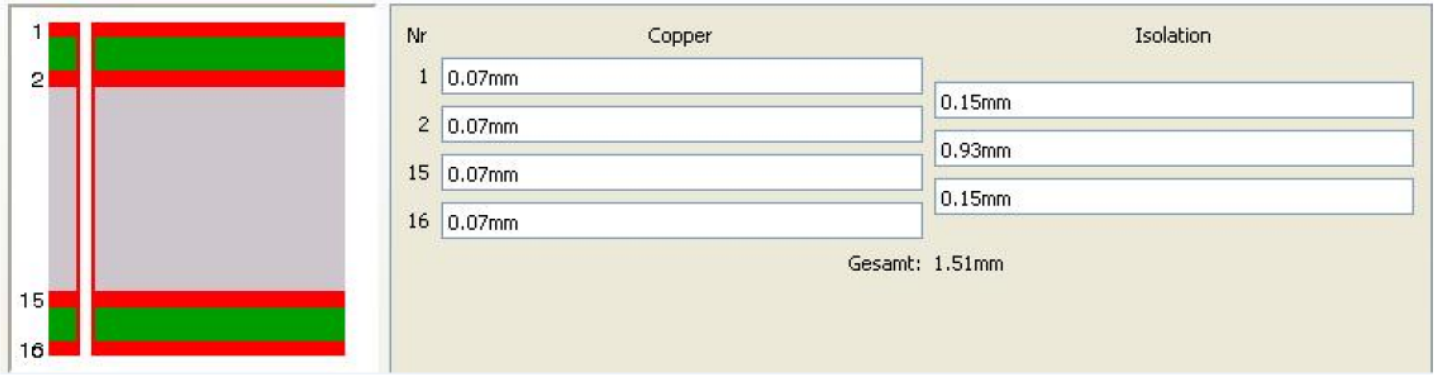
PCB structure





PCB-Stackup



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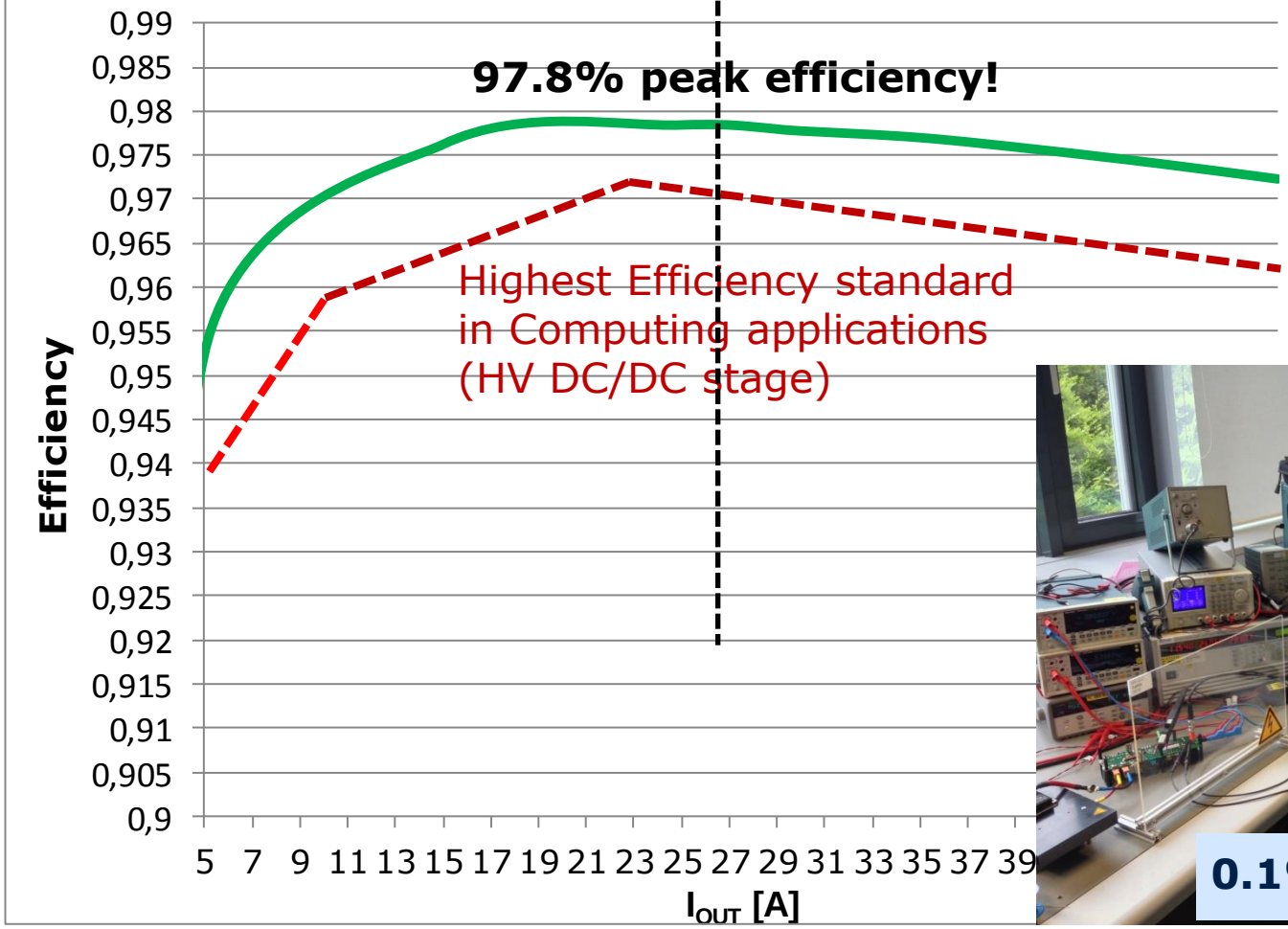
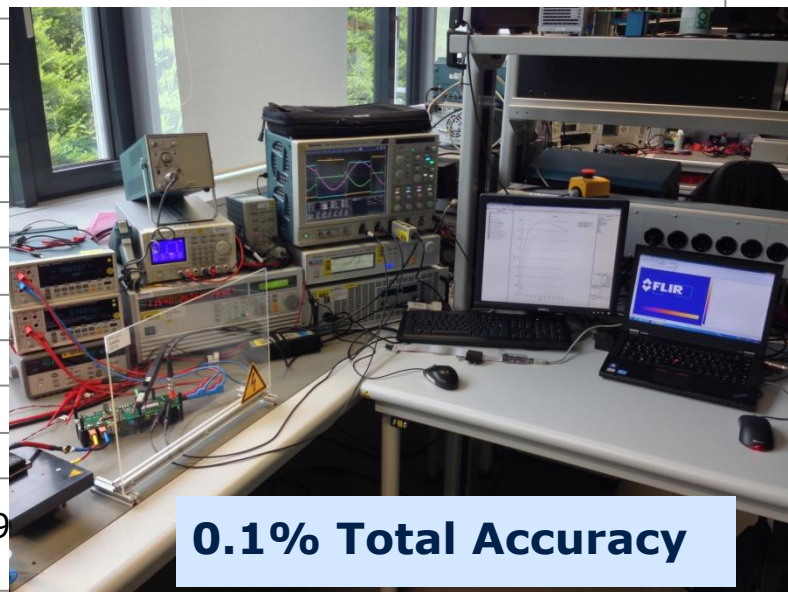
Automated Efficiency Measurement

