600 W half-bridge LLC evaluation board

EVAL_600W_12V_LLC_CFD7

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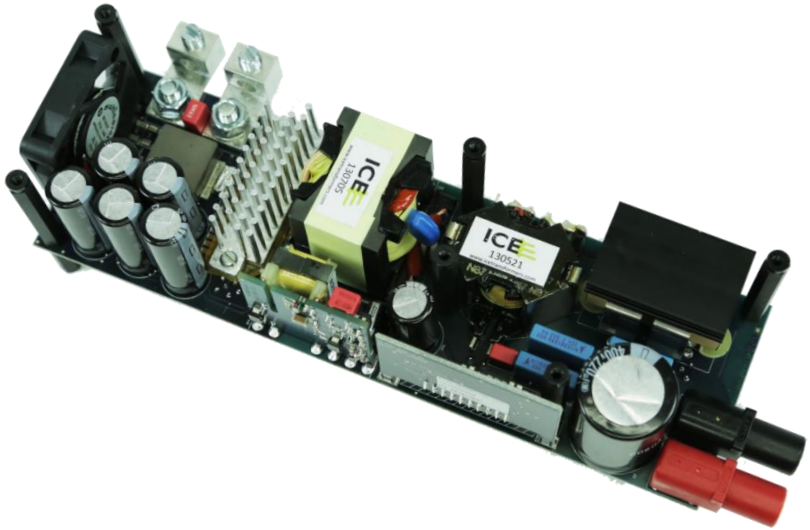
General description

The **"EVAL_600W_LLC_12V_CFD7"** - 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. For this purpose the following components have been used: latest 600 V CoolMOS™ CFD7 SJ MOSFET technology (IPP60R170CFD7) on the primary side and OptiMOS™ 40 V low voltage power MOSFET (BSC010N04LS) in the synchronous rectification secondary stage, in combination with quasi-resonant CoolSET™ (ICE2QR2280Z), EiceDRIVER™ Compact 2EDL hi-low side driver (2EDL05N06PF), 2EDN EiceDRIVER™ low side gate Driver (2EDN7524F) and analog LLC controller (ICE2HS01G).

Summary of features:

- Output voltage: 12 V
- Output current: 50 A
- Peak efficiency @ 50% load >97.4%
- Efficiency @ 10% load >94%



The following variants are available:

- 600 W 12 V LLC **analog** version with CoolMOS™ CFD7, EVAL_600W_12V_LLC_CDF7
  - Control card kit „from analog to digital" can be ordered additionally KIT_600W_LLC_DI_CTRL
  - Additional analog control card KIT_600W_LLC_AN_CTRL

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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}	350-410 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™ IPP60R170CFD7**
  Reduced gate charge (Q_g)
- Reduced E_{off}
- High body diode ruggedness

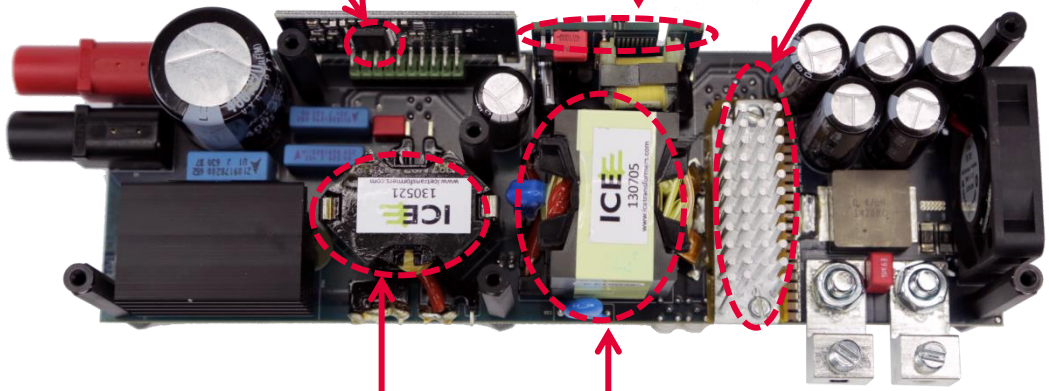
SR MOSFETs
- **OptiMOS™ BSC010N04LS**
  New generation
- Best FOM $R_{DS(on)}$ x Q_g
- Best FOM $R_{DS(on)}$ x Q_{oss}

HB gate driver IC
2EDL05N06PF
Non isolated LS gate drive
2EDN7524F
LLC controller
Analog ICE2HS01G

Bias QR flyback controller
ICE2QR2280Z

SR MOSFETs
BSC010N04LS





Resonant inductor
RM12 core

Transformer
PQ35/35 core

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Control card boards

Infineon's 600 W LLC evaluation board delivered with analog control, digital control card kit online available

Analog

With 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 1 MHz switching frequency
- 50% duty cycle for both primary and secondary gate drives
- Adjustable dead time with high accuracy

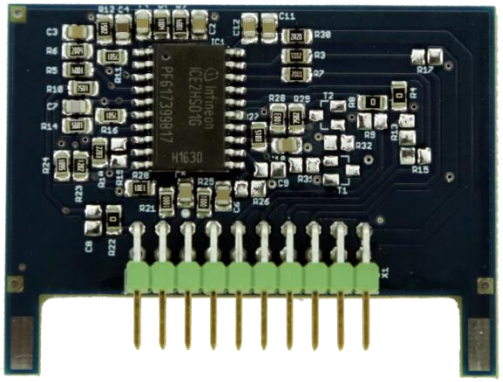
Order code: **KIT_600W_LLC_AN_CTRL**

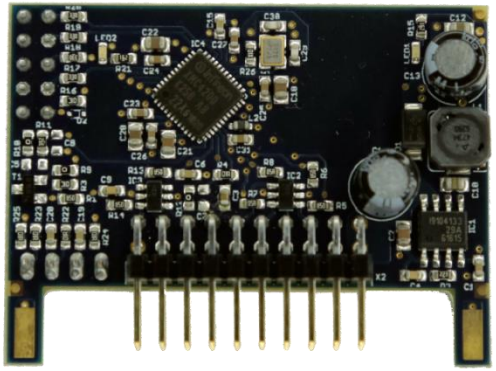
Digital (on request)

