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Design Note – DN05131/D

5-V/300-A Two-Switch Forward Ac-Dc Converter

Devices	Applications	Input voltage	Output power	Topology	Board Size
NCL30125	Lighting	176-265 V rms	300 W	Two-Switch Forward	148 x 152 x 53 mm
Output spec.	**Turn on time**	**Efficiency**	**Operating temperature**	**Cooling**	**Standby power**
5 V/60 A	< 200 ms	above 89 % @ full load	0 – 40 °C	Open Frame in Still Air	Does not apply

Description

This design note provides elementary information about a two-switch forward converter built with the NCL30125 operated in current-mode control. This controller offers many features to build an energy-efficient converter with all the needed protections like cycle-by-cycle current limit with a 500-mV sense voltage, over temperature protection with a dedicated NTC pin and brown-out feature. In addition to the low side MSOFET drive, the controller integrates also an high-side section to drive the floating N-channel power MOSFET. Dedicated pins are available to adjust the switching frequency (RT pin – pin 6) or the soft-start duration (SS pin – pin 7). Finally, a high-voltage current source with Dynamic-Self Supply (DSS) is embedded to quickly start the power supply and maintain the V_{cc} voltage in light load or standby.

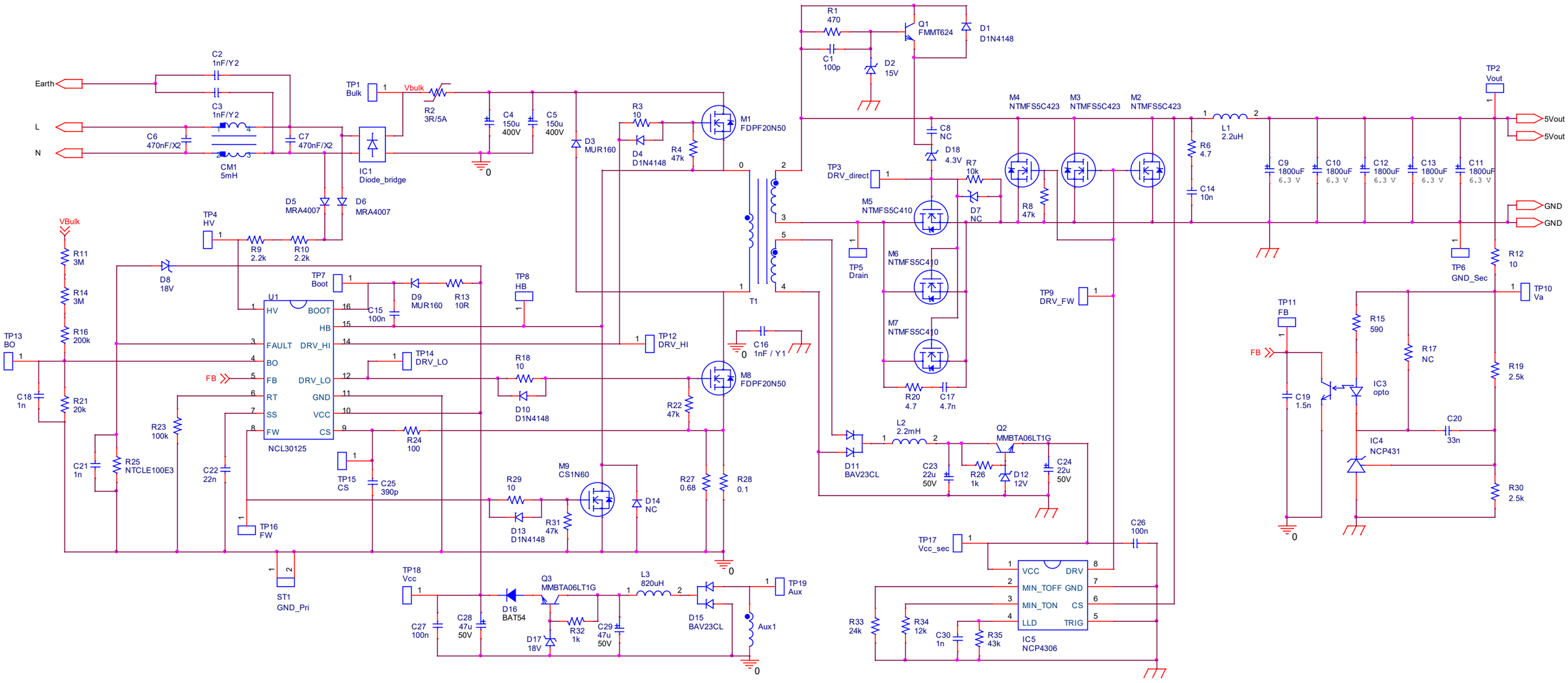
The primary-side section drives a transformer whose primary inductance is 3.8 mH. The energy accumulated in this inductance is sending back to the bulk capacitor thanks to the freewheel components. One of the classical freewheel diode has been replaced by a MOSFET M_9 driven by the controller in order to refresh the bootstrap capacitor. The current is sensed via a 87-mΩ resistance. The switching frequency of 100 kHz and the soft-start duration are set by two individual components (R_{23} for f_{SW} and C_{22} for SS).

The power stage is made of two switching N-channel transistors M_1 and M_8. These two transistors are switched in same time and seen the input voltage as maximum. In the secondary side, three MOSFETs are self-driven by the transformer but require regulation transistors Q_9 and Q_{10} to limit the maximum V_{GS} these elements can accept. The three forward MOSFETs M_2, M_3 and M_4 are driven by the NCP4306 synchronous rectification controller. The regulation is ensured by a TL431 wired in a type-2 configuration. Loop gain measurements show a 74° phase margin at a 60-A output obtained with a 230-V rms source.