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

Proper selection of SR LV device and secondary side design





0.1% Total Accuracy

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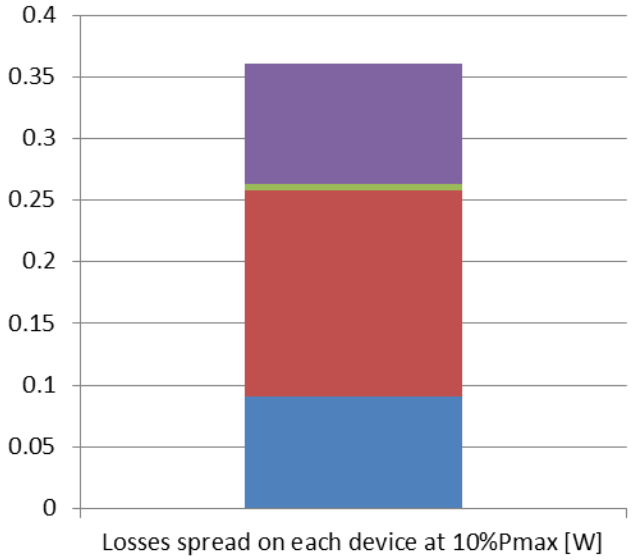
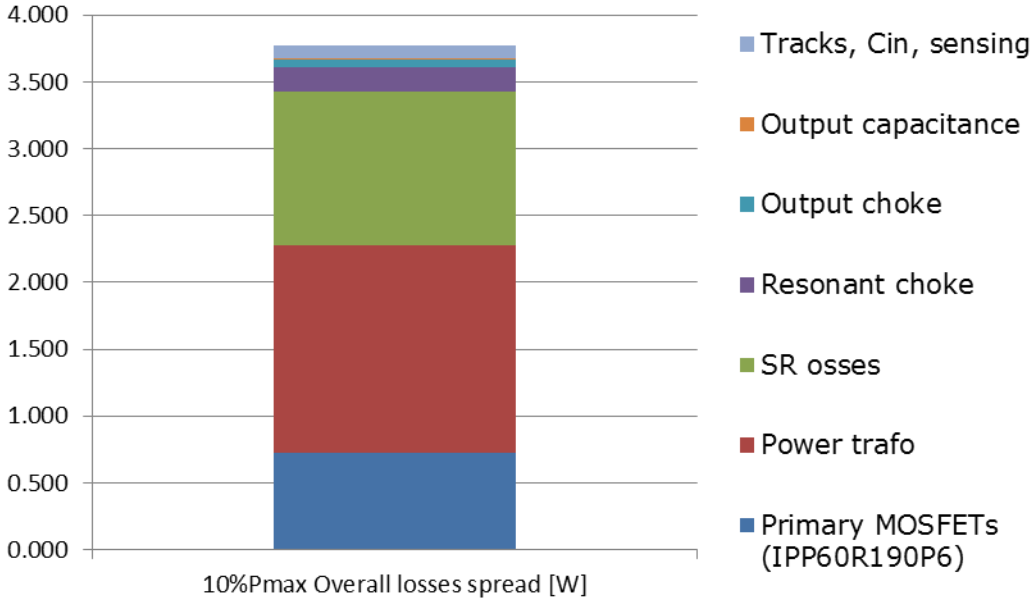
10%P_{max} V_{in}=380V_{dc}





