600 W Half-Bridge LLC evaluation board

EVAL_600W_LLC_12V_C7_D digital & analog

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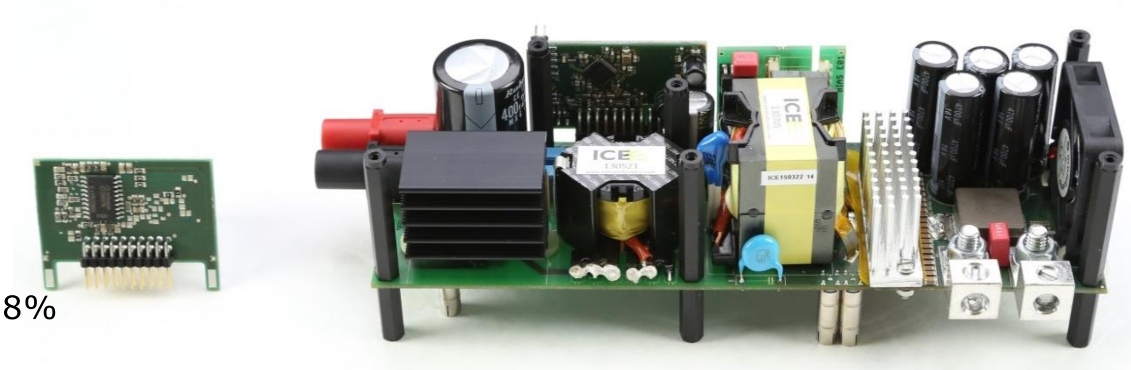
General

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 uH
L_m	195 uH

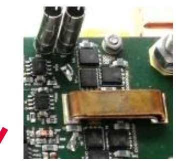
Primary HV MOSFETs
CoolMOS™ IPP60R180C7
Reduced gate charge (Q_g)
- Reduced E_{off}
- High body diode ruggedness

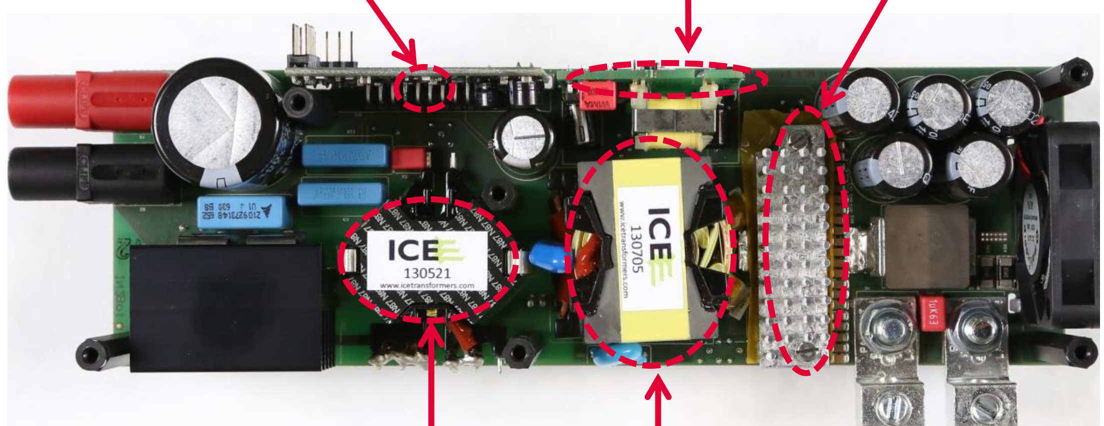
SR MOSFETs
OptiMOS™ BSC010N04LS
New generation
- Best FOM $R_{DS(on)}$ x Q_g
- Best FOM $R_{DS(on)}$ x Q_{oss}

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

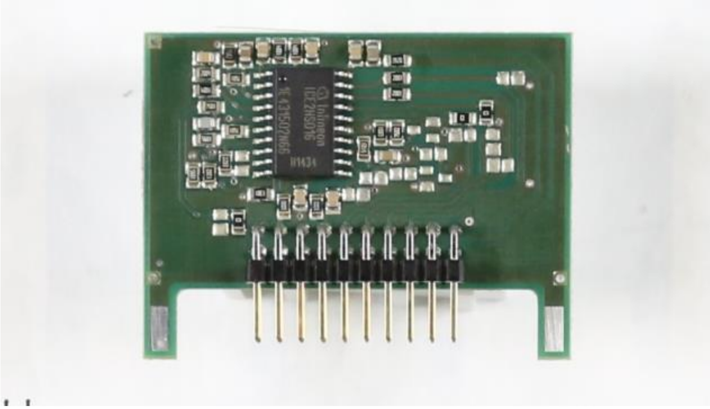
Two possible solution to control Infineon`s 600 W LLC evaluation board