Key Features

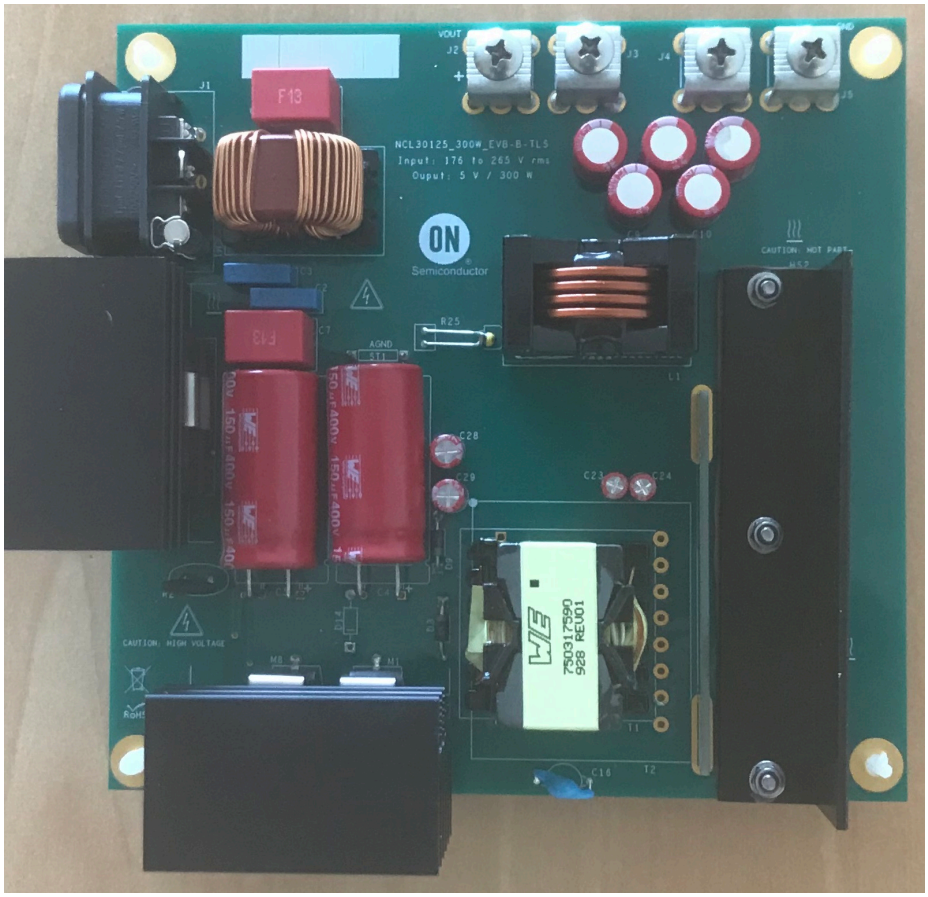
- Integrated High-side driver
- Adjustable switching frequency up to 300 kHz
- Peak current-mode control
- Skip mode to maximize performance in light load conditions
- Internal 600-V start-up source operated in dynamic self-supply during start-up or skip mode.
- Brown-out (BO) detection
- Adjustable soft-start duration
- 15-ms timer-based short-circuit protection with auto-recovery or latched operation
- Auto-recovery or Latched OVP on V_{cc}
- Latched OVP/OTP input for improved robustness
- +0.9 A / -1.2 A peak source/sink drive capability

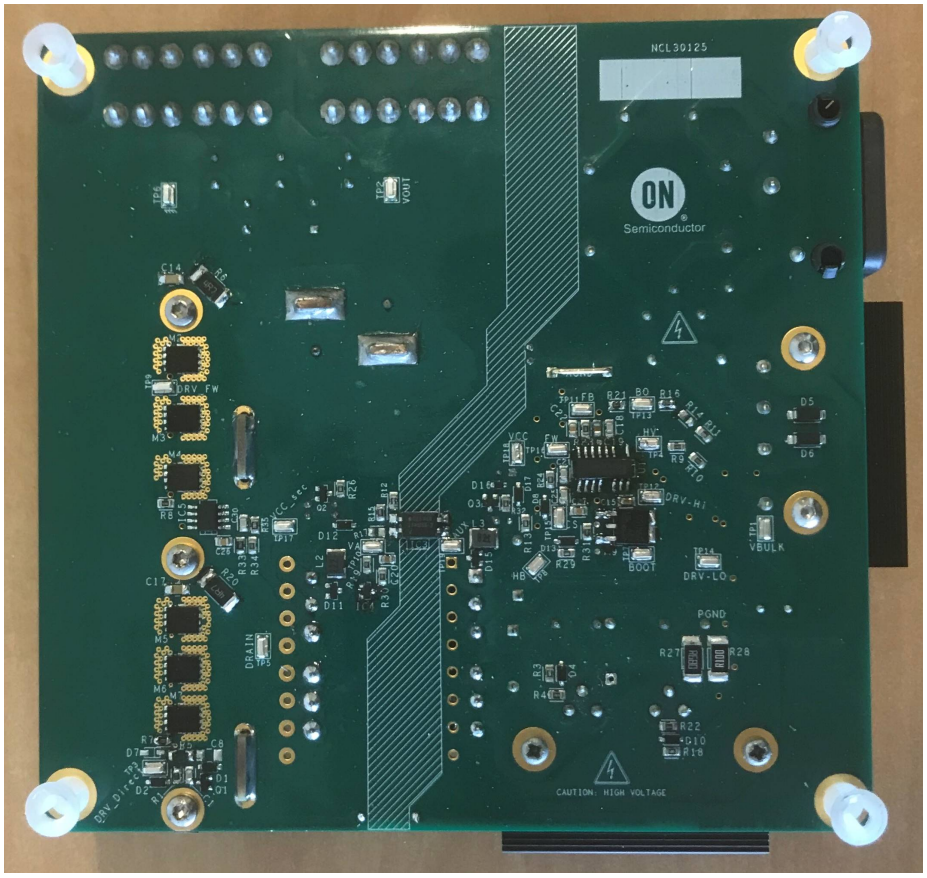
Demonstration Board Schematic Diagram



NCL30125 5 V/300 W Power Converter

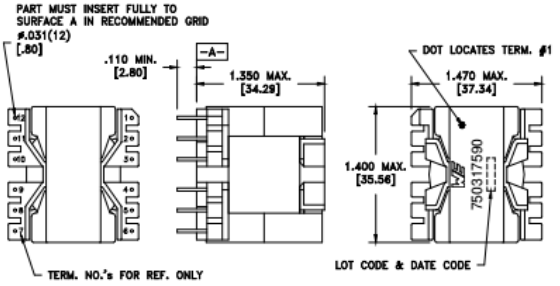
Board Pictures

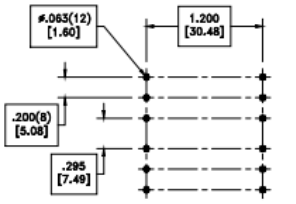


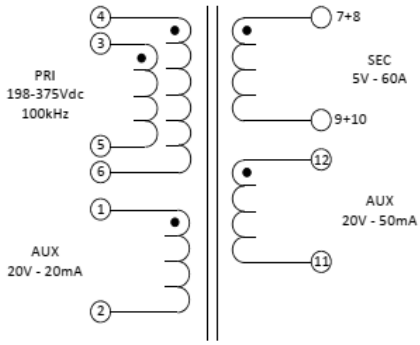


Transformer Data

CUSTOMER TERMINAL	RoHS	LEAD(Pb)--FREE
Sn 96%, Ag 4%	Yes	Yes







Application of the transformer allows for the leadwires between terminals 7&8 and 9&10 to solder bridge.

Customer to tie terminals 3+4, 5+6, 7+8, and 9+10 on PC board.