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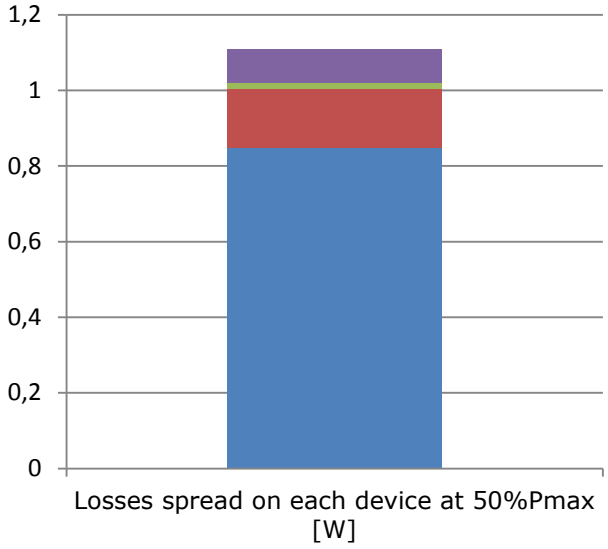
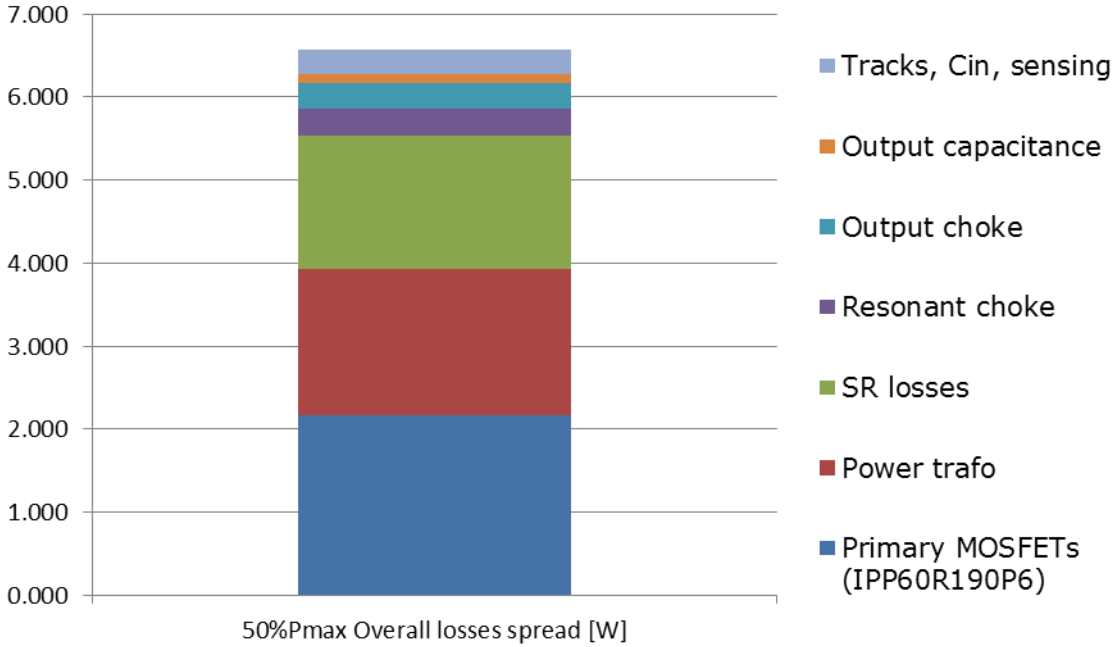
50%P_{max} V_{in}=380V_{dc}





