Prototype Report

AC/DC Converter (Power Supply) using FAN7601 Fairchild PWM Controller and FCP11N60 SuperFET™

- AC European Input Voltage: 185V_{RMS} – 265V_{RMS}
- Total Output Power: 600W
- One DC Output: 150V / 4A

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2 Warning

This Evaluation Board may employ high voltages so appropriate safety precautions should be used when operating this board. Replace components on the Evaluation Board only with those parts shown on the BOM. Contact an authorized Fairchild representative with any questions.

3 Introduction

This document describes the proposed solution for a 600W Power Supply using the FAN7601 Fairchild PWM Controller. The input voltage range is $185V_{RMS}$ – $265V_{RMS}$ and there is one DC output with 150V / 4A.
This document contains the power supply specification, schematic, bill of materials and transformer documentation as well as typical operating characteristics.

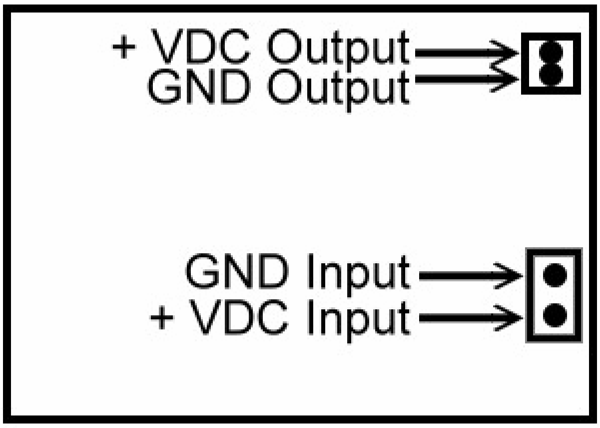
4 PSU Specification

4.1 Electrical Specification

Minimum Line Voltage	185 V_{RMS}
Maximum Line Voltage	265 V_{RMS}
Line Frequency	50Hz
Outputs	150V / 4A

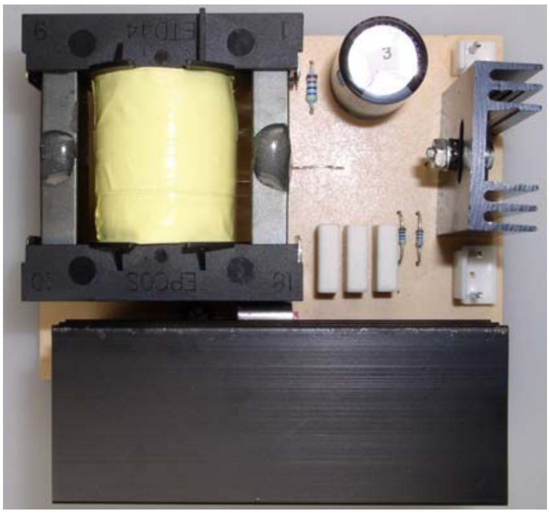
4.2 Mechanical Specification

The board size is 94.0mm x 86.0mm x 48.0mm (L x W x H)