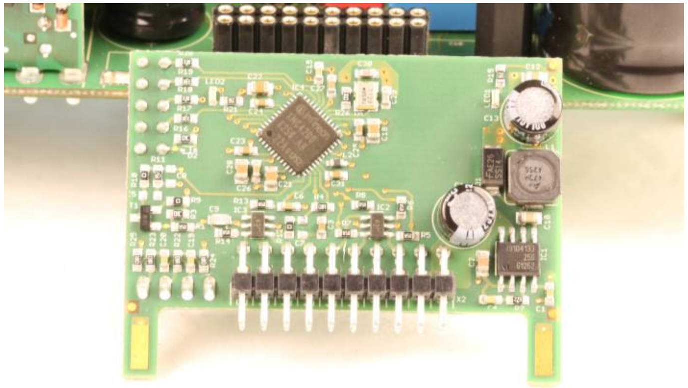
Analog - ICE2HS01G

- 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

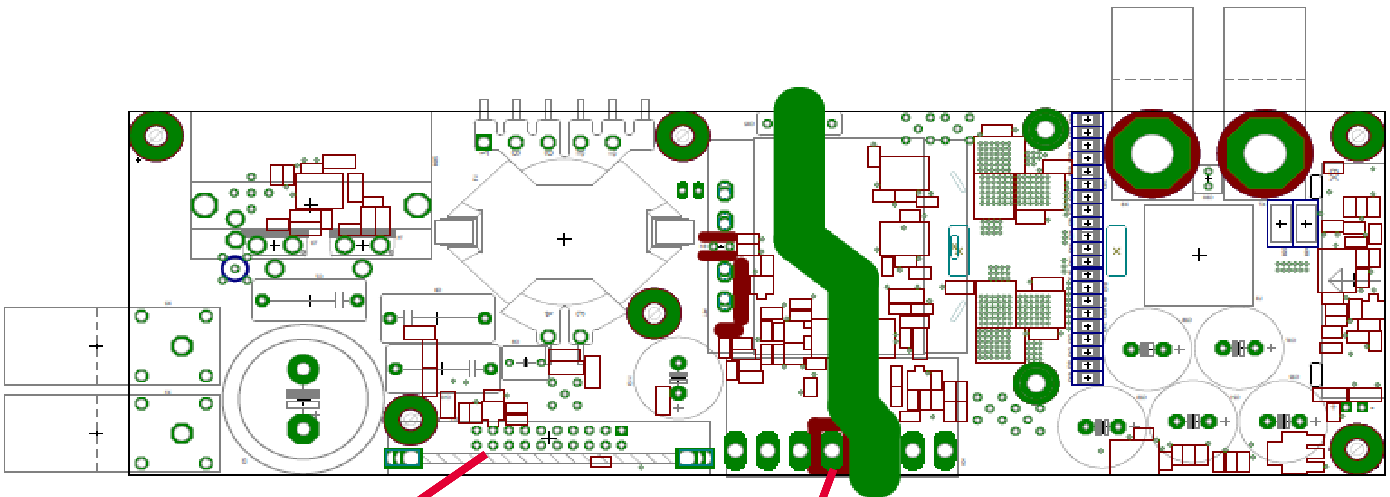
Digital - XMC4200-Q48K256 AB

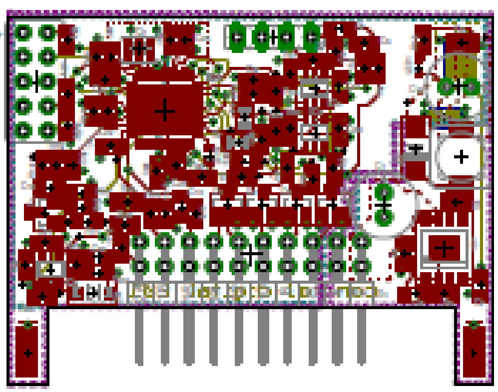
- ARM® Cortex®-M4, 80 MHz, incl. single cycle DSP MAC and floating point unit (FPU)
- 8-channel DMA + dedicated DMA for USB
- USB 2.0 full-speed device
- CPU Frequency: 80 MHz
- eFlash: 256 kB including hardware ECC
- 40 kB SRAM
- Package: PG-LQFP-48



