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DN06074/D

65 W Off-Line Adapter

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DESIGN NOTE

Device	Application	Input Voltage	Output Voltage	Output Current	Topology
NCP1236	Notebook Adapter	85 - 265 Vac	19 V	3.42 A	Flyback

Table 1. 65 W AC-DC ADAPTER BOARD SPECIFICATIONS

Output power	65	W
Output voltage	19	V
Output current	3.42	A
Minimum input voltage	85	V
Maximum input voltage	265	V
Average efficiency (as per ENERGY STAR 2.0 guidelines)	> 87	%
No-load input power	< 100	mW
Maximum output voltage ripple	< 200	mV

Overview

When designing adapters, the important defining regulations for efficiency and no load power requirements are the ENERGY STAR® specifications. With the release of the EPS 2.0 standard, the light load input power consumption and the standby power consumption have became more important, reflecting more accurately the actual usage of a laptop adapter which spends a considerable amount of its time with no-load or a minimal load (laptop in sleep mode) attached.

When focusing on the light load efficiency of adapter design, the key losses need to be identified. Switching losses play a major role in determining the light load efficiency, and are directly linked to the control methodology. These losses are caused by the energy stored in the sum of all capacitances at the drain node (MOSFET output capacitance, stray capacitance of the transformer and other parasitic capacitances on PCB) together with the gate charge losses associated with driving the MOSFET. These are proportional to the switching frequency, hence, reducing the switching frequency reduces the losses and improves the efficiency. One of the best methods to achieve optimal balance between transformer design and light load efficiency is to have the switching frequency vary as a function of load. This is implemented in the NCP1234/36 family of PWM controllers as a frequency foldback function, thereby lowering the frequency at lighter loads.

Key Features

- Current Mode Control
- Dynamic Self-supply
- Frequency Foldback
- High Voltage Sensing
- Brown-out Protection
- Timer Based Overload Protection
- Overpower Protection
- Built-in Internal Slope Compensation
- Latch Protection Mode
- Skip Mode for Light Load
- Frequency Modulation for Softened EMI

Circuit Description

The solution was implemented utilizing flyback topology, giving the advantage of a dense power design. The design operates in both CCM (continuous conduction mode) and DCM (discontinuous conduction mode), allowing it to accept a wide universal input voltage range.

The CCM operation provides desired full load performance with good efficiency and low ripple of primary current. The DCM operation permits an increase of efficiency under the light load conditions, by decreasing the switching losses. The device switches at 65 kHz which represents a good trade-off between switching losses and magnetics size.

For meeting the design requirements, the NCP1236 fixed frequency controller was selected. This device is housed in a SOIC 7 lead that includes multiple features including input ac line sensing. The design of this notebook adapter is focused to obtain the maximum efficiency and lowest no load input power.

The adapter consists of several important sections. The first is an input EMI filter to reduce the conducted EMI to the ac line at the input of the adapter. The EMI filter is formed by two common-mode inductors L2, L4 and capacitors CX1, CX2, CY2 and CY3. The varistor R7 is used protect the adapter against the line overvoltage peaks. The resistors RD100, RD101 and RD102 are used for discharging the X2 capacitors while the adapter unplugged from the power line.

The next block is the rectifier with bulk capacitor. It is important to note that the HV pin of the controller is connected to the ac side of the rectifier to decrease average power consumed by high voltage sensing circuitry.

The main power stage of the flyback converter utilizes the low RDSon MOSFET SPP11N60C3 along with a custom designed transformer TR1 KA5038-BL, from the Coilcraft company. Secondary rectification is provided by a low drop Schottky diode NTST30100SG from ON Semiconductor. A simple RC snubber across the secondary rectifier damps any high frequency ringing caused the unclamped leakage inductance at secondary side of the transformer.

The programmable reference TL431 provides the output voltage regulation. The TL431 output is coupled via the optocoupler to the controller a NCP1236B 65 kHz version. The last stage of the adapter is the output filter consisting of primary filter capacitors COUT1 and COUT2 and secondary filter made up of L3, COUT3 and high frequency common-choke L1.

The detailed step by step design procedure of this adapter is described in the application note AND8461/D at ON Semiconductor website: http://onsemi.com

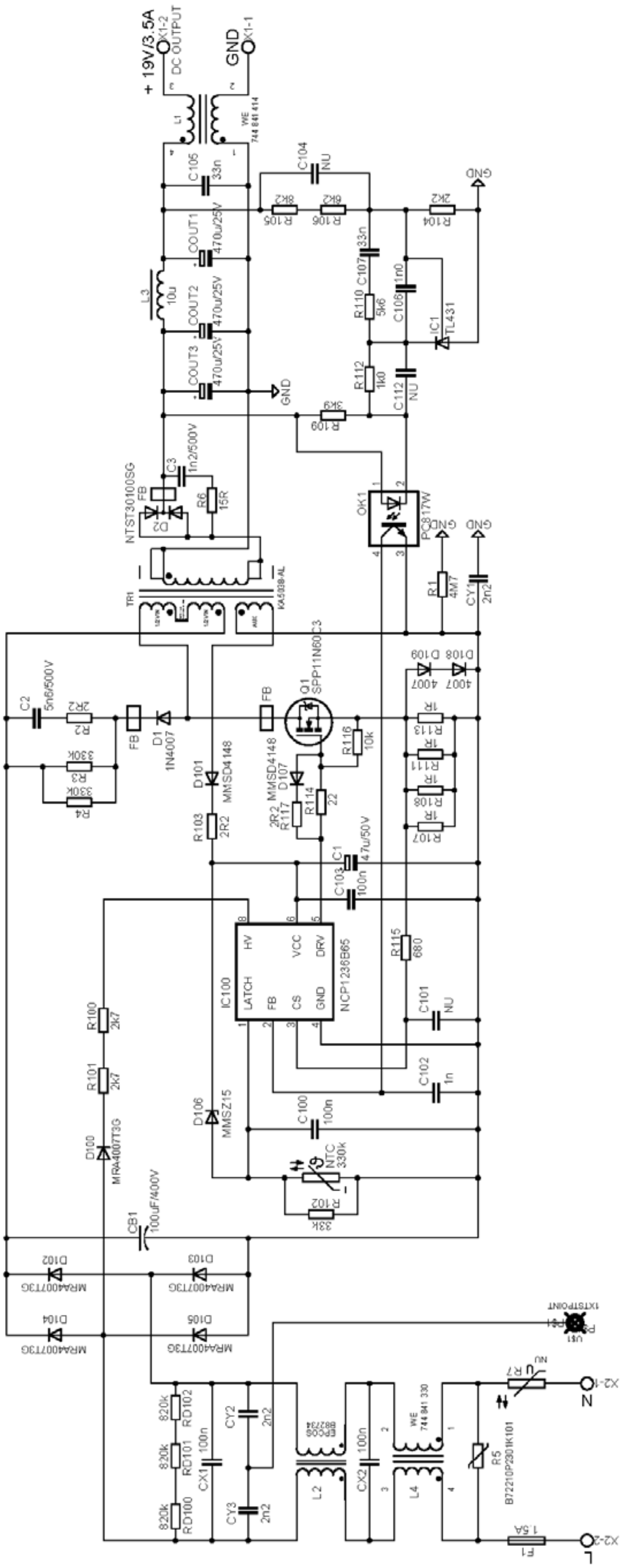

Figure 1. Notebook Adapter Schematic

Performance Results

The efficiency and no-load input power consumption were measured by the YOKOGAWA WT210 wattmeter. The average efficiency was calculated from the efficiency measurements at 25%, 50%, 75% and 100% of rated output power. However, a significant error appeared during the no-load input power measurement due to high input reactive power of the input EMC filter (5-8 VAR dependent on the ac line voltage). This effect caused an error from 50% to 100% at read value of no load input power.

To overcome this issue, no load consumption was measured by the dc method as a dc current between the ac rectifier and the bulk capacitor. The measurement was done 5 minutes after switching on the power supply to eliminate the influence of the bulk capacitor polarization current. The consumption of the X capacitor discharge resistors RD100, RD101 and RD102 was added numerically to measured values. For the dc measurement 162.6 V was set as a peak value corresponding to 115 V line voltage and 325.3 V as a peak value for 230 V line voltage.

The connected ammeter and whole application should be floating to avoid any additional ground currents. It is recommended to use battery supplied ammeter or classical electromechanical dc ammeter system.

Table 2. EFFICIENCY VERSUS OUTPUT POWER AND INPUT LINE VOLTAGE

Vin = 115 Vac/60 Hz			
Pout/Poutmax [%]	**Pout [W]**	**Pin [W]**	**Efficiency [%]**
100.2	65.10	72.95	89.24
75.4	49.02	54.64	89.71
50.8	33.05	36.63	90.22
25.1	16.34	18.11	90.22
10.4	6.76	7.58	89.19
5.3	3.46	3.94	87.81
1.6	1.02	1.24	82.12
0.8	0.51	0.68	75.61
Vin = 230 Vac/50 Hz			
Pout/Poutmax [%]	**Pout [W]**	**Pin [W]**	**Efficiency [%]**
100.1	65.05	71.85	90.55
75.4	49.01	54.24	90.36
49.9	32.44	35.90	90.36
25.1	16.34	18.16	89.97
10.4	6.76	7.75	87.24
5.3	3.46	4.09	84.61
1.6	1.01	1.33	76.60
0.8	0.51	0.73	70.27

Table 3. AVERAGE EFFICIENCY AND NO LOAD INPUT POWER

Input Line	115 Vac/60 Hz	230 Vac/50 Hz
Average Efficiency [%]	89.8	90.3
No Load Input Power [mW]	64.6	87.9