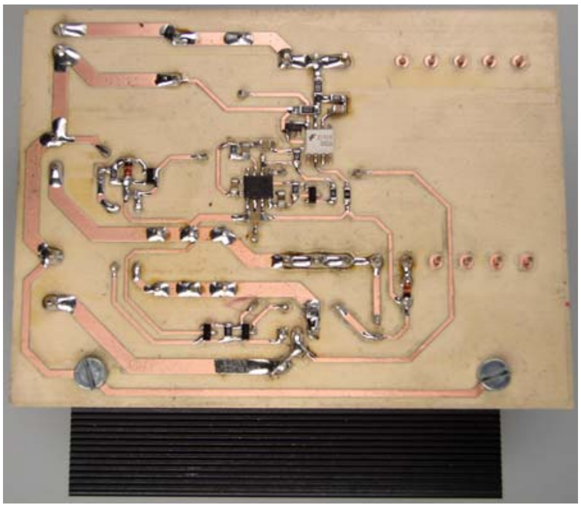


PCB photo

TOP view

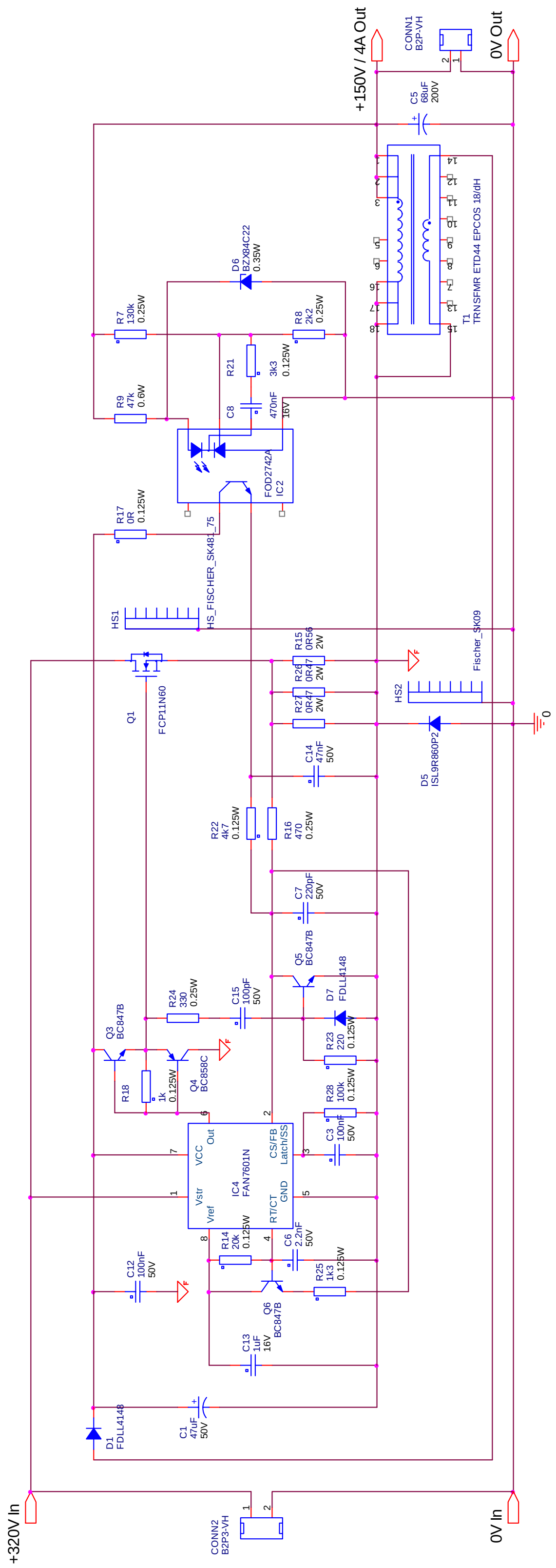


Bottom view



5 Schematic Diagram and Circuit Description

5.1 Schematic Diagram



5.2 Circuit Description

The PSU is a continuous conduction mode (CCM) Buck converter using the FAN7601 Fairchild PWM controller (IC4), the FCP11N60 SuperFET™ (Q1) and the FOD2741A Optically Isolated Error Amplifier (IC2). The optically isolated error amplifier combines the functionality of a standard KA431 reference and an optocoupler.

The main Buck converter consists of the switching element FCP11N60 SuperFET™ (Q1), the choke integrated in T1 (W1), freewheeling STEALTH™ diode ISL9R860P2 (D5) and the output capacitor C5.

The PWM controller FAN7601 (IC4) gets its start-up voltage directly from the DC line input and its soft-start time is determined by C3 and R28. Switching frequency is determined by R14 and C6 (50kHz). The self supply voltage Vcc for the IC is generated by transformer T1 where the primary winding (W1) is basically the inductance for the Buck converter but W2 acts as secondary winding like in a flyback converter. Vcc is then rectified and filtered by D1 and C1.

Feedback is taken directly from the output. The output voltage is given by the voltage divider network (R7 and R8) and the internal voltage reference of the optocoupler IC2. C8 and R21 are for frequency compensation. R9 drives the LED of the optocoupler. The feedback signal is first filtered by C14 and R22 before it is fed in Pin 2 of the PWM controller FAN7601 (IC4).

The current sense signal is generated using the sense resistors R15, R26 and R27. It is then filtered by R16 and C7. R24,C15, R23, D7 and Q5 form an leading edge blanking network which processes the current sense signal before it is fed in Pin 2 of IC4.

Q6 and R25 are for slope compensation due to a duty cycle greater than 50%.

The switching element FCP11N60 SuperFET™ (Q1) is driven from the output of IC4 Pin 6. Q3, Q4 and R18 form a gate-driver circuit for Q1.

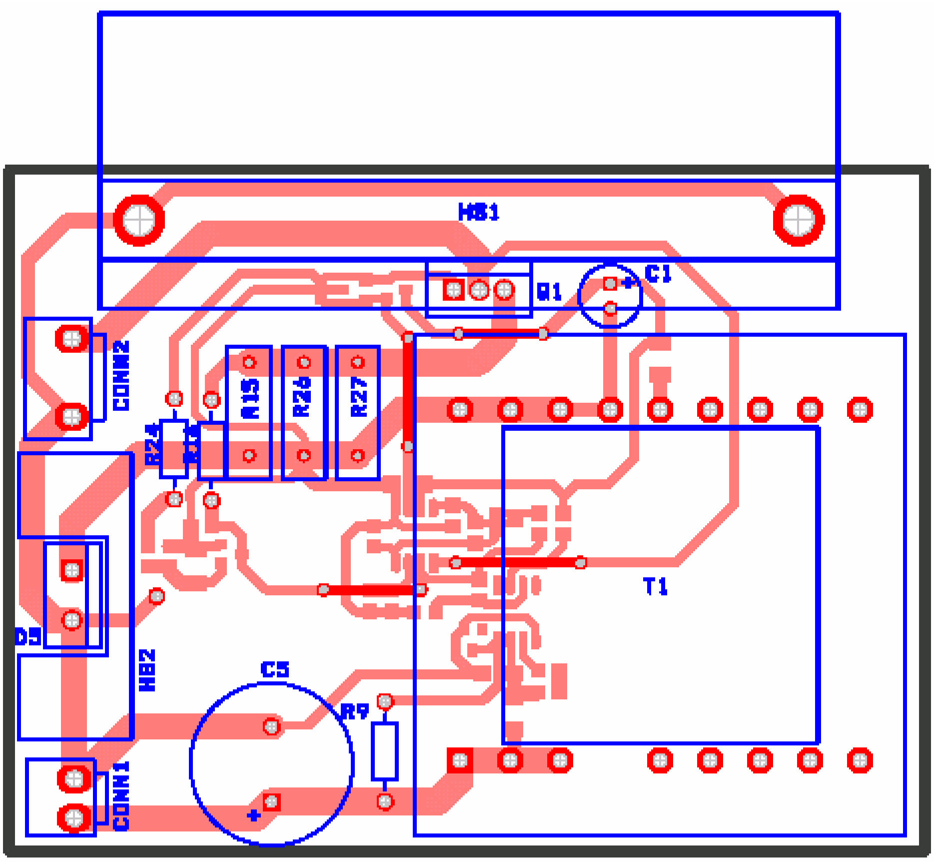
The PSU is short-circuit-proof.

