

600 W Half-Bridge LLC evaluation board

EVAL_600W_LLC_12V_C7_D
digital & analog

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General

Description:

The **"EVAL_600W_LLC_12V_C7"** - evaluation board 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 latest CoolMOS™ technology [IPP60R180C7](#) 600 V 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](#), low-side Gate Driver [2EDN7524F](#) and a LLC Controller [ICE2HS01G](#) for the analog or [XMC4200](#) in the digital version.

Summary of features:

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



The following variants are available:

- › 600W 12V LLC **analog** version with CoolMOS™ C7, [IPP60R180C7](#), EVAL_600W_LLC_12V_C7
- › 600W 12V LLC **digital** version with CoolMOS™ C7, [IPP60R180C7](#), EVAL_600W_LLC_12V_C7_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™ IPP60R180C7
 Reduced gate charge (Q_g)

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

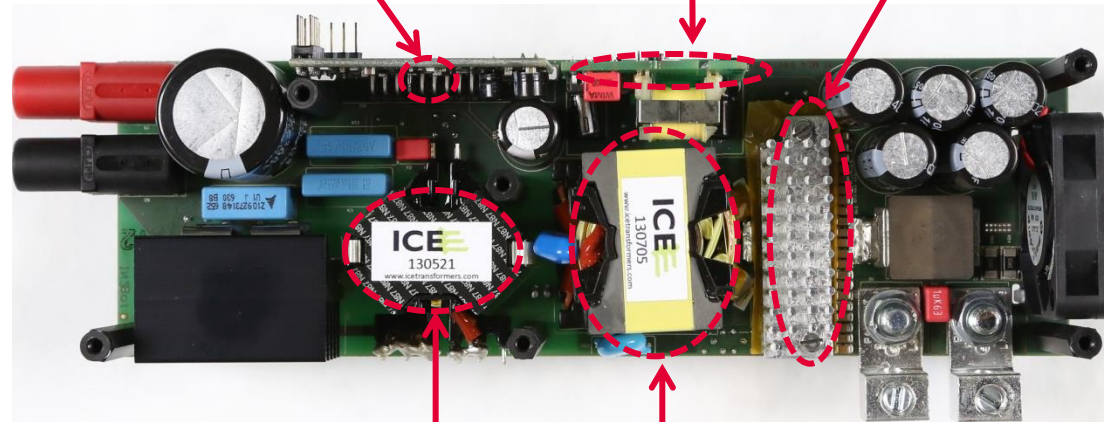
SR MOSFETs
OptiMOS™ BSC010N04LS
 New generation

- › 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

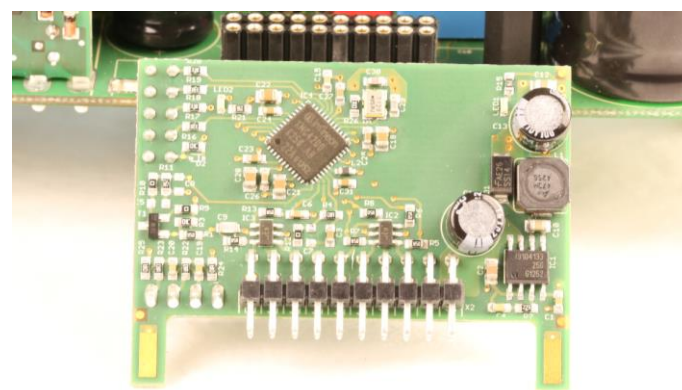
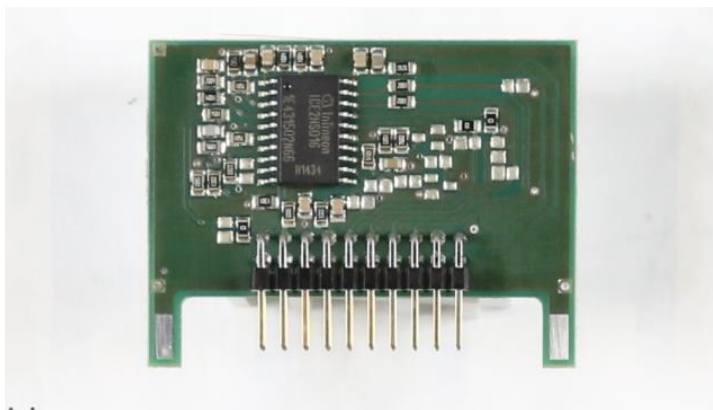
Two possible solution to control Infineon`s 600 W LLC evaluation board