With 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

Order code: **KIT_600W_LLC_DI_CTRL**





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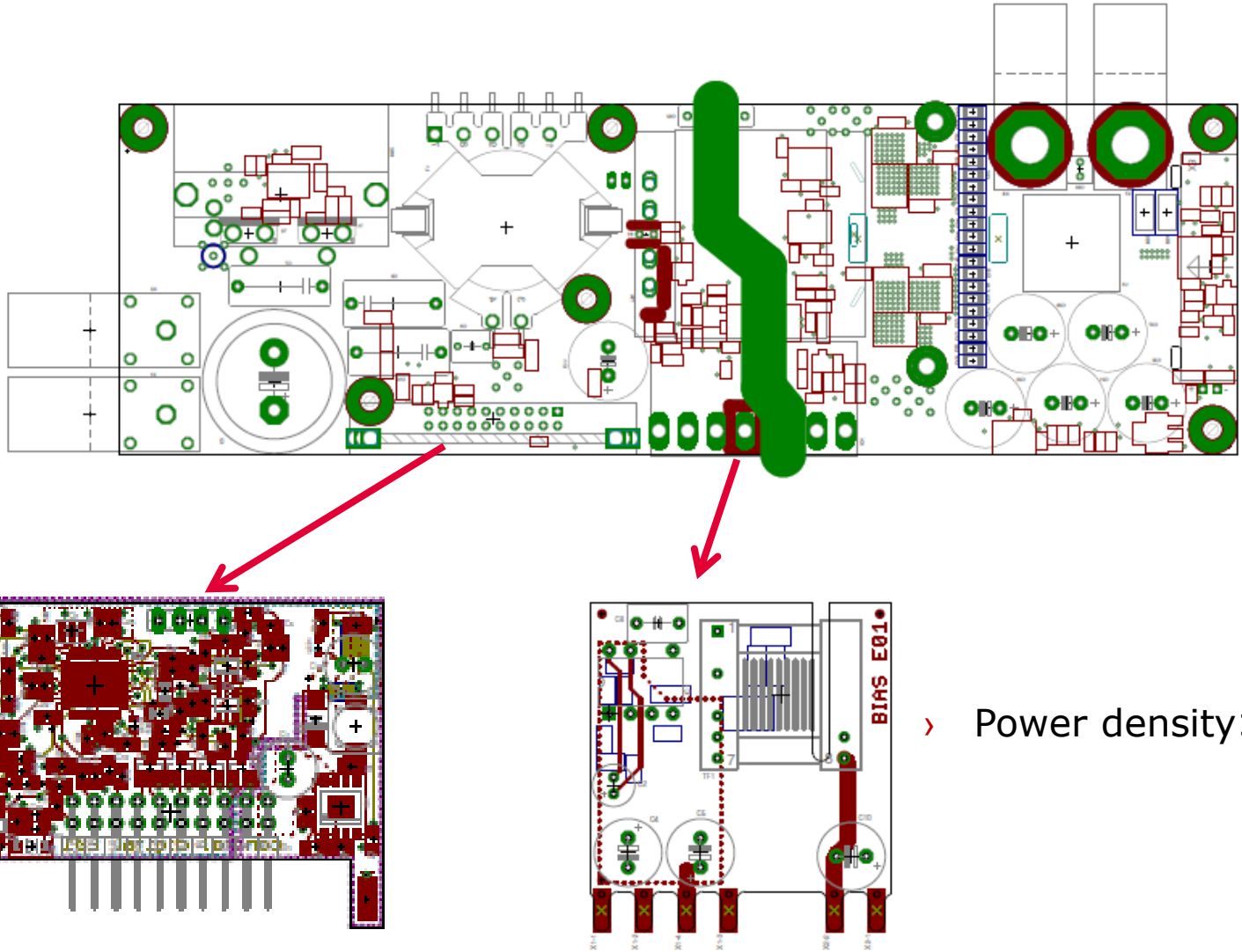
PCB boards layout: main power board and control and bias daughter boards