5.3 PWM Controller FAN7601

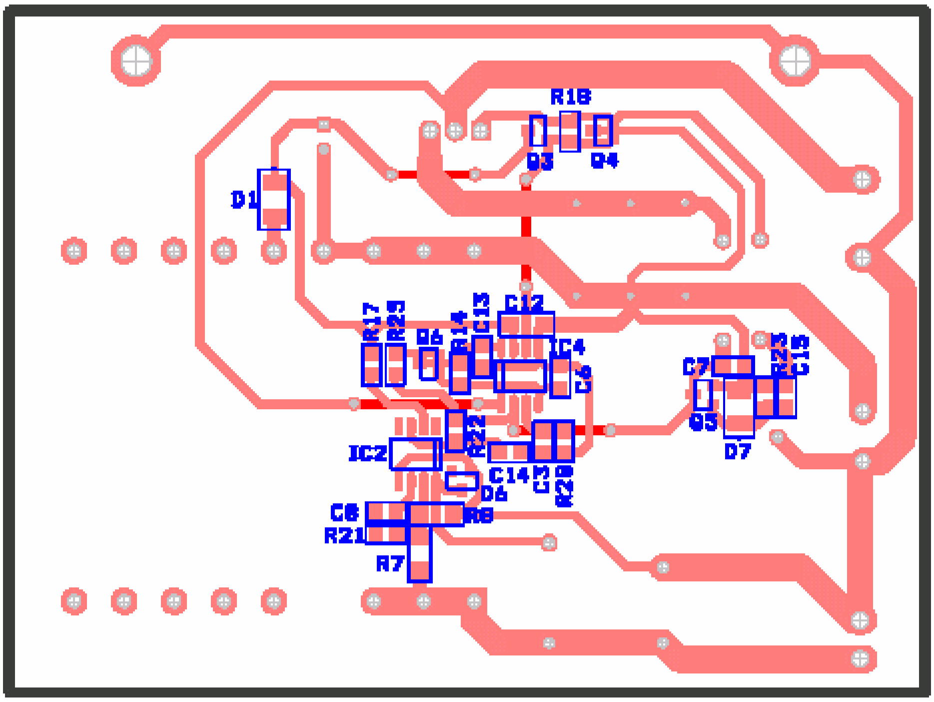
The FAN7601 is a green programmable frequency current mode PWM controller. It is specially designed for the off-line adapter application and the auxiliary power supplies which require high efficiency at a light load and no load. The internal high voltage start-up switch and the burst mode reduce the power loss. The FAN7601 includes some protections such as latch protection and over voltage protection. The latch protection can be used for over voltage protection and/or thermal protection and so on. And the soft start prevents the output voltage over shoot at start up.

