60W Evaluation Board with ICE3DS01

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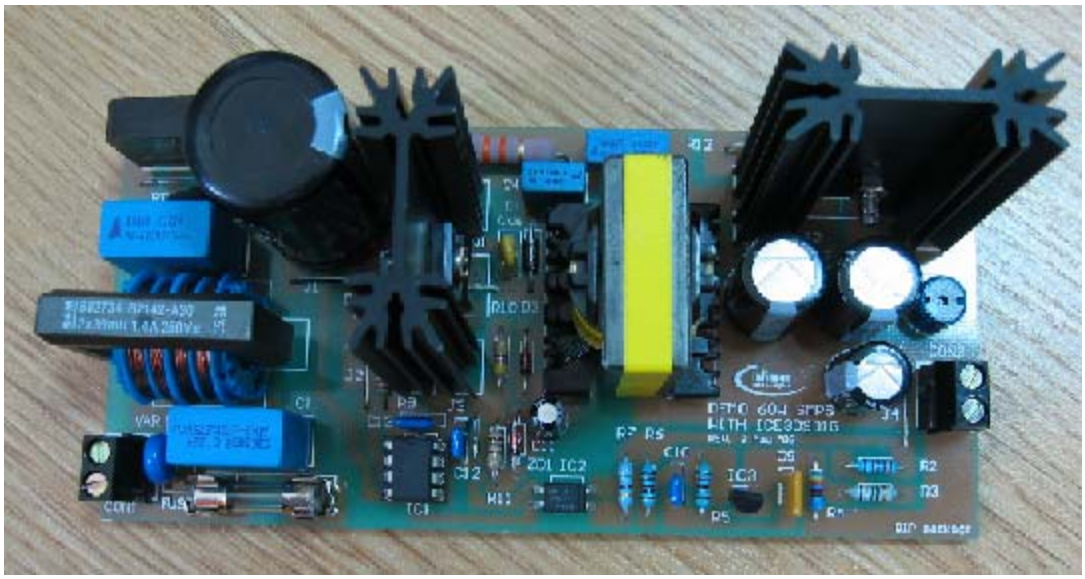
The board described here was designed as a typical power supply in flyback converter topology with secondary control. It is particularly suitable as an AC/DC power supply for LCD monitors, adapters for printers and notebook computers, DVD players and set-top boxes in addition to industrial auxiliary power supplies. ICE3DS01 which is used for this application is a current-controlled pulse width modulator. The F3 controller provides Active Burst Mode to reach the lowest Standby Power Requirements < 100mW at no load. Furthermore Latched Off Mode is entered in case of Overtemperature, Overvoltage or Short Winding. Upon entering Latched Off Mode, the controller can only be reset by disconnecting it from the main lines. Auto Restart Mode is entered in case of failure modes like open loop or overload. An adjustable blanking window prevents the IC entering Auto Restart Mode or Active Burst Mode in case of high load jumps.

Evaluation Board



Technical Specifications:

Input Voltage	85VAC~265VAC
Input Frequency	50Hz, 60Hz
Output Voltage and Current	16V, 3.75A
Output Power	60W
Efficiency	80%
Switching Frequency	110KHz
Standby Power	<100mW

Normal Operating Mode

The internal Startup Cell, which is connected to the DC input voltage at HV pin, is activated as soon as the SMPS is plugged to the main AC-line. It provides 1mA charge current to charge the external capacitor C_{11} at V_{CC} pin. The SMPS enters into Normal Operating Mode once V_{CC} reaches 15V after startup and remains in the range of 8.5V to 20V as long as V_{FB} > 1.3V & < 4.75V with V_{SOFTST} > 4V. At this state, the Startup Cell is switched off to eliminate losses. R_{10}, R_{11} and ZD_1 are inserted at Vcc pin to protect the IC from overloaded. When V_{CC} falls below 8.5V, the controller is switched off. The Startup Cell is then activated again and the SMPS goes into Auto Restart Mode.

Active Burst Mode

At light load condition, the SMPS enters into Active Burst Mode. The controller is always active at this state. V_{CC} must therefore be above the switch off threshold V_{CCoff} = 8.5V. C_{12} is used to avoid Vcc falling below V_{CCoff}. While supporting low ripple on V_{OUT} and fast response on load jump, efficiency also increased significantly during Active Burst Mode. When the voltage level at FB falls below 1.32V, capacitor C_{13} at SOFTST pin is allowed to charge starting from the clamped voltage level at 4.4V in normal operating mode. Active Burst Mode is entered if V_{SOFTST} exceeds 5.4V. A time window which can be adjusted by manipulating C_{13} is generated to avoid a sudden entering of burst mode due to load jump. During Active Burst Mode the current sense voltage limit at I_{SENSE} pin, V_{ISENSE}, is set to 0.257V to reduce the conduction losses. All the internal circuits are switched off except the reference and bias voltages to reduce the total V_{CC} current consumption to below 1.1mA. The FB voltage is changing like a sawtooth between 1.32V and 4V.