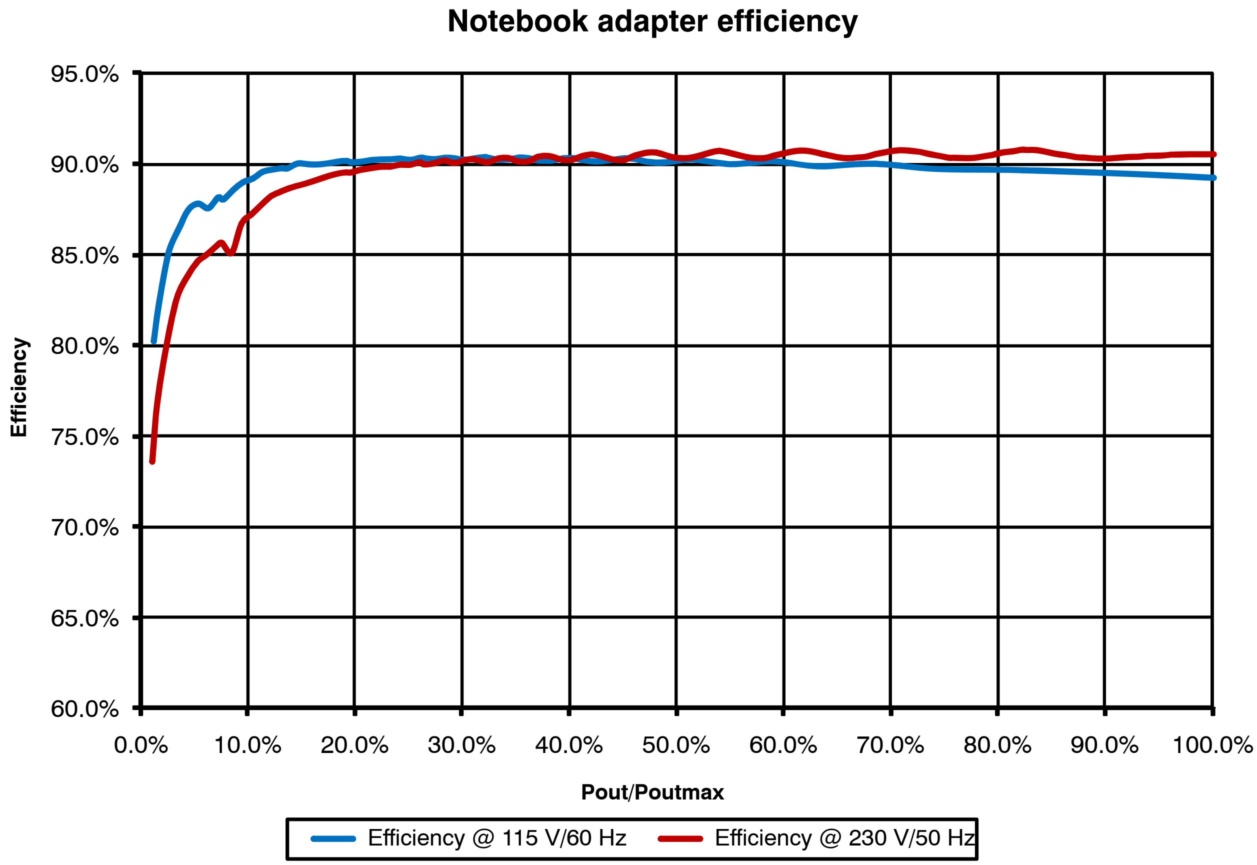

Figure 2. Efficiency versus Output Power and Input Line Voltage

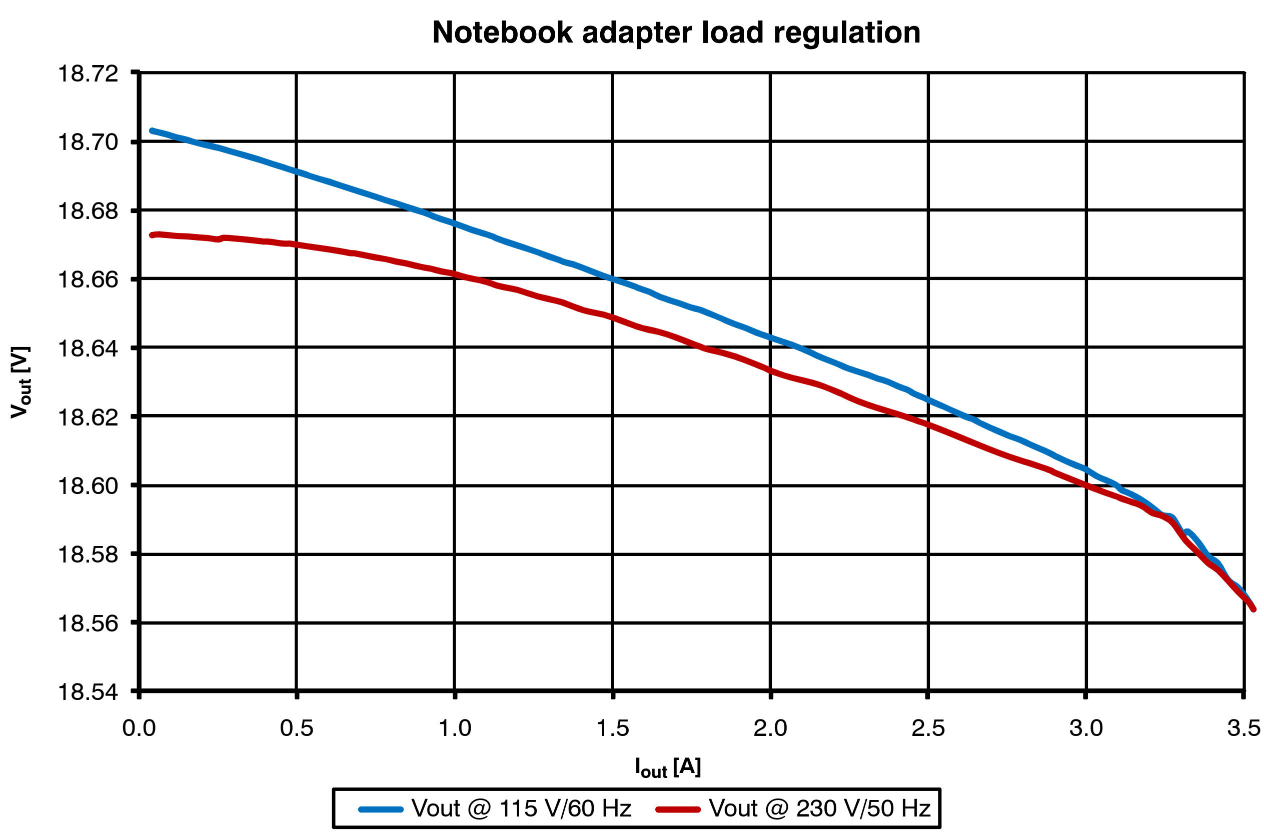

Figure 3. Load Regulation for Low and High Input Line

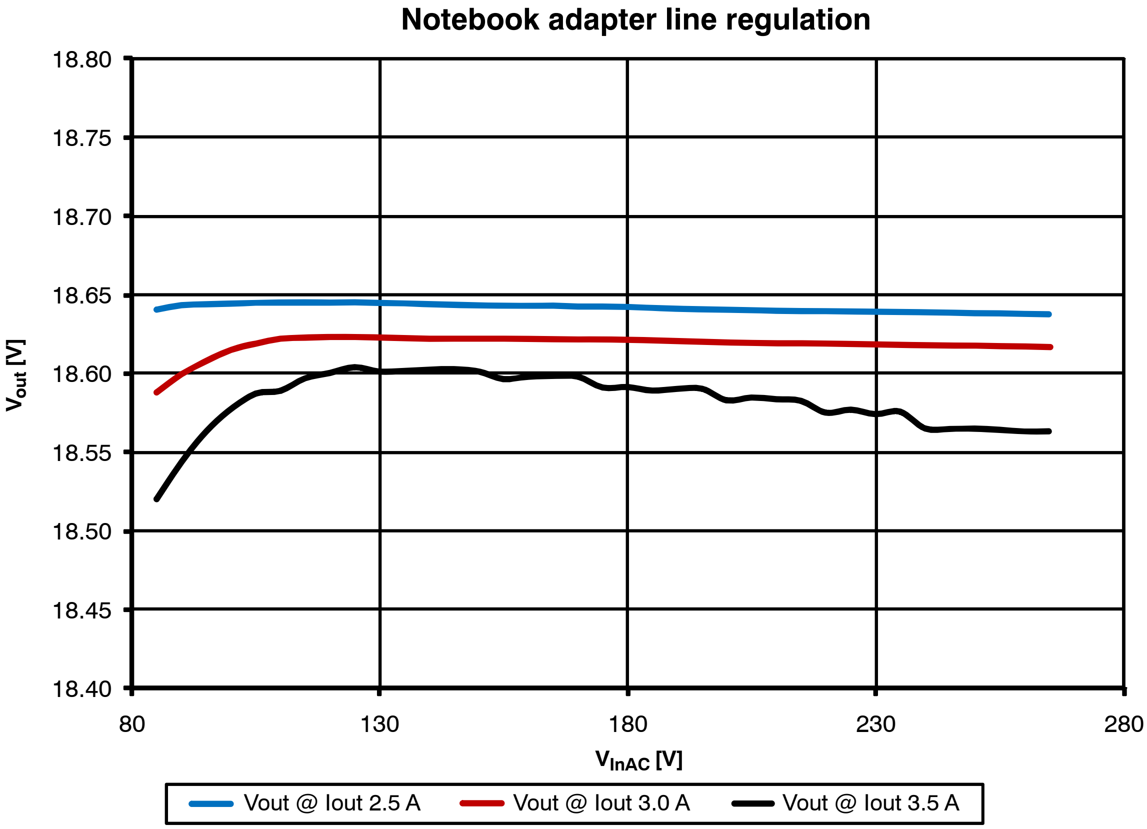

Figure 4. Line Regulation for High Output Loads

Following figures demonstrate the operation of the converter under different operating conditions and highlight various features such as transition from CCM to DCM, frequency foldback, pulse skipping, transient load response, stability in CCM, frequency jitter, overload protection etc. under both 115 V and 230 V input conditions as appropriate. The conducted EMI performance was checked via the LISN network under the full load conditions as well.

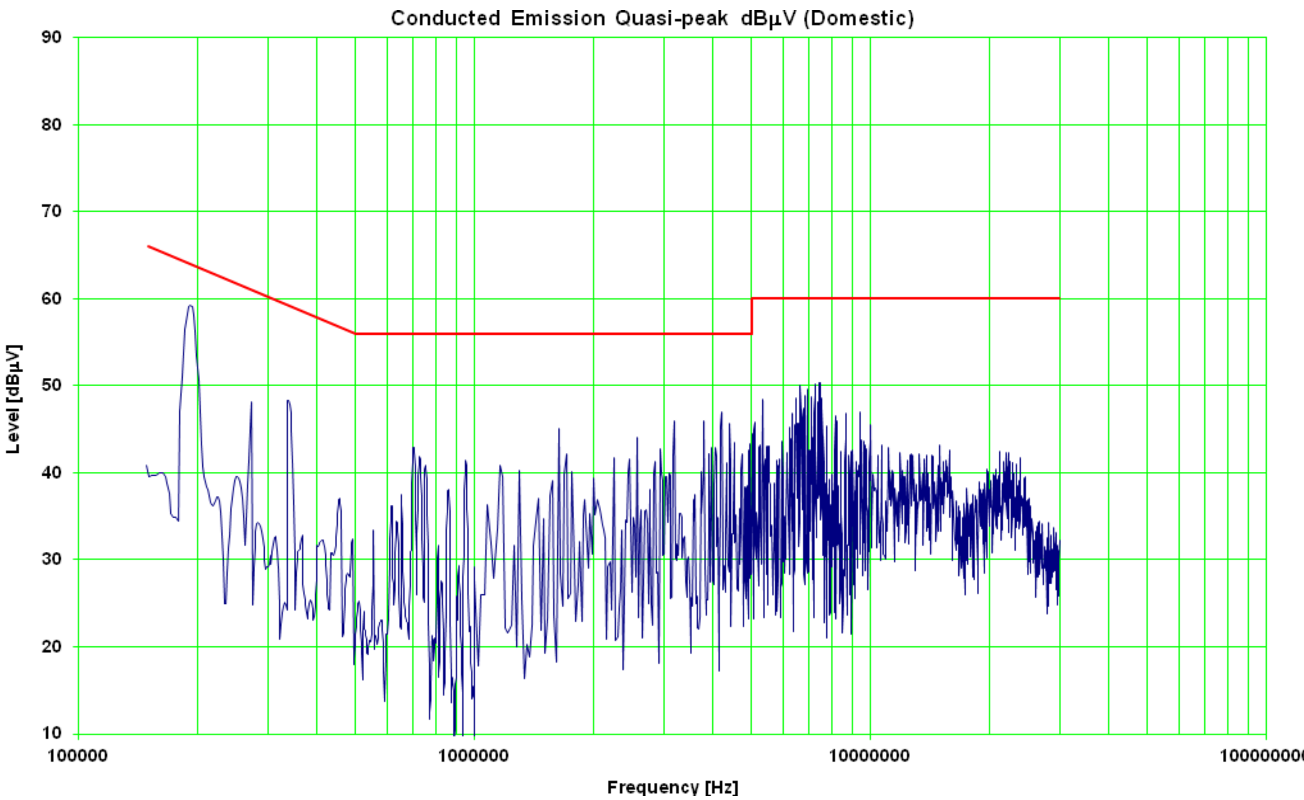

Figure 5. Harmonic Components of the Input Current at 115 V/60 Hz Input and Fully Loaded Output

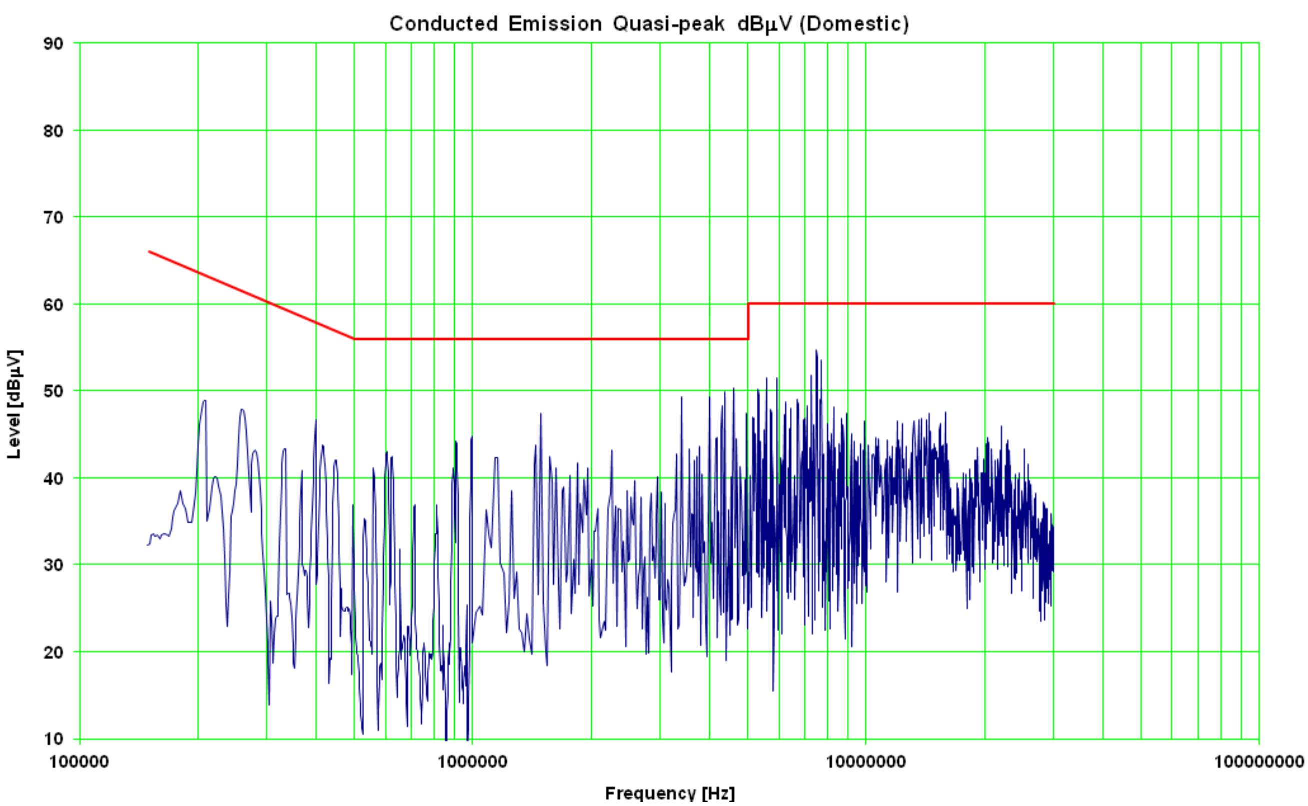

Figure 6. Harmonic Components of the Input Current at 230 V/50 Hz Input and Fully Loaded Output