ELECTRICAL SPECIFICATIONS @ 25° C unless otherwise noted:

PARAMETER		TEST CONDITIONS	VALUE
D.C. RESISTANCE	4-6	tie(3+4, 5+6), @20ºC	0.062 ohms ±10%
D.C. RESISTANCE	1-2	@20ºC	0.060 ohms ±20%
D.C. RESISTANCE	7-9	tie(7+8, 9+10), @20ºC	0.006 ohms max.
D.C. RESISTANCE	12-11	@20ºC	0.073 ohms ±10%
INDUCTANCE	4-6	tie(3+4, 5+6),10kHz, 100mV, Ls	2.50mH min.
LEAKAGE INDUCTANCE	4-6	tie(3+4, 5+6, 7+8+9+10+11+12),100kHz, 100mV, Ls	4.3µH typ., 8.0µH max.
DIELECTRIC	1-12	tie(2+3+4, 9+10+11), 3900VAC, 1 second	3900VAC, 1 minute
DIELECTRIC	1-6	tie(3+4), 625VAC, 1 second	
DIELECTRIC	7-12	tie(9+10), 625VAC, 1 second	
TURNS RATIO		(4-6):(3-5)	1:1, ±1%
TURNS RATIO		(4-6):(1-2)	7.25:1, ±1%
TURNS RATIO		(4-6):(7-9), tie(7+8, 9+10)	14.5:1, ±1%
TURNS RATIO		(4-6):(12-11)	5.8:1, ±1%

GENERAL SPECIFICATIONS:

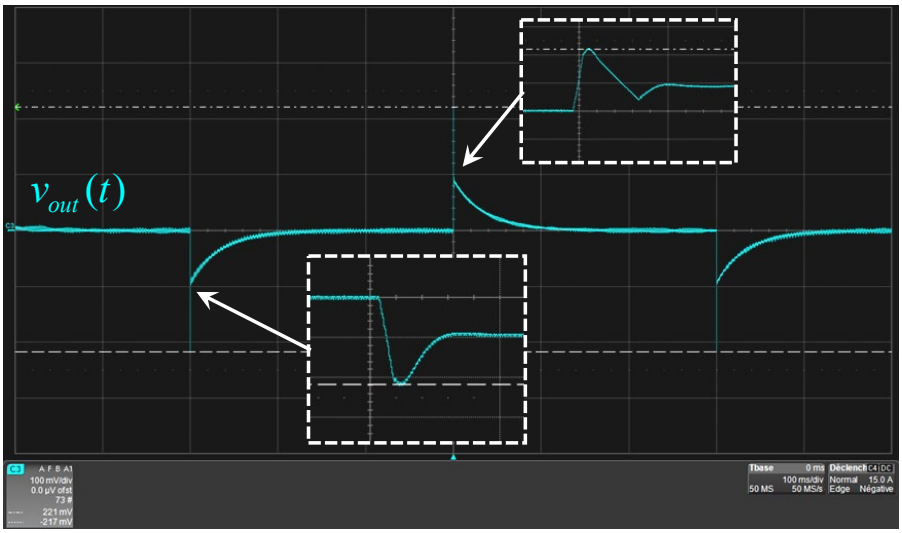
OPERATING TEMPERATURE RANGE: -40ºC to +125ºC including temp rise.

990V·µsec rating at 2500 Gauss for a unipolar square wave pulse

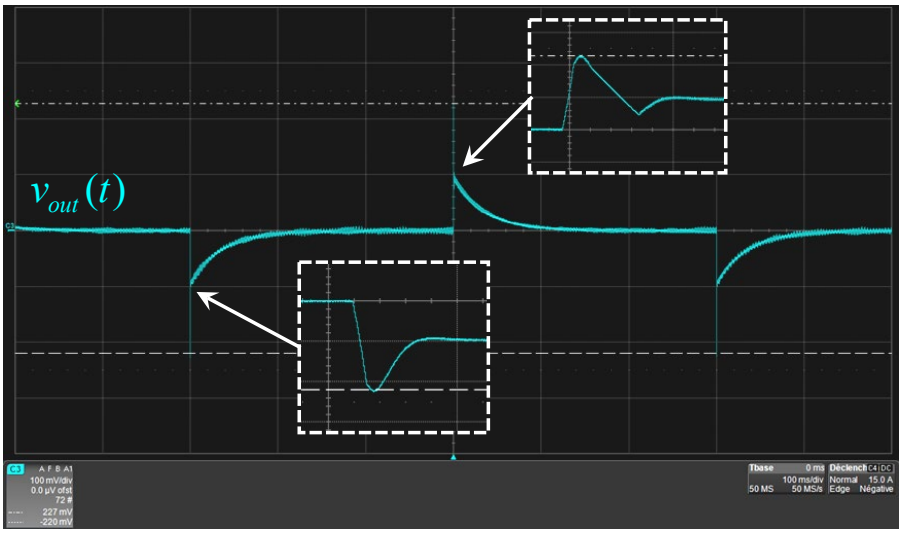
Wire insulation & RoHS status not affected by wire color. Wire insulation color may vary depending on availability.

DFM	SP	Packaging Specifications	Tolerances unless otherwise specified:	DRAWING TITLE	PART NO.
DATE	4/13/2018	Method: Tray	Angles: ±1° Decimals: ±.005 [.13]	TRANSFORMER	750317590
ENG	KLM	PKG-0825	Fractions: ±1/64 Footprint: ± .001 [.03]		
REV.	01	CONVENTION PLACEMENT	This drawing is dual dimensioned. Dimensions in brackets are in millimeters.		
DATE	7/11/2019	www.we-online.com/midcom			SPECIFICATION SHEET 1 OF 1