A high load jump causes FB voltage to exceed 4.8V immediately. This resets the Active Burst Mode and turns the SMPS into Normal Operating Mode. Maximum current can now be provided to stabilize V_{OUT}.

Protection Modes

Types Of System Failures	Protection Mode
V_{CC} Overvoltage	Latched Off Mode
Overtemperature	Latched Off Mode
Short Winding/Short Diode	Latched Off Mode
Overload	Auto Restart Mode
Open Loop	Auto Restart Mode
V_{CC} Undervoltage	Auto Restart Mode
Short Optocoupler	Auto Restart Mode

Two categories of Protection Modes are provided by ICE3DS01 to protect it against different types of systems failure.

Latched Off Mode

Overvoltage is detected when V_{CC} exceeds 21V. To ensure that it is not triggered by small voltage overshoots, Latched Off Mode is only activated when V_{FB} is also higher than 4.8V.

During Open Loop, when the output voltage V_{OUT} increases due to light load conditions and Auto Restart Mode, V_{CC} also increases. After Auto Restart Mode is activated for a few cycles, V_{CC} exceeds 21V and Latched Off Mode is entered to block the SMPS.

When a junction temperature higher than 140^{o}C is detected Latched Off Mode is entered. The signals coming from temperature and V_{CC} overvoltage detection are fed into a spike blanking with a constant of 8µs to ensure system reliability.

In normal operating mode, the maximum V_{ISENSE} at ISENSE pin is 1V. If there is a failure such as short winding or short diode, the limit is being raised to 1.66V. When this limit is exceeded, the IC enters the Latched Off Mode to keep the SMPS in a safe state.

Latched Off Mode can only be reset by decreasing V_{CC} < 6V. In this stage only the Undervoltage Lockout, UVLO, of the controller is working; it controls the startup cell by switching on/off at V_{CCON}/V_{CCOFF} and the average current consumption is only 300µA.

Auto Restart Mode

FB exceeds 4.8V when there is an Overload or Open Loop. At the same time V_{SOFTST} at pin1,which is at 4.4V in normal operation mode, is released and allowed to rise. If V_{SOFTST} exceeds 5.4V, Auto Restart Mode is entered. To prevent the system from entering Auto Restart Mode due to large load jumps a

blanking window similar as for the Active Burst Mode is generated. This window can be adjusted by the external C_{13}.

In case of V_{CC} undervoltage the UVLO starts a new startup cycle. Short Optocoupler leads to V_{CC} undervoltage as there is no self supply after activating the internal reference and bias

Current Limiting

A cycle by cycle current limiting is achieved with the sensing resistors R_8//R_{8A} which converts the primary current to a corresponding voltage level at ISENSE pin. A 220ns leading edge blanking is provided to avoid leading edge spikes from distorting the current limiting.

Propagation delay compensation is integrated to compensate the overshoot of peak primary current from current sense to switch off of the PWM-driver. The influence of the AC input voltage on the maximum output power can thereby be minimized.