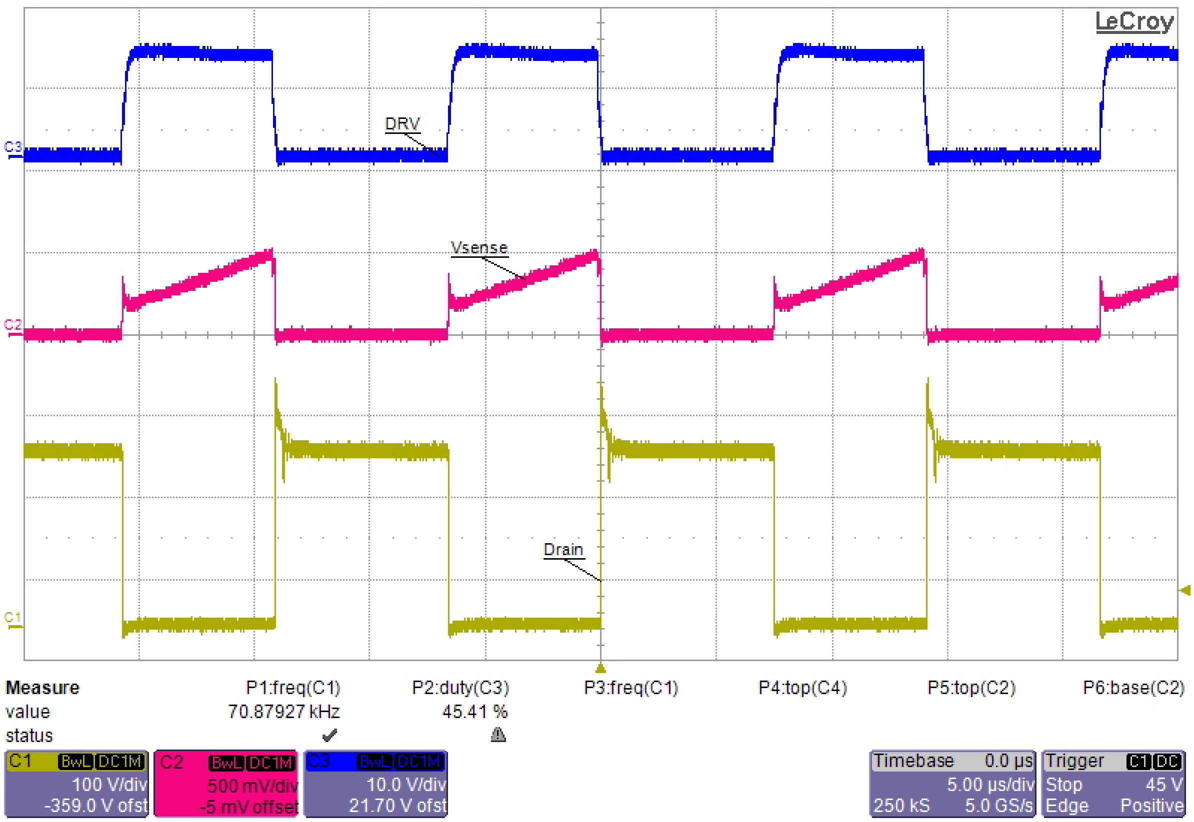

Figure 7. CCM Operation at Full Load (3.5 A) and 85 V/50 Hz Input

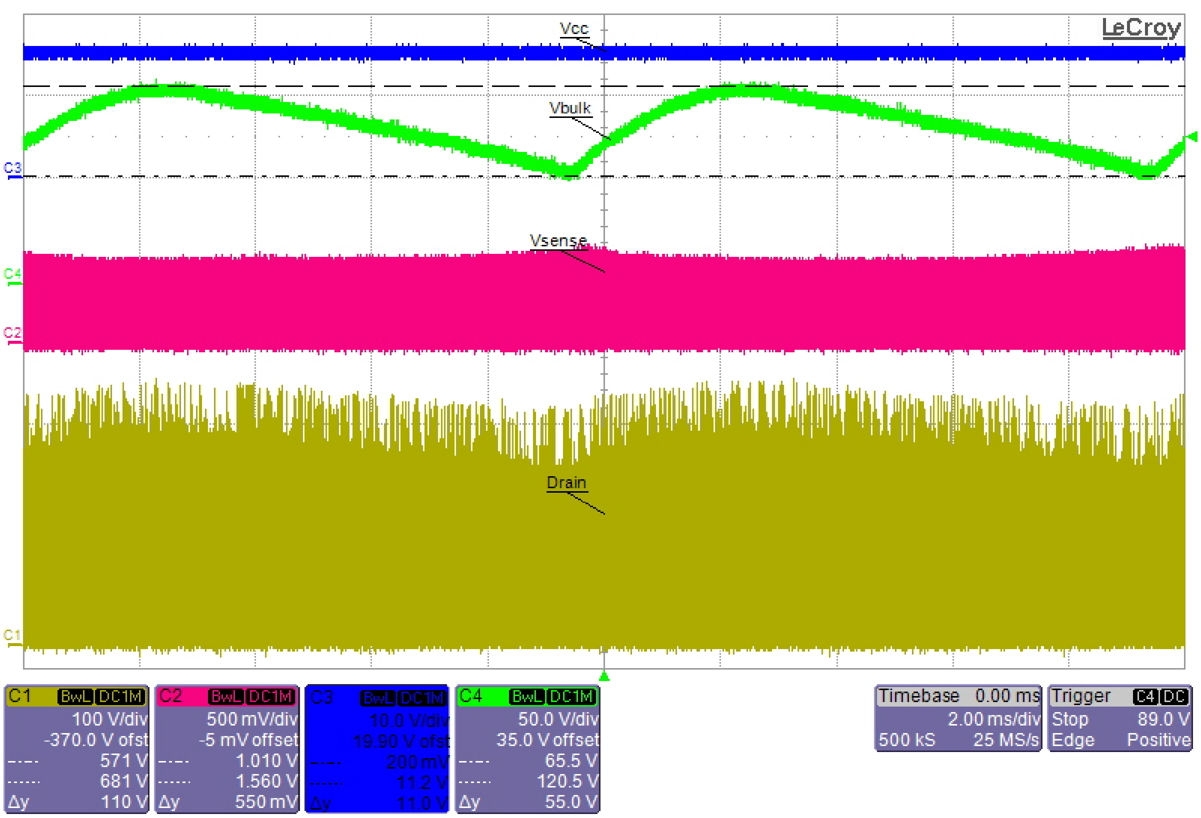

Figure 8. Ripple at the Bulk Capacitor is 55 V at Full Load (3.5 A) and 85 V/50 Hz Input

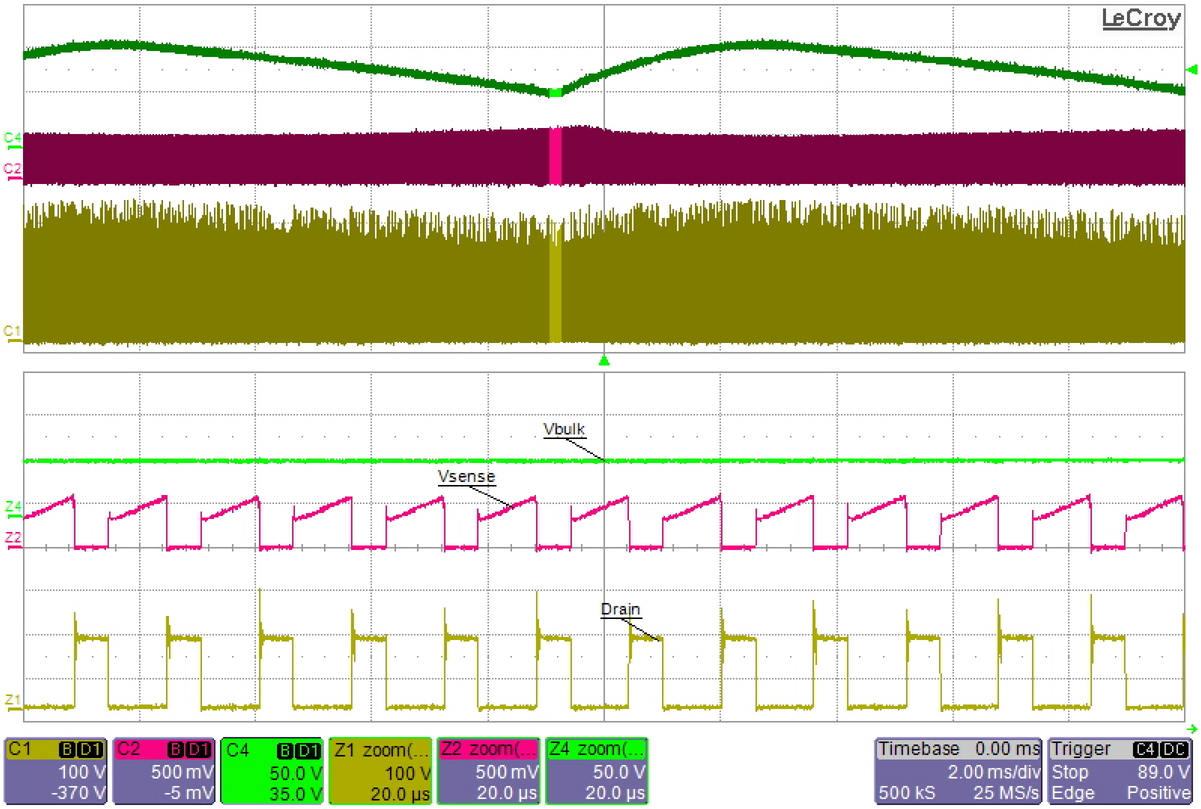

Figure 9. No Subharmonic Oscillations Appear under Full Load (3.5 A) and CCM Operation, with D > 50%, 85 V/45 Hz Input