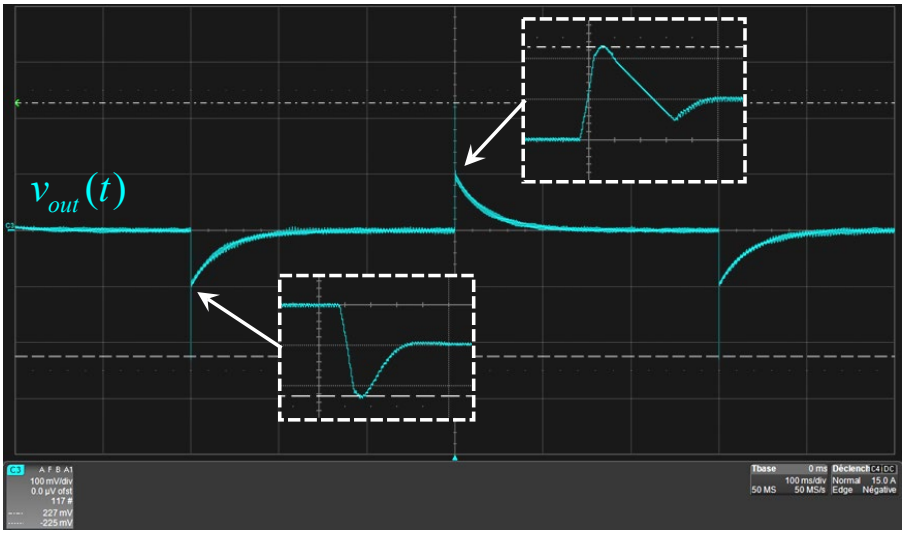
Test Data



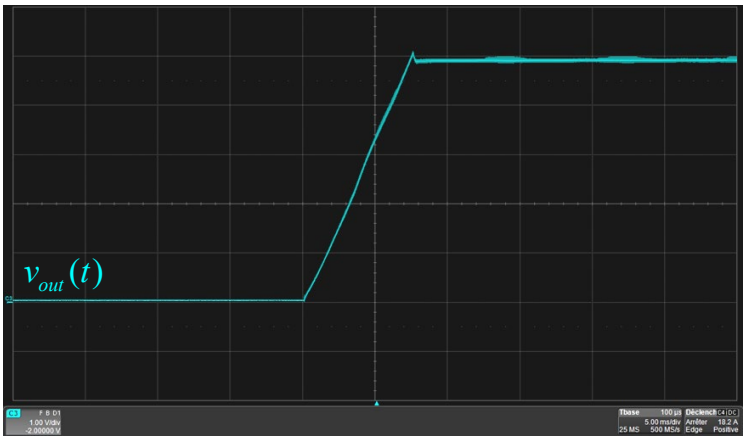
V_{in} = 176 V rms – 6 to 60 A – 1 A/µs

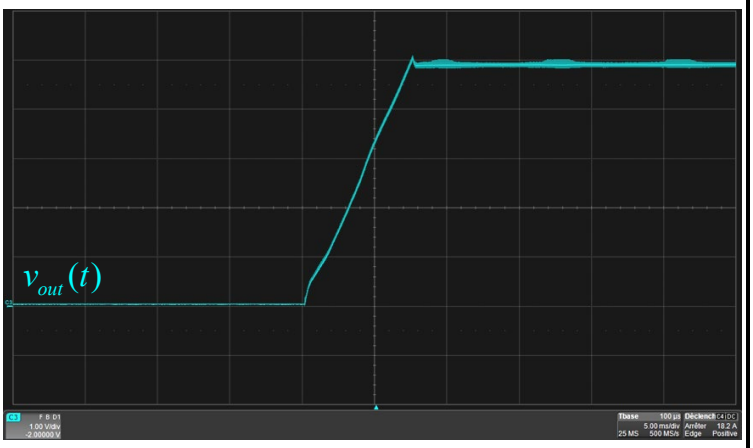


V_{in} = 230 V rms – 6 to 60 A – 1 A/µs

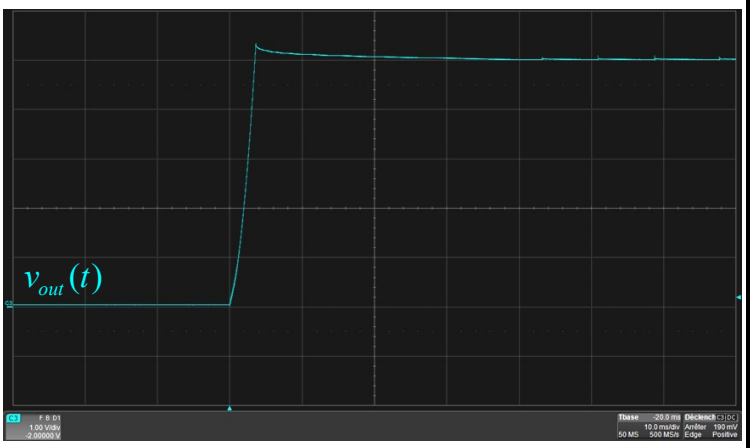


V_{in} = 265 V rms – 6 to 60 A – 1 A/µs


$v_{out}(t)$


$v_{out}(t)$


$v_{out}(t)$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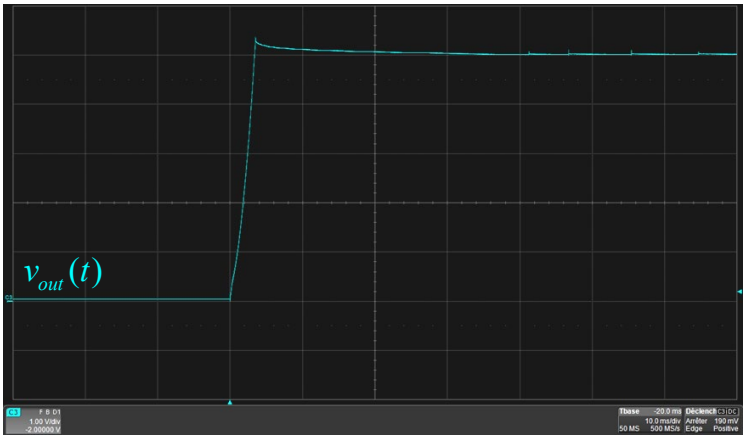
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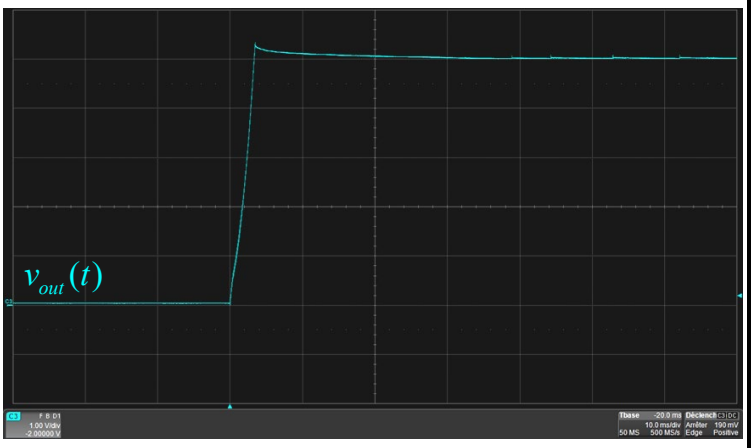
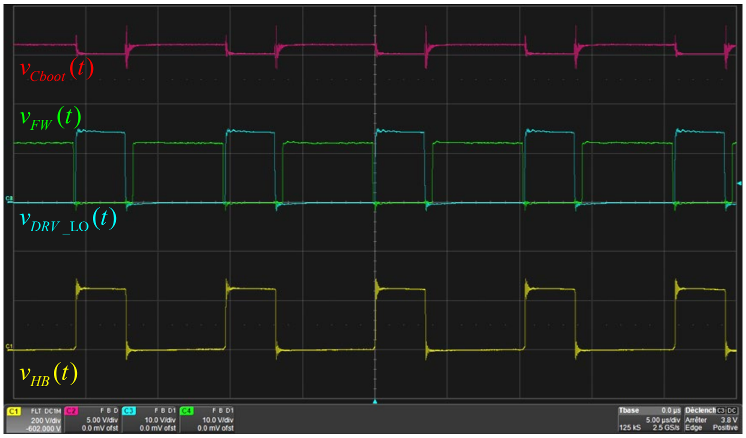

