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Design Note – DN05128/D

5-V/10-A Active-Clamp Forward Dc-Dc Converter

Devices	Applications	Input voltage	Output power	Topology	Board Size
NCP1566	Telecom	37-57 V dc	50 W	Active-Clamp Forward	70 x 60 x 20 mm
Output spec.	**Turn on time**	**Efficiency**	**Operating temperature**	**Cooling**	**Standby power**
5 V/10 A	< 100 ms	above 92 % @ full load	0 – 50 °C	Open Frame in Still Air	Does not apply

Description

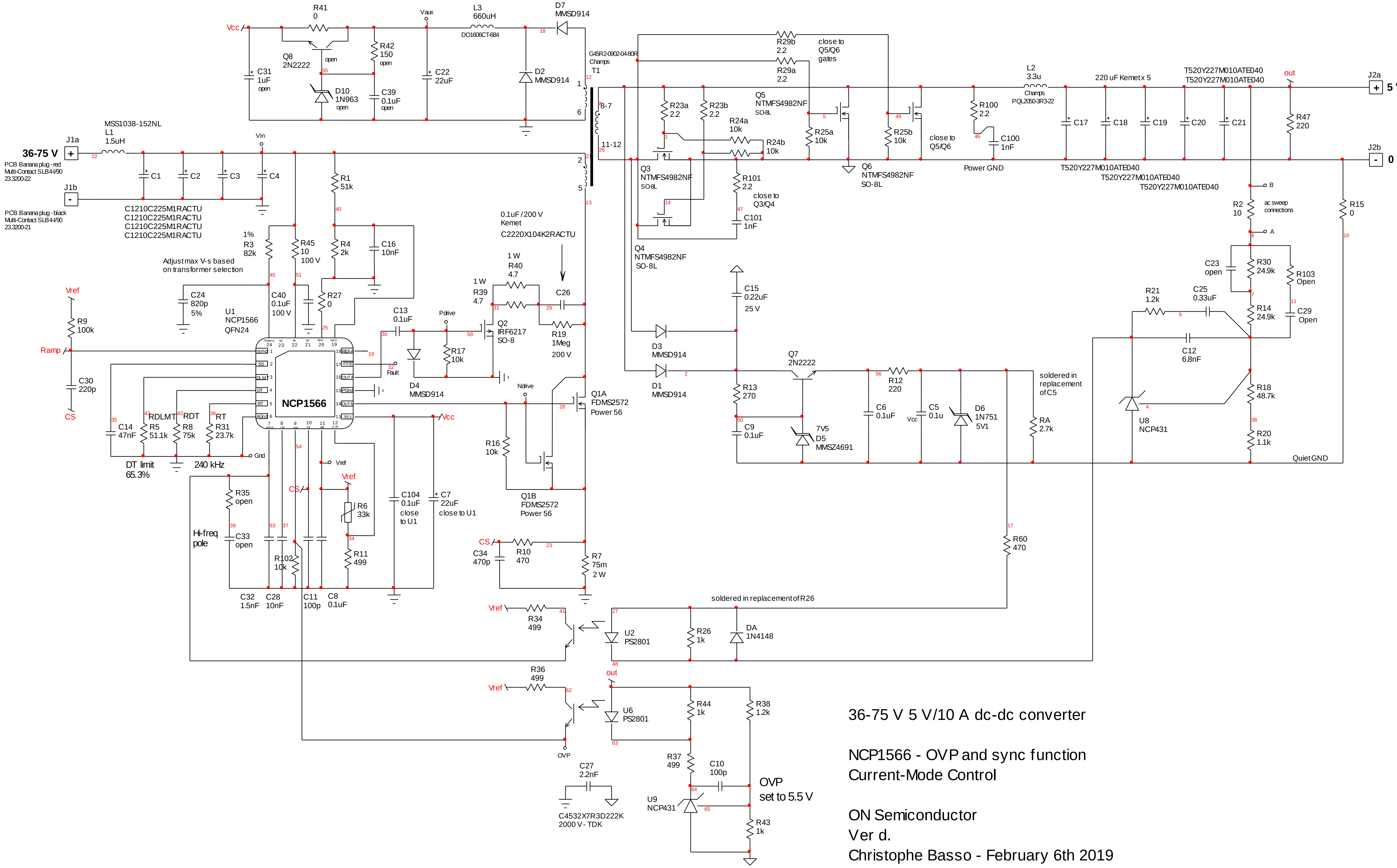
This design note provides elementary information about an active-clamp forward converter built with the NCP1566 operated in current-mode control. This controller offers many features to build an energy-efficient converter with all the needed protections like cycle-by-cycle current limit with a 500-mV sense voltage, over current protection (OPP) for a stable maximum output current limit, over temperature protection with a dedicated NTC pin and a pin to sense an output voltage runaway (loop failure for instance). The controller drives a N-channel MOSFET as with any classical forward converter plus a P-channel for the active-clamp portion. A user-adjustable deadtime is inserted to let the drain voltage fall sufficiently low to minimize switching losses. This controller can be configured to work in voltage- or current-mode control.

The primary-side section drives a transformer whose primary inductance is 80 µH. The energy accumulated in this inductance will help drive down the drain voltage prior to turning the MOSFET on again. The characteristics of this transformer impose a duty ratio clamp below 65% which ensures a safe operation during large transient steps. The current is sensed via a 75-mΩ resistance and limits the maximum output current owing to an average current emulation inside the chip. The board is rated to 10 A but you can load it up to 15 A without problems. The switching frequency of 240 kHz, the dead time and the maximum duty ratio are set by three individual resistors. The power stage is made of two switching transistors: a N-channel for the main switching section and a P-channel for the active-clamp circuitry. These two transistors are operated with a small dead time between the transitions, giving time for the drain voltage to reduce prior to turning the power switch on again. In the secondary side, four MOSFETs are self-driven by the transformer without additional regulation circuitry. The loop is closed by a NCP431 wired in a type-2 configuration. Loop gain measurements show a 70° phase margin at a 10-A output obtained with a 36-V dc source.