6 PCB Layout

6.1 Top Side View



6.2 Bottom Side View



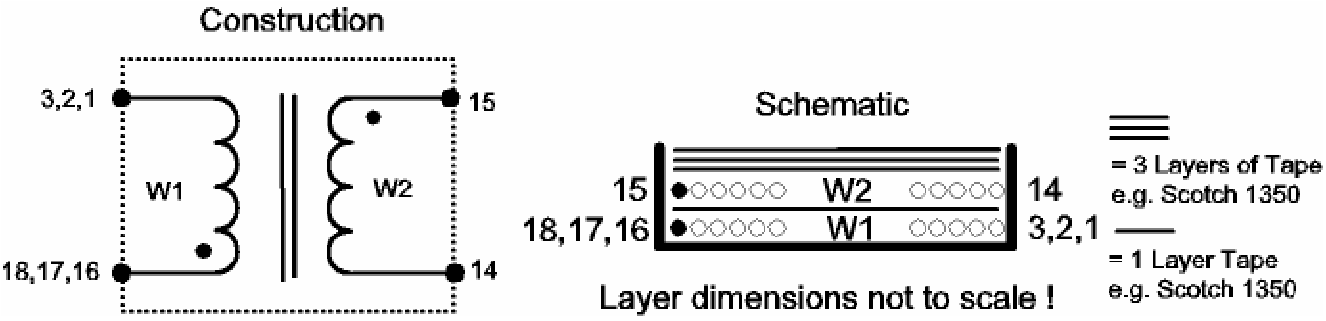
7 Bill of Materials

Item	Qty	Reference	Value / Specification	Series	Manufacturer
1	1	CONN1	B2P-VH	VH	JST
2	3	CONN2,CONN3,CONN4	B2P3-VH	VH	JST
3	1	C1	47uF / 50V	SD	Samwha
4	1	C3	100nF / 50V	X7R SMD 0805	AVX
5	1	C12	100nF / 50V	X7R SMD 1206	AVX
6	1	C5	68uF / 200V	B43858-A2686-M000	Epcos
7	1	C6	2.2nF / 50V	X7R SMD 0805	AVX
8	1	C7	220pF / 50V	COG SMD 0805	AVX
9	1	C8	470nF / 50V	X7R SMD 0805	AVX
10	1	C13	1uF / 16V	X7R SMD 0805	AVX
11	1	C14	47nF / 50V	X7R SMD 0805	AVX
12	1	C15	100pF / 50V	COG SMD 0805	AVX
13	2	D1,D7	FDLL4148		Fairchild Semiconductor
14	1	D5	ISL9R860P2		Fairchild Semiconductor
15	1	D6	BZX84C22 / 0.35W		Fairchild Semiconductor
16	1	HS1	SK481 75mm		Fischer
17	1	HS2	SK09 37.5mm		Fischer
18	1	IC2	FOD2742A		Fairchild Semiconductor
19	1	IC4	FAN7601N		Fairchild Semiconductor
20	1	Q1	FCP11N60		Fairchild Semiconductor
21	3	Q3,Q5,Q6	BC847B		Fairchild Semiconductor
22	1	Q4	BC858C		Fairchild Semiconductor
23	1	R7	130k / 0.25W		any
24	1	R8	2k2 / 0.25W		any
25	1	R9	47k / 0.6W		any
26	1	R14	20k / 0.125W		any
27	1	R15	0R56 / 2W Low inductance		any
28	1	R16	470 / 0.25W		any
29	1	R17	0R / 0.125W		any
30	1	R18	1k / 0.125W		any
31	1	R21	3k3 / 0.125W		any
32	1	R22	4k7 / 0.125W		any
33	1	R23	220 / 0.25W		any
34	1	R24	330 / 0.25W		any
35	1	R25	1k3 / 0.125W		any
36	2	R26,R27	0R47 / 2W Low inductance		any
37	1	R28	100k / 0.125W		any
38	1	T1	ETD44 18 Pin Horizontal		Epcos

8 Transformer Specification

8.1 Winding Details

Name	Pins (Start → End)	# of Layers	Strands x Wire ø	Turns	Construction	Material
W1	18,17,16 → 3,2,1	3	90 x 0.1mm	67	Perfect solenoid	CuLL
W2	15 → 14	1	1 x 0.22mm	7	Spaced winding	CuLL



8.2 Electrical Characteristics

Parameter	Pins	Specification	Conditions
Primary Inductance	18,17,16 → 3,2,1	700µH +/- 5%	10kHz, 100mV, all secondaries open
Leakage inductance	18,17,16 → 3,2,1	220uH maximum	10kHz, 100mV, all secondaries short

Note: The high value of the leakage inductance results from the usage of HF litzwire for the main choke (W1). The advantage of the HF litzwire is a better thermal behaviour for the choke due to a lower AC resistance for high frequencies.

8.3 Core and Bobbin

Core: ETD 44
Material: N87 (Epcos) or equivalent
Bobbin: ETD 44 horizontal / 18 pins
Gap in center leg: approx. 1.33 mm for A_L of 156 nH/Turns^2

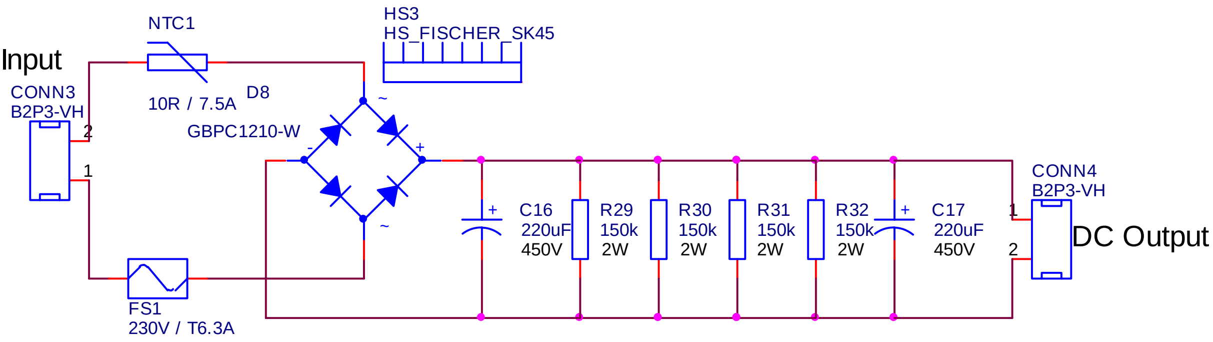
8.4 Safety

High voltage test: 3000V_{RMS} for 1 minute between primary (pins 18, 17, 16 to 3, 2, 1) and secondary
(pins 15 to 14)

9 Electrical Performance

9.1 AC Line Adapter

For the electrical performance an AC line adapter was used. The input used for the power measurements was the DC input of the module (Conn 2).