Analog - ICE2HS01G

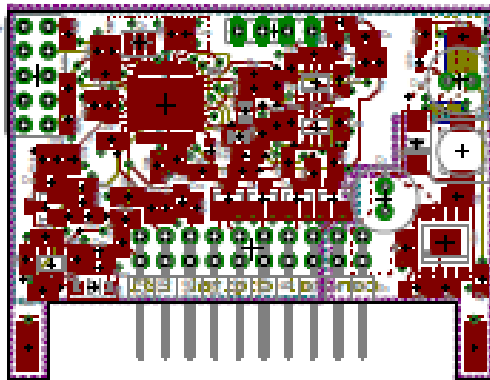
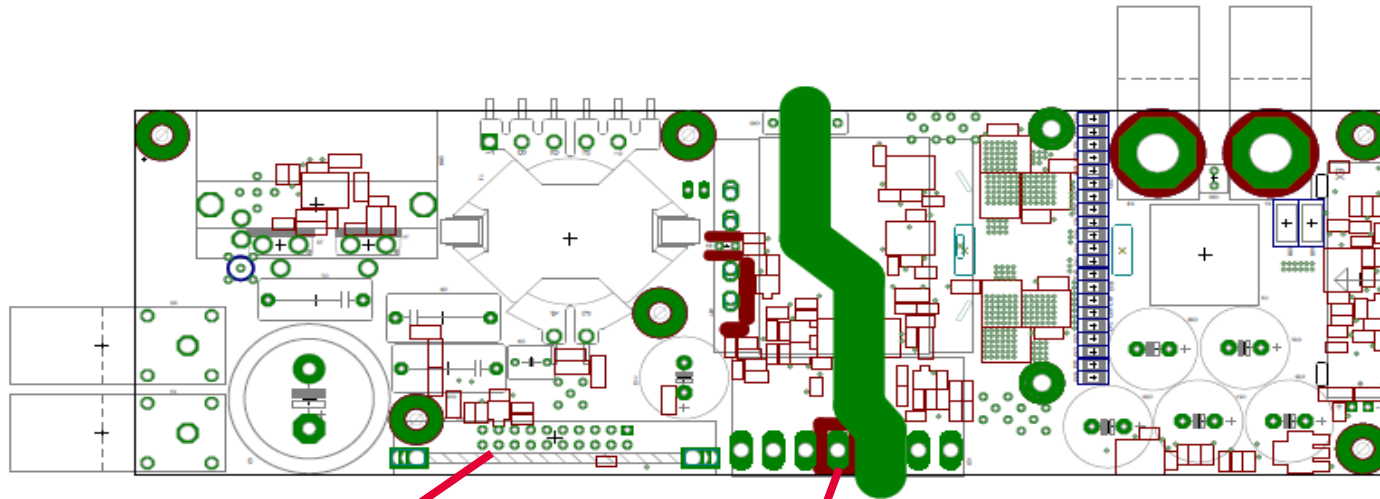
- › Resonant mode controller for Half-Bridge LLC resonant converter with synchronous rectification drives
- › Driving signal for synchronous rectification which support full operation of Half-Bridge LLC resonant converter
- › 20-pin DSO package
- › 30 kHz to 1MHz switching frequency
- › 50% duty cycle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

Digital - XMC4200-Q48K256 AB

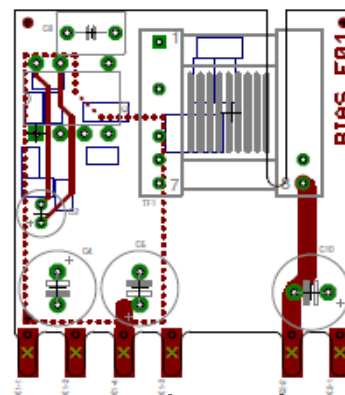
- › ARM® Cortex®-M4, 80 MHz, incl. single cycle DSP MAC and floating point unit (FPU)
- › 8-channel DMA + dedicated DMA for USB
- › USB 2.0 full-speed device
- › CPU Frequency: 80 MHz
- › eFlash: 256 kB including hardware ECC
- › 40 kB SRAM
- › Package: PG-LQFP-48