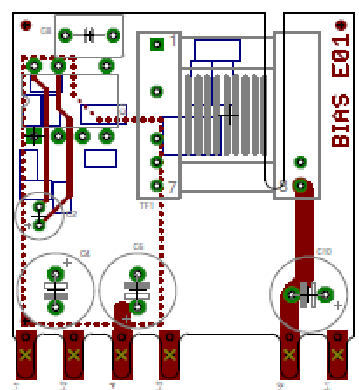


PCB boards layout: main power board and control and bias daughter boards





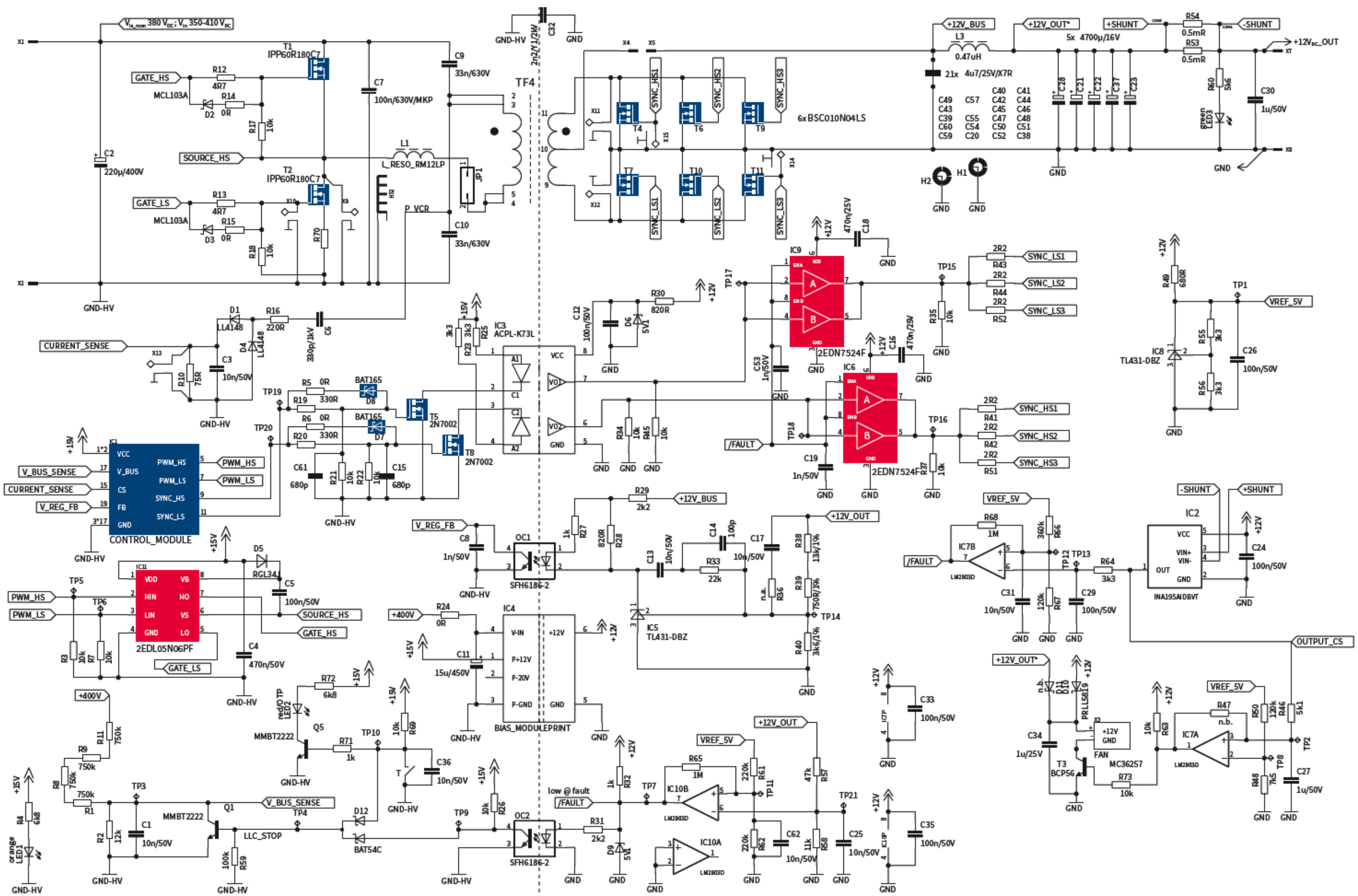
Controller board



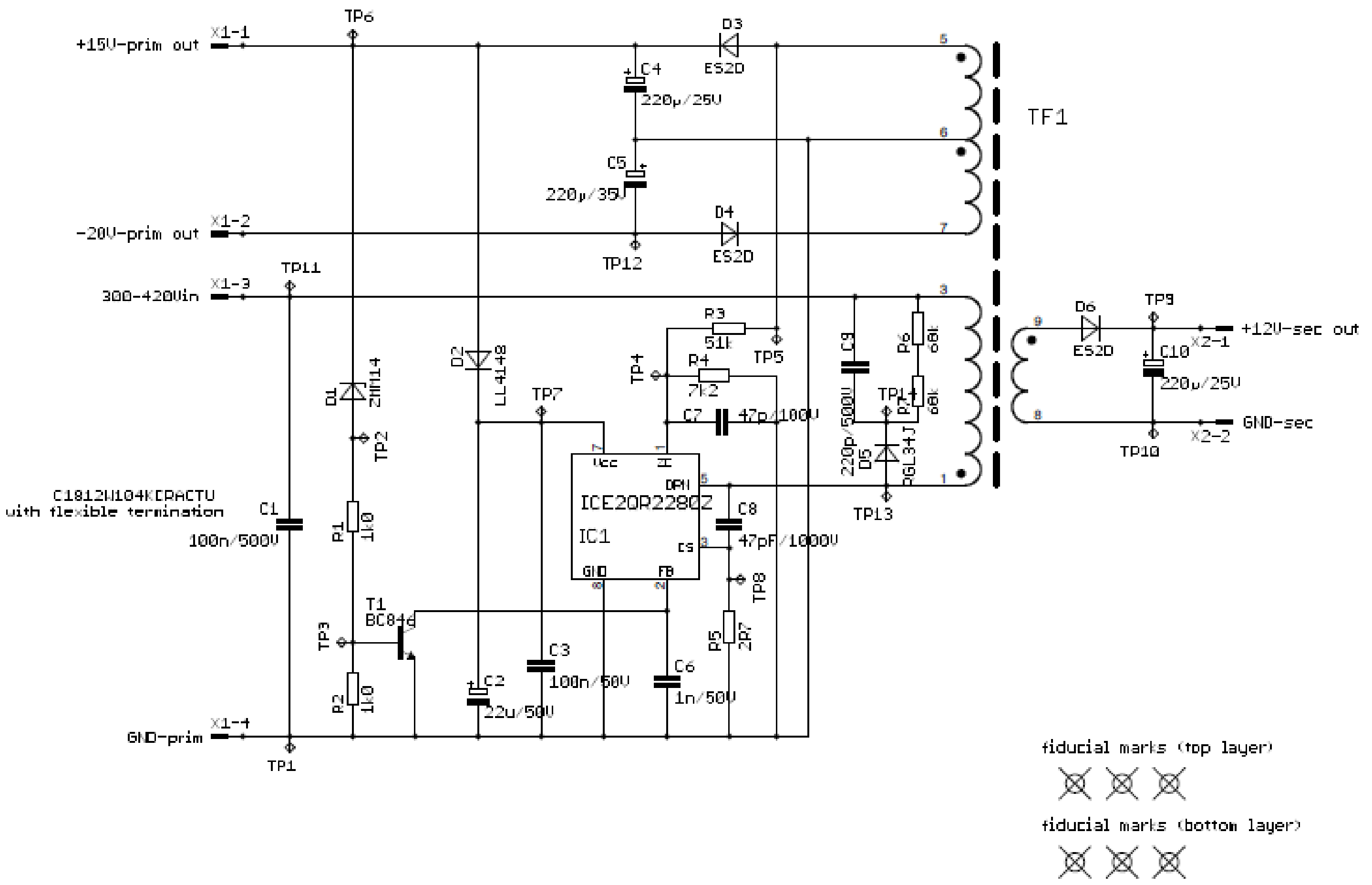
Bias board

- Power density >20 W/inch^3

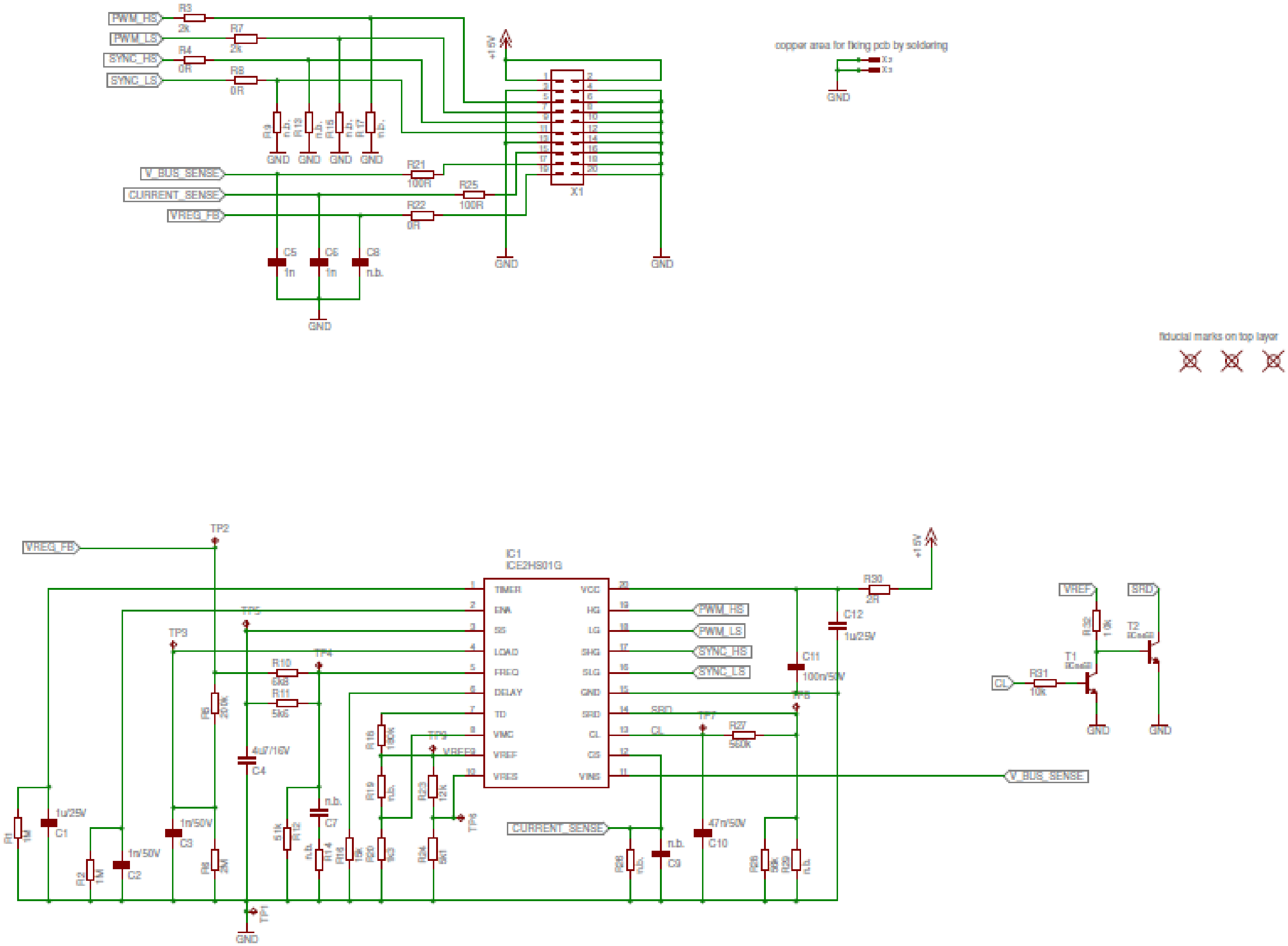
Main power board schematic (digital)