Item	Qty	Reference	Value / Specification	Series	Manufacturer
1	2	CONN3,CONN4	B2P3-VH	VH	JST
2	2	C16,C17	220uF / 450V		BC
3	1	D8	GBPC1210-W		Fairchild Semiconductor
4	1	HS3	SK45 / 50mm		Fischer
5	1	FS1	230V / T6.3A		any
6	1	NTC1	10 / 7.5A	S364	EPCOS
7	4	R29,R30,R31,R32	150k / 2W		any

9.2 Test Equipment

Oscilloscope: Tektronix TDS784C (1GHz / 4GS/s)

Multimeter: RMS MULTIMETER FLUKE 85 II

Electronic Load: Prodigit 3000C Base unit using 3314C, Hoecherl & Hackl DS440VS500

Power Analyzer: LEM NORMA 5000

AC Source: EPS Typ5315

Temperature Probe: Greisinger dual channel digital thermometer GMH3230 using two GTF300 NiCr-Ni thermocouples

The ambient temperature for all tests was 25 ºC if not noted otherwise.

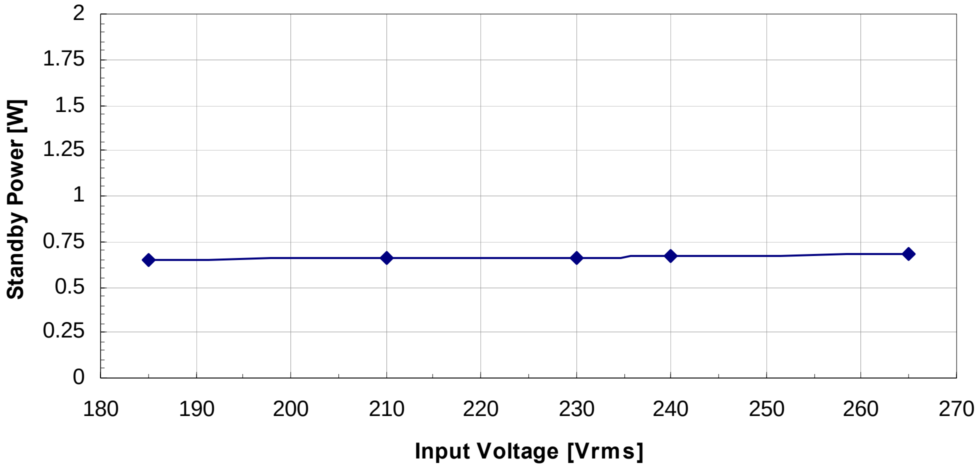
9.3 Standby Power vs. Input Voltage

9.3.1 Test Condition and Method

The input power for various input voltages was measured with no load and with 10% of rated load. The standby power was calculated as $P_{STDBY} = P_{IN} - P_{OUT}$.

9.3.2 No Load Standby Power

V_{IN} [V_{RMS}]	185	210	230	240	265
P_{IN} [W]	0.71	0.72	0.72	0.73	0.74
P_{OUT} [W]	0.06	0.06	0.06	0.06	0.06
P_{STDBY} [W]	0.65	0.66	0.66	0.67	0.68



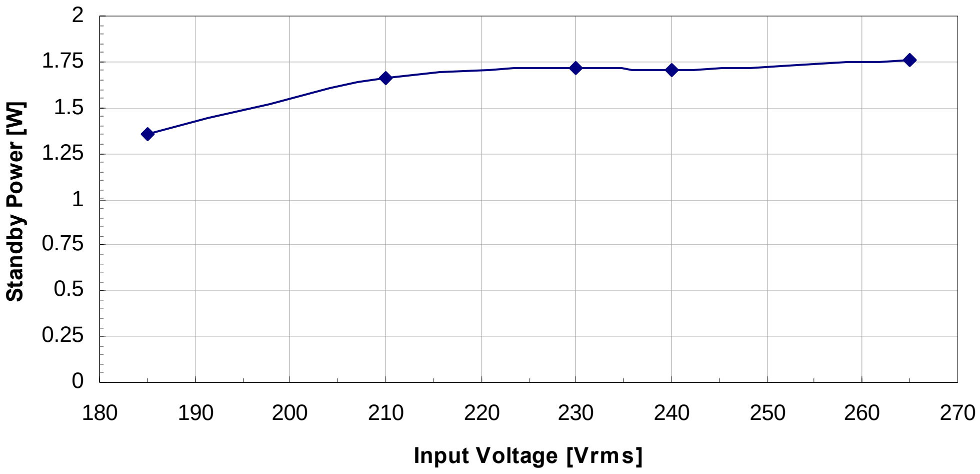
9.3.3 Accuracy of Output Voltages with No Load

The minimum and maximum values in the table below are calculated as deviations from the output voltage as specified in section 4.1.

V_{IN} [V_{RMS}]	185	210	230	240	265		**Min [%]**	**Max [%]**
V_1 [V]	148.77	148.76	148.76	148.75	148.75		-0.8	-0.8

9.3.4 Power Consumption with 10% of Rated Load

V_{IN} [V_{RMS}]	185	210	230	240	265
P_{IN} [W]	61.3	61.6	61.66	61.64	61.69
P_{OUT} [W]	59.95	59.94	59.94	59.93	59.93
P_{STDBY} [W]	1.35	1.66	1.72	1.71	1.76



9.3.4.1 Accuracy of Output Voltages with 10% of Rated Load

The minimum and maximum values in the table below are calculated as deviations from the output voltage as specified in section 4.1.