Controller board

Bias board

› Power density>20 W/inch^3

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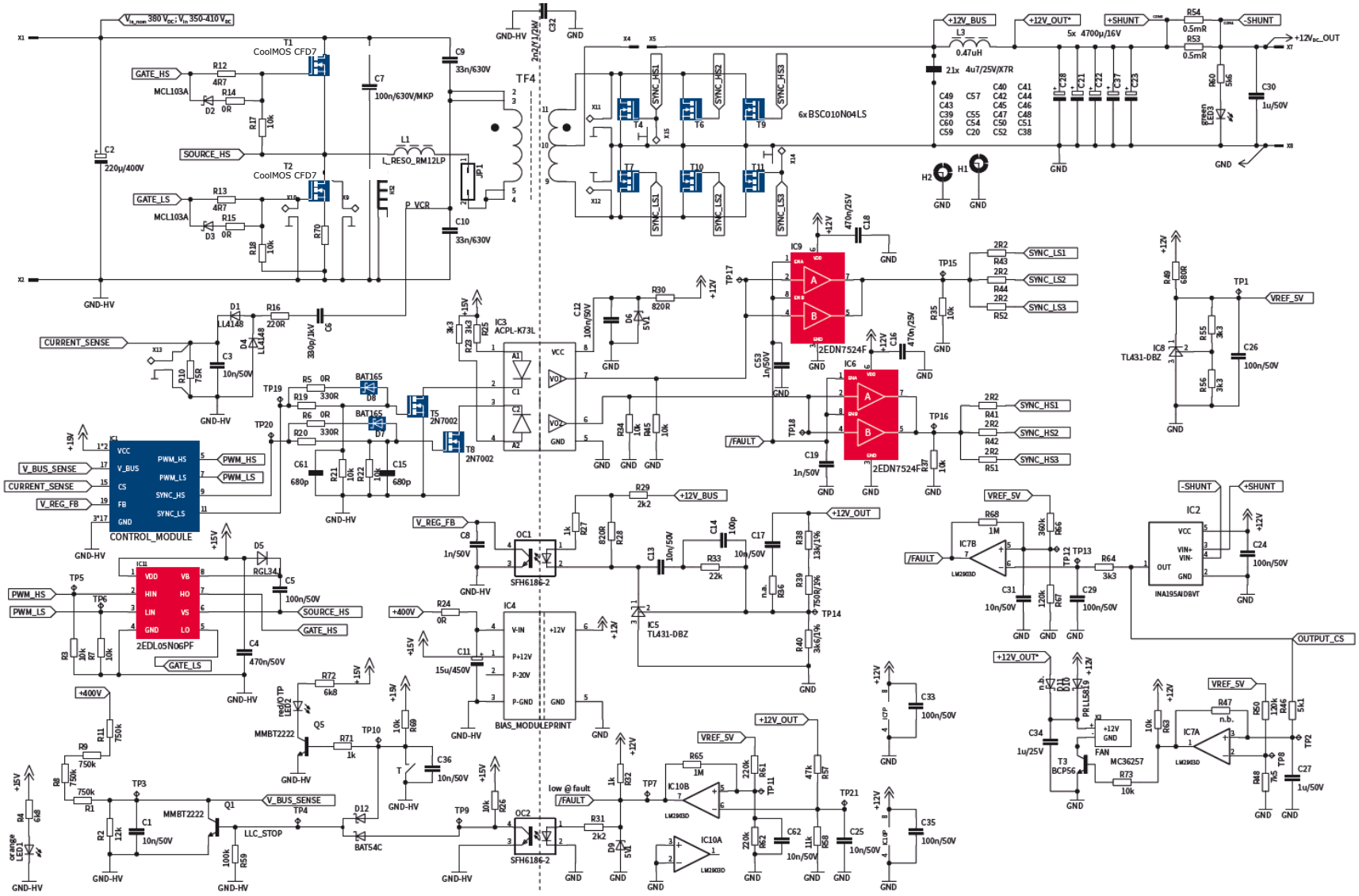
Main power board schematic



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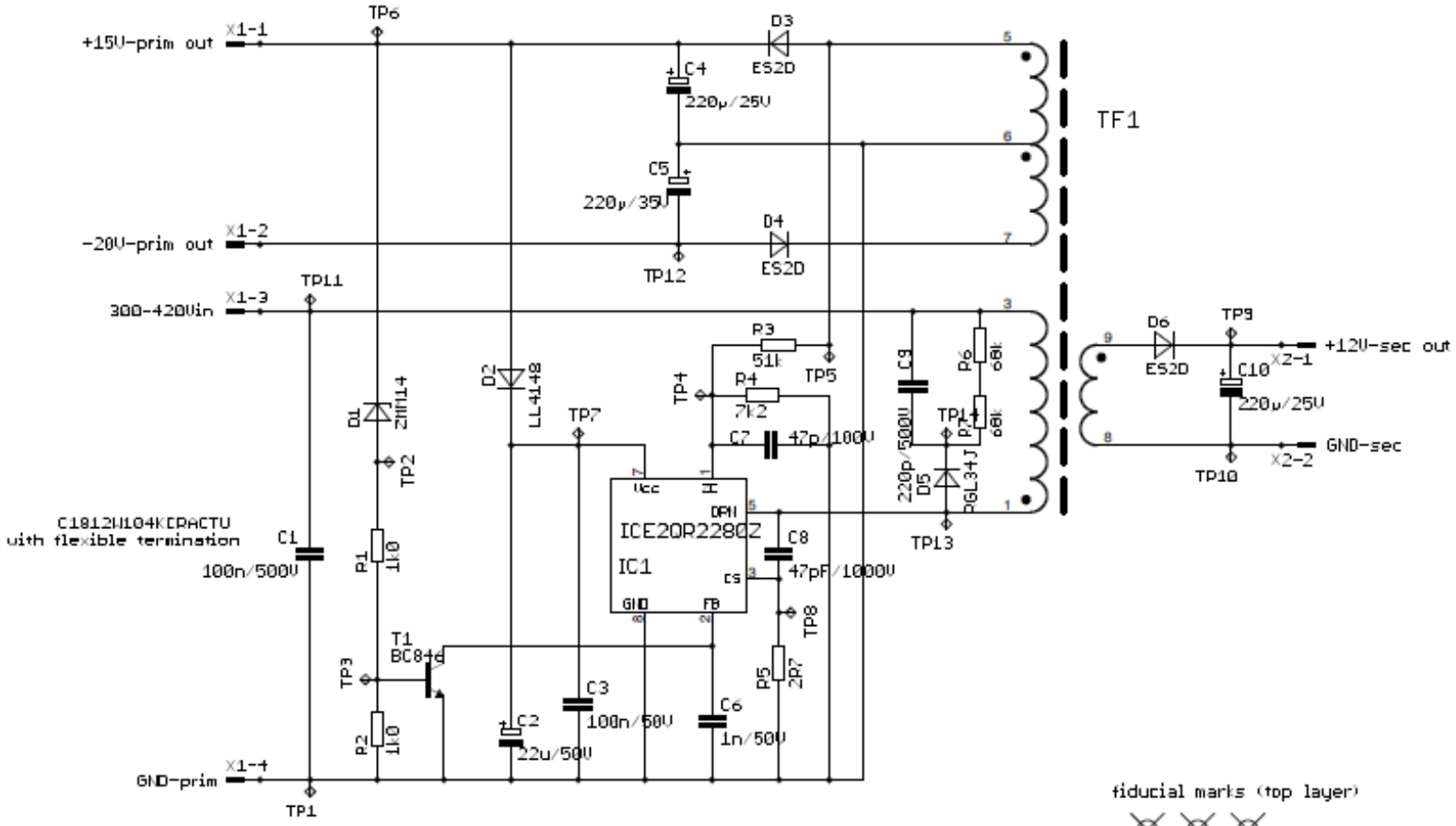
Bias board schematic