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



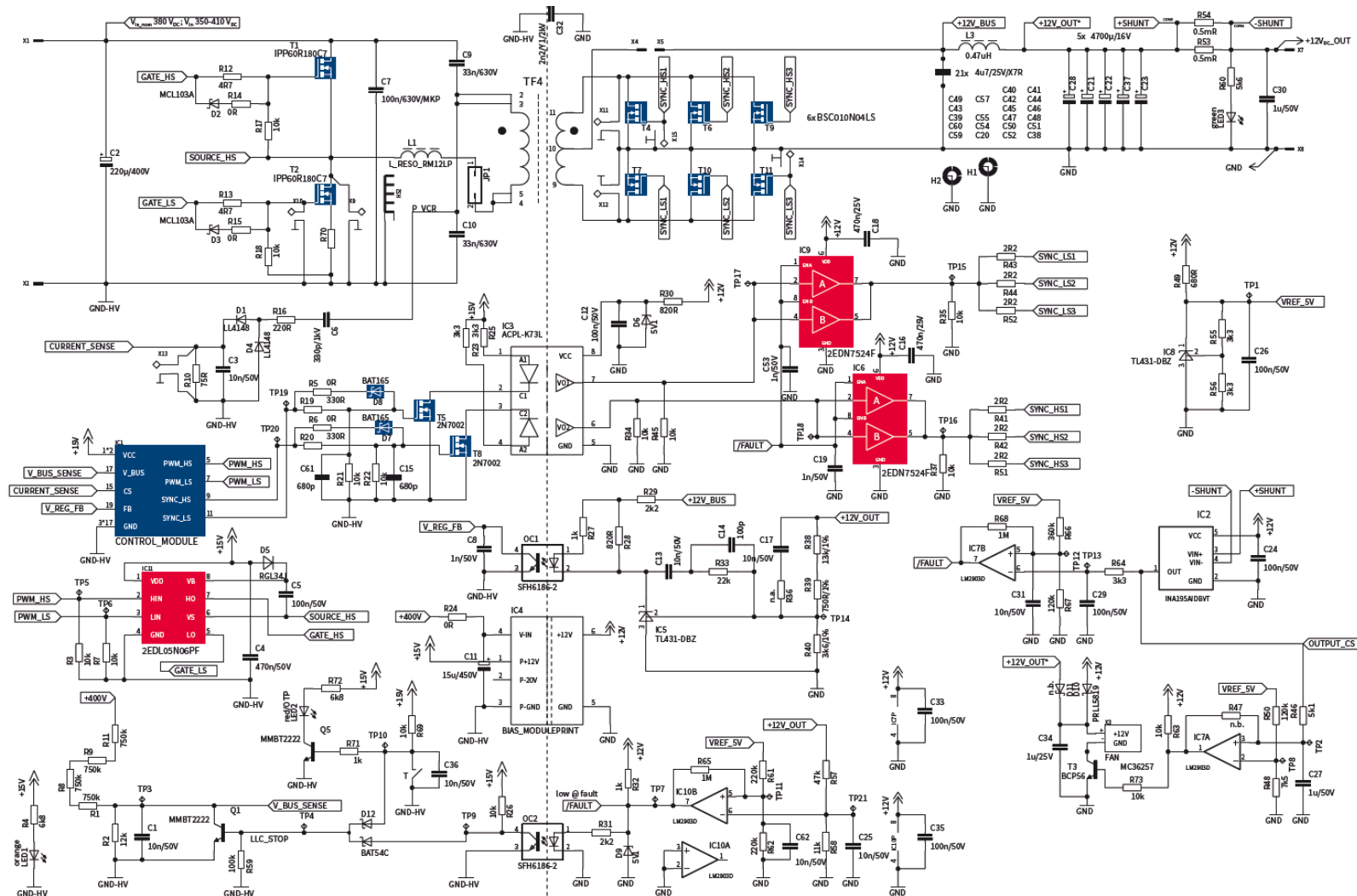
Controller board



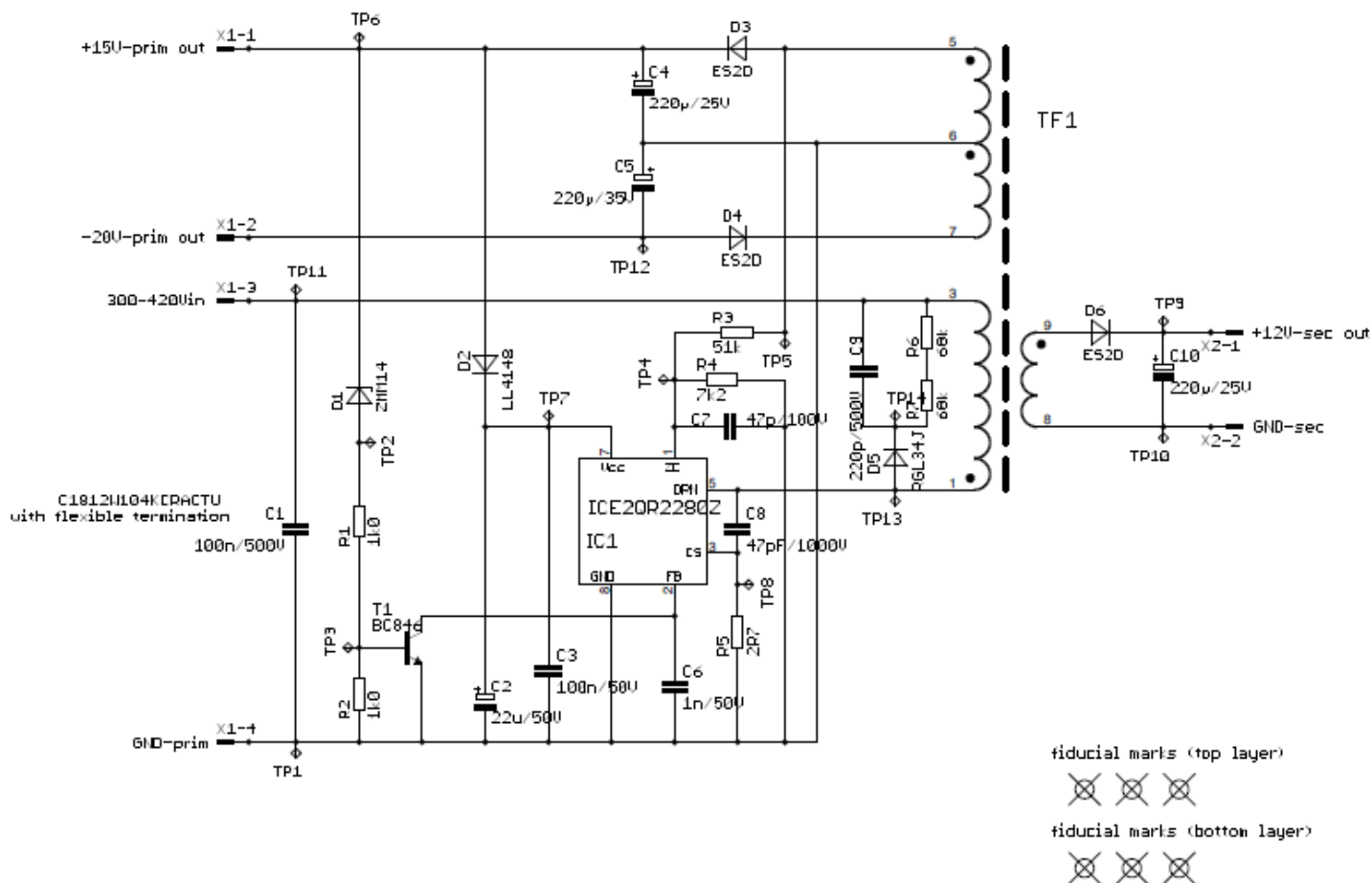
Bias board

- Power density $> 20 \text{ W/inch}^3$

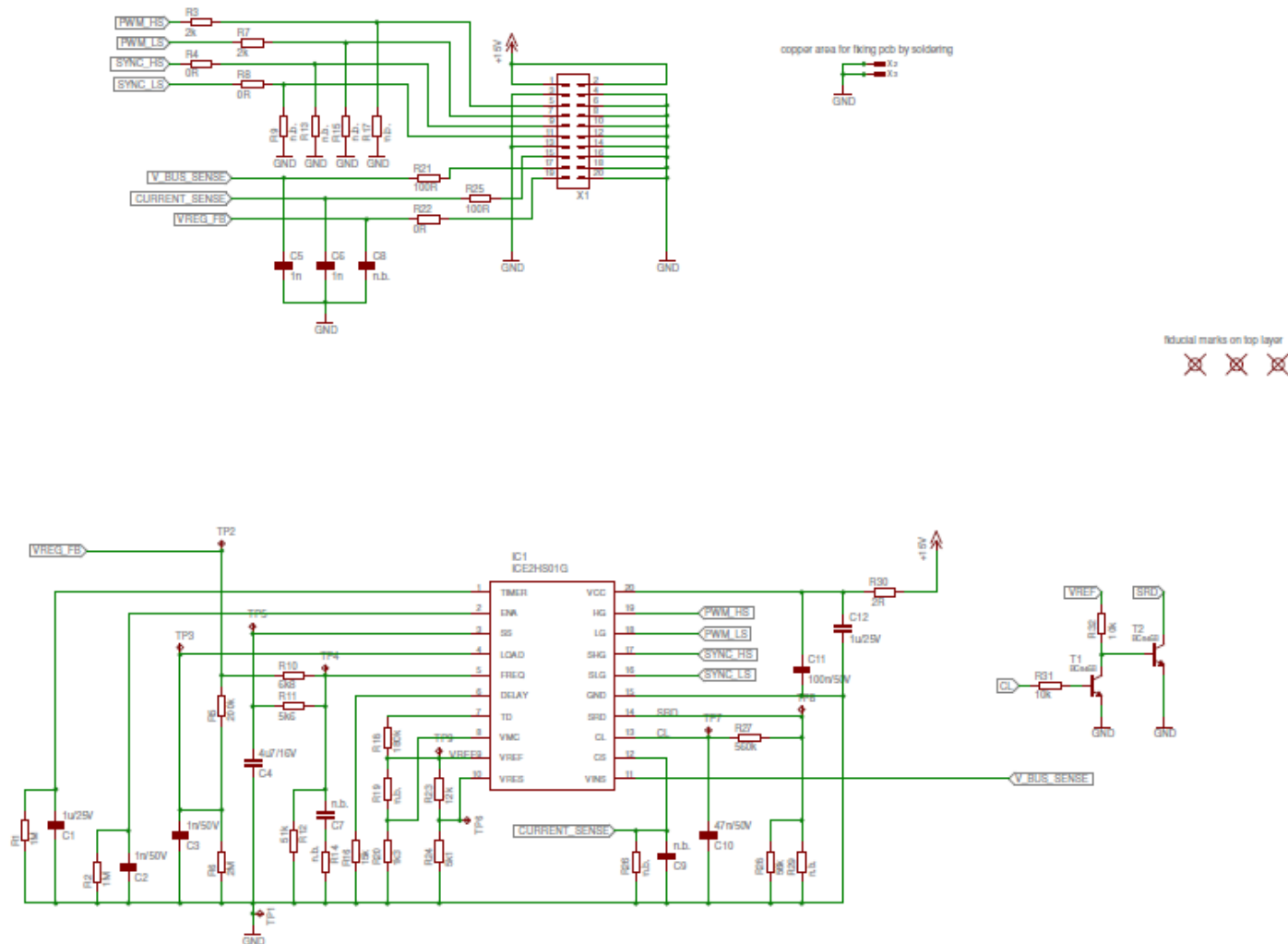