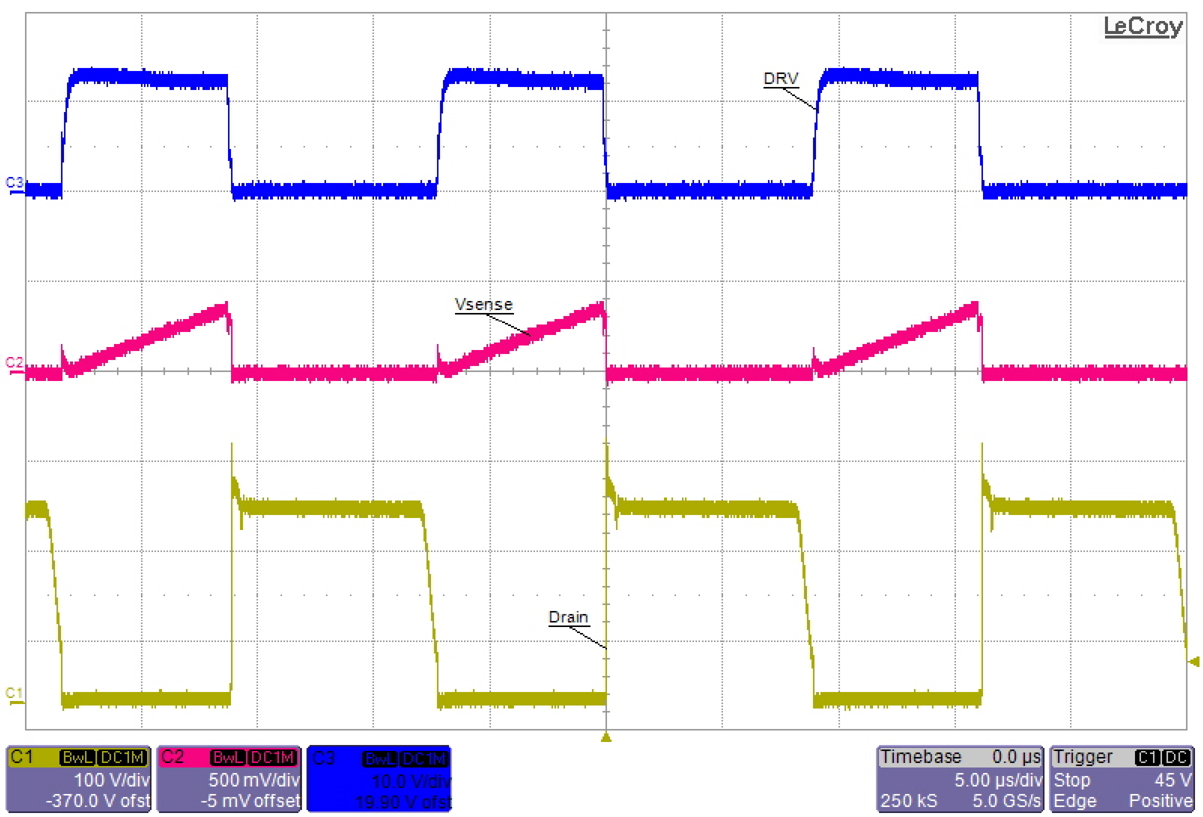

Figure 10. The DCM Mode Starts at 1.85 A of Load Current at 85 V/50 Hz Input

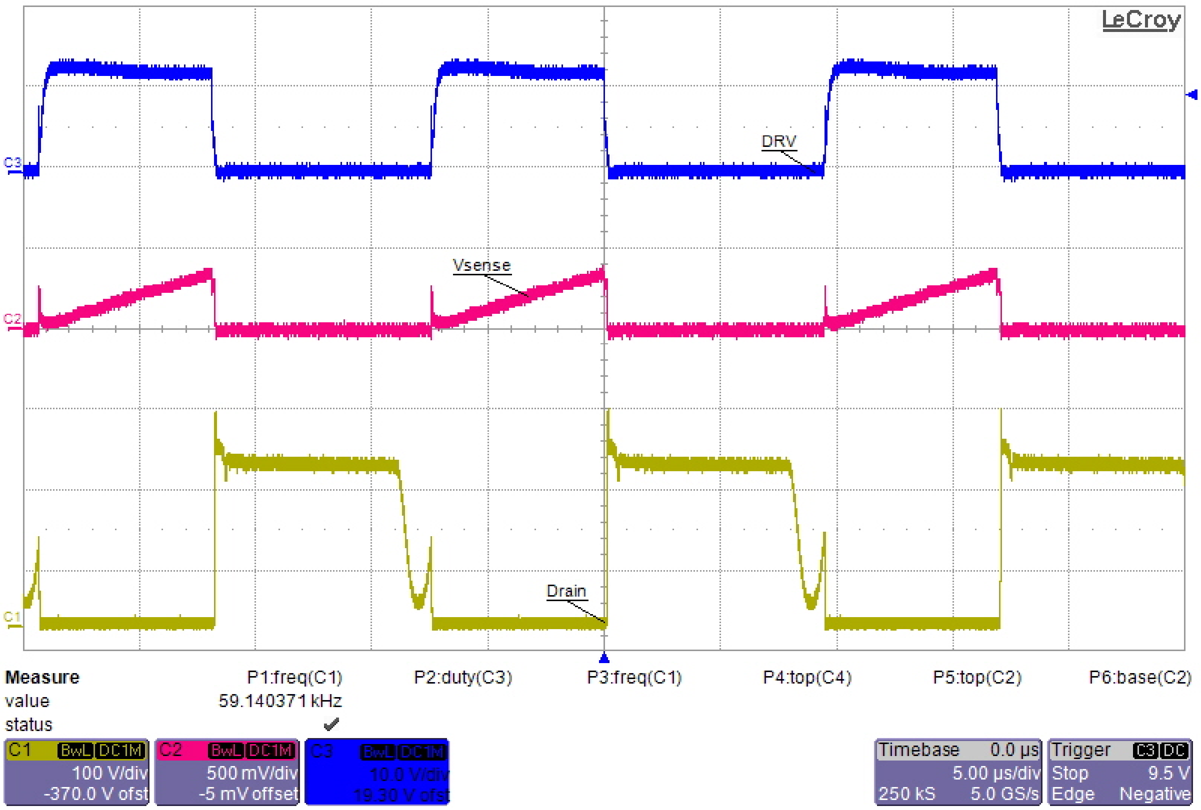

Figure 11. The Frequency Foldback Mode Starts at 1.58 A of Load Current at 85 V/50 Hz Input

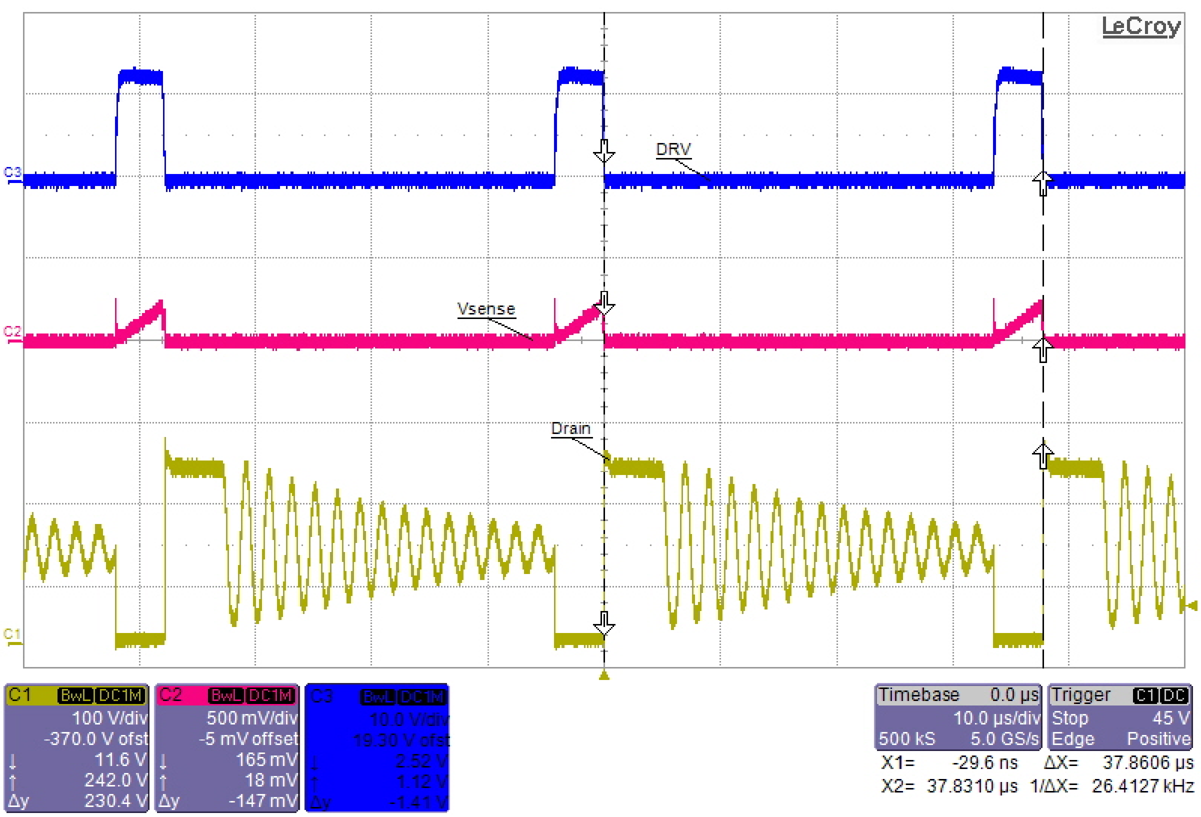

Figure 12. The Frequency Foldback is Finished at 0.27 A of Load Current at 85 V/50 Hz Input