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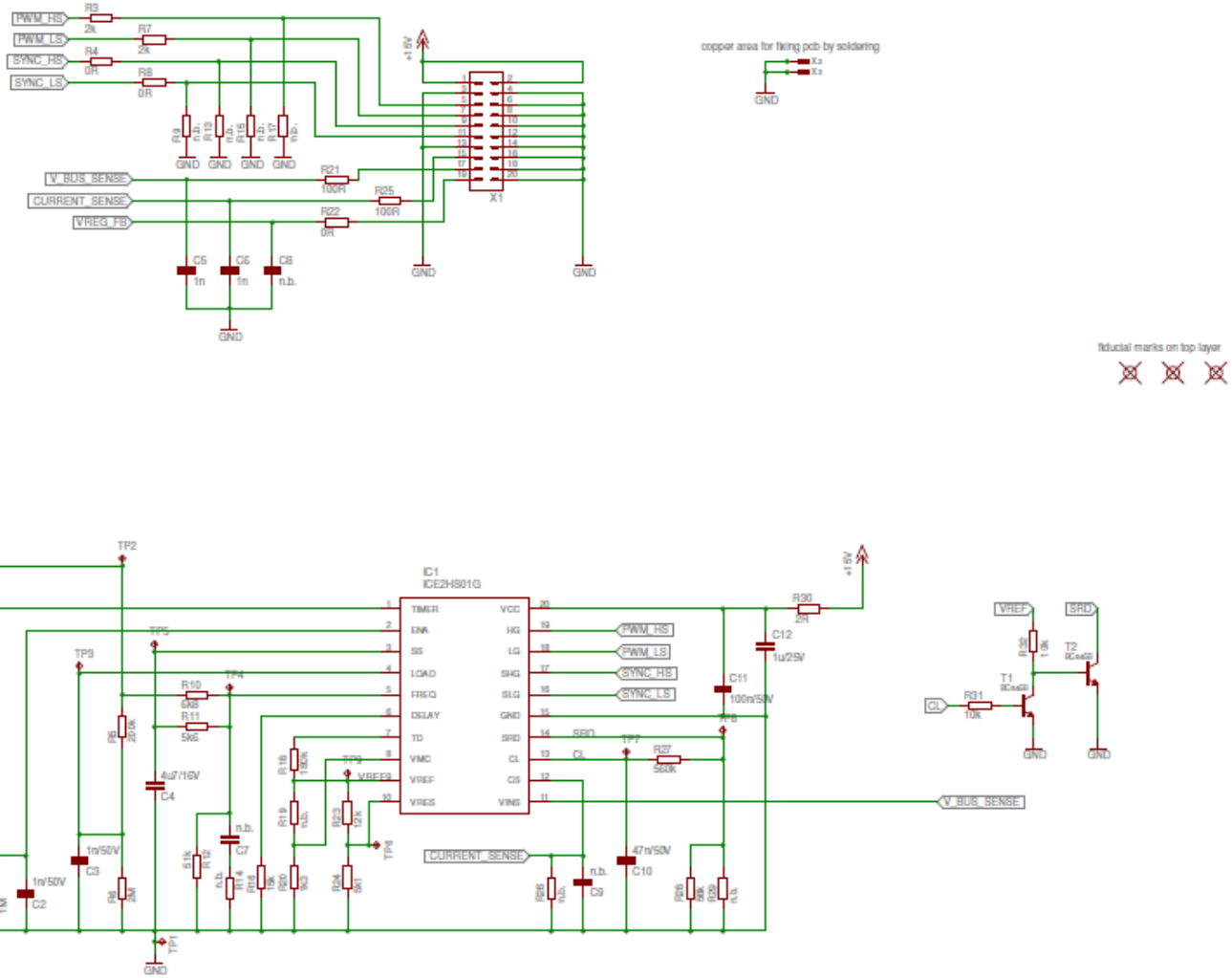
Analog control board schematic