$v_{out}(t)$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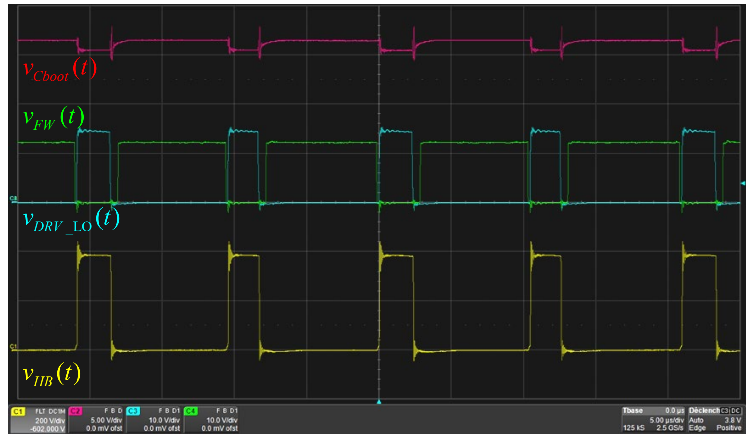
$v_{FW}(t)$
$v_{DRV\_LO}(t)$
$v_{HB}(t)$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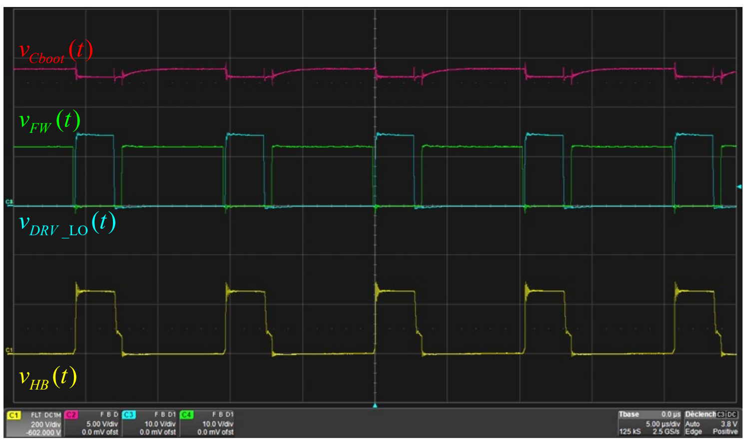
$v_{FW}(t)$
$v_{DRV\_LO}(t)$
$v_{HB}(t)$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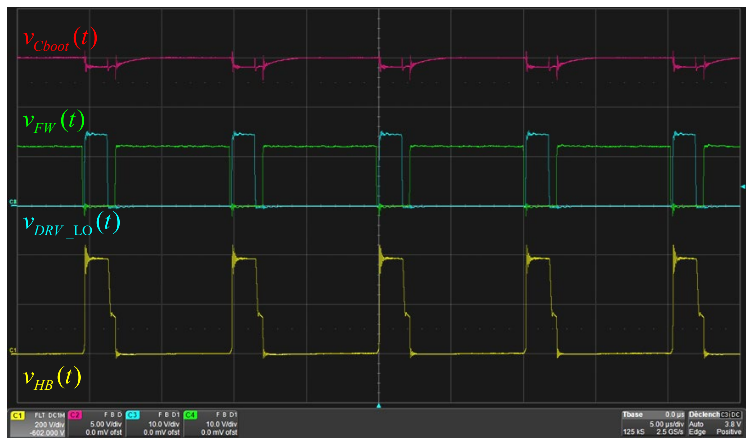