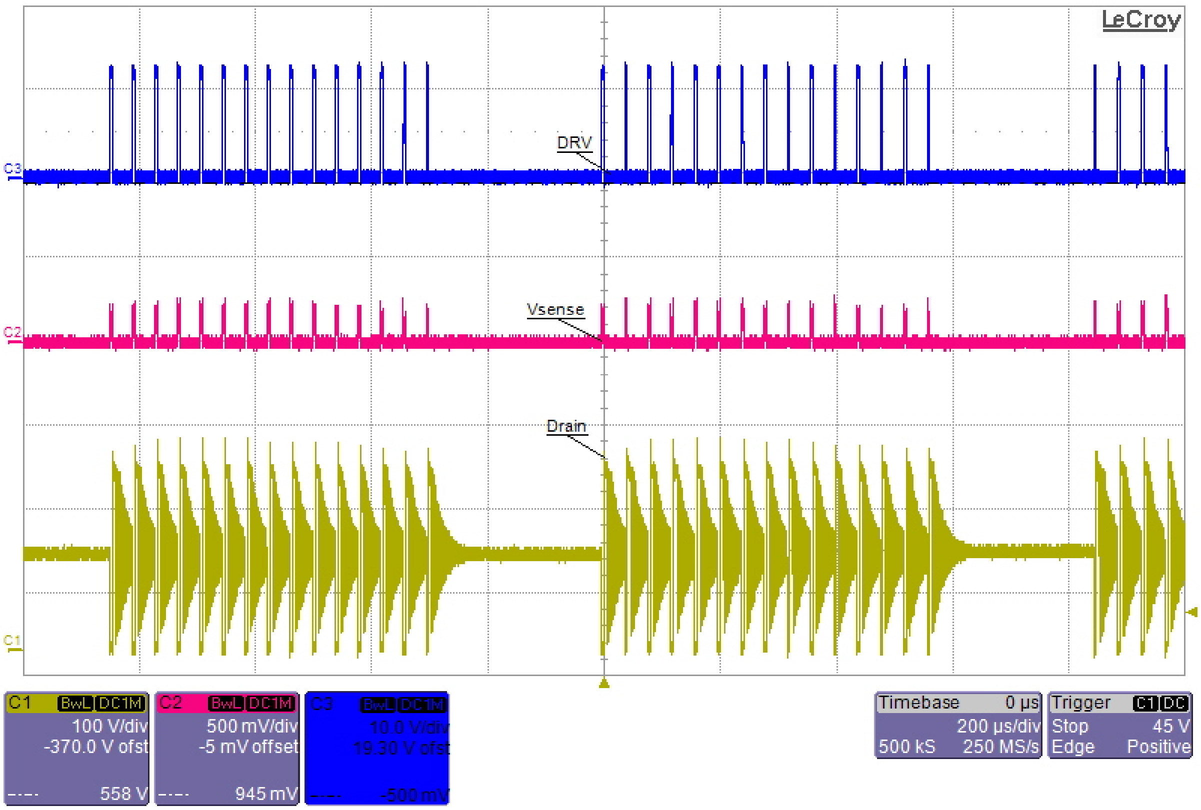

Figure 13. The Skip Mode Starts at 0.19 A of Load Current at 85 V/50 Hz Input

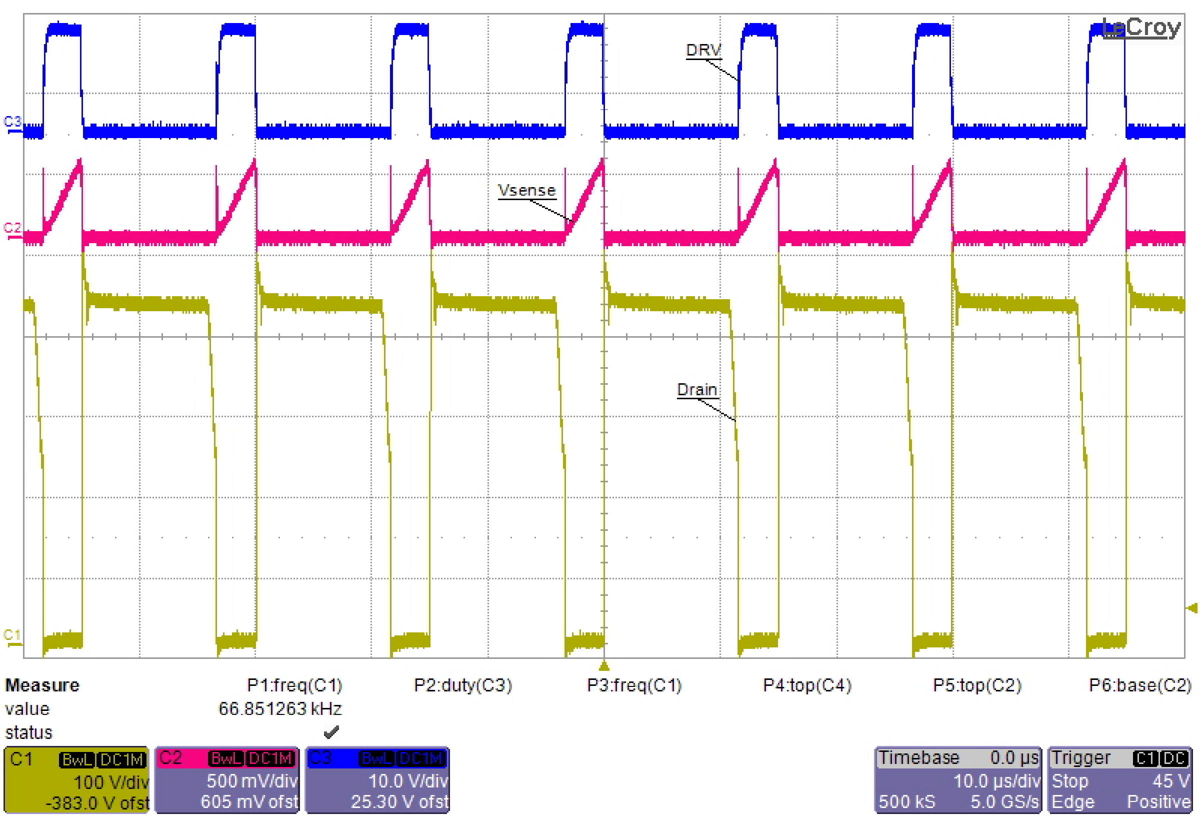

Figure 14. The DCM Mode Starts at Full Load (3.5 A) at 230 V/50 Hz Input

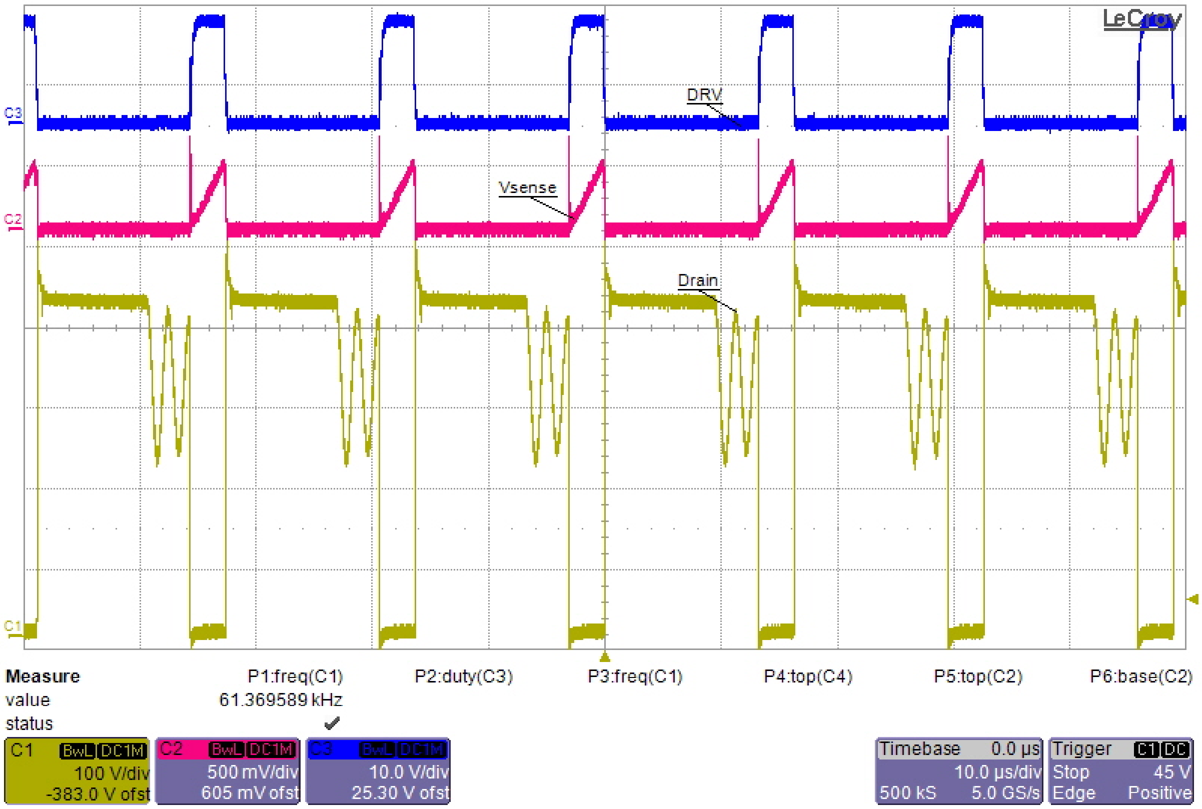

Figure 15. The Frequency Foldback Mode Starts at 2.5 A of Load Current at 230 V/50 Hz Input

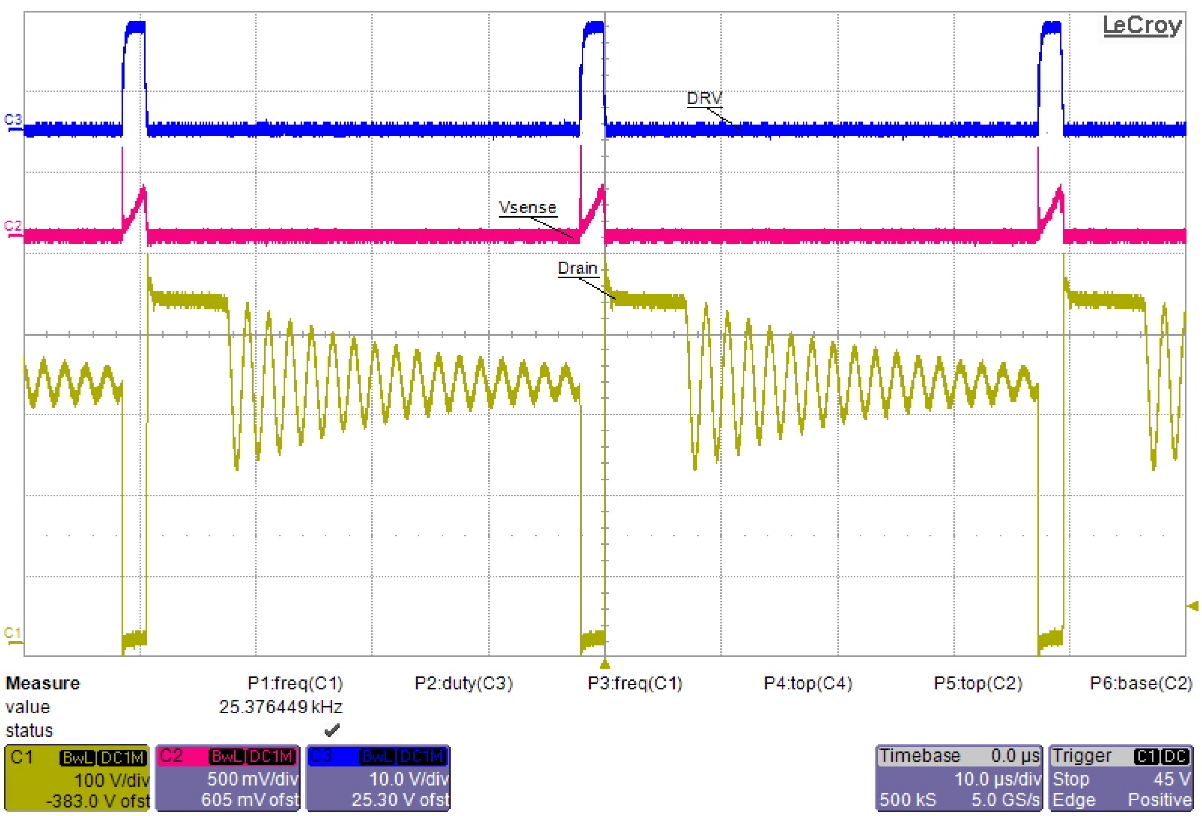

Figure 16. The Frequency Foldback is Finished at 0.53 A of Load Current at 230 V/50 Hz Input