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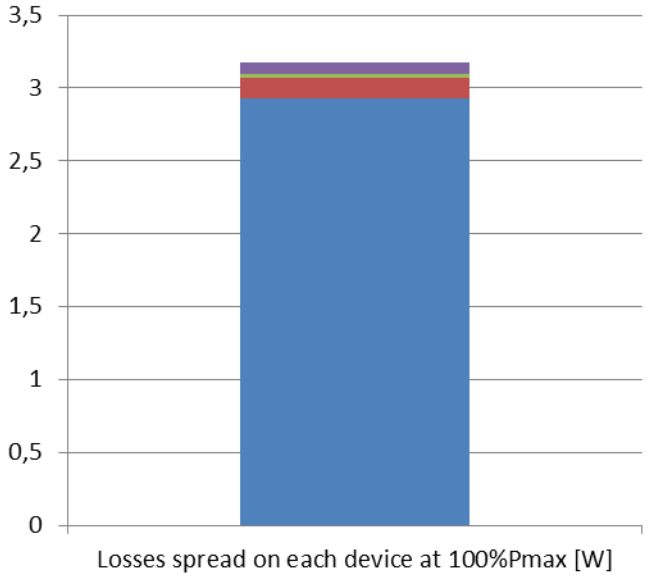
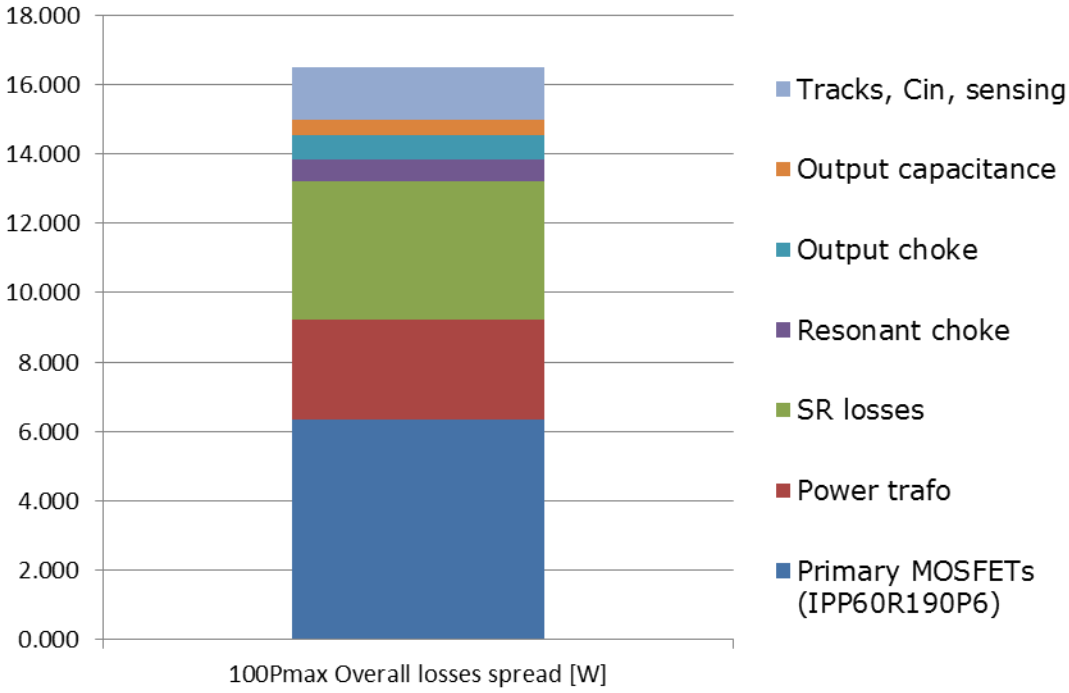
100%P_{max} V_{in}=380V_{dc}





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Design Procedure: Input Data

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

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

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

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Resonant Tank Components and Related Resonant Frequencies