$v_{FW}(t)$
$v_{DRV\_LO}(t)$
$v_{HB}(t)$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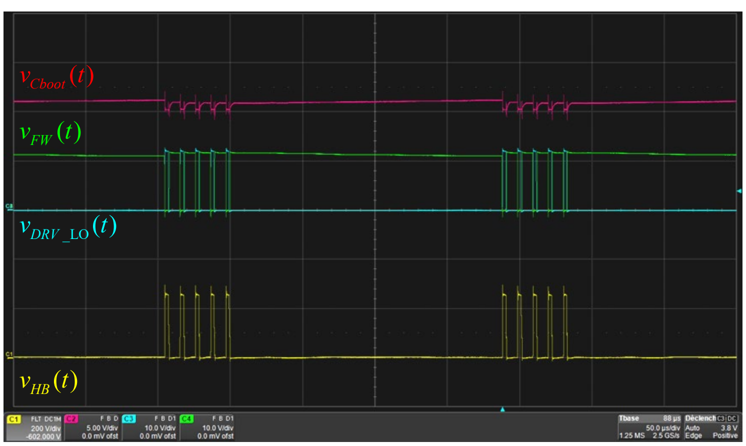
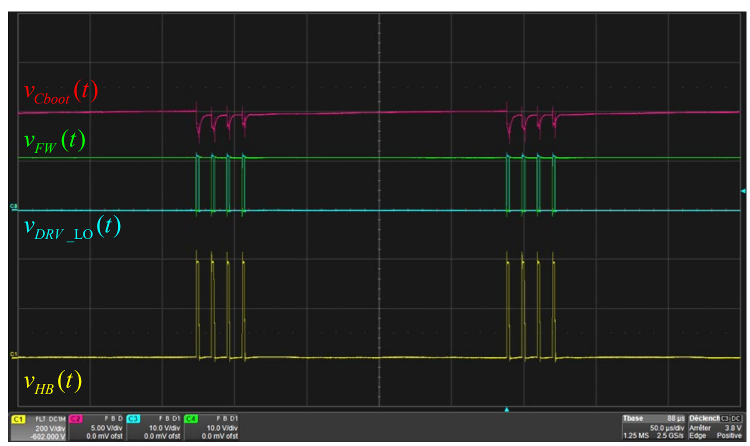
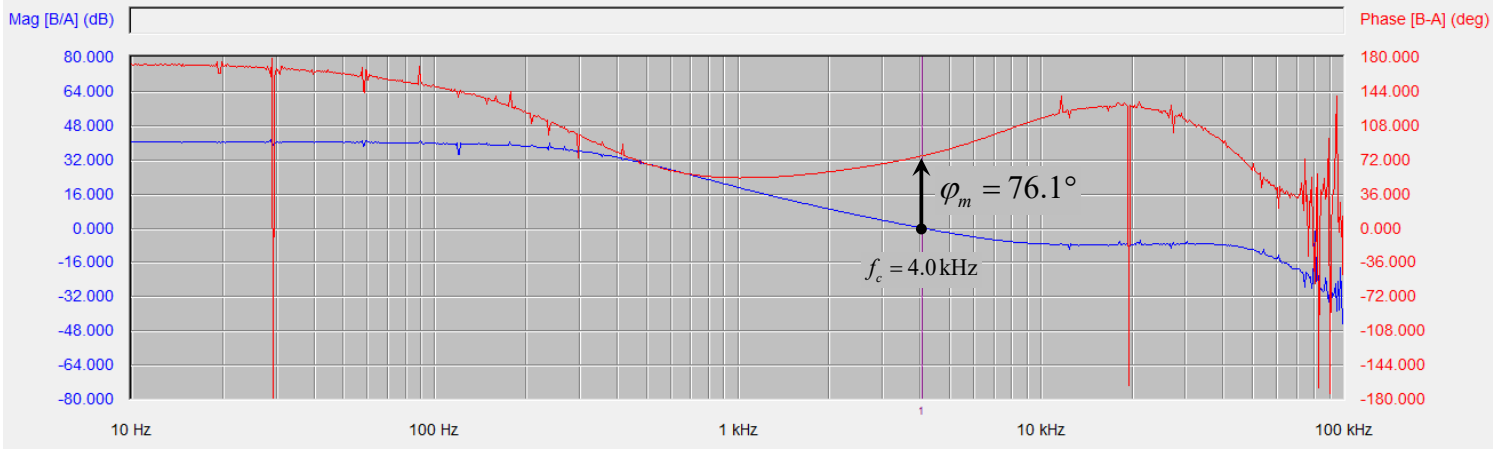
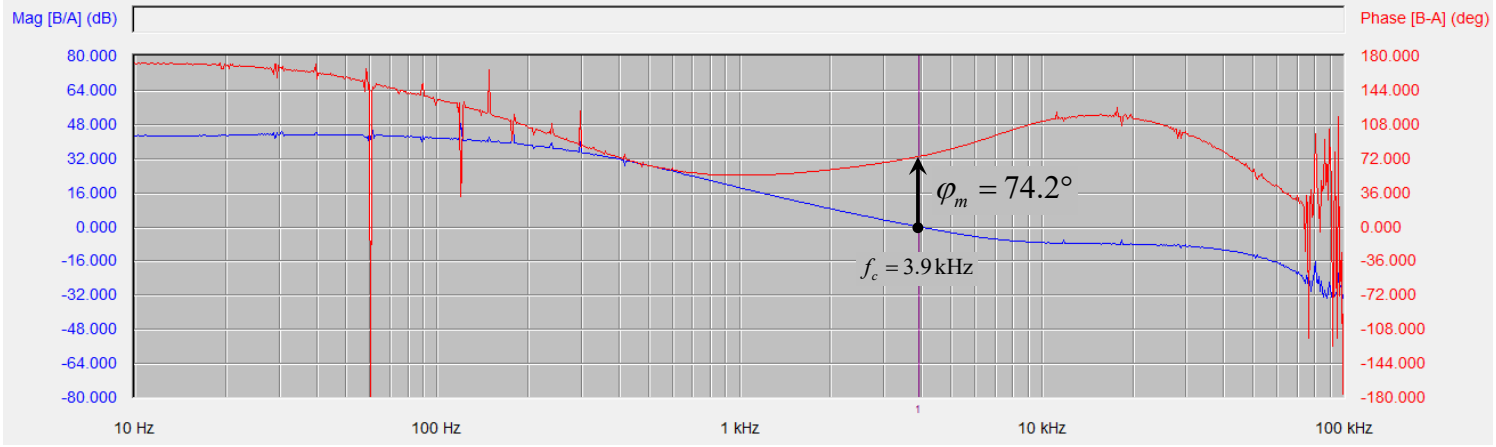
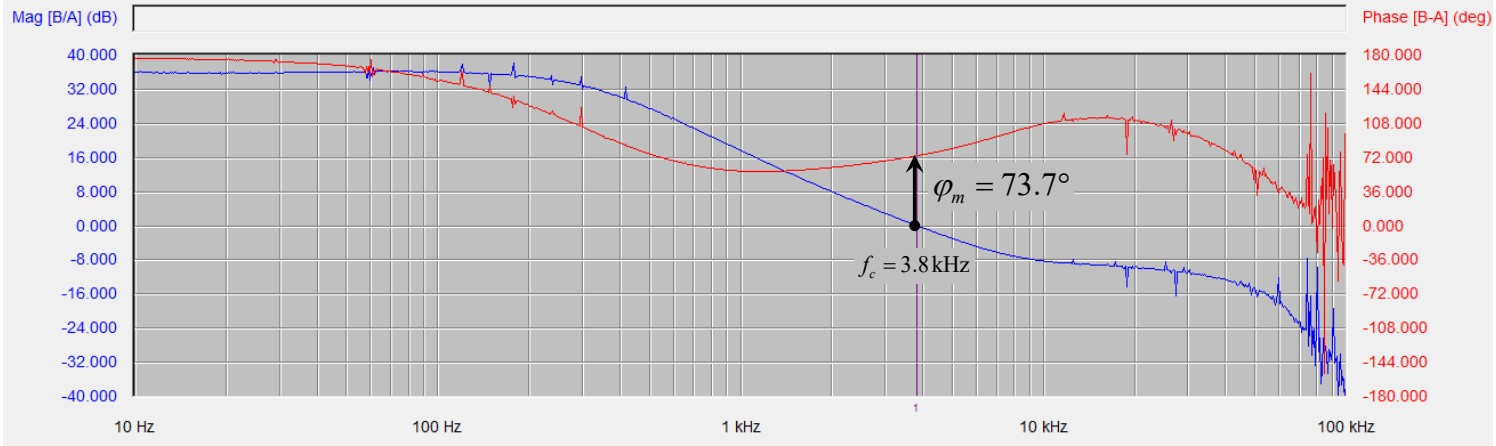
$v_{FW}(t)$
$v_{DRV\_LO}(t)$
$v_{HB}(t)$