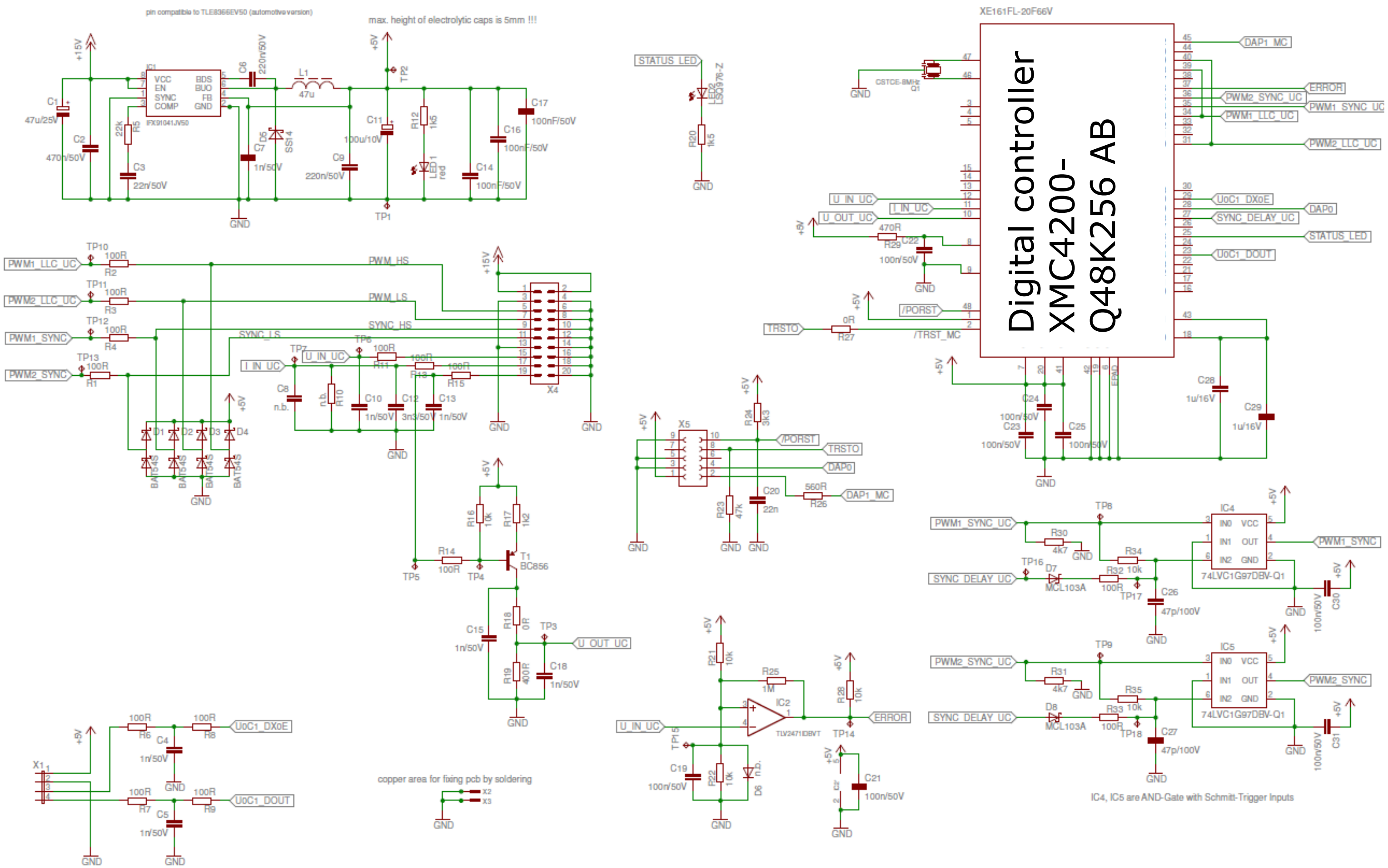
Bias board schematic



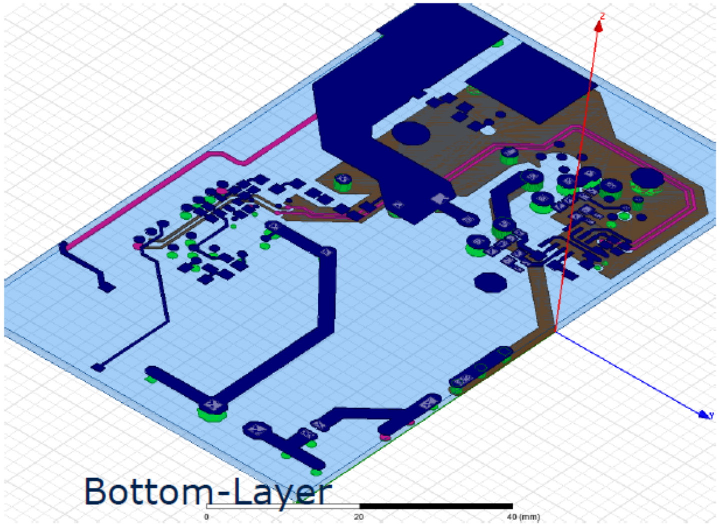
Analog control board schematic

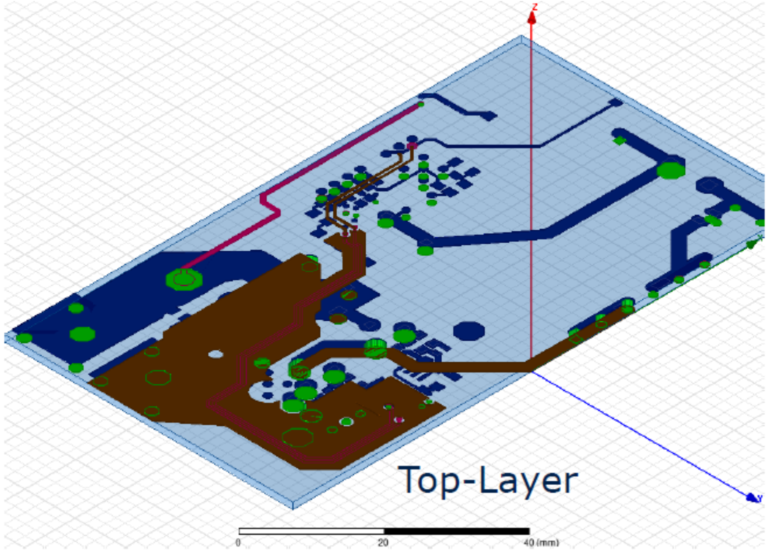


Digital control board schematic

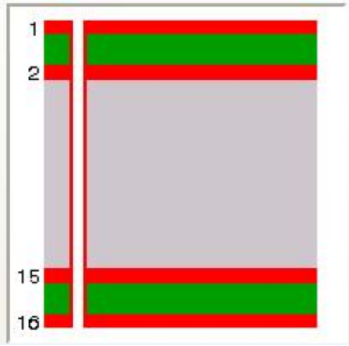


PCB structure





PCB-Stackup