Main power board schematic (digital)



Bias board schematic

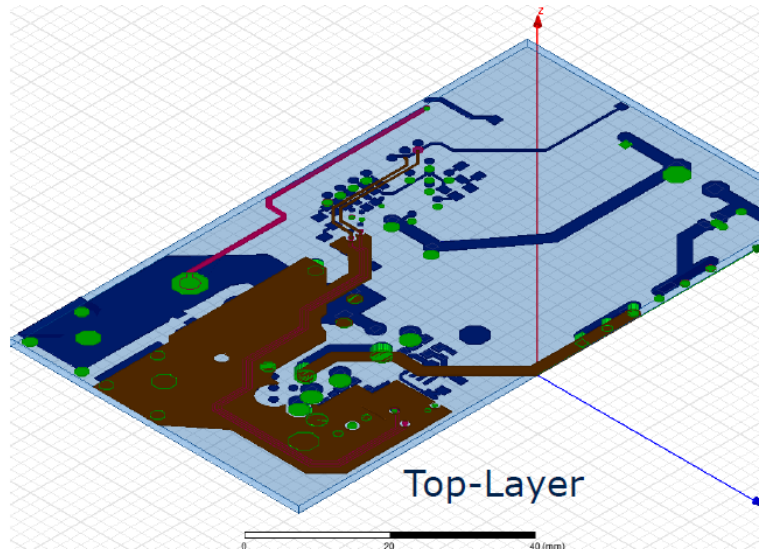
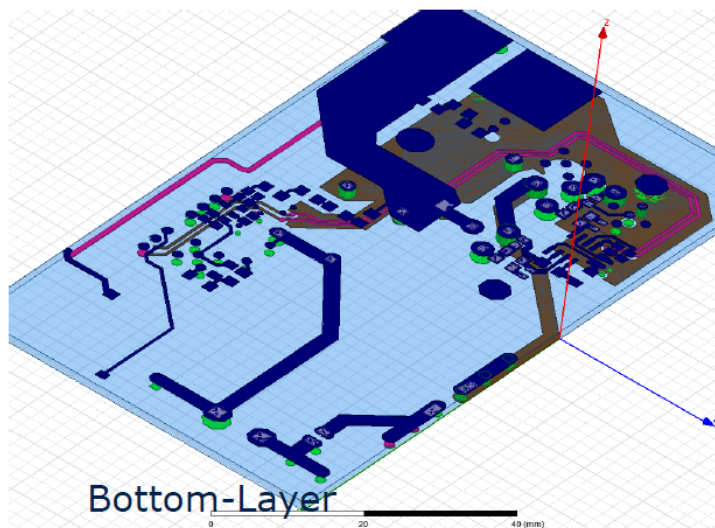


Analog control board schematic





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				

BOM (rework from digital to analog)