- $n=V_{in\_nom}/(2xV_o)=380/(2*12)\approx16$
- $L_m=195\mu H$
- $L_r=15.5\mu H$
- $L_n=L_m/L_r=12.5$
- $C_r=66nF$

$$fo=\frac{1}{2\pi\cdot\sqrt{Lr\cdot Cr}}=157kHz$$

$$fp=\frac{1}{2\pi\cdot\sqrt{(Lr+Lm)\cdot Cr}}=42.7kHz$$

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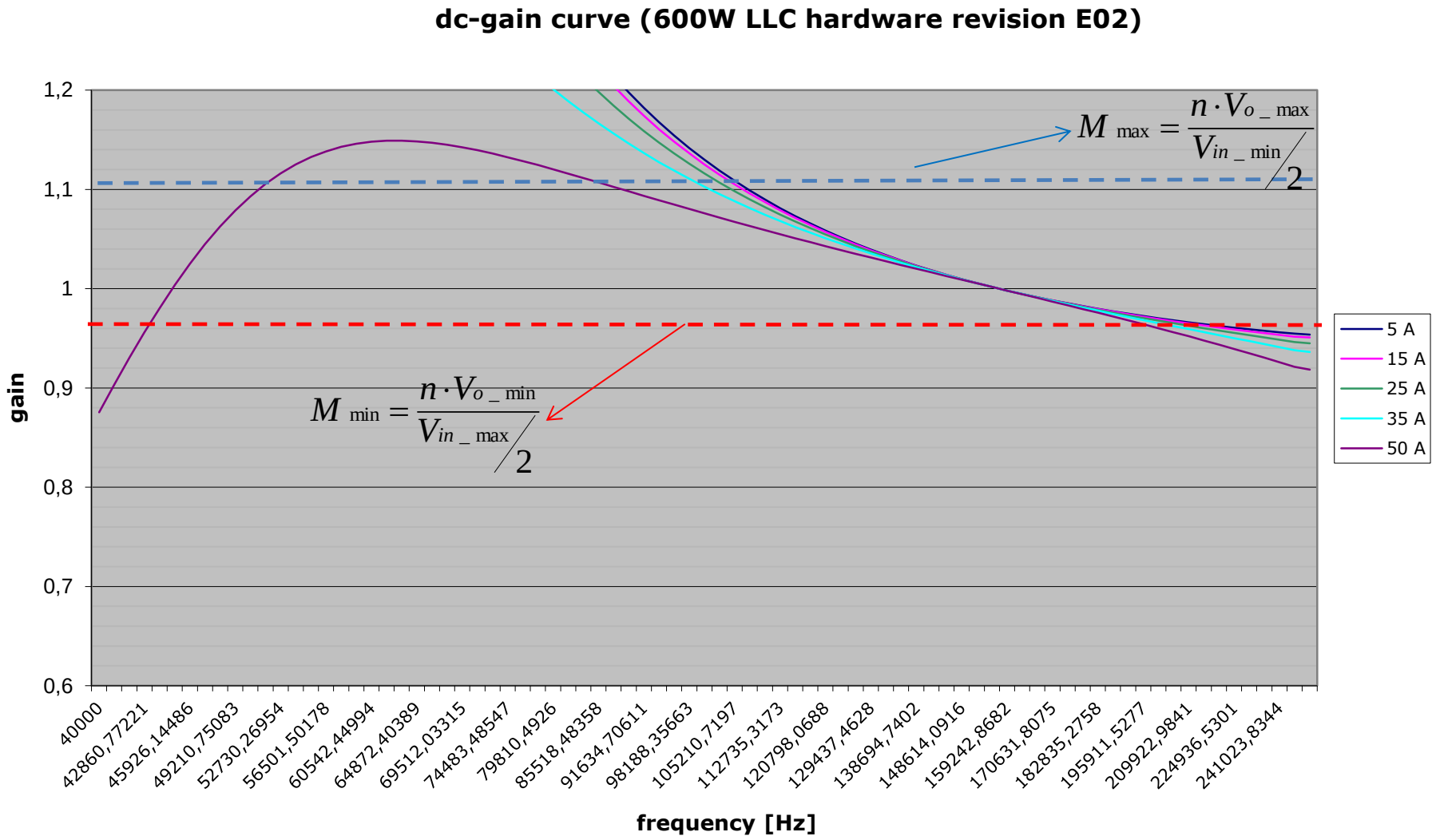
Gain Curves



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Energy Related Calculations (Ref. IPP60R190P6 Device Parameters)