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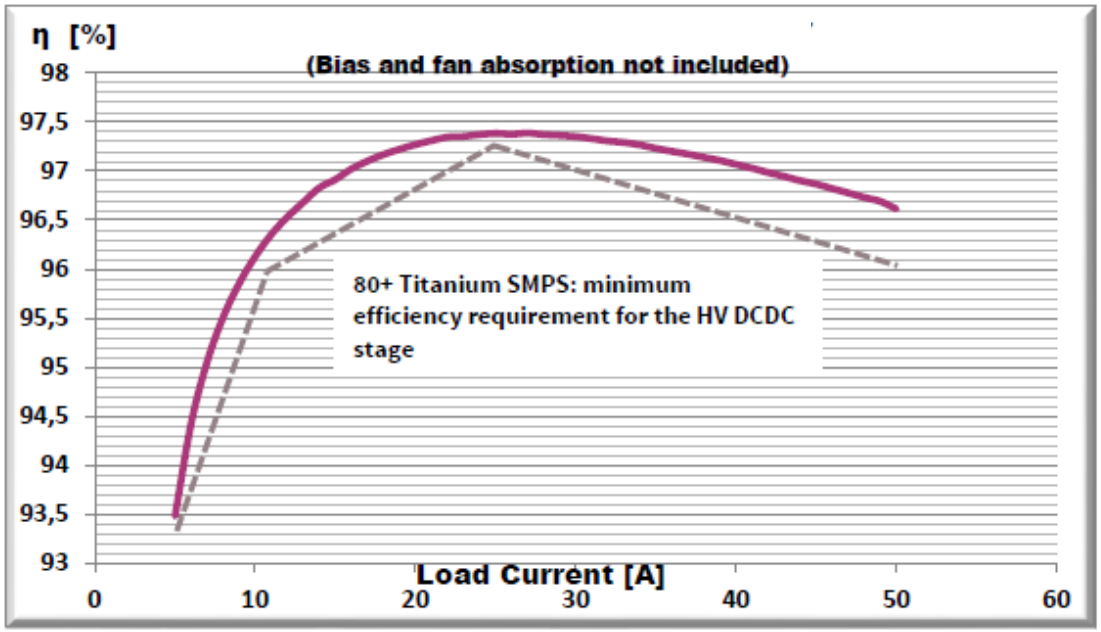
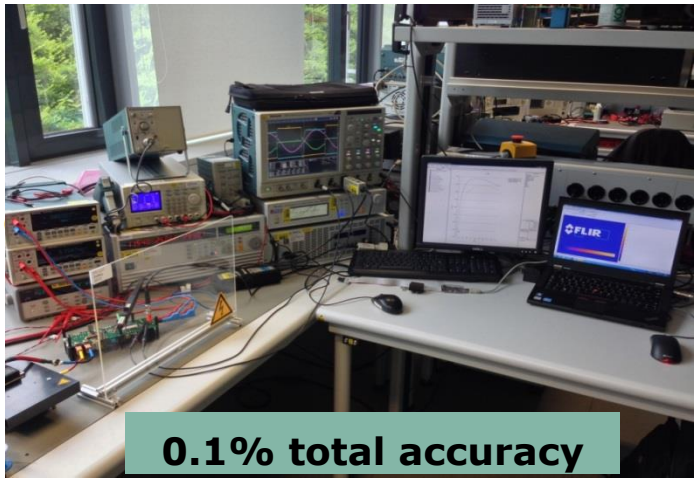
Automated efficiency measurement

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

Proper selection of SR LV device and secondary side design



Output voltage: 12 V_{DC}
Output current: 50 A



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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

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

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

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

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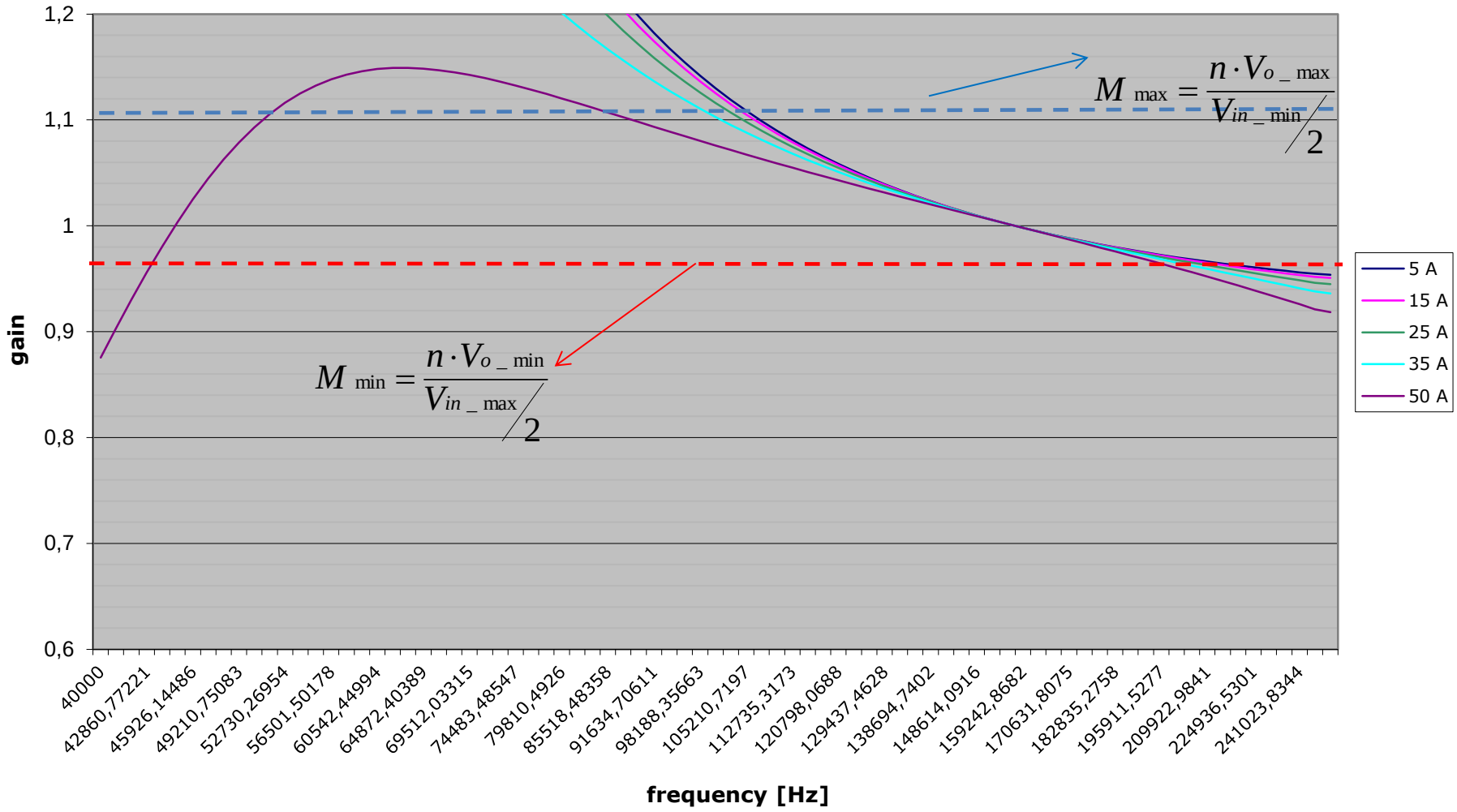
Gain curves