V_{IN} [V_{RMS}]	185	210	230	240	265		Min [%]	Max [%]
V_1 [V]	148.65	148.64	148.63	148.63	148.63		-0.9	-0.9

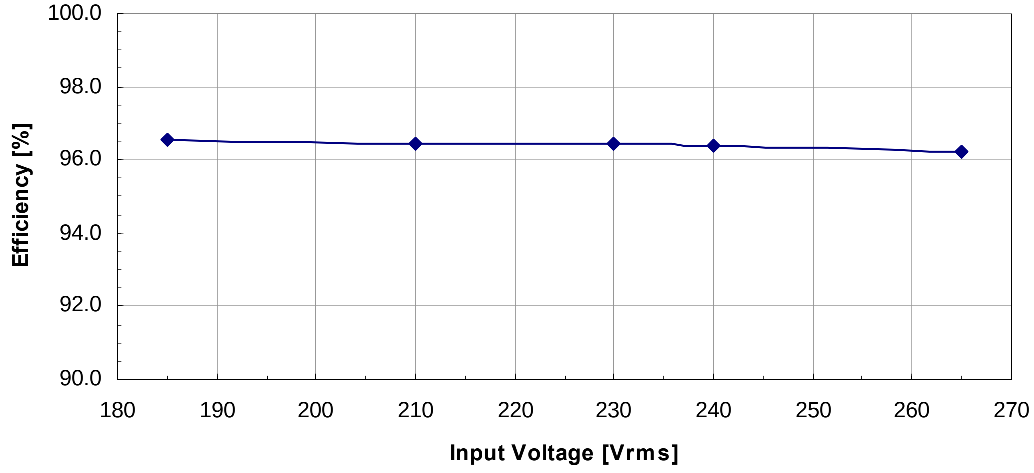
9.4 Full Load Efficiency vs. Input Voltage

9.4.1 Test Condition and Method

The power supply was set up with its output loaded at rated load as defined in Section 4.1.The input voltage was swept across the specified range. The output load was kept constant. The input power was measured and efficiency calculated.

9.4.2 Result

V_{IN} [V_{RMS}]	185	210	230	240	265
P_{OUT} [W]	587.73	600.1	600.3	599.5	600.5
P_{IN} [W]	608.75	622.05	622.3	622.1	624.2
Efficiency [%]	96.5	96.5	96.5	96.4	96.2



9.5 Line Regulation

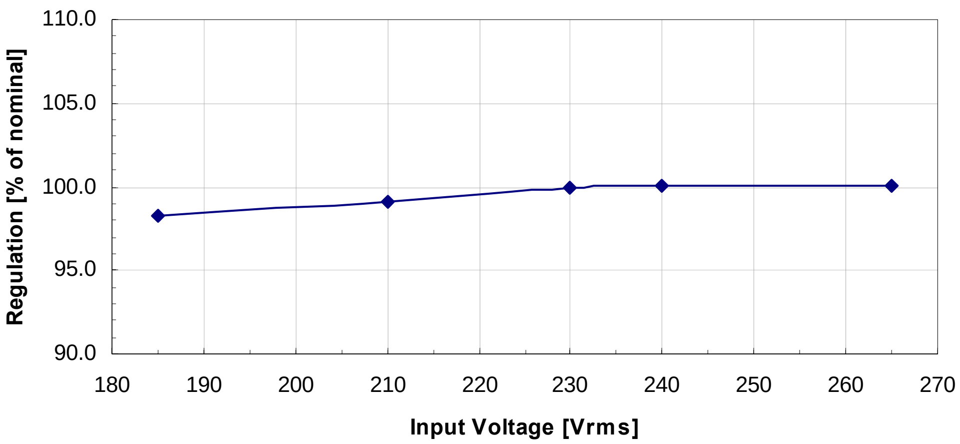
9.5.1 Test Condition and Method

The power supply was set up with its output loaded at rated load. The input voltage was swept across its specified range. Output voltage was measured for each input voltage and was displayed relative to the nominal output voltage. The nominal voltage in this case is the voltage measured for the output at V_{IN} = 230V_{RMS}.

9.5.2 Result

The minimum and maximum values in the table below are calculated as deviations from the output voltage as specified in section 4.1.

V_{IN} [V_{RMS}]	185	210	230	240	265		**Min [%]**	**Max [%]**
V_1 [V]	145.5	146.79	148.05	148.12	148.08		-3.0	-1.3