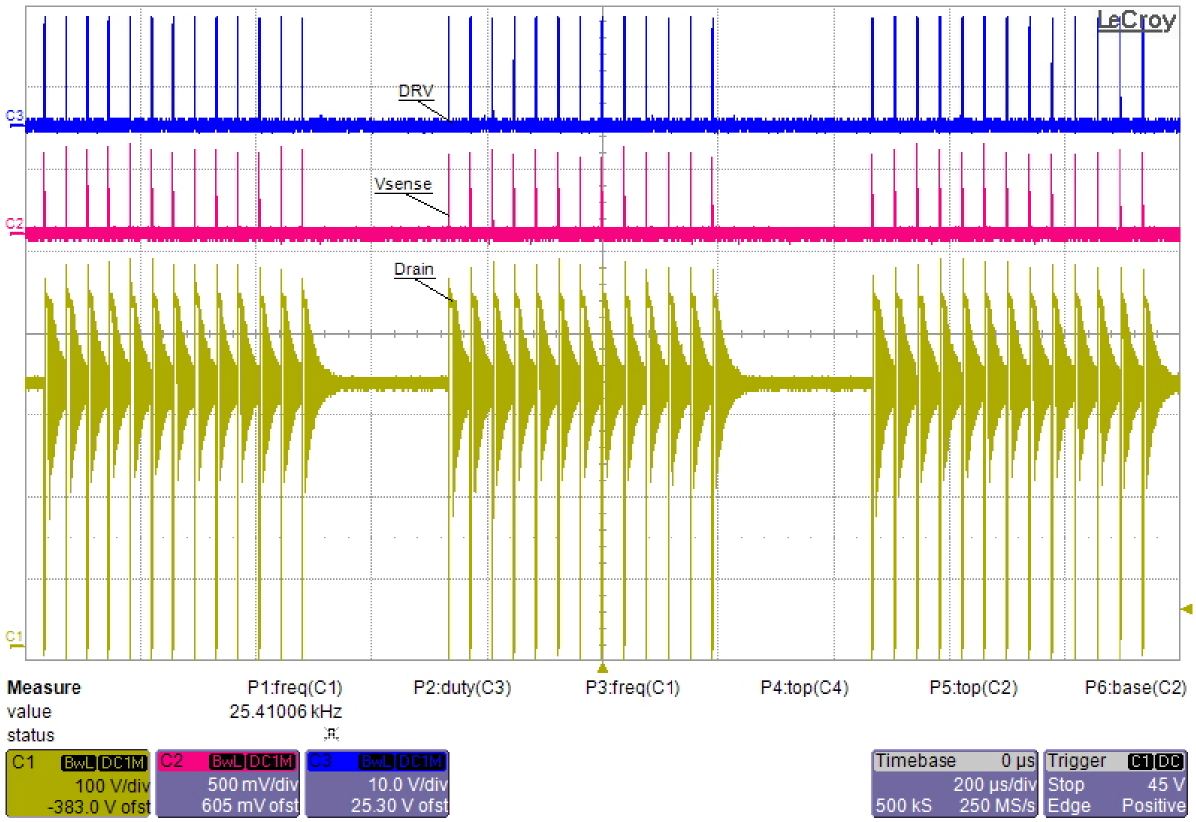

Figure 17. The Skip Mode Starts at 0.25 A of Load Current at 230 V/50 Hz Input

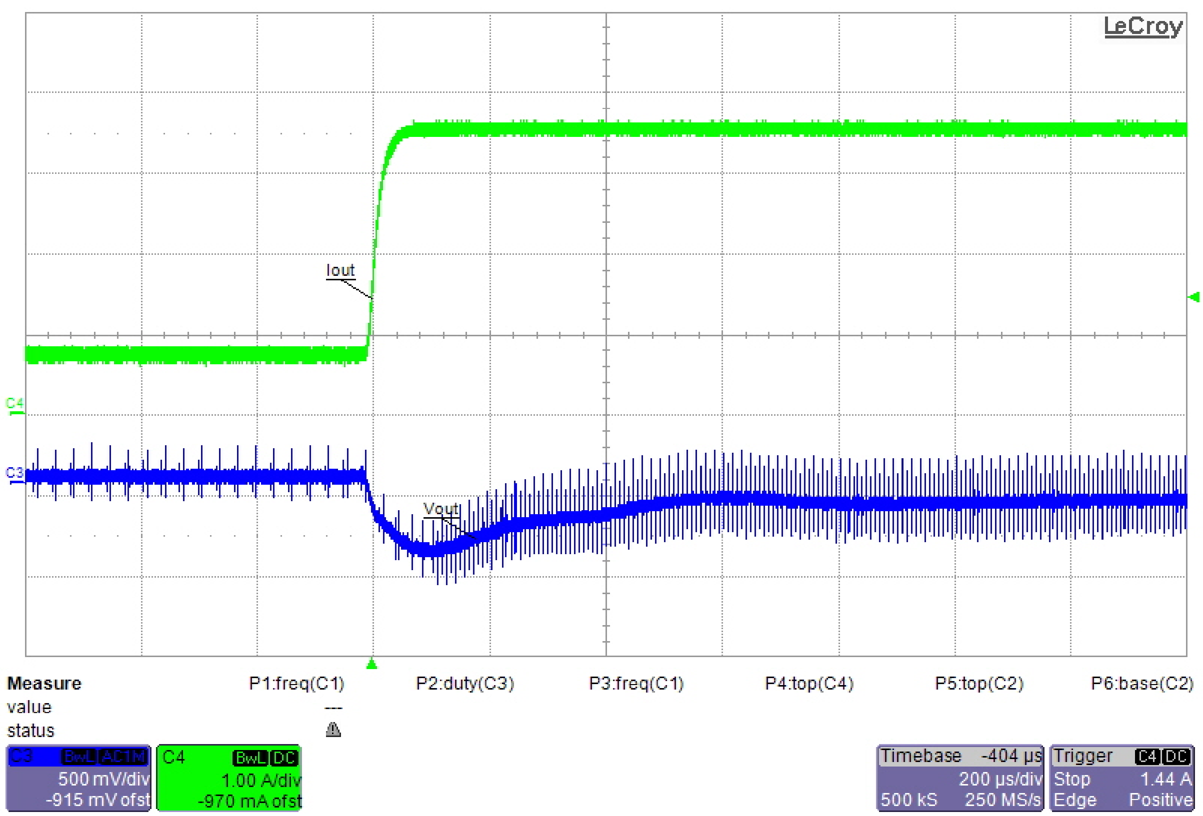

Figure 18. The Load Transient Step from 20% of Load to 100% of Load at 85 V/50 Hz Input

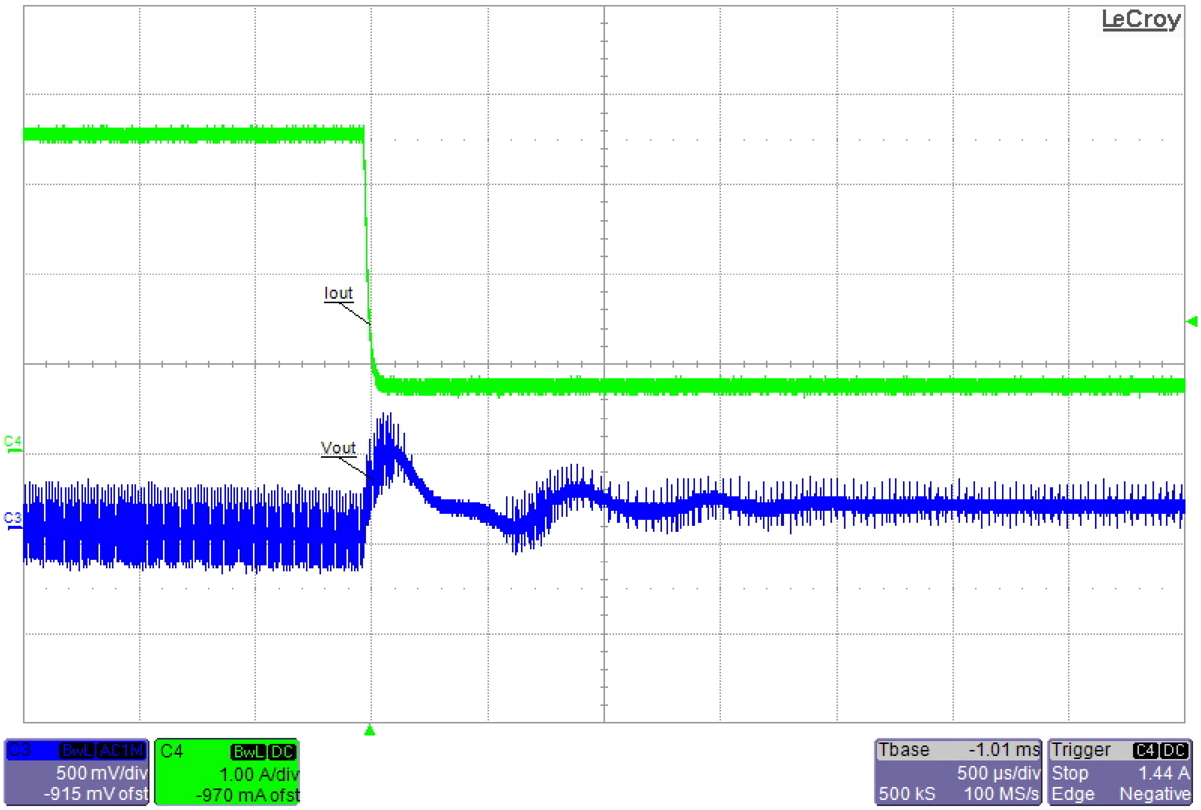

Figure 19. The Load Transient Step from 100% of Load to 20% of Load at 85 V/50 Hz Input

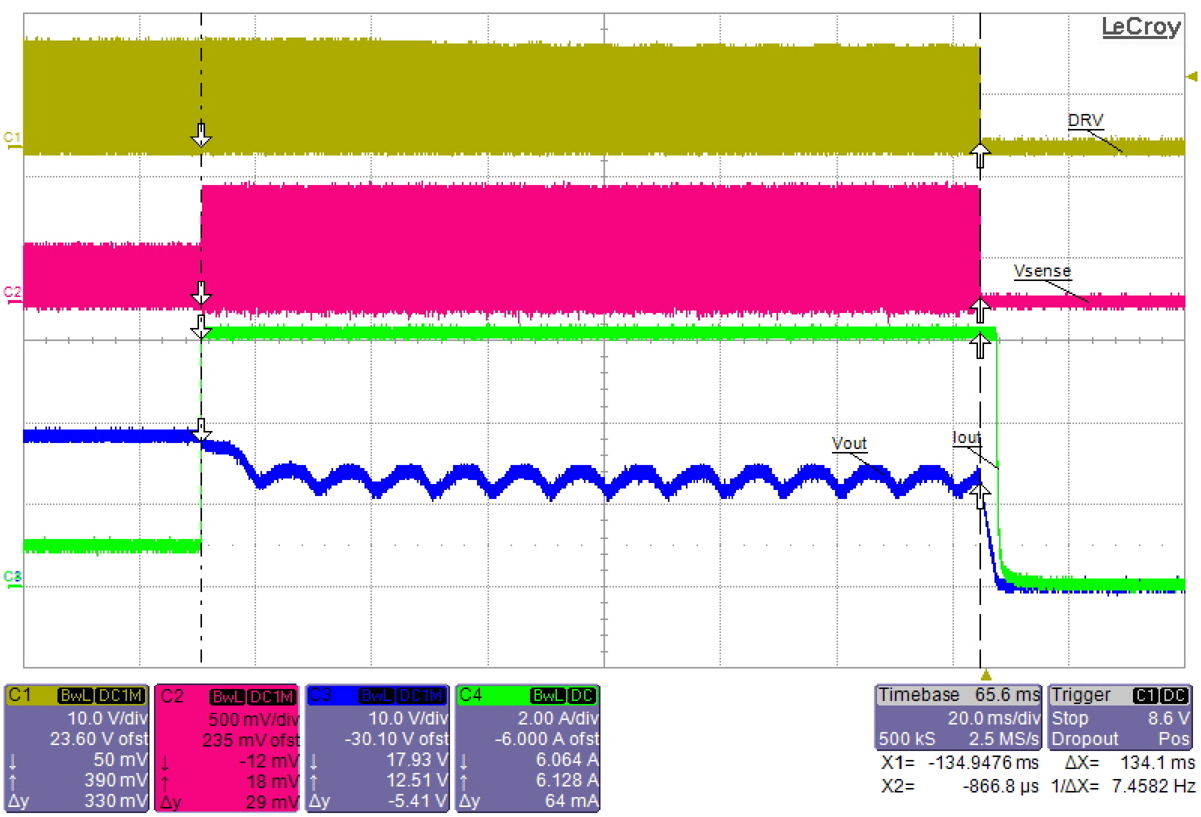

Figure 20. The Overcurrent Protection Timer Duration is 134 ms when the Adapter is Overloaded to 6 A at 85 V/50 Hz input