DC - gain curve (600 W LLC hardware revision CFD7)



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Energy related calculations (Ref. IPP60R170CFD7 device parameters)

$$I_{m\,ag_min} = \frac{2\cdot\sqrt{2}}{\pi}\cdot\frac{n\cdot V_o}{2\pi\cdot f_{sw_max}\cdot L_m} = 0.672\ A$$

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

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

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

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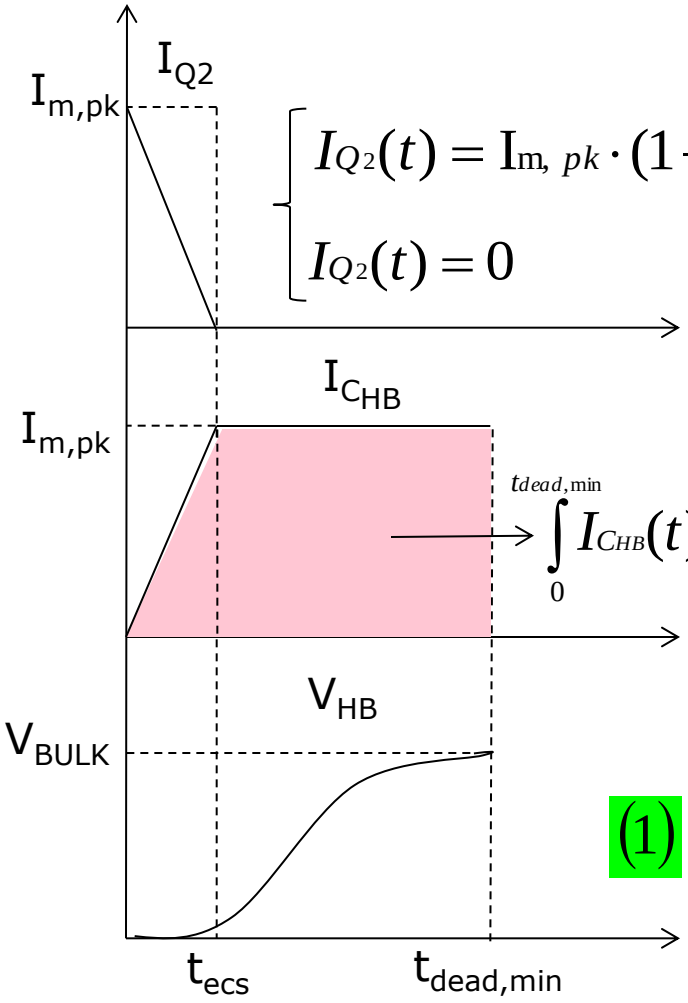
Q_{oss}, $I_{mag,pk}$, $t_{dead,min}$, t_{ecs} relationship



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

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

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

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

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Time related calculations (Ref. IPP60R170CFD7 device parameters)

$$I_{m\,ag_min} = \frac{2\cdot\sqrt{2}}{\pi}\cdot\frac{n\cdot V_o}{2\pi\cdot f_{sw_max}\cdot L_m} = 0.672\,A$$

$$I_{m\,ag_max} = \frac{2\cdot\sqrt{2}}{\pi}\cdot\frac{n\cdot V_o}{2\pi\cdot f_{sw_min}\cdot L_m} = 1.66\,A$$

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

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

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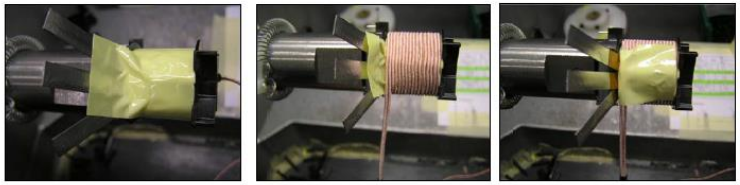
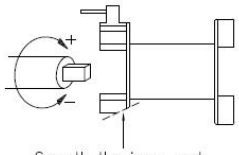
Main transformer structure: PQ35/35 core with TDK PC95 ferrite material

Wind.	Conductor	N°. of Turns	Rotat	Output pin	Winding layer	N°. layer	Sleeves Col.	Ref. M.L.	Total length mm.	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											

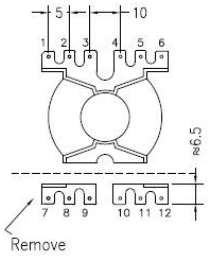


Insert piece of tape after the insulation of N2–N3. Wind N1b. Refold tape, block and connect the wires to pin