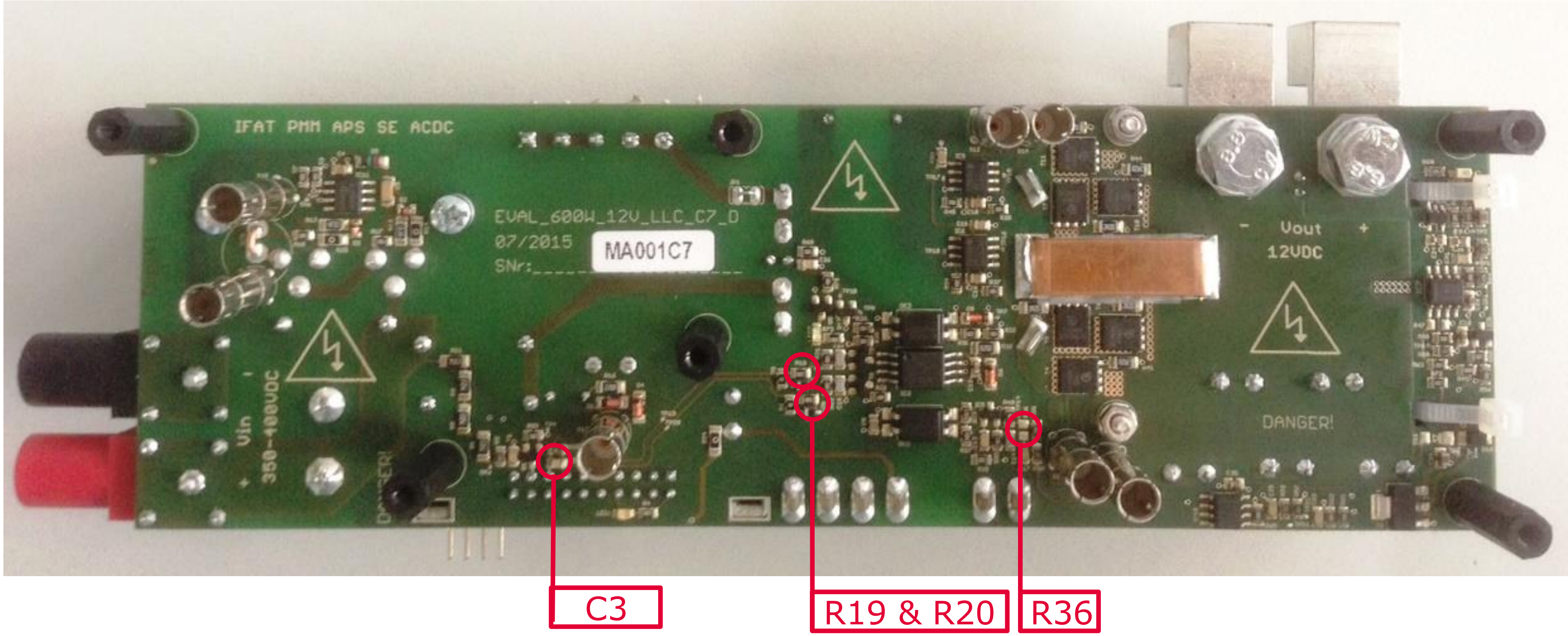


Nr	Copper	Isolation
1	0.07mm	
		0.15mm
2	0.07mm	
		0.93mm
15	0.07mm	
		0.15mm
16	0.07mm	

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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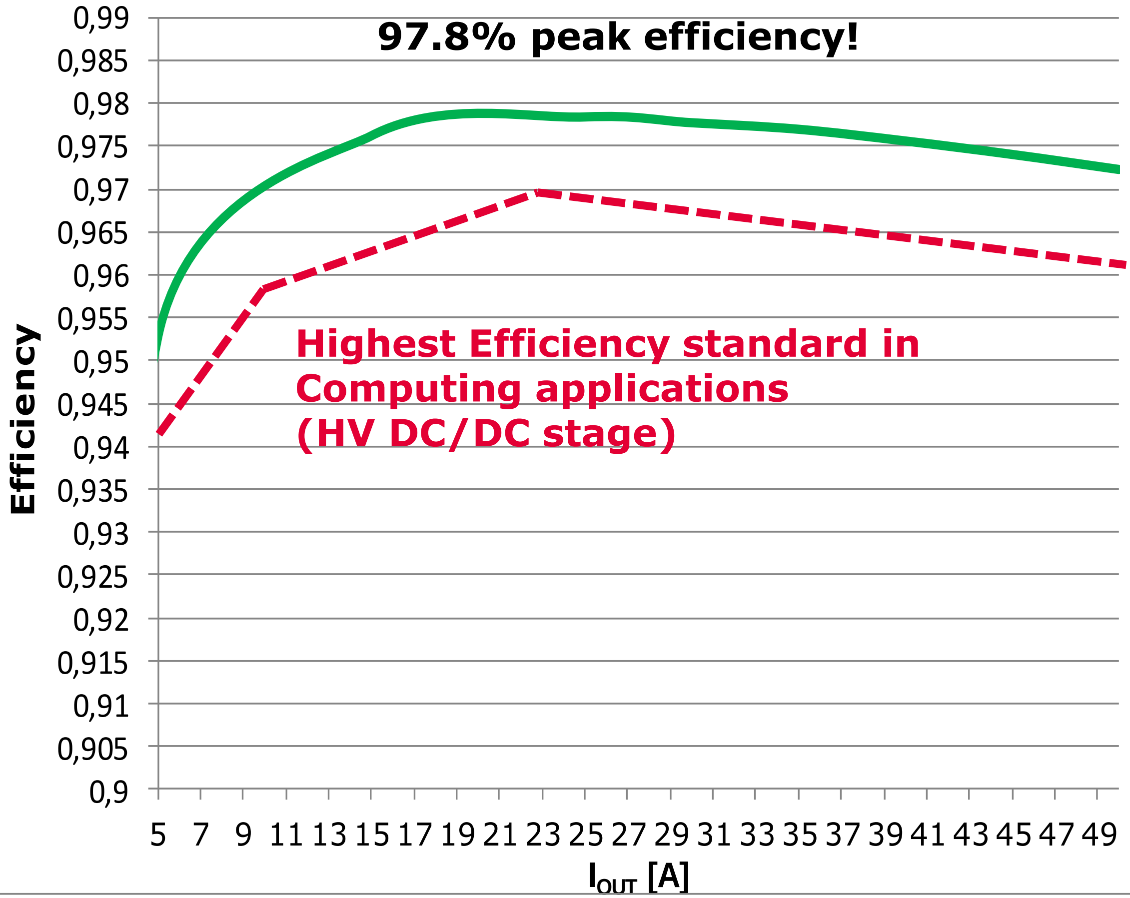
Automated efficiency measurement