Key Features

- Internal 120-V start-up source operated in dynamic self-supply during start-up or skip mode.
- Voltage- or current-mode control operation
- Adaptive dead time for improved efficiency
- Line compensation for over power protection
- Maximum V-s limit and duty ratio clamp
- Short circuit protection
- Over voltage protection
- 5-V/2% voltage reference
- Over temperature protection via an NTC
- Fault reporting pin also used for shutdown
- Synchronization capability via dedicated pin

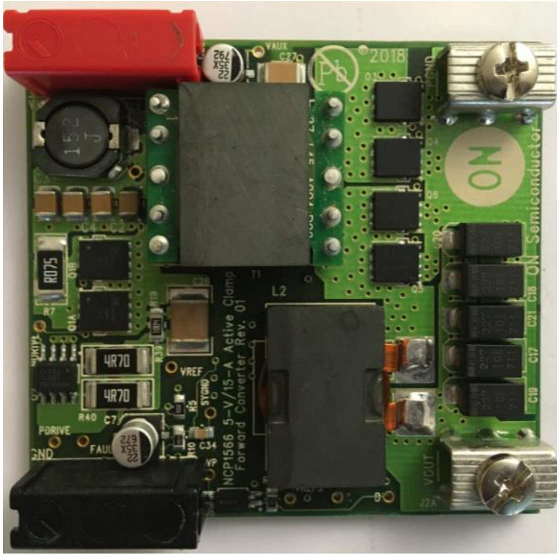
Demonstration Board Schematic Diagram

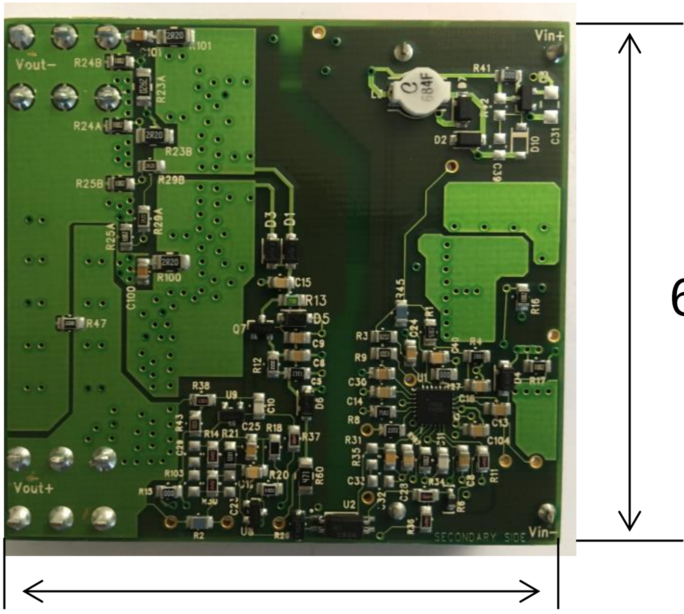


NCP1566 5-V/10-A Power Converter

Board Pictures

Input

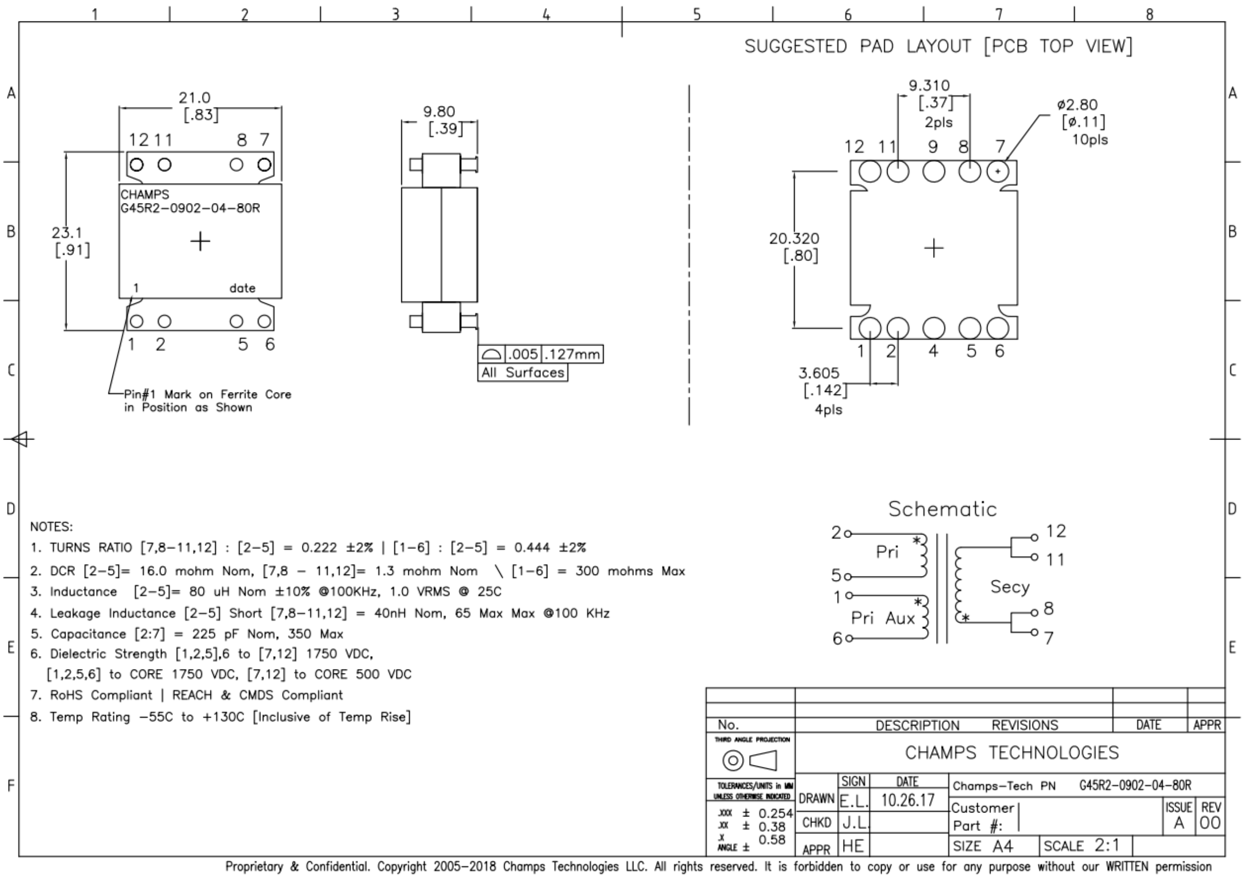


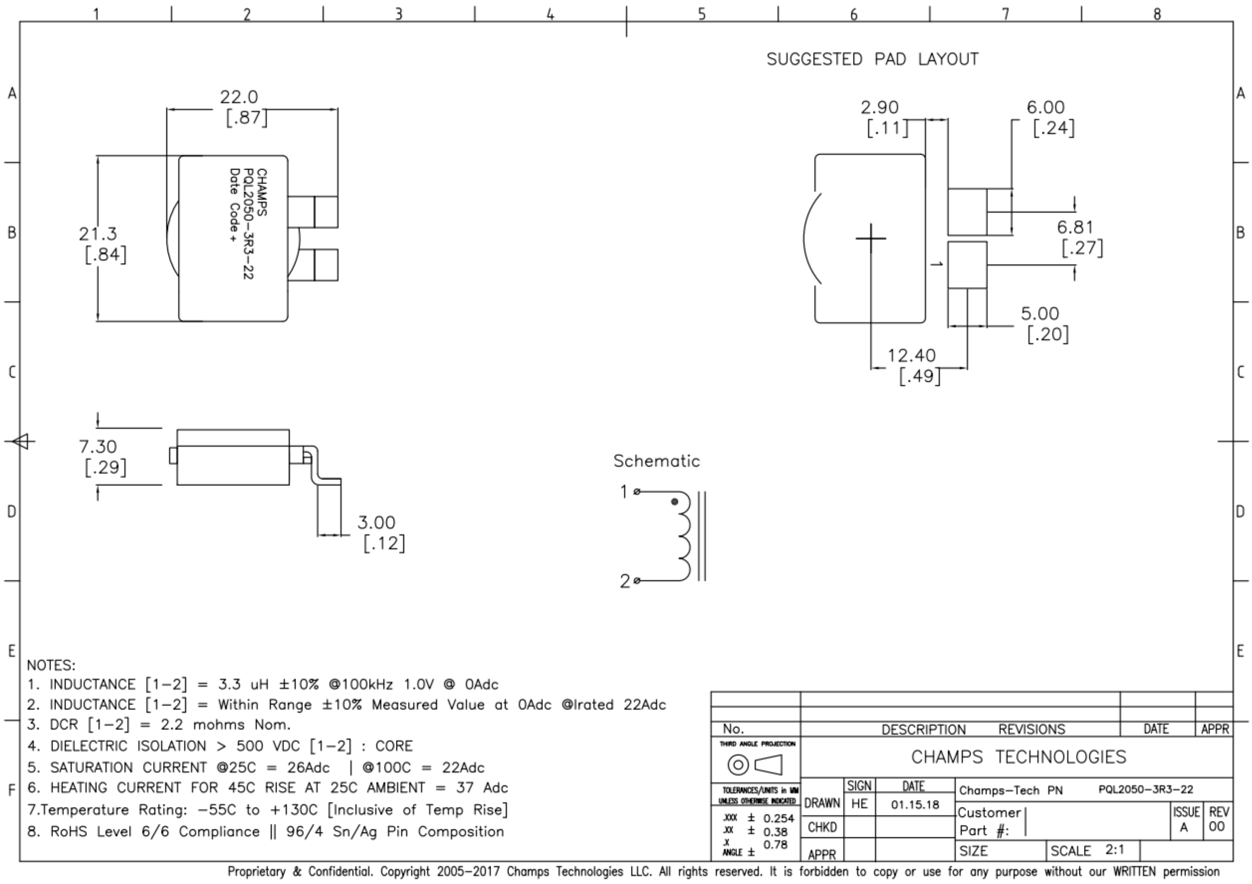


60 mm

70 mm

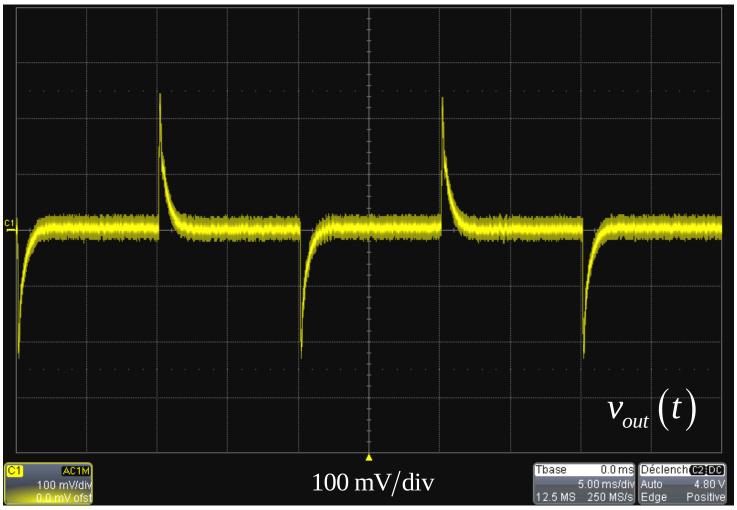
Magnetics Data



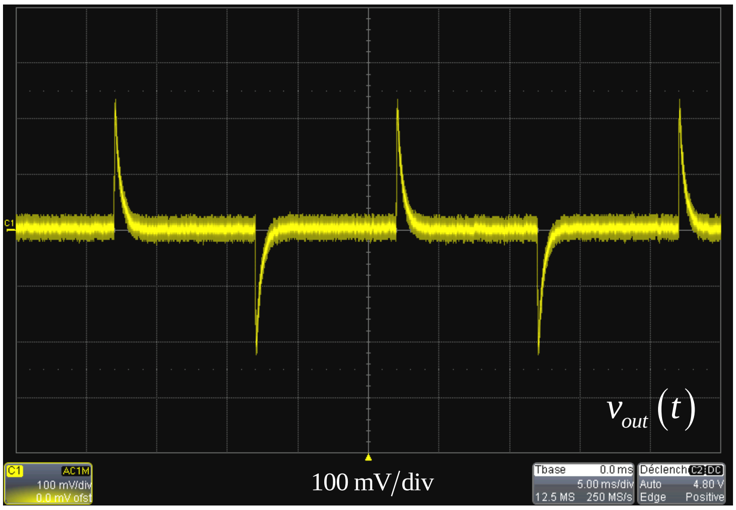


Test Data

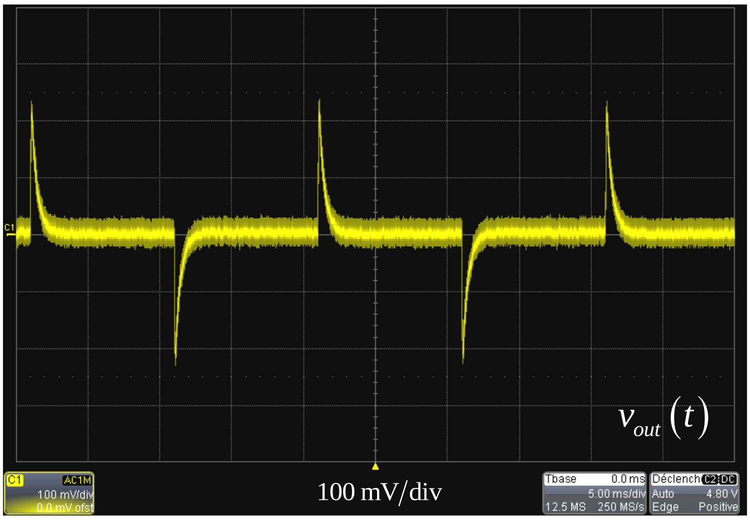
Transient Load Test:



V_{in} = 36 V – 5 to 10 A – 1 A/µs

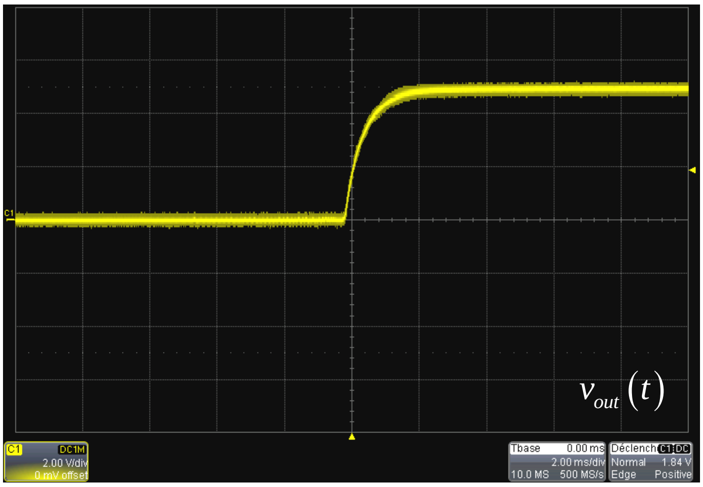


V_{in} = 48 V – 5 to 10 A – 1 A/µs

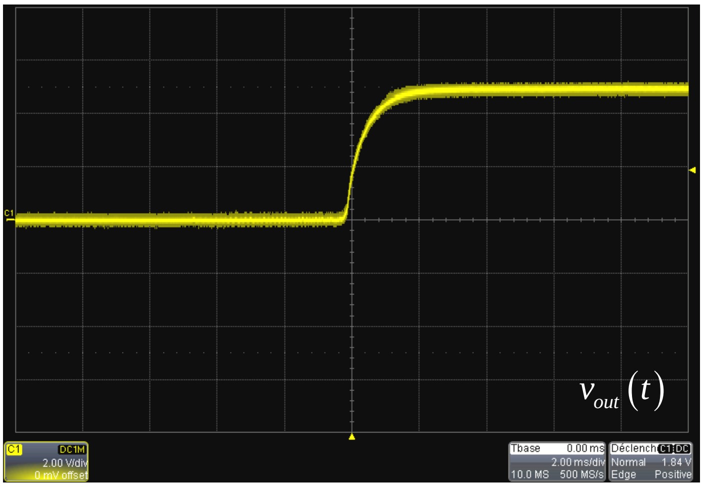


V_{in} = 72 V – 5 to 10 A – 1 A/µs

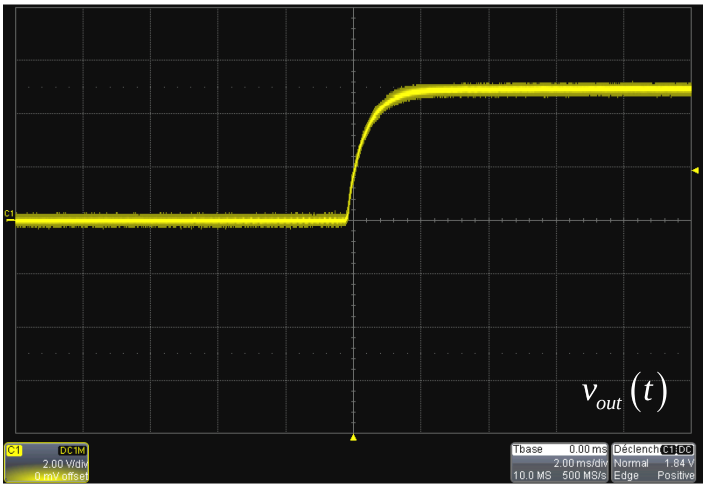
Start-up Sequence:



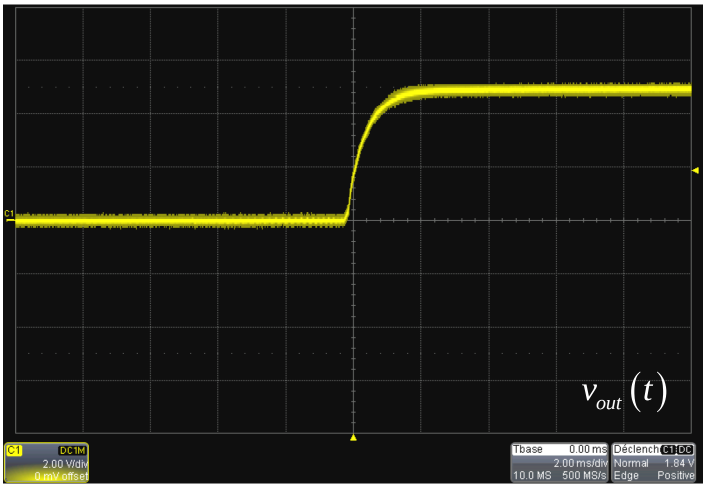
V_{in} = 36 V – I_{out} = 1 A



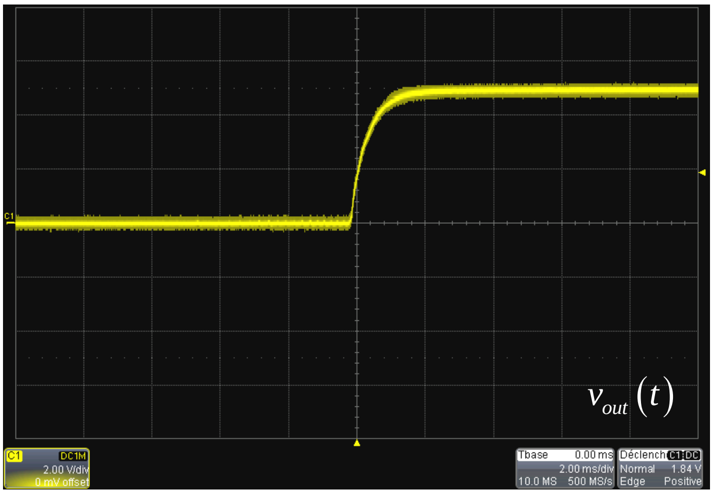
V_{in} = 36 V – I_{out} = 10 A



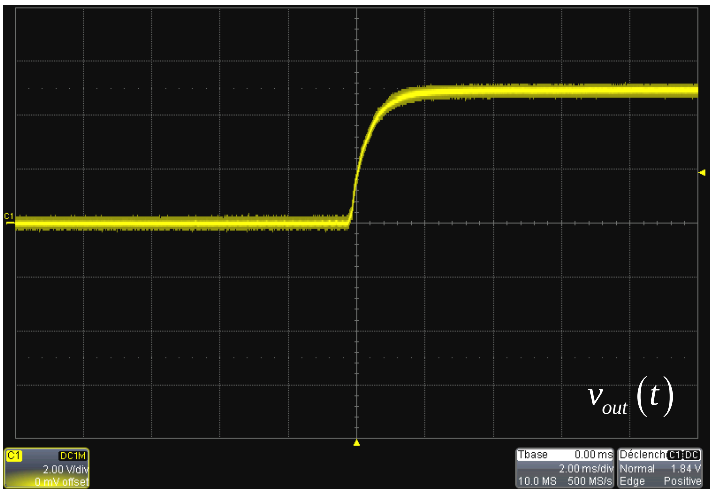
V_{in} = 48 V – I_{out} = 1 A



V_{in} = 48 V – I_{out} = 10 A

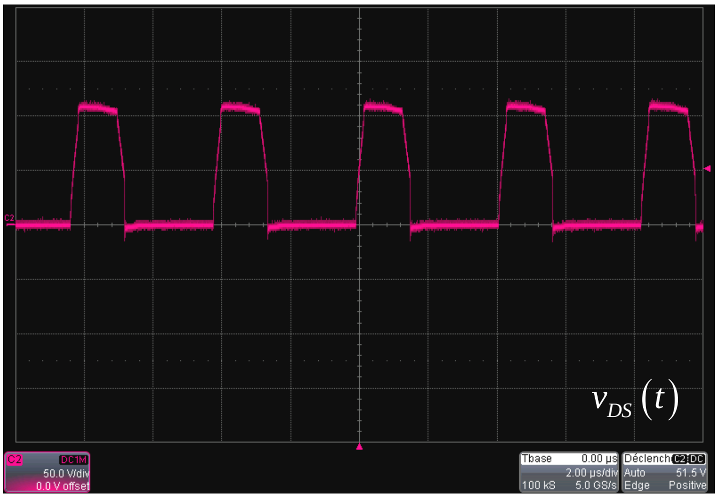


V_{in} = 72 V – I_{out} = 1 A

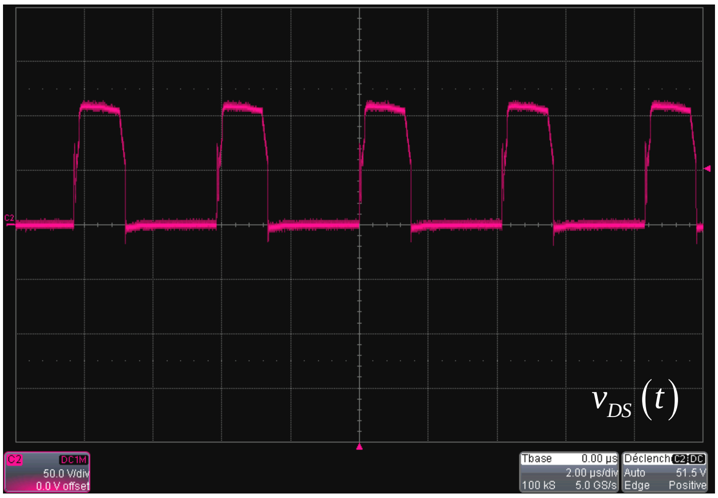


V_{in} = 72 V – I_{out} = 10 A

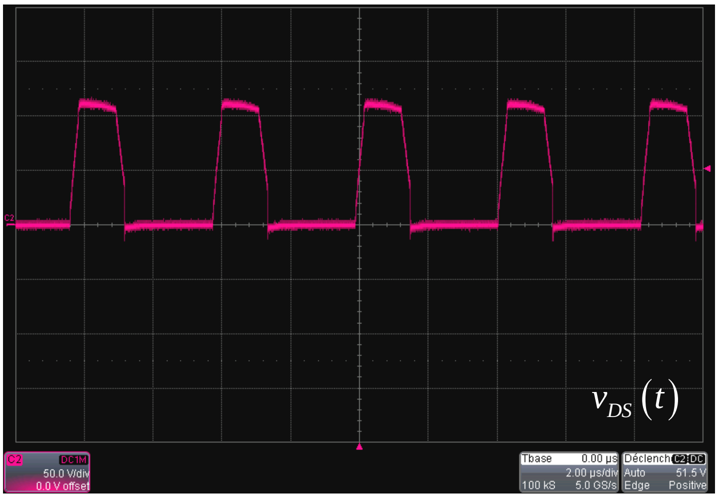
Drain-Source Voltage Waveforms:



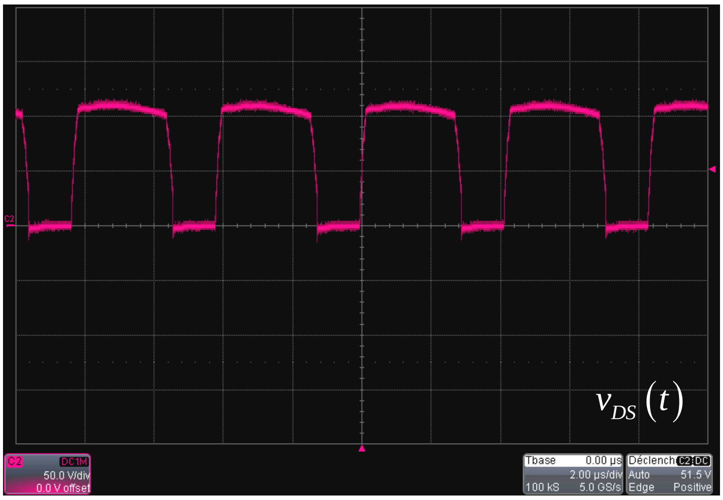
V_{in} = 36 V – I_{out} = 1 A



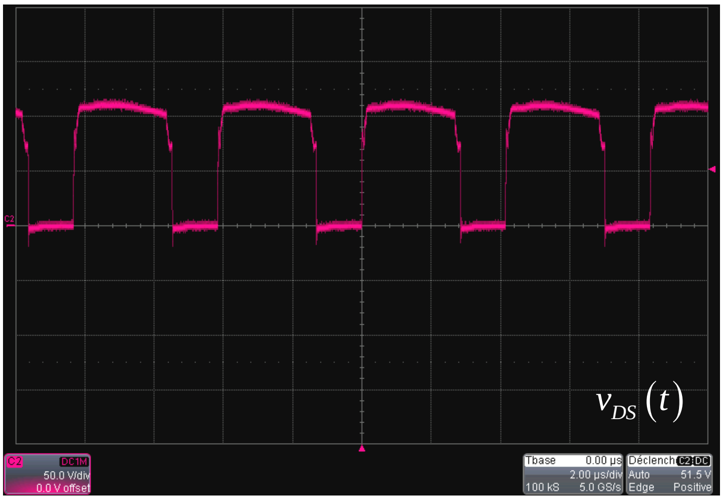
V_{in} = 36 V – I_{out} = 10 A



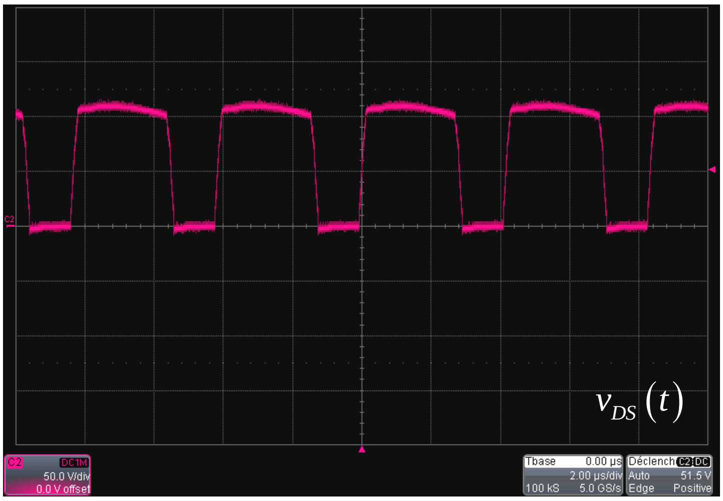
V_{in} = 36 V – I_{out} = 0 A



V_{in} = 72 V – I_{out} = 1 A

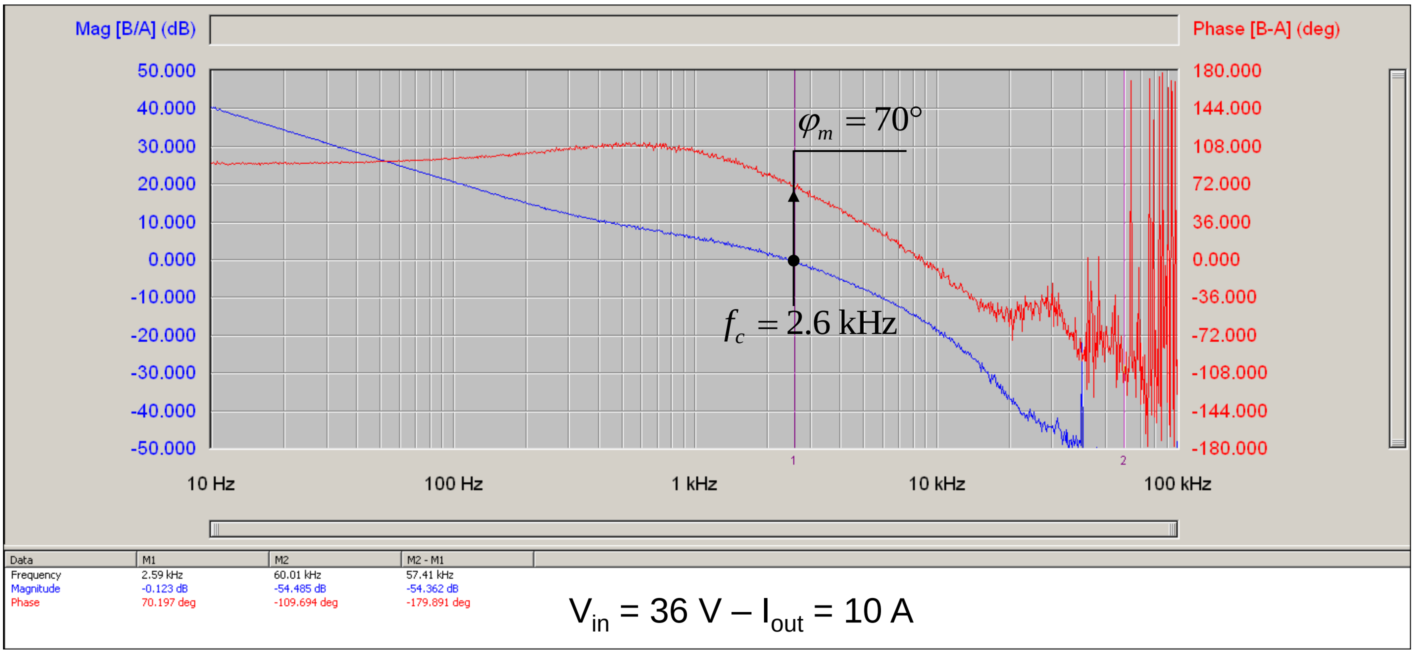


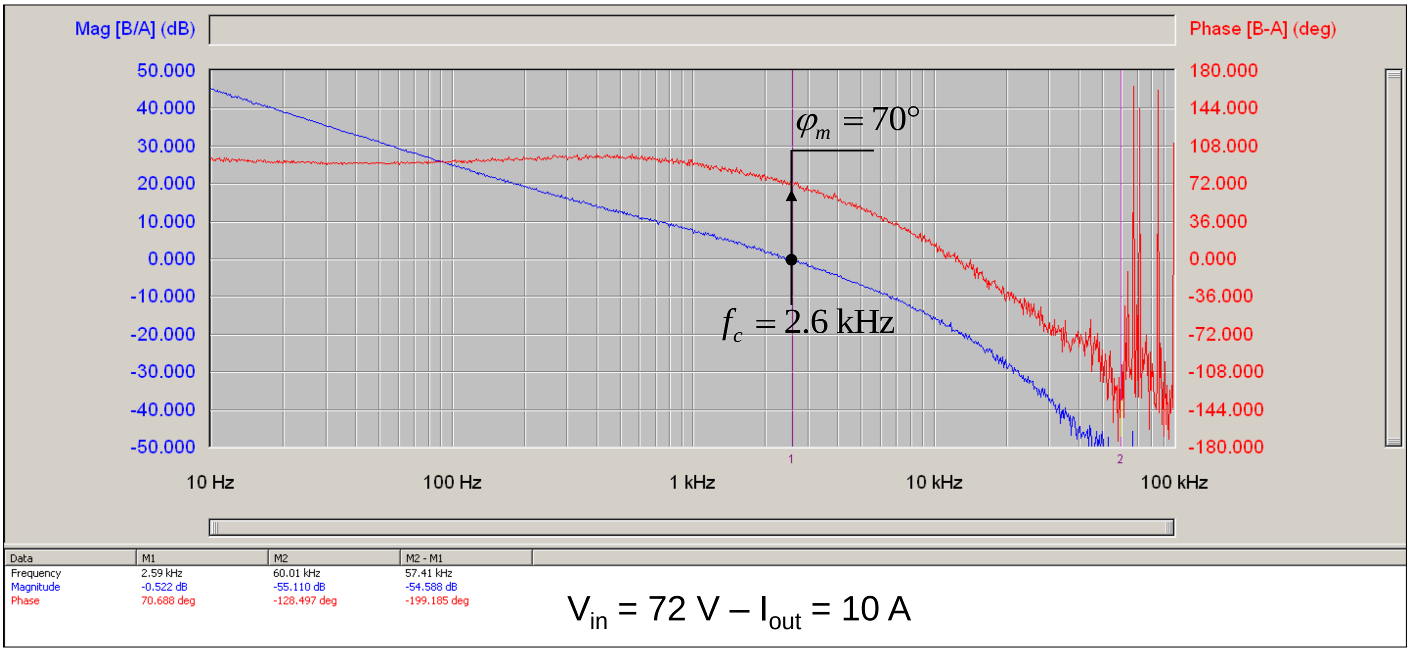
V_{in} = 72 V – I_{out} = 10 A



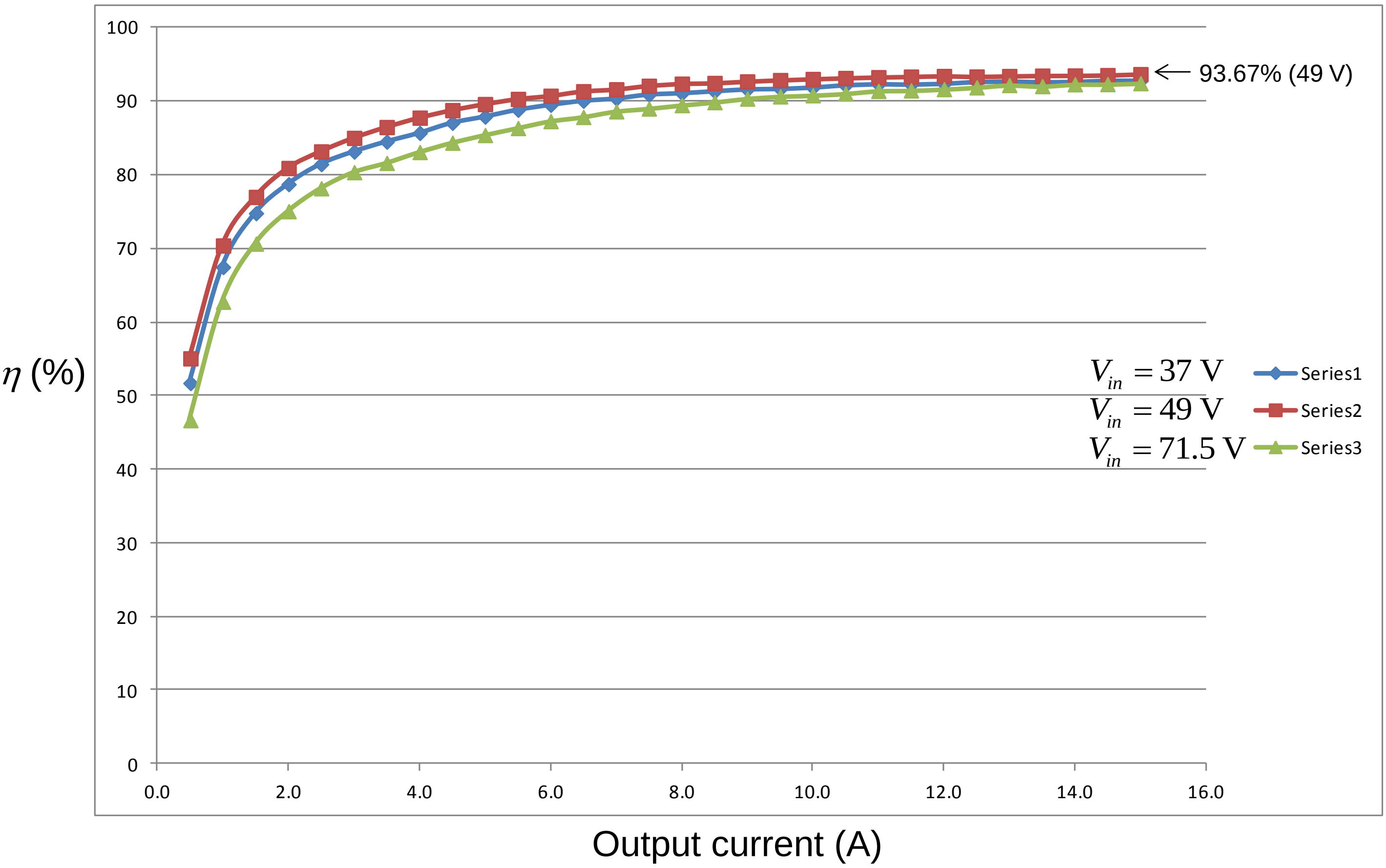
V_{in} = 72 V – I_{out} = 0 A

Loop gain Bode plots:





Efficiency data:



Bill of materials

Designator	Quantity	Description	Value	Rating	Tolerance	Footprint	Manufacturer	Manufacturer Part Number
C1	1	MLC capacitor	2.2 µF	100 V	-		Kemet	C1210C225M1RACTU
C2	1	MLC capacitor	2.2 µF	100 V	-		Kemet	C1210C225M1RACTU
C3	1	MLC capacitor	2.2 µF	100 V	-		Kemet	C1210C225M1RACTU
C4	1	MLC capacitor	2.2 µF	100 V	-		Kemet	C1210C225M1RACTU
C5	1	Ceramic capacitor	0.1 µF	16 V	20%	805	Generic	
C6	1	Ceramic capacitor	0.1 µF	16 V	20%	805	Generic	
C7	1	Electrolytic Capacitor	22 µF	25 V	-		Generic	EXV226M035A9DAA
C8	1	Ceramic capacitor	0.1 µF	16 V	20%	805	Generic	
C9	1	Ceramic capacitor	0.1 µF	16 V	20%	805	Generic	