Part	Value	Pcs	Tolerance	Device	Package	Description	Assembling info	Supplier
C3	470n/50V	1		C-EU_C0805	C0805	CAPACITOR	Replace 10n/50V with 470n/50V	
R19	4K3	1	±1%	R-EU_R0805	R0805	RESISTOR	Replace 330R with 4K3	
R20	4K3	1	±1%	R-EU_R0805	R0805	RESISTOR	Replace 330R with 4K3	
R36	56R	1	±1%	R-EU_R0805	R0805	RESISTOR	Assemble n.a. with 56R	
IC1	Board	1		Board	PCB	Analog_Controlcard		IFX

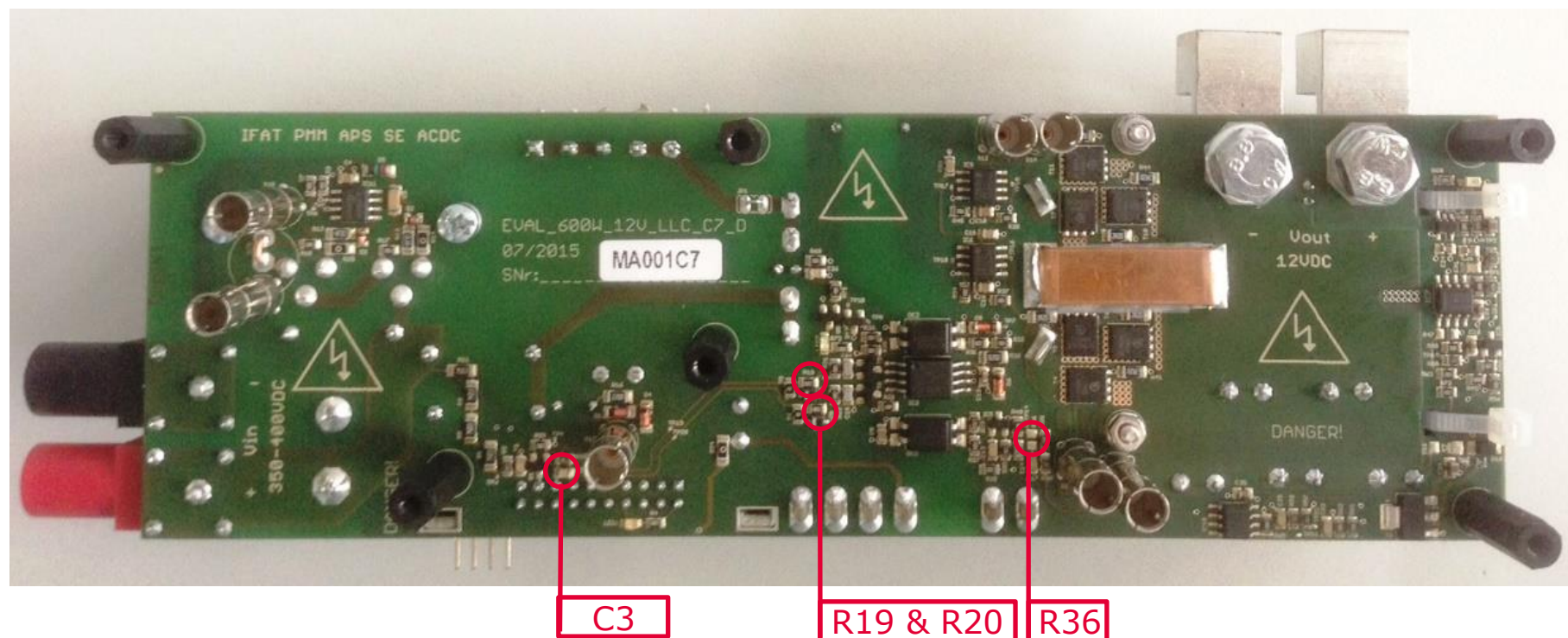


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I General description