Transformer

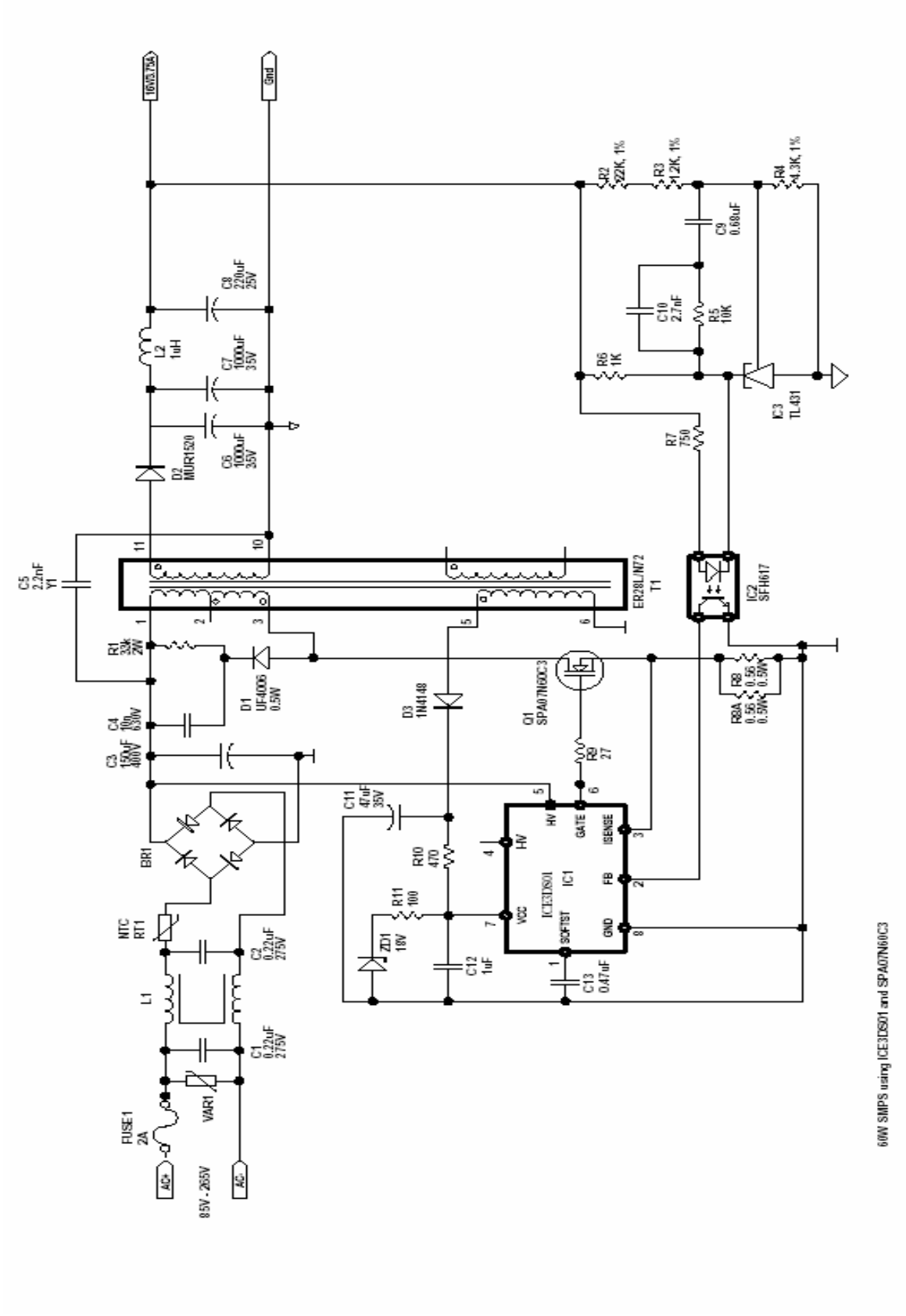
The transformer is designed for Discontinuous Conduction Mode operation with primary inductance L_P = 94µH. Number of turns for the primary winding is N_1=24, whereas the secondary winding is N_2=5. This results in a reflected output voltage of V_{OR}=82V at the primary side. The maximum peak primary current, $I_{1PEAK(MAX)}$, is about 3.8A. Core size ER28 is used. A 600V/7A power MOSFET in T0220-Fullpack package, SPA07N60C3, is chosen to drive the transformer.

Output Voltage and Regulation

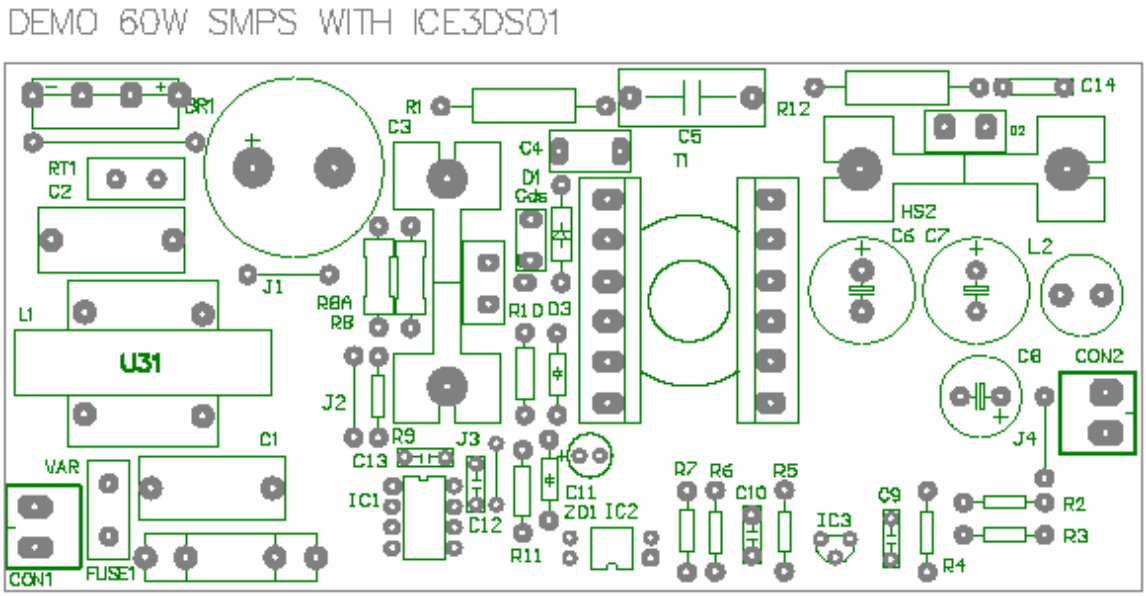
To maximize the SMPS efficiency while maintaining low cost design, an ultra fast output rectifier diode 200V/15A, MUR1520, is used. Very low ESR capacitors C_6 and C_7 are selected to minimized losses as well as output voltage ripple caused by the switching current. The output voltage ripple is further reduced by L_2 and C_8. The output voltage is set by resistors R_2, R_3 and R_4 which also provide minimum loading.