C10	1	Ceramic capacitor	100 pF	16 V	20%	805	Generic	
C11	1	Ceramic capacitor	100 pF	16 V	20%	805	Generic	
C12	1	Ceramic capacitor	6.8 nF	16 V	20%	805	Generic	
C13	1	Ceramic capacitor	0.1 µF	16 V	20%	805	Generic	
C14	1	Ceramic capacitor	47 nF	16 V	20%	805	Generic	
C15	1	Ceramic capacitor	0.22 µF	25 V	20%	805	Generic	
C16	1	Ceramic capacitor	10 nF	16 V	20%	805	Generic	
C17	1	Tantalum capacitor	220 µF	10 V	-		Kemet	T520Y227M010ATE040
C18	1	Tantalum capacitor	220 µF	10 V	-		Kemet	T520Y227M010ATE040
C19	1	Tantalum capacitor	220 µF	10 V	-		Kemet	T520Y227M010ATE040
C20	1	Tantalum capacitor	220 µF	10 V	-		Kemet	T520Y227M010ATE040
C21	1	Tantalum capacitor	220 µF	10 V	-		Kemet	T520Y227M010ATE040
C22	1	Electrolytic Capacitor	22 µF	25 V	-		Generic	EXV226M035A9DAA
C23	0	Ceramic capacitor	-	16 V			Generic	
C24	1	Capacitor	820 pF	100 V	20%	805	Generic	
C25	1	Capacitor	0.33 µF	16 V	20%	805	Generic	
C26	1	MLC capacitor	0.1 µF	200 V	-	2220	Kemet	C2220X104K2RACTU
C27	1	Capacitor - Y type	2.2 nF	2 kV	-	1812	TDK	C4532X7R3D222K
C28	1	Ceramic capacitor	10 nF	16 V	20%	805	Generic	
C29	0	Ceramic capacitor	-					