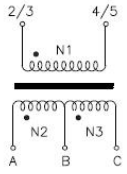
Positioning coilformer – pin side



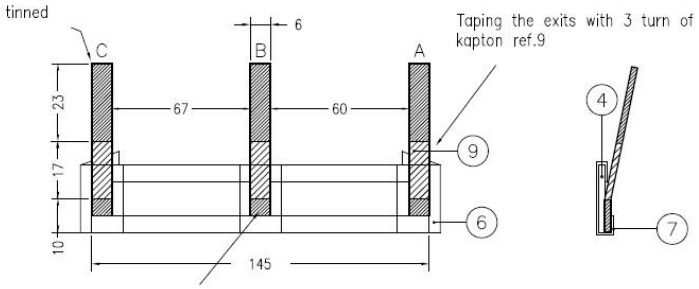
Bottom view



Electrical diagram



Copper foil preparation



finished part



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. AQ 05.09

DOCUMENT TYPE	CODE	REVISION	RELEASE DATE	PAGE
P.F.	8065.0703.001	02	24.01.14	1of2

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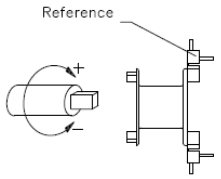
Resonant choke:
RM12 core, material N87

Wind.	Conductor type	N. of windings	Rotation	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										

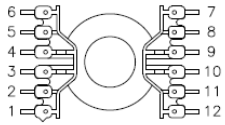
Bill of materials

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)

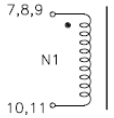
Winding rotation



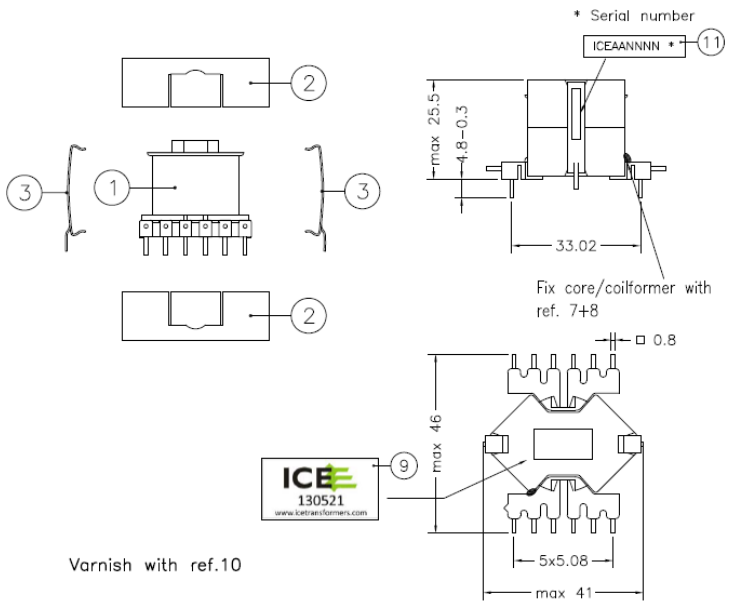
Bottom View



Electrical drawing



Assembling



Dimensions in millimeter
RoHS compliant

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

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

I.C.E. TRANSFORMERS

DESCRIPTION: Inductance RM12 LLC resonant choke (130521)

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

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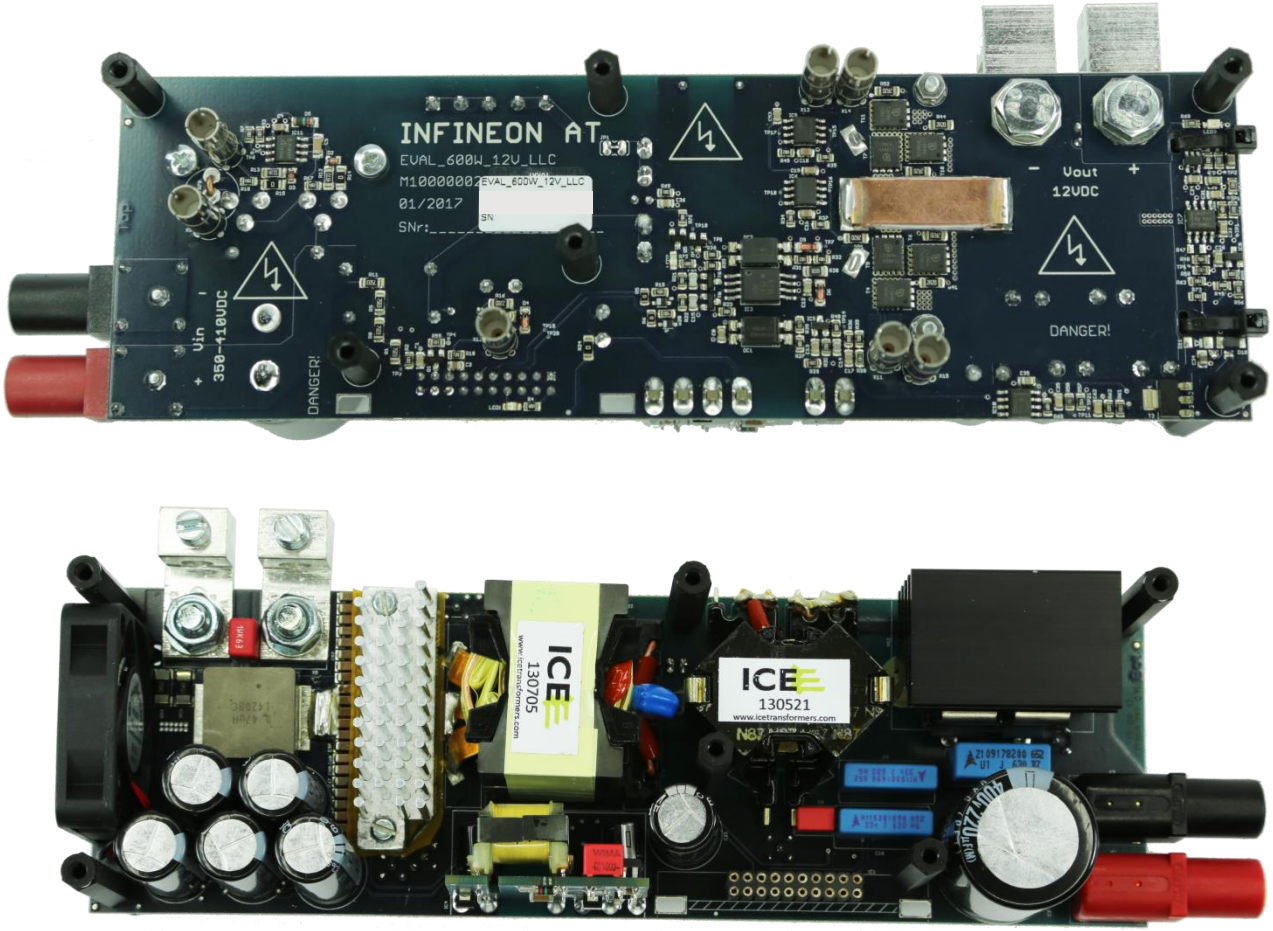
Evaluation board EVAL_600W_12V_LLC_CFD7