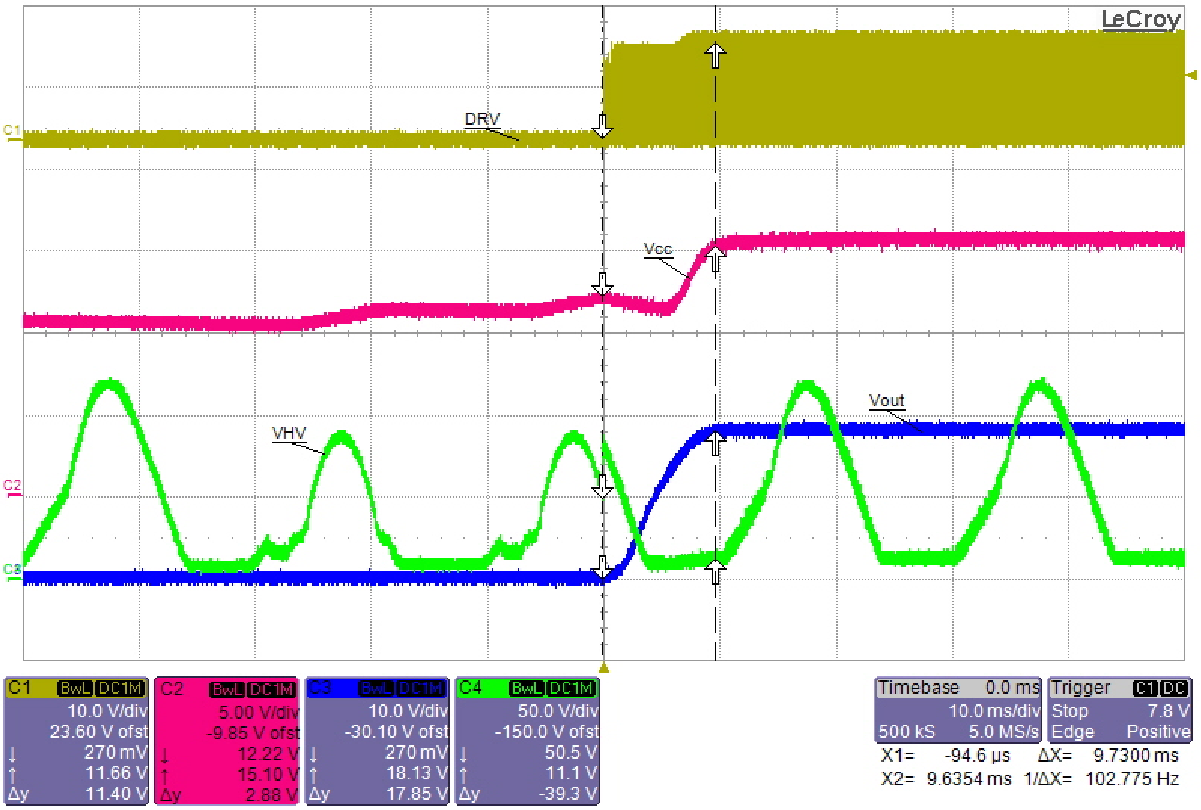

Figure 21. Adapter Start up at 85 V/50 Hz Input and 3.5 A Output Current Load

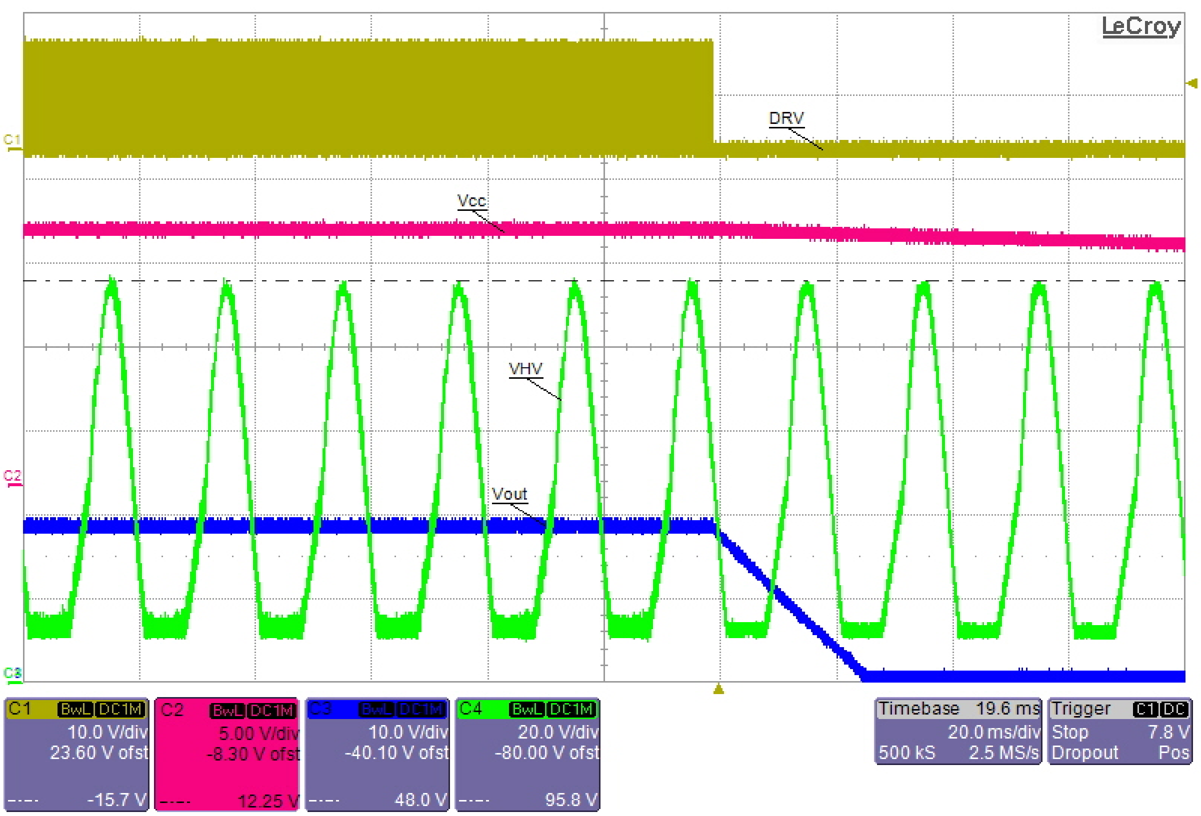

Figure 22. Brown Out Protection Reaction when the RMS AC Input Voltage Steps Down from 85 V to 66 V under 1 A Output Current Loading

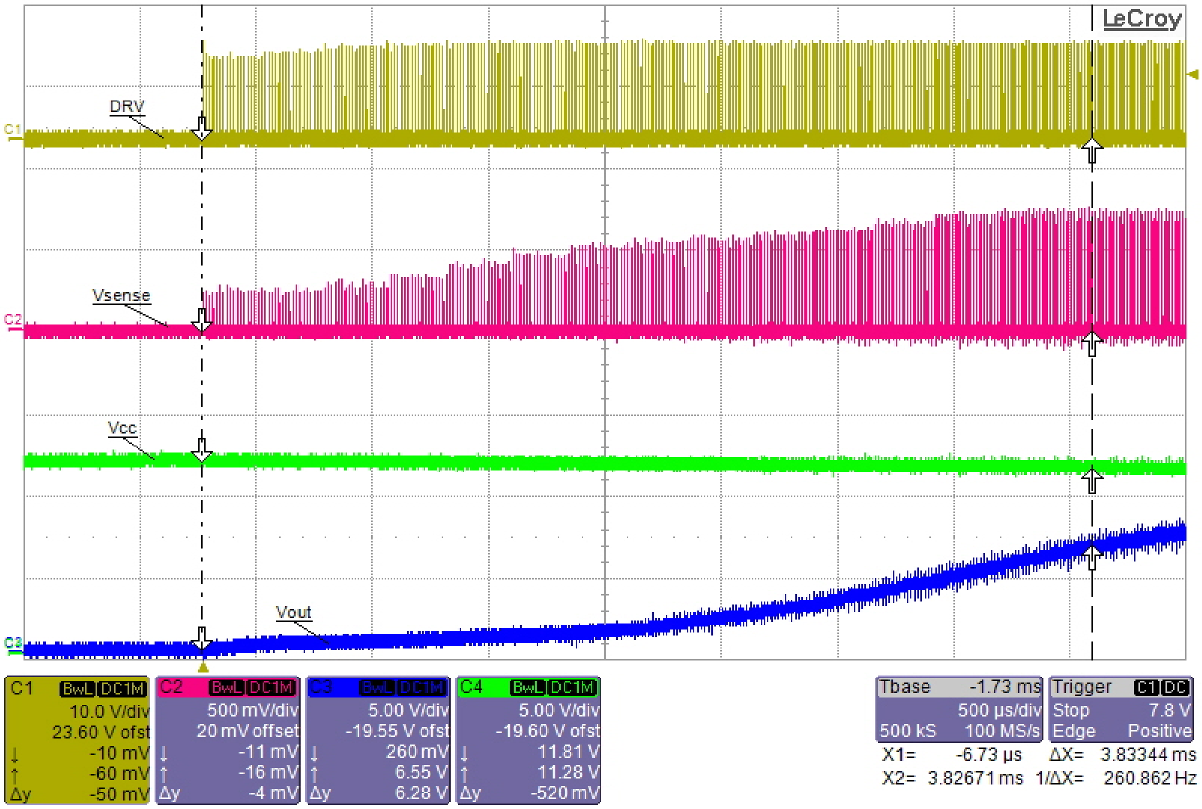

Figure 23. The Soft Start at 85 V/50 Hz Input with 5.5 A Output Current Loading

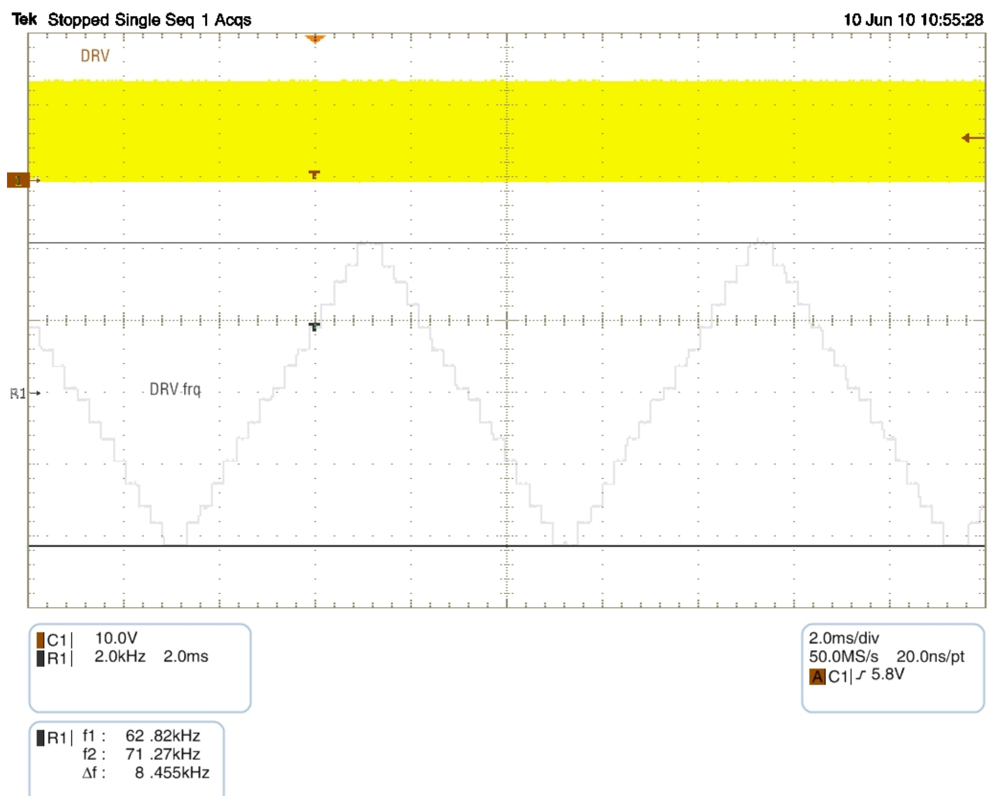

Figure 24. Frequency Deviation of the Frequency Jittering

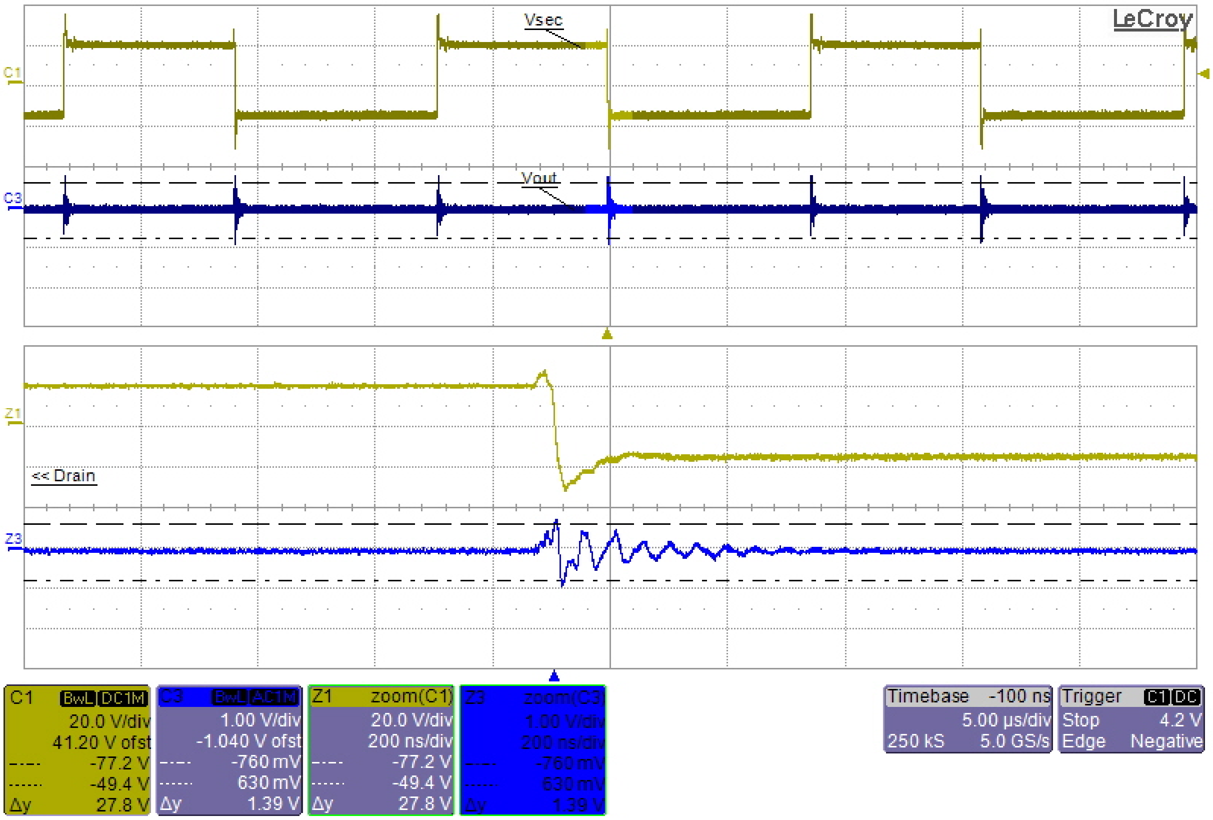

Figure 25. Detail of the Output Voltage Ripple and Voltage Across Secondary Winding of Transformer at 85 V/50 Hz Input with 3.5 A Output Current Loading (the ringing is caused by the secondary diode reverse recovery)

Results Summary

The family of controllers NCP1234/36 allows building of cost effective, easy-to-design and low no load input power consumption power supplies. The designed wide input range adapter fulfils the requirement of having no load input power lower than 100 mW over the wide input voltage range. While the complete design of the adapter must be oriented to gain the low no load input power, the controller facilitates this result by frequency foldback feature.