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

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

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

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

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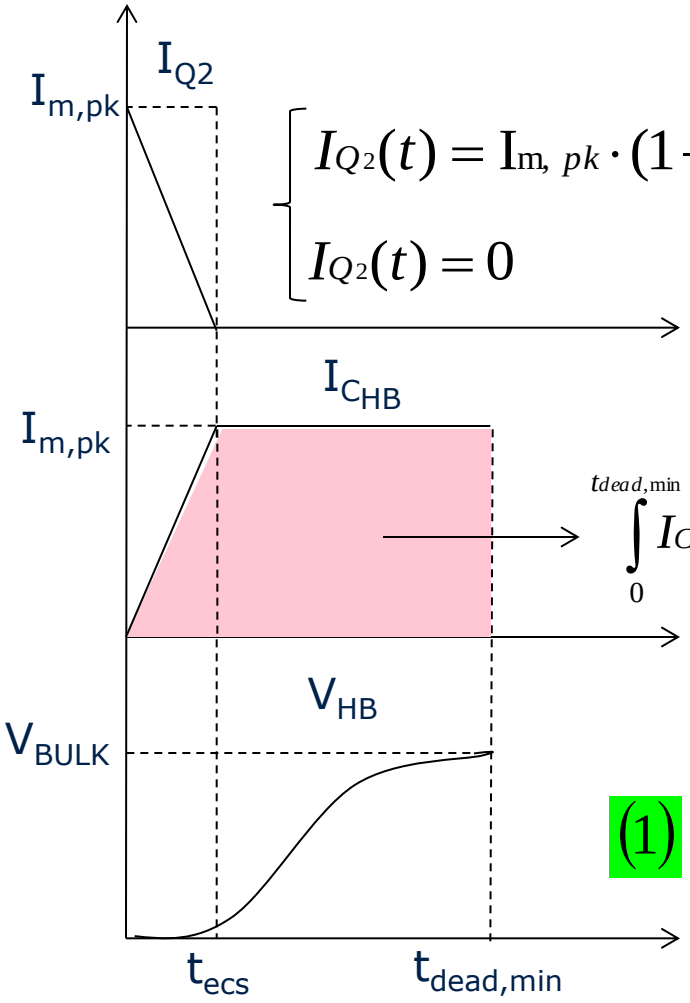
Q_{oss}, $I_{mag,pk}$, $t_{dead,min}$, t_{ecs} Relationship



$$\begin{cases} I_{Q2}(t) = \mathrm{I}_{m,\ pk} \cdot (1 - \dfrac{t}{t_{ecs}}) & \forall t \le t_{ecs} \\ I_{Q2}(t) = 0 & \forall t \ge t_{ecs} \end{cases}$$

$$t_{ecs} = f(R_{g,\,tot}, V_{gs,\,th}, \frac{C_{ds}}{C_{gd}})$$

$$\int_0^{t_{dead,\min}} I_{CHB}(t)dt = \frac{1}{2} \cdot \mathrm{I}_{m,\ pk} \cdot t_{ecs} + \mathrm{I}_{m,\ pk} \cdot (t_{dead,\,\min} - t_{ecs}) = 2 \cdot Qoss_{,\,@\,400V}$$

(1)

$$t_{dead,\,\min} = \frac{t_{ecs}}{2} + \frac{2 \cdot Q_{oss,\,@\,400V}}{\mathrm{I}_{m,\ pk}}$$

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Time Related Calculations (Ref. IPP60R190P6 Device Parameters)

$$\mathrm{Im}\,ag\_\min = \frac{2\cdot\sqrt{2}}{\pi}\cdot\frac{n\cdot V_o}{2\pi\cdot f_{sw\_\max}\cdot L_m} = 0.672A$$

$$\mathrm{Im}\,ag\_\max = \frac{2\cdot\sqrt{2}}{\pi}\cdot\frac{n\cdot V_o}{2\pi\cdot f_{sw\_\min}\cdot L_m} = 1.66A$$

$$t_{dead,\min} = \frac{t_{ecs}}{2} + \frac{2\cdot Q_{oss,@\,400V}}{\mathrm{Im}\,ag,\max} \approx 130n\,\mathrm{sec}$$

$$t_{dead,\max} = \frac{t_{ecs}}{2} + \frac{2\cdot Q_{oss,@\,400V}}{\mathrm{Im}\,ag,\min} \approx 311n\,\mathrm{sec}$$

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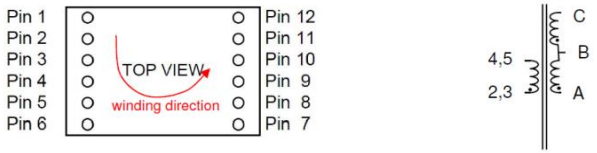
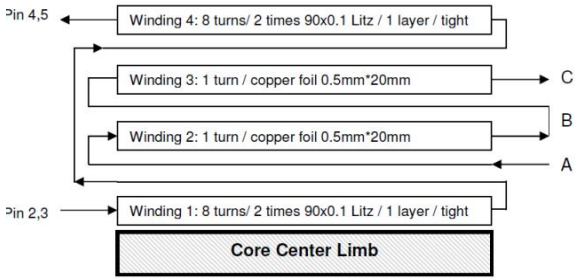
Main Transformer Structure: PQ35/35 Core with TDK PC95 Ferrite Material