C30	1	Ceramic capacitor	220 pF	-	20%	0805	Generic	
C31	0	Ceramic capacitor	1 µF	25 V	20%		Generic	
C32	1	Ceramic capacitor	1.5 nF	16 V	20%		Generic	
C33	0	Ceramic capacitor	-				Generic	
C34	1	Ceramic capacitor	470 pF				Generic	
C39	0	Ceramic capacitor	0.1 µF		20%	805	Generic	
C40	1	MLC capacitor	0.1 µF	100 V	20%	805		
C100	1	Ceramic capacitor	1 nF	30 V	20%	805	Generic	
C101	1	Ceramic capacitor	1 nF	30 V	20%	805	Generic	
C104	1	Ceramic capacitor	0.1 µF	25 V	20%	805	Generic	
RA	1	Resistor	2.7k		20%	805	Generic	
R1	1	Resistor	51k	0.25 W	1%	0805	Generic	
R2	1	Resistor	10	0.25 W	1%	0805	Generic	
R3	1	Resistor	82 k	0.25 W	1%	0805	Generic	
R4	1	Resistor	2 k	0.25 W	1%	0805	Generic	
R5	1	Resistor	51.1 k	0.25 W	1%	0805	Generic	
R6	1	NTC	33 k@25 °C	-	1%	0603	AVX	NB 21 M 0 0333
R7	1	Resistor	75m	2 W	0.5%	2512	Generic	MCLRP12FTDSR075
R8	1	Resistor	75 k	0.25 W	1%	0805	Generic	
R9	1	Resistor	100 k	0.25 W	1%	0805	Generic	
R10	1	Resistor	470	0.25 W	1%	0805	Generic	
R11	1	Resistor	499	0.25 W	1%	0805	Generic	
R12	1	Resistor	220	0.25 W	1%	0805	Generic	
R13	1	Resistor	270	0.25 W	1%	0805	Generic	
R14	1	Resistor	24.9 k	0.25 W	1%	0805	Generic	
R15	1	Resistor	0	0.25 W	1%	0805	Generic	
R16	1	Resistor	10 k	0.25 W	1%	0805	Generic	
R17	1	Resistor	10 k	0.25 W	1%	0805	Generic	
R18	1	Resistor	48.7 k	0.25 W	1%	0805	Generic	
R19	1	Resistor	1 Meg	0.25 W	5%	0805	Generic	
R20	1	Resistor	1.1 k	0.25 W		0805	Generic	
R21	1	Resistor	1.2 k	0.25 W	1%	0805	Generic	
R22	0	Resistor	-	0.25 W	1%	0805	Generic	

R23a	1	Resistor	2.2	0.25 W	1%	0805	Generic	
R23b	1	Resistor	2.2	0.25 W	1%	0805	Generic	
R24a	1	Resistor	10 k	0.25 W	1%	0805	Generic	
R24b	1	Resistor	10 k	0.25 W	1%	0805	Generic	
R25a	1	Resistor	10 k	0.25 W	1%	0805	Generic	
R25b	1	Resistor	10 k	0.25 W	1%	0805	Generic	
R26	1	Resistor	1 k	0.25 W	1%	0805	Generic	
R27	1	Resistor	0			0805	Generic	
R29a	1	Resistor	2.2	0.25 W	1%	0805	Generic	
R29b	1	Resistor	2.2	0.25 W	1%	0805	Generic	
R30	1	Resistor	24.9 k	0.25 W	1%	0805	Generic	
R31	1	Resistor	23.7 k	0.25 W	1%	0805	Generic	
R34	1	Resistor	499	0.25 W	1%	0805	Generic	
R35	0	Resistor	-	0.25 W		0805	Generic	
R36	1	Resistor	499	0.25 W	1%	0805	Generic	
R37	1	Resistor	499	0.25 W	1%	0805	Generic	
R38	1	Resistor	1.2 k	0.25 W	1%	0805	Generic	
R39	1	Resistor	4.7	1 W	1%	2512	Generic	ASC2512-4R7FT4
R40	1	Resistor	4.7	1 W	1%	2512	Generic	ASC2512-4R7FT4
R41	1	Resistor	0	0.25 W	1%	0805	Generic	
R42	0	Resistor	150	0.25 W	1%	0805	Generic	
R43	1	Resistor	1k	0.25 W	1%	0805	Generic	
R44	1	Resistor	1k	0.25 W	1%	0805	Generic	
R45	1	Resistor	10	0.25 W - 100 V	1%	0805	Generic	
R47	1	Resistor	220	0.25 W	1%	0805	Generic	
R60	1	Resistor	470	0.25 W	1%	0808	Generic	
R100	1	Resistor	2.2	0.5 W	1%	1206	Generic	
R101	1	Resistor	2.2	0.5 W	1%	1206	Generic	
R102	1	Resistor	10k	0.25 W	1%	0805	Generic	
R103	0	Resistor	-					
L1	1	Inductor	1.5 µH	7.5 A			Coilcraft	MSS1038-152NL
L2	1	Inductor	3.3 µH	15 A			Champs Technology	PQL2050-3R3-22

L3	1	Inductor	660 µH	2.3 A			Coilcraft	DO1606CT-684
T1	1	Transformer	-	75 W			Champs Technology	G45R2-0902-04-80R
J1a	1	Banana plug	-	24 A			Multi-Contact	23.3200-22
J1b	1	Banana plug	-	24 A			Multi-Contact	23.3200-21
J2a	1	30 A PC screw	-	30 A			Keystone	CAT. NO. 8199
J2b	1	30 A PC screw	-	30 A			Keystone	CAT. NO. 8199
Q1A	1	N-channel MOSFET	FDMS2572	150 V/27 A		Power 56	Fairchild	FDMS2572
Q1B	1	N-channel MOSFET	FDMS2572	150 V/27 A		Power 56	Fairchild	FDMS2572
Q2	1	P-channel MOSFET	IRF6217	150 V/0.7 A		SO-8	International Rectifier	IRF6217
Q3	1	N-channel MOSFET	NTMFS4982NF	30 V/207 A		SO-8FL	ON Semiconductor	NTMFS4982NFT1G
Q4	1	N-channel MOSFET	NTMFS4982NF	30 V/207 A		SO-8FL	ON Semiconductor	NTMFS4982NFT1G
Q5	1	N-channel MOSFET	NTMFS4982NF	30 V/207 A		SO-8FL	ON Semiconductor	NTMFS4982NFT1G
Q6	1	N-channel MOSFET	NTMFS4982NF	30 V/207 A		SO-8FL	ON Semiconductor	NTMFS4982NFT1G
Q7	1	Bipolar transistor	MMBT2222A				ON Semiconductor	
Q8	1	Bipolar transistor	MMBT2222A				ON Semiconductor	
U1	1	PWM Controller	NCP1566				ON Semiconductor	
U2	1	optocoupler	PS2801				CEL	PS2801-1
U6	1	optocoupler	PS2801				CEL	PS2801-1
U8	1	shunt regulator	NCP431			SOT-23	ON Semiconductor	NCP431ACSNT1G
U9	1	shunt regulator	NCP431			SOT-23	ON Semiconductor	NCP431ACSNT1G
DA	1	signal diode	MMSD914			SOD-123		
D1	1	signal diode	MMSD914			SOD-123		
D2	1	signal diode	MMSD914			SOD-123		
D3	1	signal diode	MMSD914			SOD-123		
D4	1	signal diode	MMSD914			SOD-123		
D5	1	Zener diode	MMSZ4693	7.5 V		SOD-123		
D6	1	Zener diode	MMSZ4689	5.1 V		SOD-123		
D7	1	signal diode	MMSD914			SOD-123		
D10	0	Zener diode	MMSZ4702T1G	15 V		SOD-123		

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Design note created by Christophe Basso – April 2019