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

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

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

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

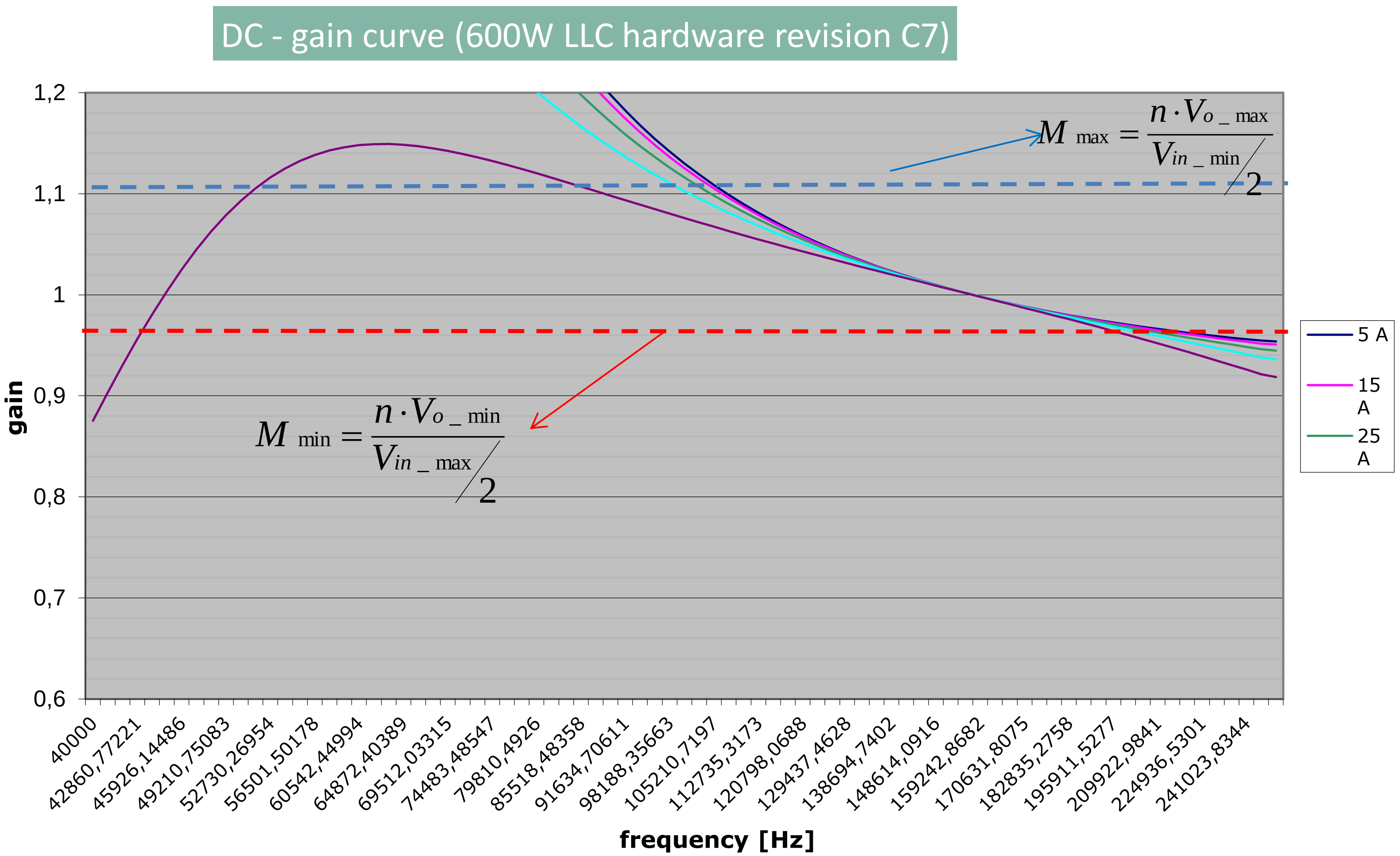
Resonant tank components and related resonant frequencies

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

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

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

Gain curves


DC - gain curve (600W LLC hardware revision C7)
1,2
1,1
1
0,9
0,8
0,7
0,6
gain
$M_{max} = \frac{n \cdot V_{o\_max}}{V_{in\_min}/2}$
$M_{min} = \frac{n \cdot V_{o\_min}}{V_{in\_max}/2}$
5 A
15 A
25 A
40000
42860,77221
45926,14486
49210,75083
52730,26954
56501,50178
60542,44994
64872,40389
69512,03315
74483,48547
79810,4926
85518,48358
91634,70611
98188,35663
105210,7197
112735,3173
120798,0688
129437,4628
138694,7402
148614,0916
159242,8682
170631,8075
182835,2758
195911,5277
209922,9841
224936,5301
241023,8344
frequency [Hz]

Energy related calculations (Ref. IPP60R180C7 device parameters)

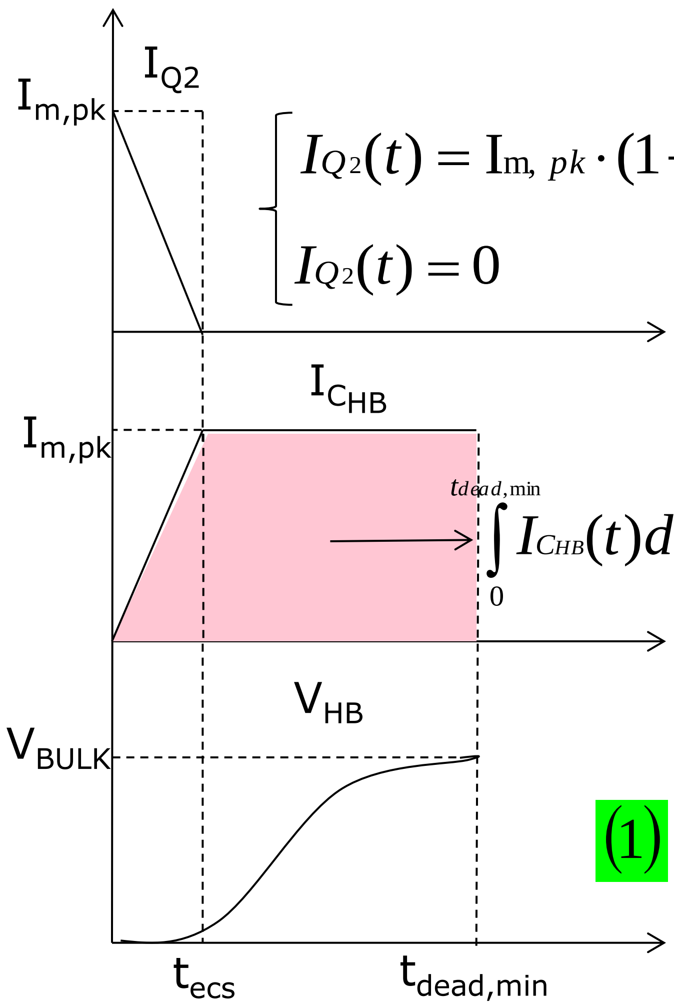
$$I_{mag\_min} = \frac{2 \cdot \sqrt{2}}{\pi} \cdot \frac{n \cdot V_o}{2\pi \cdot f_{sw\_max} \cdot L_m} = 0.672\ A$$