LLC main transformer

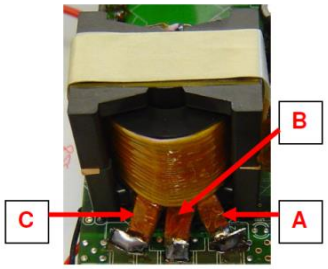
Core form and material	PQ35/35, PC95 (TDK)
Bobbin	Epcos, B65882E0012T001
Primary inductance L_p	195uH, measured between 2,3 and 4,5, other pins open
Leakage inductance L_{lk}	1.5uH, measured between 2,3 and 4,5, other pins shorted
Isolation voltage V_{iso}	2500V_{rms} / 50Hz, 1min (between 2,3,4,5 and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





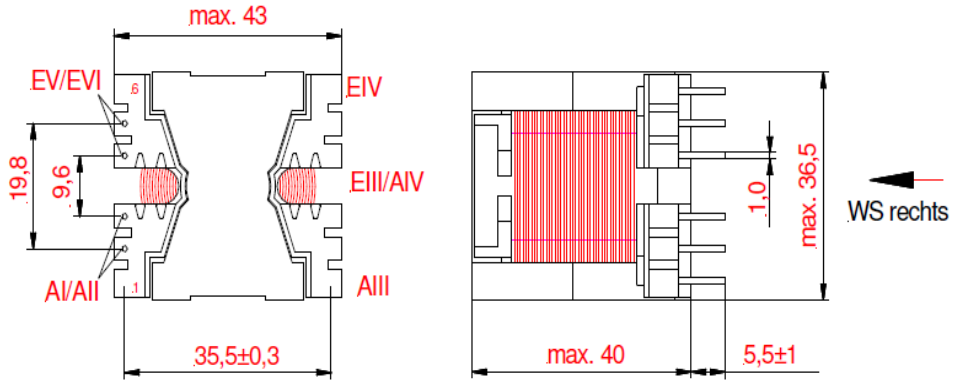
Windings	Start	End	Wire	Turns	Layers	Method
1	2,3	Float	2 times 90x0.1mm Litz	8	1	Tight
2	A	B	0.5mm*20mm copper foil	1	1	Tight
3	B	C	0.5mm*20mm copper foil	1	1	Tight
4	Float	4,5	2 times 90x0.1mm Litz	8	1	Tigh

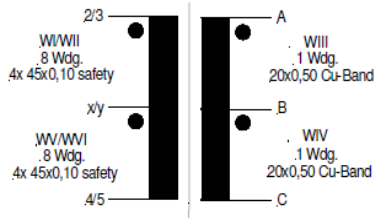
Connection of secondary copper foil:



Technical Data Sheet

Customer :	Part designation :	Customer part number :
Infineon Technologies	SP-PQ 35/35	





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)

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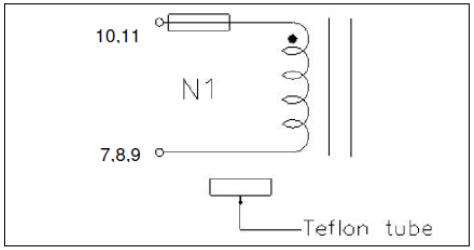
Resonant Choke: RM12 Core, Material N87

LLC resonant choke

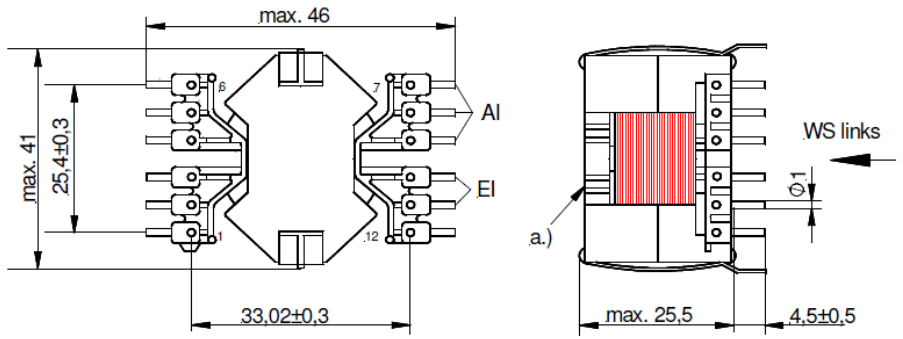
Core form and material	RM12, N87 (Epcos)
Bobbin	Epcos, B65816C1512T001
Inductance L	14uH