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Support

Technical Material	› Application Notes › Simulation Models › Datasheets › PCB Design Data	› EVAL_600W_12V_LLC_CFD7
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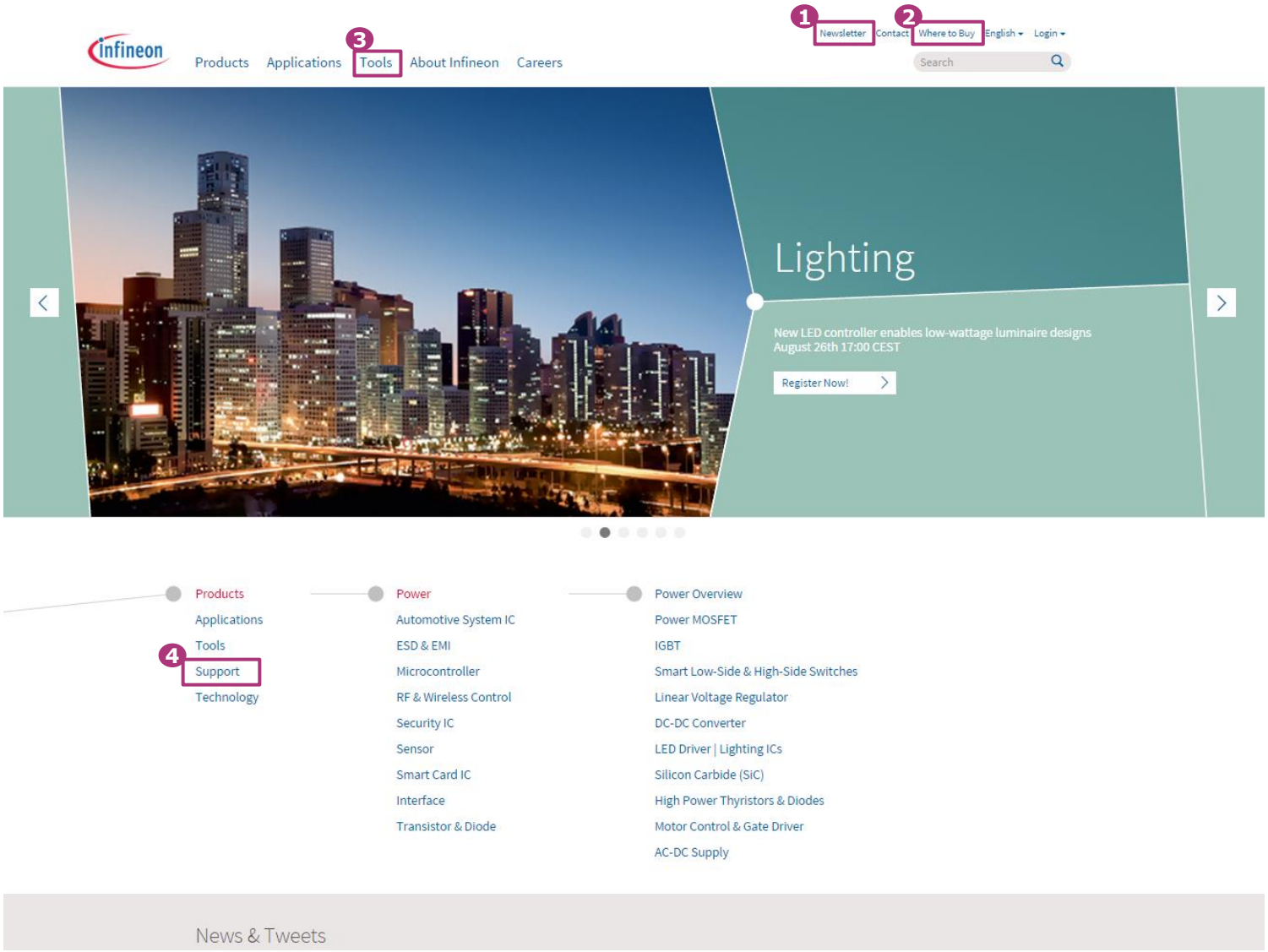

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