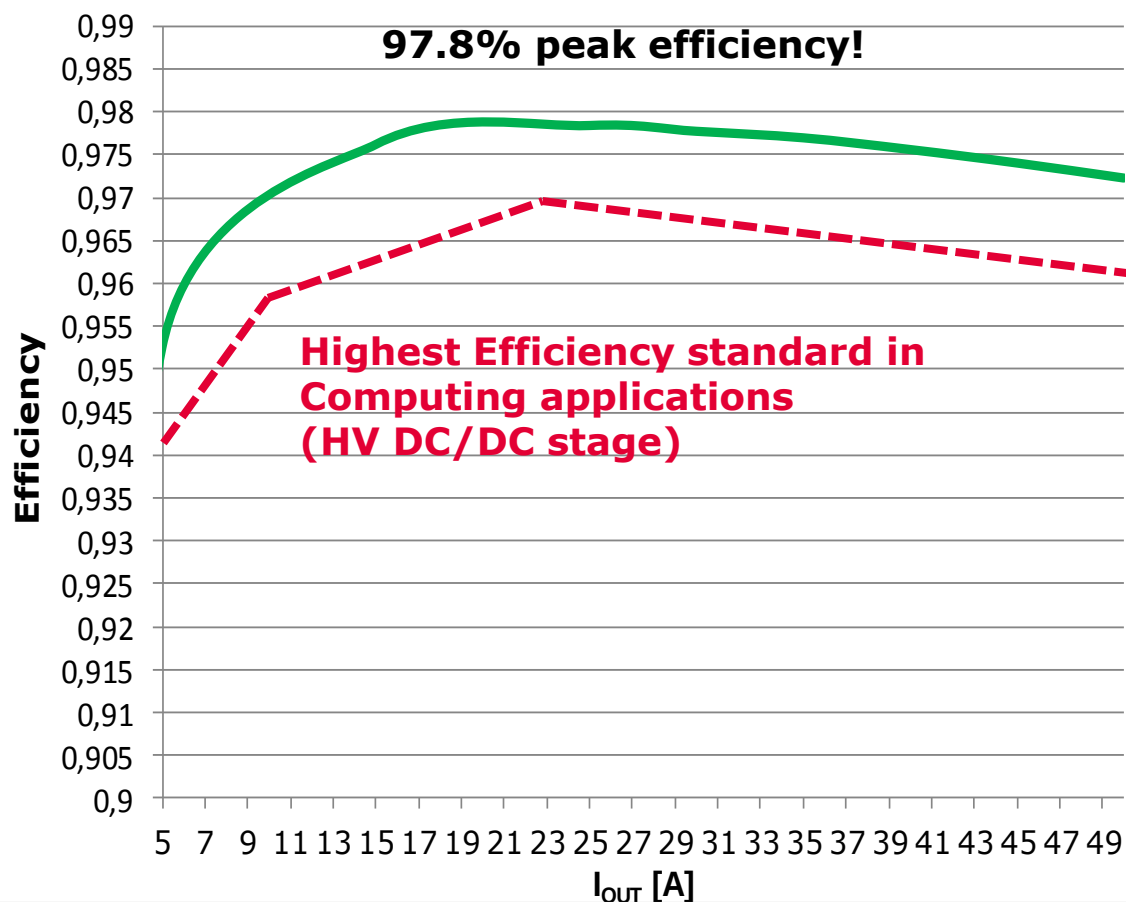
II Efficiency results

III Design concept

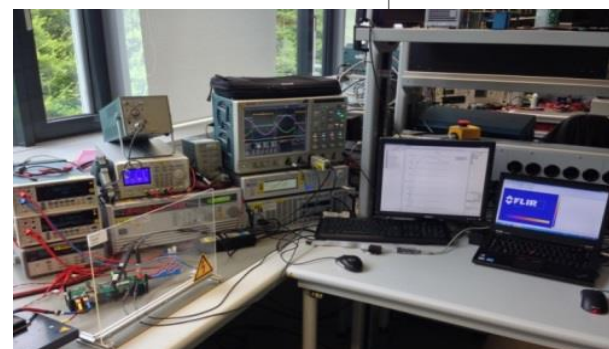
Automated efficiency measurement

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

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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

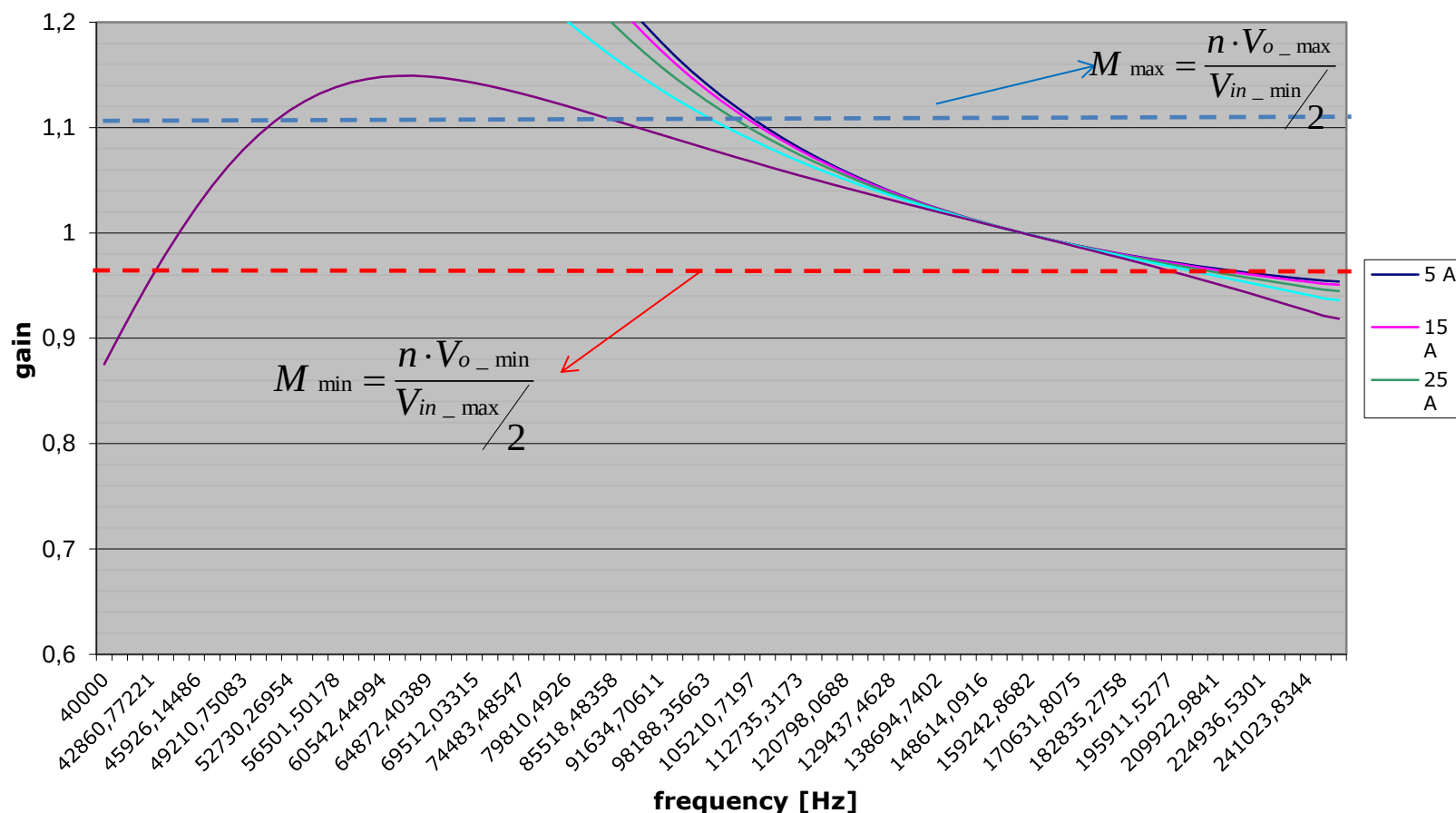
- › $n = V_{in_nom} / (2 \times V_o) = 380 / (2 \times 12) \approx 16$
- › $L_m = 195 \mu H$
- › $L_r = 15.5 \mu H$
- › $L_n = L_m / L_r = 12.5$
- › $C_r = 66 nF$