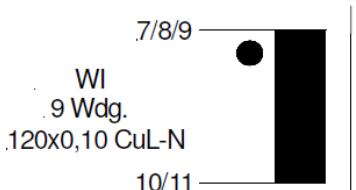


Windings	Start	End	Wire	Turns	Layers	Method
N1	7,8,9	10,11	120x0.1mm Litz	9	1	Tight

Technical Data Sheet

Customer :	*Part designation :*	*Customer part number :*
Infineon Technologies	**SP-RM 12**	





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)

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Support Slides
600W LLC Evaluation Board

Evaluation Board Page

- Technical Description
- Datasheets
- Parameters
- Related material
- Videos

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

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- Product Brief
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- Selection Guides
- Datasheets and Portfolio
- Videos
- Simulation Models

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- www.infineon.com/xmc
- Resonant Mode Controller
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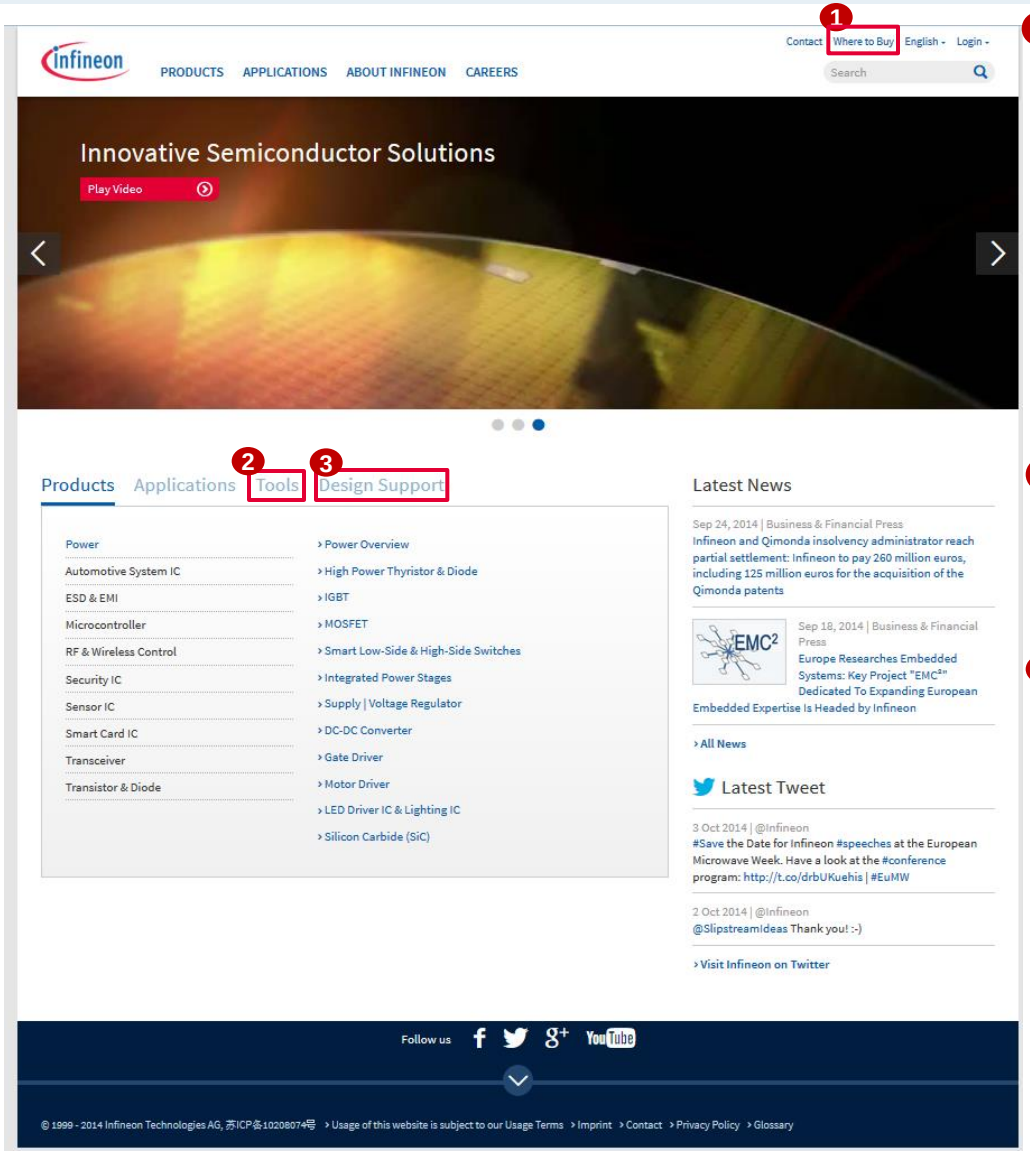
Online Tools and Services



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