The obtained average efficiency is 89.8% for the low line condition (115 V/60 Hz) and 90.3% at high line conditions (230 V/50 Hz) for this adapter design. The excellent efficiency is obtained thanks to low forward drop diode NSTS30100SG from ON Semiconductor, dedicated transformer KA5038-BL, with dedicated design for this application and the low loss EMI filters.

The very good conducted EMI is obtained by the low EMI oriented design, usage the robust input and low EMI oriented layout of the PCB.

Thanks

I would like to thank the COILCRAFT Company for provided samples, custom design of the flyback transformer used in this board and the support.

I would like to thank the EPCOS Company for providing the samples of the input EMI filters and varistors. The WURTH Company provided the samples of the high frequency input and output EMI filters, that's why I would like to thank them as well.

Figure 26. Photograph of the Designed Prototype (Real Dimensions are 146.6 x 50.8 mm)

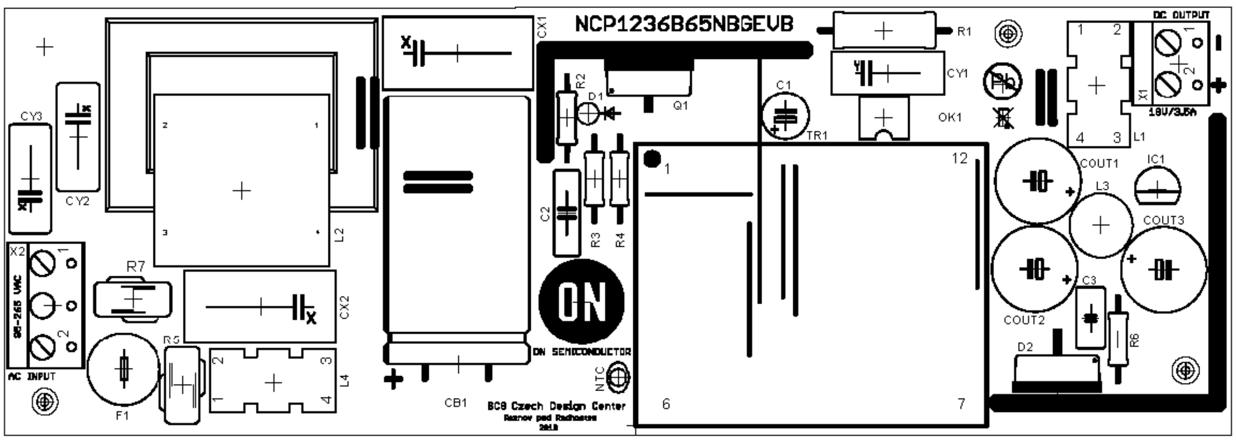

Figure 27. Component Placement on the Top Side (Top View)

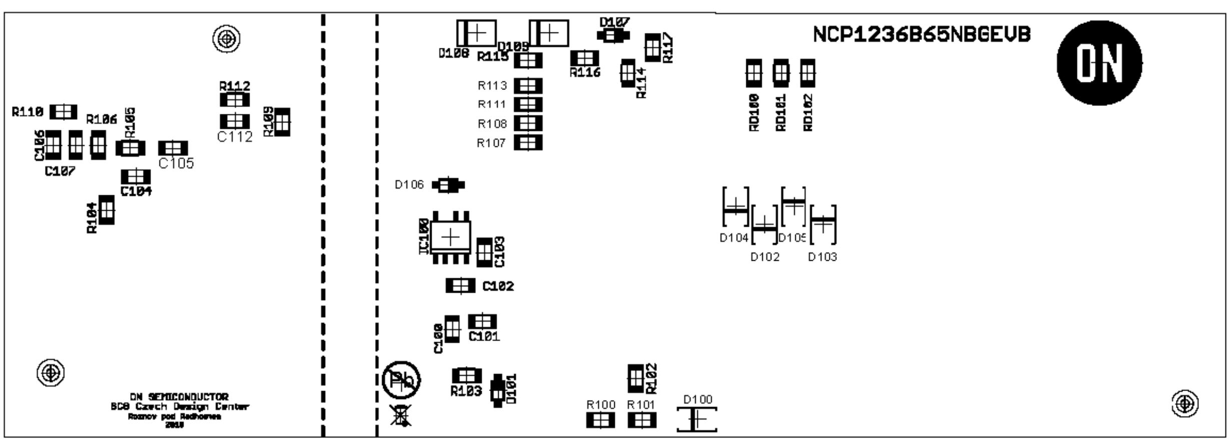

Figure 28. Component Placement on the Bottom Side (Bottom View)

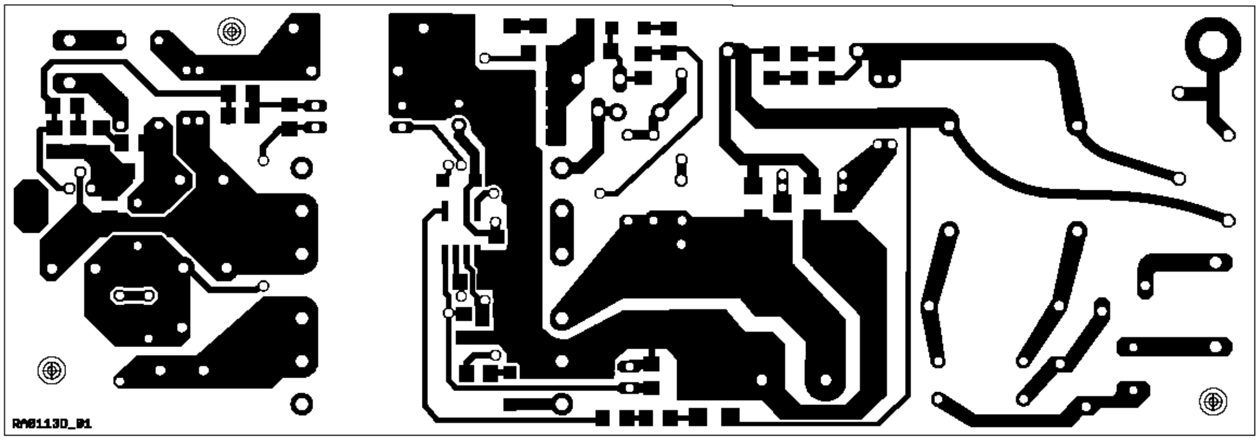

Figure 29. Bottom Side (Bottom View)

Table 4. BILL OF MATERIALS

Designator	Qty	Description	Value	Toler-ance	Footprint	Manufacturer	Manufacturer Part Number
C1	1	Electrolytic Capacitor	47 μF/0 V	20%	Radial	Koshin	KLH-050V470ME110
C100, C103	2	Ceramic Capacitor	100 nF	10%	1206	Kemet	C1206C104K5RAC
C101, C104	2	Ceramic Capacitor	NU	-	1206	-	-
C102, C106	2	Ceramic Capacitor	1.0 nF	10%	1206	Kemet	C1206C102K5RAC
C105, C107	2	Ceramic Capacitor	33 nF	10%	1206	Kemet	C1206C333K5RAC
C2	1	Ceramic Capacitor	5.6 nF/630 V	5%	Radial	TDK Corporation	FK20C0G2J562J
C3	1	Ceramic Capacitor	1.2 nF/630 V	5%	Radial	TDK Corporation	FK26C0G2J122J
CB1	1	Bulk Capacitor	100 μF/400 V	20%	Through Hole	United Chemi-Con	EKXG401ELL101MMN3S
COUT1, COUT2, COUT3	3	Electrolytic Capacitor	470 μF/25 V	20%	Radial	Panasonic - ECG	ECA-1EHG471
CX1, CX2	2	Suppression Film Capacitors	100 nF	10%	Through Hole	Epcos	B32922C3104K
CY1, CY2, CY3	3	Ceramic Capacitor	2.2 nF/X1/Y1	20%	Disc - Radial	Murata	DE1E3KX222MA5B
D1	1	Standard Recovery Rectifier	1N4007	-	DO41-10B	ON Semiconductor	1N4007G
D100, D102, D103, D104, D105,D108, D109	7	Standard Recovery Rectifier	MRA4007T3G	-	SMA	ON Semiconductor	MRA4007T3G
D101, D107	2	Diode	MMSD4148	-	SOD123	ON Semiconductor	MMSD4148T3G
D106	1	Zener diode	MMSZ15	5%	SOD123	ON Semiconductor	MMSZ15T3G
D2	1	Diode Schottky 150 V 15 A	NTST30100S G	-	TO220	ON Semiconductor	NTST30100SG
F1	1	Fuse (MST ser.)	1.6 A	-	Through Hole	Schurter Inc	0034.6617

Table 4. BILL OF MATERIALS

Designator	Qty	Description	Value	Toler-ance	Footprint	Manufacturer	Manufacturer Part Number
IC1	1	Programmable Precision Reference	TL431	-	TO-92	ON Semiconductor	TL431BCLPG
IC100	1	SMPS Controller	NCP1236B65	-	SOIC-08	ON Semiconductor	NCP1236BD65R2G
L1	1	Inductor	744 841 414	-	744 841 414	Würth Elektronik	744 841 414
L2	1	Inductor	2 x 20 mH/2 A		B82734W	Epcos	B82734W2202B030
L3	1	Inductor	10 μH	10%	DR0810	Coilcraft	DR0810-103L
L4	1	Inductor	744 841 330	-	744 841 330	Würth Elektronik	744 841 330
NTC	1	Sensing NTC Thermistor	330 kΩ	5%	Disc - Radial	Vishay	NTCLE100E3334JB0
OK1	1	Optocoupler	PC817	-	4-DIP	Sharp	PC817X2J000F
Q1	1	N MOSFET Transistor	SPP11N60C3	-	TO220	Infineon	SPP11N60C3
R1	1	Resistor Through Hole, High Voltage	4.7 MΩ	5%	Axial Lead	Welwyn	VRW37-4M7JI
R100, R101	2	Resistor SMD	2.7 kΩ	1%	1206	Rohm	MCR18EZHF2701
R102	1	Resistor SMD	33 kΩ	1%	1206	Rohm	MCR18EZHF3302
R103, R117	2	Resistor SMD	2.2 Ω	1%	1206	Rohm	MCR18EZHFL2R20
R104	1	Resistor SMD	2.2 kΩ	1%	1206	Rohm	MCR18EZHF2201
R105	1	Resistor SMD	8.2 kΩ	1%	1206	Rohm	MCR18EZHF8201
R106	1	Resistor SMD	6.2 kΩ	1%	1206	Rohm	MCR18EZHF6201
R107, R108, R111, R113	4	Resistor SMD	1.0 Ω	1%	1206	Rohm	MCR18EZHFL1R00
R109	1	Resistor SMD	3.9 kΩ	1%	1206	Rohm	MCR18EZHF3901
R110	2	Resistor SMD	5.6 kΩ	1%	1206	Rohm	MCR18EZHF1001
R112	2	Resistor SMD	1.0 kΩ	1%	1206	Rohm	MCR18EZHF1001
R114	1	Resistor SMD	22 Ω	1%	1206	Rohm	MCR18EZHF22R0
R115	1	Resistor SMD	680 Ω	1%	1206	Rohm	MCR18EZPF6800
R116	1	Resistor SMD	10 kΩ	1%	1206	Vishay	MCR18EZHF1002
R2	1	Resistor	2.2 Ω	1%	0207	Vishay	MBB02070C2208FRP00
R3, R4	2	Resistor	330 kΩ	1%	0207	Vishay	HVR2500003303FR500
R5	1	Surge protecting varistor	B72210P2301 K101	20%	Disc - Radial	Epcos	B72210P2301K101
R6	1	Resistor	15 Ω	1%	0207	Vishay	MRS25000C1509FRP00
R7	1	NTC Thermistor	NU	-	Disc - Radial	-	-
RD100, RD101, RD102	3	Resistor SMD	820 kΩ	1%	1206	Rohm	MCR18EZHF8203
TR1	1	Transformer	KA5038-BL	-	KA5038-BL	CoilCraft	KA5037-BL
X1	1	Terminal Block, 2 Way	CTB5000/2	-	W237-102	Cadem El.	CTB5000/2
X2	1	Terminal Block, 3 Way	CTB5000/3	-	W237-113	Cadem El.	CTB5000/3

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