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

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

Gain curves

DC - gain curve (600W LLC hardware revision C7)



Energy related calculations (Ref. IPP60R180C7 device parameters)

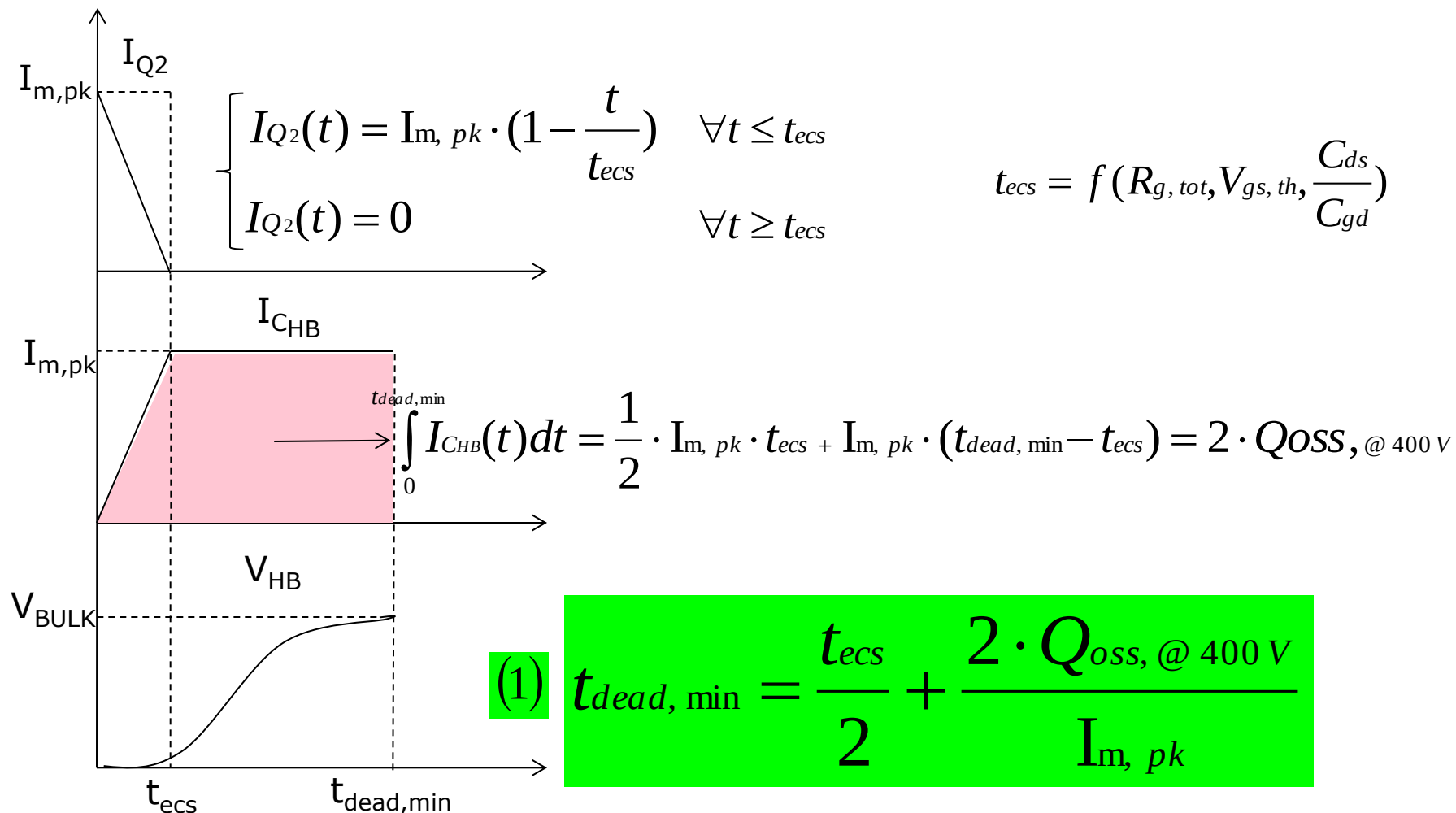
$$I_{mag_min} = \frac{2 \cdot \sqrt{2}}{\pi} \cdot \frac{n \cdot V_o}{2\pi \cdot f_{sw_max} \cdot L_m} = 0.672 \text{ A}$$

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

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

$$\Rightarrow En_{res_min} > En_{cap_max}$$

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



Time related calculations (Ref. IPP60R180C7 device parameters)

$$I_{mag_min} = \frac{2 \cdot \sqrt{2}}{\pi} \cdot \frac{n \cdot V_o}{2\pi \cdot f_{sw_max} \cdot L_m} = 0.672 \text{ A}$$

$$I_{mag_max} = \frac{2 \cdot \sqrt{2}}{\pi} \cdot \frac{n \cdot V_o}{2\pi \cdot f_{sw_min} \cdot L_m} = 1.66 \text{ A}$$