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

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

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

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



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

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

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

$$(1) \quad t_{dead,\,\min} = \frac{t_{ecs}}{2} + \frac{2 \cdot Q_{oss,\,@\,400\,V}}{\mathrm{I}_{m,\,pk}}$$

Time related calculations (Ref. IPP60R180C7 device parameters)

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

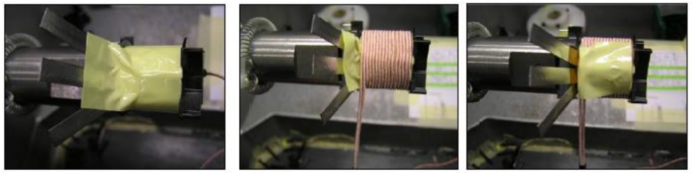
$$I_{mag\_max} = \frac{2 \cdot \sqrt{2}}{\pi} \cdot \frac{n \cdot V_o}{2\pi \cdot f_{sw\_min} \cdot L_m} = 1.66\,A$$

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

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

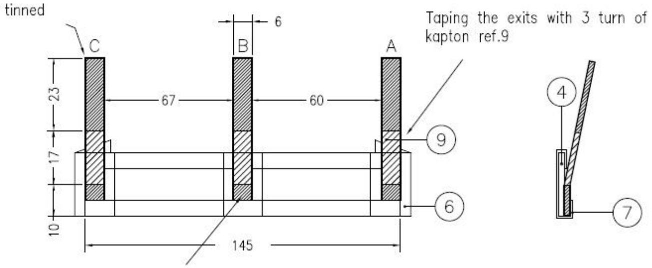
Main transformer structure:
PQ35/35 core with TDK PC95 ferrite material

Wind.	Conductor	N°. of Turns	Rotat	Output pin	Winding layer	N°. layer	Sleeves Col.	Sleeves Ref. M.L.	Sleeves Total length mm.	Sleeves Free length mm.	Notes
N1a	2xLitz 90x0.10 Ref.3	0 8	+	2–3 *	8	1	Re Re	8 8	20 20	/ /	2 wires in 1 sleeve.
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 8	+	* 4–5	8	1	Re	8	20	/	2 wires in 1 sleeve. Don't need correspondence
Insulation: 3 turns of polyester adhesive tape Ref.6											



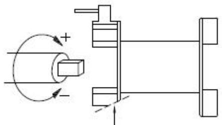
Insert piece of tape after the insulation of N2–N3. Wind N1b. Refold tape, block and connect the wires to pin

Copper foil preparation



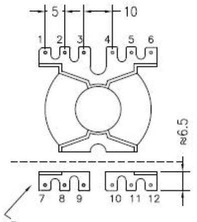
finished part

Positioning coilformer – pin side



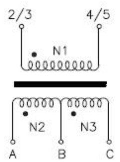
Smooth the inner part

Bottom view



Remove

Electrical diagram



REV	APPR. DATE	REF. MOD.	DESCRIPTION OF MODIFICATION	EDITING	CHECKING AND APPROVAL
02	21.07.15		Inserted label and pictures	C. Picciani	D. Di Giorgio
01	24.01.14		Release	C. Picciani	D. Di Giorgio

I.C.E. TRANSFORMERS

DESCRIPTION **Trasformatore PQ35/35 600W LLC converter (130705)**

Mod.	DOCUMENT TYPE	CODE	REVISION	RELEASE DATE	PAGE
AQ 05.09	**P.F.**	**8065.0703.001**	**02**	24.01.14	1of2

Resonant choke:
RM12 core, material N87

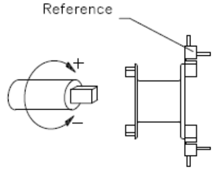
Wind.	Conductor type	N. of windings	Rotat	output pin	Winding Layer	N. of Layer	Tube Color	Tube Ref.	Tube Length mm	Notes
N1	Litz 120x0.10 Ref. 4	0 9	+	7+8+9 10+11	9	1	/ Red	/ 6	/ 20	Perpendicular crossing on tape ref.5

Insulation: 2 turns polyester tape Ref.5

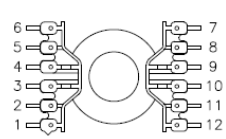
Bill of materials

Ref.	Description
1	Coil Former RM12 12pins (B65816–C1512–T1 Epcos mat.Valox420 E45329)
2	Ferrite core RM12 gap 1.1mm (B65815–R87 Epcos)
3	RM12 clamp (B65816–A2002 Epcos)
4	Litz wire 120x0.100mm G1 (155°C E125660 or equivalent)
5	Polyester adhesive tape H=16mm thickness 0.06mm (P31 E178430 or equivalent)
6	Tube glass/silicone Ø1.5mm 4KV 20mm (GVES2500 E311983 or equivalent)
7	Activator for epoxy resin (IN1005 or equivalent)
8	Epoxy resin (36T or equivalent)
9	PVC label 24x12mm
10	Insulating varnish classH (AC43 E317427 or equivalent)
11	Polyestere label 4.7x14mm (7816 MH16411 or equivalent)