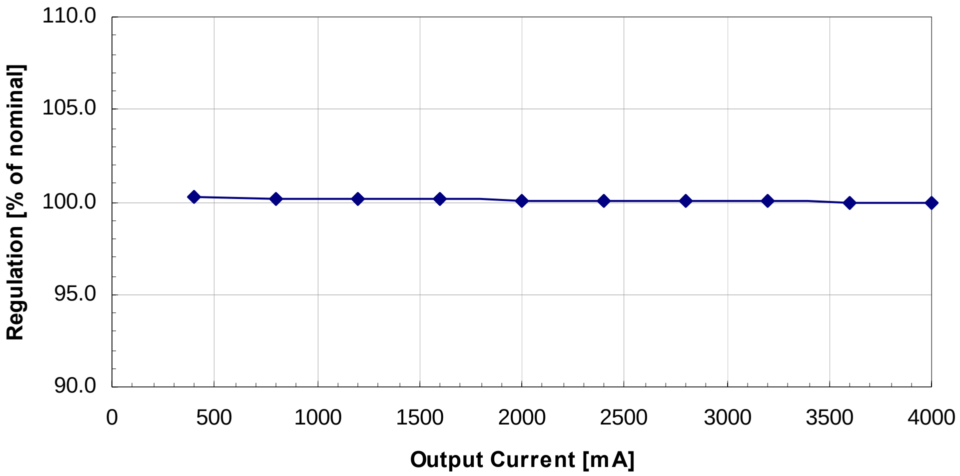
9.6 Load Regulation

9.6.1 Test Condition and Method

The load current of the output is swept from 10% to 100% of its rated current. These measurements are done at V_{IN} = 230V_{RMS}. The results are displayed normalized to the voltage measured when the output is at 100% load.

9.6.2 Result for V_1 (150V)

I_1 [mA]	400	800	1200	1600	2000	2400	2800	3200	3600	4000
V_1 [V]	148.54	148.46	148.38	148.32	148.27	148.23	148.2	148.18	148.15	148.15

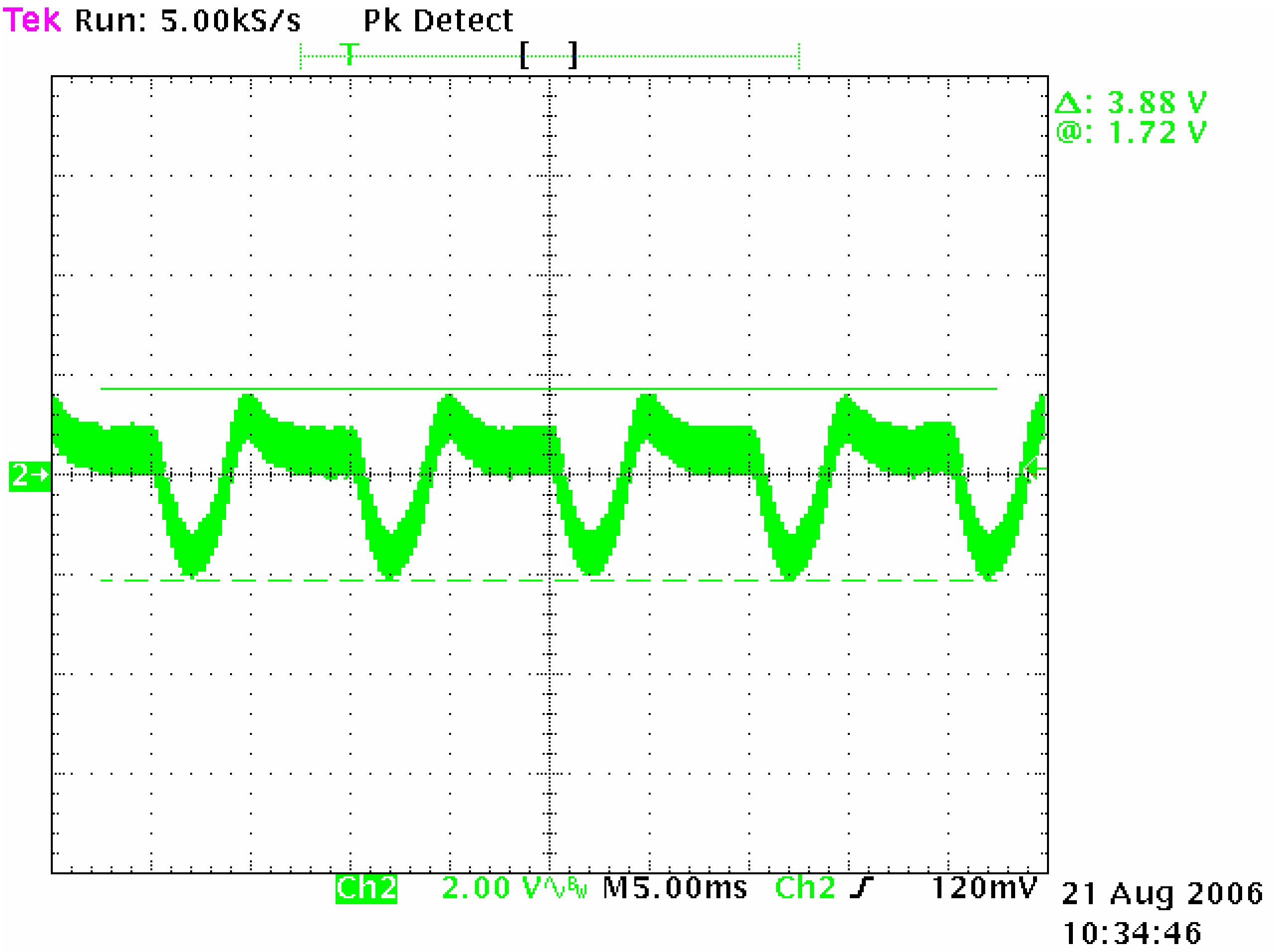


9.7 Output Ripple & Noise

9.7.1 Test condition and Method

The output was loaded at rated load and V_{IN} = 230V_{RMS}. The so-called PARD (periodic and random disturbance) method was used to measure ripple and noise voltages. See for example Celestica application note AN-1259-1-R2. **IMPORTANT NOTE:** Output voltage ripple measurements cannot be made using a normal oscilloscope probe set-up. Magnetic field coupling into the ground connection for the oscilloscope probe could cause noise voltages far greater than the true ripple voltage.