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

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

Main transformer structure: PQ35/35 core with TDK PC95 ferrite material

Wind.	Conductor	N° of Turns	R.p.p	Output pin	Winding layer	N° layer	Sleeves			Notes
							Col.	Ref. W.L	Total length mm.	
N1a	2xLitz 90x0.10 Ref.3	0	+	2-3 *	8	1	Re	8	20	/
Insulation: 3 turns of polyester adhesive tape Ref.6										
N2 N3	Copper foil 0.50x0.20 Ref.4	0 1	+	A B C	1 1	/	/	/	/	/
Insulation: 1 turns of polyester adhesive tape Ref.6 + 1 piece as showed in pictures										
N1b	2xLitz 90x0.10 Ref.3	0	+	* 4-5	8	1	Re	8	20	/
Insulation: 3 turns of polyester adhesive tape Ref.6										



Insert piece of tape after the insulation of N2-N3. Wind N1b. Refold tape, block and connect the wires to pin

Positioning coilformer — pin side	Bottom view	Electrical diagram
Smooth the inner part	Remove	

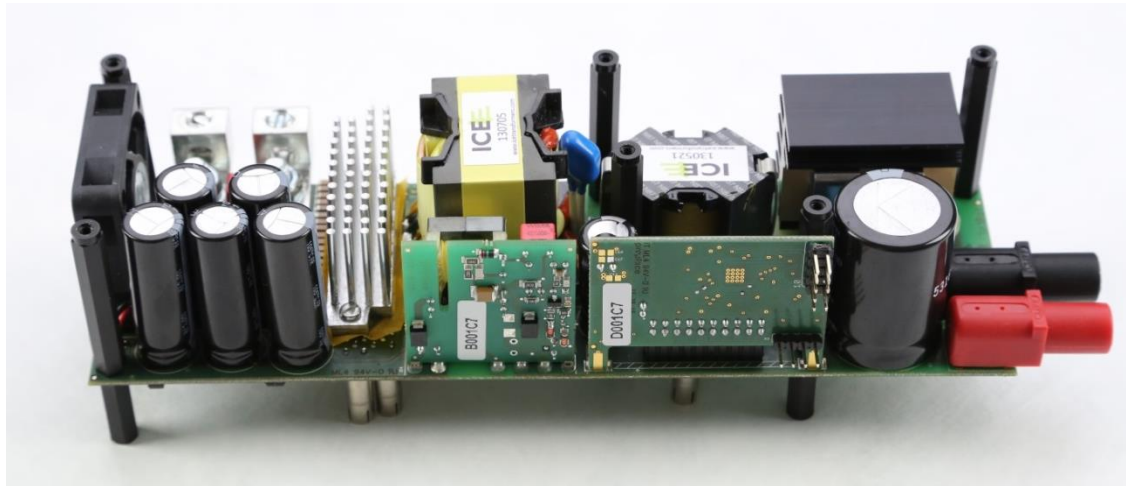
Copper foil preparation																																						
tinned Taping the exits with 3 turn of kapton ref.9 Solder the exits A-B-C ref. 5 on copper foil ref.4 Insulate the foil with tape ref.7 and the welding with tape ref.6																																						
finished part																																						
<table border="1"> <tr> <td rowspan="4"> </td><td>02</td><td>21.07.15</td><td>Inserted label and pictures</td><td>C. Piccini</td><td>D. Di Giorgio</td></tr> <tr> <td>01</td><td>24.01.14</td><td>Release</td><td>C. Piccini</td><td>D. Di Giorgio</td></tr> <tr> <td>REV APPR DATE</td><td>REF. MOD.</td><td>DESCRIPTION OF MODIFICATION</td><td>EDITING</td><td>CHECKING AND APPROVAL</td></tr> <tr> <td colspan="5"> TRANSFORMERS DESCRIPTION Trasformatore PQ35/35 600W LLC converter (130705) </td></tr> <tr> <td>Mod. AQ 05.09</td><td>DOCUMENT TYPE</td><td>CODE</td><td>REVISION</td><td>RELEASE DATE</td><td>PAGE</td></tr> <tr> <td></td><td>P.F.</td><td>8065.0703.001</td><td>02</td><td>24.01.14</td><td>1 of 2</td></tr> </table>							02	21.07.15	Inserted label and pictures	C. Piccini	D. Di Giorgio	01	24.01.14	Release	C. Piccini	D. Di Giorgio	REV APPR DATE	REF. MOD.	DESCRIPTION OF MODIFICATION	EDITING	CHECKING AND APPROVAL	TRANSFORMERS DESCRIPTION Trasformatore PQ35/35 600W LLC converter (130705)					Mod. AQ 05.09	DOCUMENT TYPE	CODE	REVISION	RELEASE DATE	PAGE		P.F.	8065.0703.001	02	24.01.14	1 of 2
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Resonant choke: RM12 core, material N87

Wind.	Conductor type	N. of windings	R. output pin	output pin	Winding Layer	N. of Layer	Tube			Notes
							Color	Ref.	Length mm	
N1	Litz 120x0.10 Ref. 4	0 9	+	7+8+9 10+11	9	1	/ Red	/ 6	/ 20	Perpendicular crossing on tape ref.5
Insulation: 2 turns polyester tape Ref.5										

Evaluation board

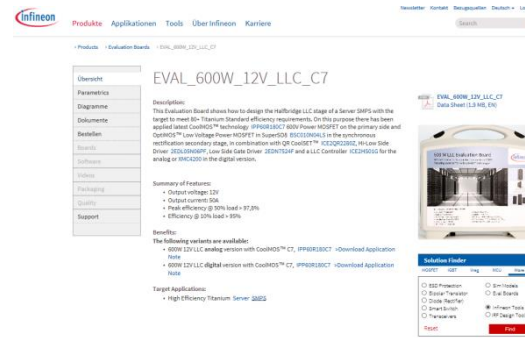
EVAL_600W_12V_LLC_C7



Support slides 600W LLC evaluation board

Evaluation board page

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



- [EVAL_600W_12V_LLC_C7](#)

Product family pages

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



- [650V CoolMOS™ C7](#)
- [XMC 32-Bit Industrial Microcontroller](#)
- [Resonant Mode Controller](#)
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