$v_{Cboot}(t)$
$v_{FW}(t)$
$v_{DRV\_LO}(t)$
$v_{HB}(t)$

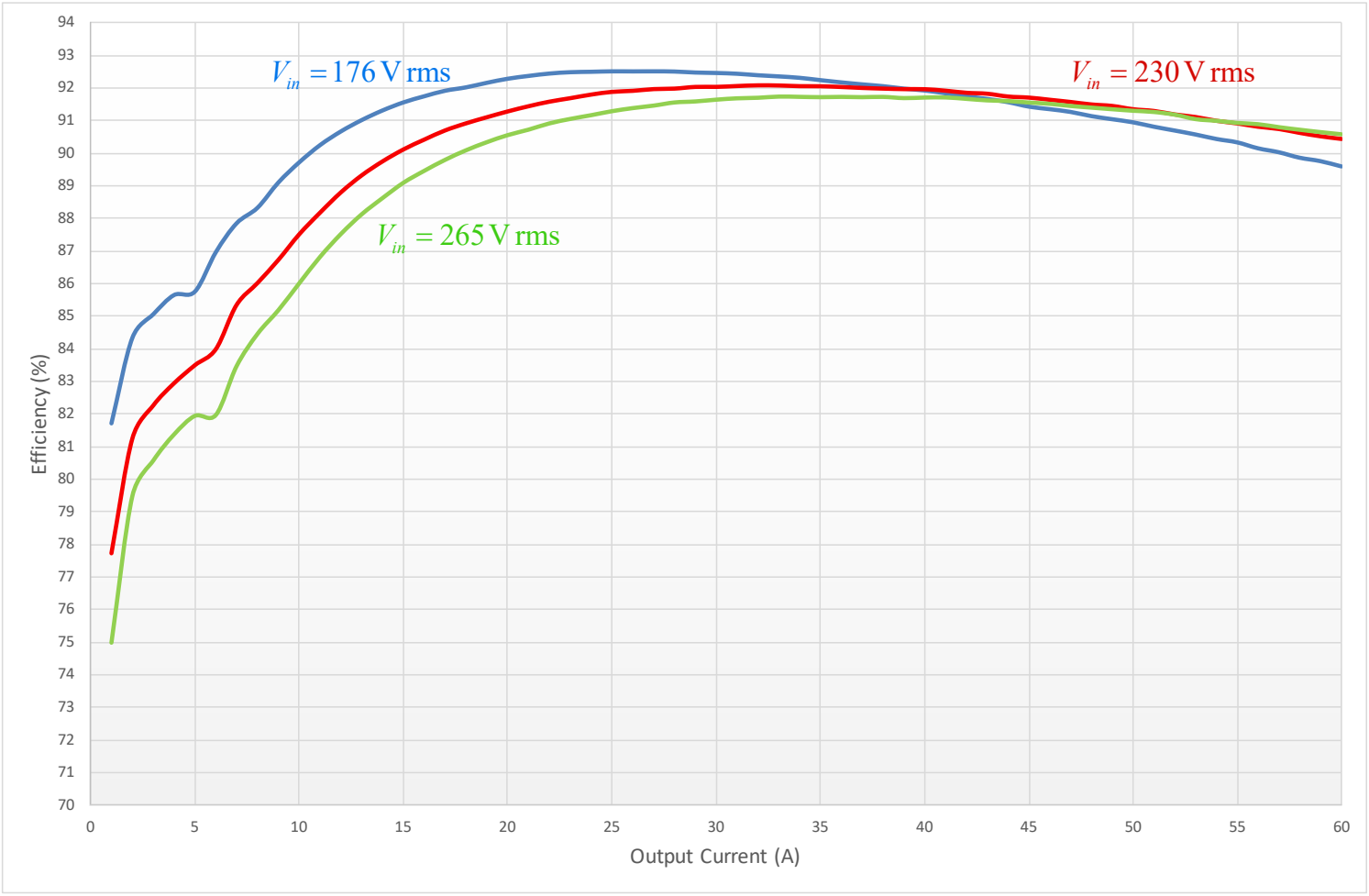

$v_{Cboot}(t)$
$v_{FW}(t)$
$v_{DRV\_LO}(t)$
$v_{HB}(t)$


Mag [B/A] (dB)
Phase [B-A] (deg)
80.000
64.000
48.000
32.000
16.000
0.000
-16.000
-32.000
-48.000
-64.000
-80.000
180.000
144.000
108.000
72.000
36.000
0.000
-36.000
-72.000
-108.000
-144.000
-180.000
$\varphi_m = 76.1°$
$f_c = 4.0\,\text{kHz}$
10 Hz
100 Hz
1 kHz
10 kHz
100 kHz


Mag [B/A] (dB)
Phase [B-A] (deg)
80.000
64.000
48.000
32.000
16.000
0.000
-16.000
-32.000
-48.000
-64.000
-80.000
180.000
144.000
108.000
72.000
36.000
0.000
-36.000
-72.000
-108.000
-144.000
-180.000
$\varphi_m = 74.2°$
$f_c = 3.9\,\text{kHz}$
10 Hz
100 Hz
1 kHz
10 kHz
100 kHz


Mag [B/A] (dB)
Phase [B-A] (deg)
40.000
32.000
24.000
16.000
8.000
0.000
-8.000
-16.000
-24.000
-32.000
-40.000
180.000
144.000
108.000
72.000
36.000
0.000
-36.000
-72.000
-108.000
-144.000
-180.000
$\varphi_m = 73.7°$
$f_c = 3.8\,\text{kHz}$
10 Hz
100 Hz
1 kHz
10 kHz
100 kHz

Efficiency Data



Bill of materials

Designator	Quantity	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number	Substitution Allowed
C1	1	Ceramic capacitor	100 pF	10%, 50 V	0805	Generic	Standard	Yes
C2, C3	2	Y2 capacitor	1 nF	20%, 300 Vac	through-hole	Epcos	B32021A3102M000	Yes
C4, C5	2	Electrolytic capacitor	150 µF	400 V	D18_H40_P7.5	Wurth Elektronik	860021381022	No
C6, C7	1	X2 capacitor	470 nF	275 V ac	L15_W10_P12.5	Wurth Elektronik	890324024005	No
C9, C10, C11, C12, C13	5	Electrolytic capacitor	2000 µF	10%, 6.3 V	D10_H12.5_P5	Wurth Elektronik	870025175013	No
C14	1	Ceramic capacitor	10 nF	10%, 100 V	1206	Generic	Standard	Yes
C15, C26, C27	3	Ceramic capacitor	100 nF	10%, 50 V	0805	Generic	Standard	Yes
C16	1	Y1 capacitor	1 nF	20%, 250 Vac	through-hole	Murata	DE1E3KX102MA4BN01F	Yes
C14	1	Ceramic capacitor	4.7 nF	10%, 100 V	1206	Generic	Standard	Yes
C18, C21, C30	3	Ceramic capacitor	1 nF	10%, 50 V	0805	Generic	Standard	Yes
C19	1	Ceramic capacitor	1.5 nF	10%, 50 V	0805	Generic	Standard	Yes
C20	1	Ceramic capacitor	33 nF	10%, 50 V	0805	Generic	Standard	Yes
C22	1	Ceramic capacitor	22 nF	10%, 50 V	0805	Generic	Standard	Yes
C23, C24	1	Electrolytic capacitor	22 µF	50 V	D6.3_H11_P2	Wurth Elektronik	860080672001	No
C25	1	Ceramic capacitor	390 pF	10%, 50 V	0805	Generic	Standard	Yes
C28, C29	2	Electrolytic capacitor	47 µF	50 V	D6.3_H11_P2.5	Wurth Elektronik	860010673012	No
CM1	1	Common choke	5 mH	30%, 6 A	through-hole	Wurth Elektronik	744825605	No
D1, D4, D10, D13	4	Switching diode	MMSD4148	100 V	SOD-123	ON Semiconductor	MMSD4148	No
D2	1	Zener diode	15 V		SOD-123	ON Semiconductor	Standard	Yes
D3, D9, D14	3	Power rectifiers	MUR160	1 A, 600 V	through-hole	ON Semiconductor	MUR160G	No
D5, D6	2	Power rectifiers	MRA4007	1 A, 1 kV	SMA	ON Semiconductor	MRA4007T3G	No
D8, D17	2	Zener diode	18 V		SOD-123	ON Semiconductor	Standard	Yes