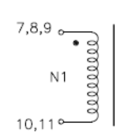
Winding rotation



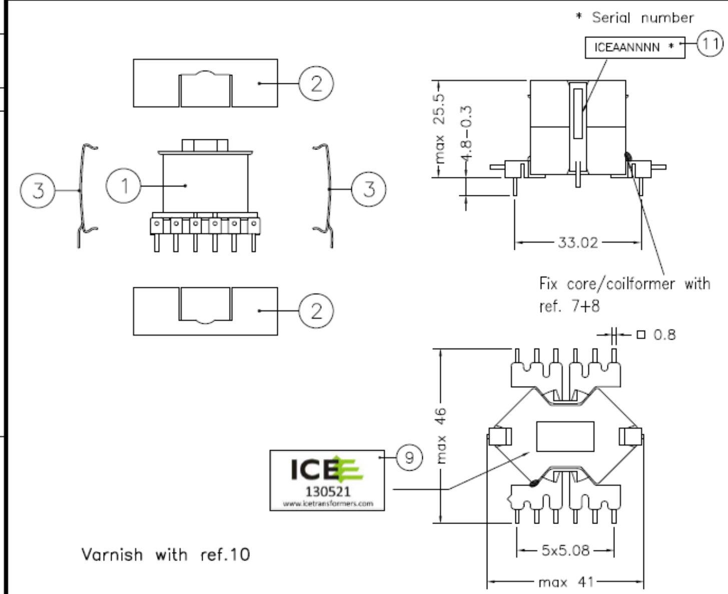
Bottom View



Electrical drawing



Assembling



Dimensions in millimeter
RoHS compliant

Electrical test

N°.	Test type	Test conditions	Limits
1	Inductance	7+8+9–10+11 @ 10 kHz – 100 mV	from 11.9 to 16.1 µH

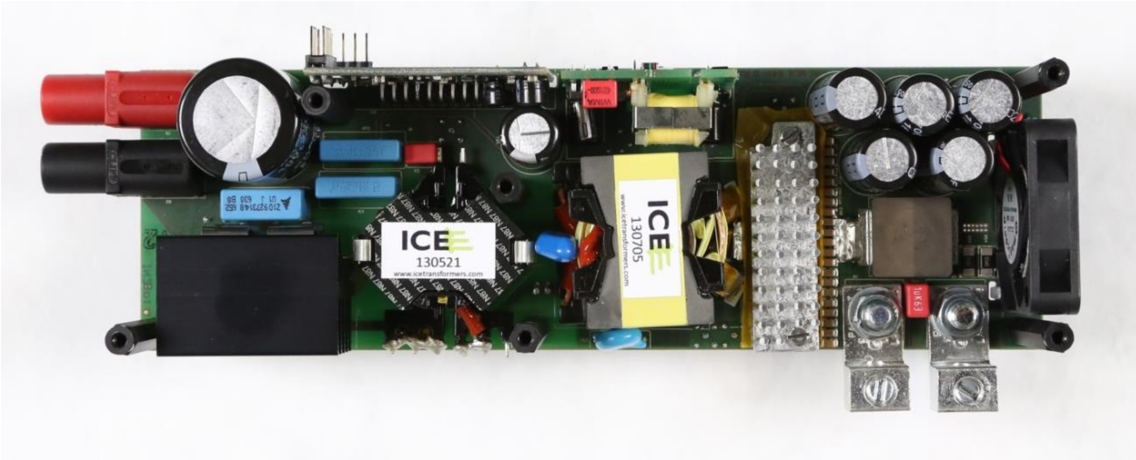
I.C.E. TRANSFORMERS

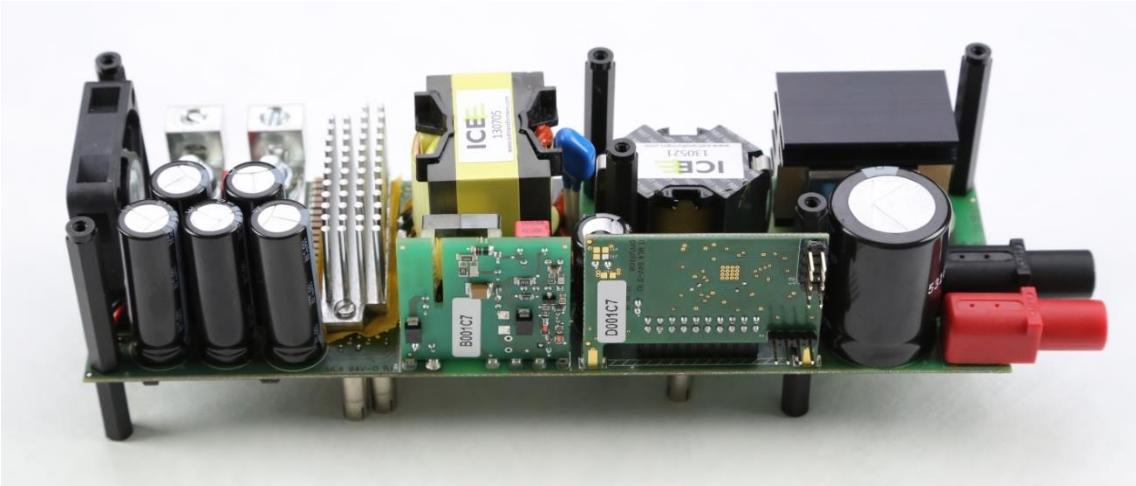
REV	Appr. date	Ref. Mod.	Modification description	Editing	Checked and Approved
02	21.07.15		Inserted new label	C. Picciani	D. Di Giorgio
01	23.01.14		Release	C. Picciani	D. Di Giorgio

DESCRIPTION: Inductance RM12 LLC resonant choke (130521)

Mod.	DOCUMENT TYPE	CODE	REVISION	EMISSION DATE	PAGE
AQ 05.09	P.F.	8017.0901.012	02	23.01.14	1 of 1

Evaluation board EVAL_600W_12V_LLC_C7

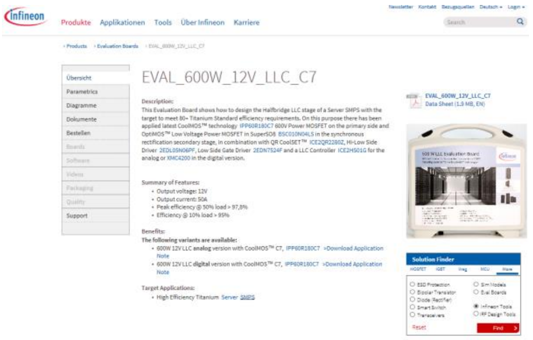




Support slides
600W LLC evaluation board

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
– OptiMOS™ 5 40V and 60V

Support

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- Помощь Конструкторского Отдела и консультации квалифицированных инженеров;
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- Поставка электронных компонентов под контролем ВП;
- Система менеджмента качества сертифицирована по Международному стандарту ISO 9001;
- При необходимости вся продукция военного и аэрокосмического назначения проходит испытания и сертификацию в лаборатории (по согласованию с заказчиком);
- Поставка специализированных компонентов военного и аэрокосмического уровня качества (Xilinx, Altera, Analog Devices, Intersil, Interpoint, Microsemi, Actel, Aeroflex, Peregrine, VPT, Syfer, Eurofarad, Texas Instruments, MS Kennedy, Miteq, Cobham, E2V, MA-COM, Hittite, Mini-Circuits, General Dynamics и др.);

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