9.7.2 Result for V_1 (150V)



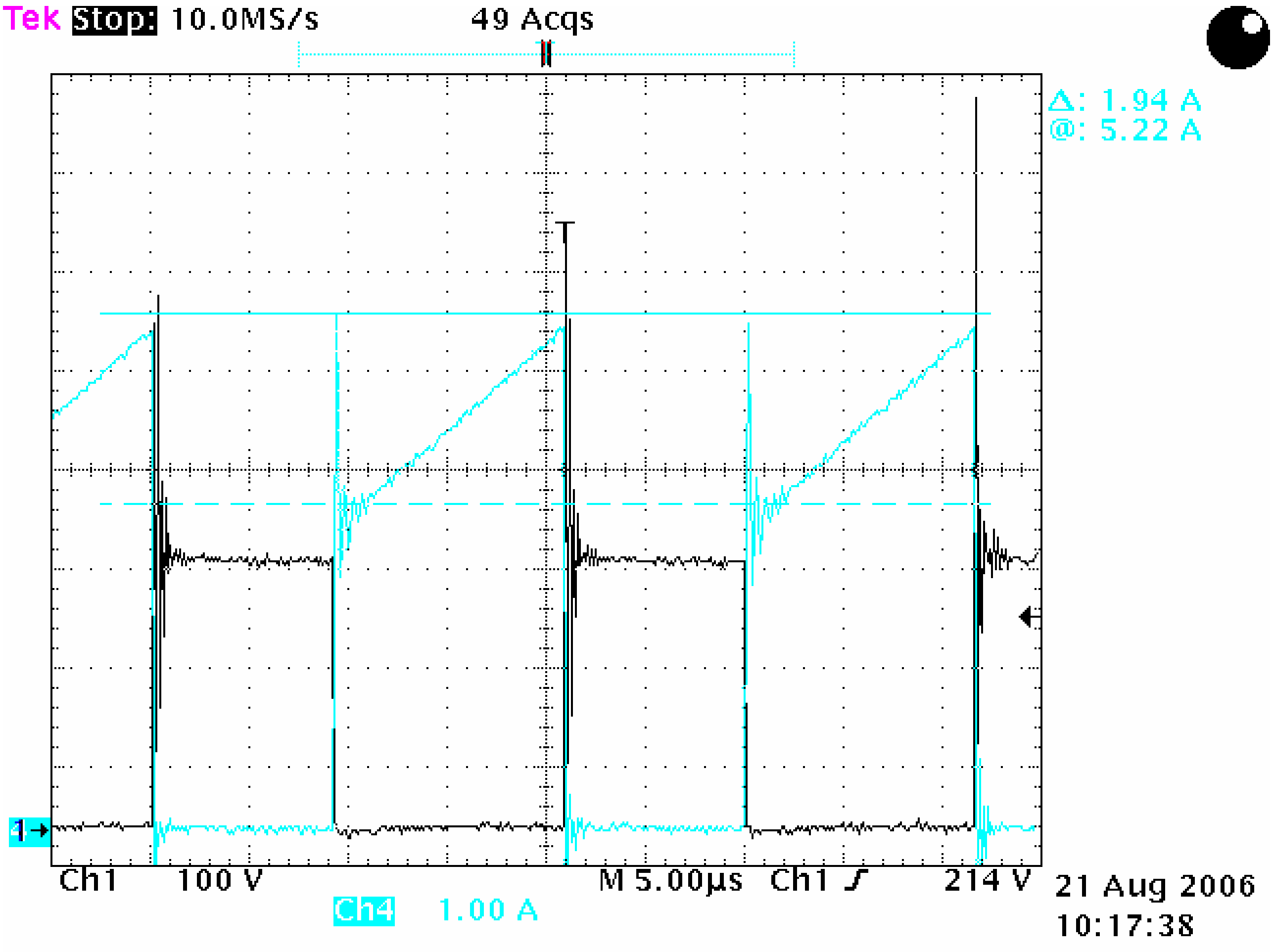
Ch1: V_1 (150V) Ripple @ 2V/div, TB @ 5ms

9.8 Typical Drain Waveforms

9.8.1 Test Condition and Method

The output was loaded at rated load and V_{IN} was set to $230V_{RMS}$. The Drain-Voltage and Drain-Current were measured.

9.8.2 Result



Ch1: Drain-Voltage @ 100V/div, Ch4: Drain-Current @ 1A/div, TB @ 5µs

10 Thermal Performance

10.1 Test Condition and Method

The temperatures of the SuperFET™, STEALTH™ diode, choke winding and the ferrite core were measured with thermocouples. The measured temperatures were monitored from start up of the PSU until a steady state was recognized. The output was set to full load with V_{IN} = 230V_{RMS}. The ambient temperature was 25°C. The thermocouples for the SuperFET™ and the STEALTH™ diode where placed on their heatsinks close to them.

10.2 Result