D11, D15	2	Dual switching diode	BAV23CL	400 mA, 250 V	SOT-23	ON Semiconductor	BAV23CL	No
D12	1	Zener diode	12 V		SOD-123	ON Semiconductor	Standard	Yes
D16	1	Schottky diode	BAT54	40 V, 300 mA	SOD-323	Generic	BAT54JFILM	Yes
F1	1	Fuse	5 A, 250 V		through-hole	Generic	0217005.MXP	Yes
HS1	1	Headsink	SK 481 50		through-hole	Fischer Elektronik	SK 481 50	Yes
HS1.1	2	Clips	THFU 2	17.8x10mm		Generic	THFU 2	Yes
HS2	1	Headsink	SWP10	100 mm, black	through-hole	Fischer Elektronik	SWP10	Yes
HS2.1	1	Insulator		100x20mm		Generic	H486A-150-1.0	Yes
HS3	1	Headsink	SK 481 50		through-hole	Fischer Elektronik	SK 481 50	Yes
HS3.1	1	Clips	THFU 2	17.8x10mm		Generic	THFU 2	Yes
IC1	1	Diode Bridge	GSIB1580	15 A, 800 V	through-hole	Vishay	GSIB1580-E3/45	Yes
IC2	1	Primary Controller			SO-16	ON Semiconductor	NCL30125B2	No
IC3	1	Optocoupler	SFH6156-2		SMD-4	Vishay	SFH6156-2T	Yes
IC4	1	Shunt Regulator	NCP431	2.5-36 V, 1-100 mA	SOT-23	ON Semiconductor	NCP431AVSNT1G	No
IC5	1	Sync. Rectification IC	NCP4306		SO-8	ON Semiconductor	NCP4306AADZZZADR2G	No
J1	1	Input Connector		10 A, 250 Vac		Generic	GSF1.1201.31	Yes
J2, J3, J4, J5	4	Output Connector			through-hole	Generic	8196	Yes
L1	1	Inductor	2.2 µH	75 A	through-hole	Wurth Elektronik	7443763521022	No
L2	1	Inductor	2.2 mH	40 mA	SMD	Wurth Elektronik	744045222	No
L3	1	Inductor	820 µH	40 mA	SMD	Wurth Elektronik	744045821	No
M1, M8	2	MOSFET	FDPF20N50	20 A, 500 V	TO-220F	ON Semiconductor	FDPF20N50	No
M2, M3, M4	3	MOSFET	NTMFS5C423	150 A, 40 V	SO-8FL	ON Semiconductor	NTMFS5C423	No
M5, M6, M7	3	MOSFET	NTMFS5C410	330 A, 40 V	SO-8FL	ON Semiconductor	NTMFS5C410	No
M9	1	MOSFET	CS1N60	0.8 A, 600 V	TO-252	Generic	CS1N60A4H	Yes
Q1	1	NPN transistor	FMMT493	1 A, 100 V	SOT-23	Diodes	FMMT493TA	No
Q2, Q3	2	NPN transistor	MMBTA06L	500 mA, 60 V	SOT-23	ON Semiconductor	MMBTA06LT1G	No
R1	1	Ceramic Resistor	470 Ω	5%	0805	Generic	Standard	Yes

R2	1	NTC Thermistor	3 Ω	5 A	through-hole	Epcos	B57236S0309M0	Yes
R3, R12, R13, R18, R29	5	Ceramic Resistor	10 Ω	5%	0805	Generic	Standard	Yes
R4, R8, R22, R31	4	Ceramic Resistor	47 kΩ	5%	0805	Generic	Standard	Yes
R5	1	Zener diode	4.3 V		SOD-123	ON Semiconductor	Standard	Yes
R6, R20	2	Ceramic Resistor	4.7 Ω	5%	2512	Generic	Standard	Yes
R7	1	Ceramic Resistor	10 kΩ	5%	0805	Generic	Standard	Yes
R9, R10	2	Ceramic Resistor	2.2 kΩ	5%	0805	Generic	Standard	Yes
R11, R14	2	Ceramic Resistor	3 MΩ	5%	0805	Generic	Standard	Yes
R15	1	Ceramic Resistor	590 Ω	5%	0805	Generic	Standard	Yes
R16	1	Ceramic Resistor	200 kΩ	5%	0805	Generic	Standard	Yes
R17	1	Ceramic Resistor	NC	5%	0805	Generic	Standard	Yes
R19, R30	1	Ceramic Resistor	2.5 kΩ	5%	0805	Generic	Standard	Yes
R6, R17, R20	3	Ceramic Resistor	NC	5%	2512	Generic	Standard	Yes
R21	1	Ceramic Resistor	20 kΩ	5%	0805	Generic	Standard	Yes
R23	1	Ceramic Resistor	100 kΩ	5%	0805	Generic	Standard	Yes
R24	1	Ceramic Resistor	100 Ω	5%	0805	Generic	Standard	Yes
R25	1	NTC, Beta = 4190	100k @ 25°C	5%	through-hole	Vishay	NTCLE100E3104JB0	No
R26, R32	2	Ceramic Resistor	1 kΩ	5%	0805	Generic	Standard	Yes
R27	1	Ceramic Resistor	0.68 Ω	5%, 1 W	2512	Generic	RL2512FK-070R68L	Yes
R28	1	Ceramic Resistor	0.1 Ω	5%, 1 W	2512	Generic	TLM3AER10JTE	Yes
R33	1	Ceramic Resistor	24 kΩ	5%	0805	Generic	Standard	Yes
R34	1	Ceramic Resistor	12 kΩ	5%	0805	Generic	Standard	Yes
R35	1	Ceramic Resistor	43 kΩ	5%	0805	Generic	Standard	Yes
ST1	1	jumper400h			through-hole	Generic	D3082F05	Yes
T1	1	Transformer			through-hole	Wurth Elektronik	750317590rev01	No
TP1 to TP19	19	Test point			SMD	Keystone	Keystone 5019	Yes
X1, X2, X3, X4	4	Support à riveter			through-hole	Generic	SFCBS-M4-12M-01	Yes

Design note created by Yann Vaquette – October 2019