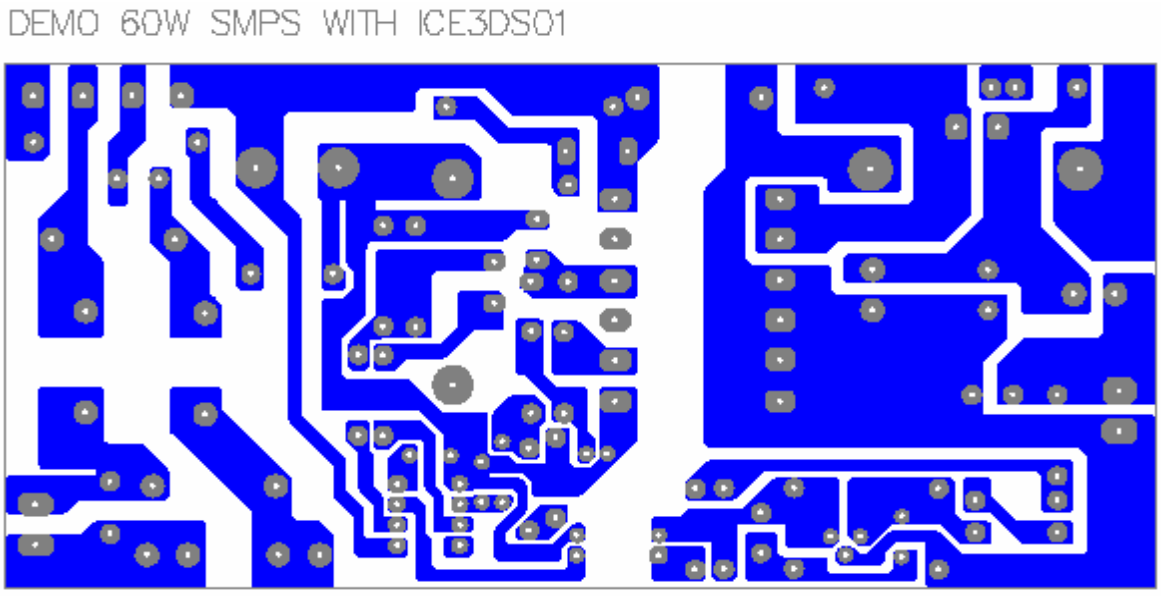
The output voltage is regulated by using IC_3, TL431, which incorporates voltage reference, error amplifier and driver stage. The external compensation network of the error amplifier of IC_3, R_5, C_9 and C_{10}, ensures fast dynamic response to load variation as well as the stability of the SMPS. Optocoupler IC_2, which meets DIN VDE884 requirements, is used for floating transmission of the control signal to FB input. The filtering of the FB input signal is implemented internally in the control IC. External component count is therefore minimized.

Circuit Diagram



PCB Layout


DEMO 60W SMPS WITH ICE3DS01
BR1
R1
C3
C4
C5
T1
R12
C14
D2
RT1
C2
D1
Cds
HS2
C6
C7
L2
J1
R8A
R8B
R1
D
D3
L1
U31
C8
CON2
J2
R9
J3
J4
C1
C13
VAR
IC1
C11
ZD1
IC2
R7
R6
R5
C10
IC3
C9
R2
R3
C12
R11
R4
CON1
FUSE1

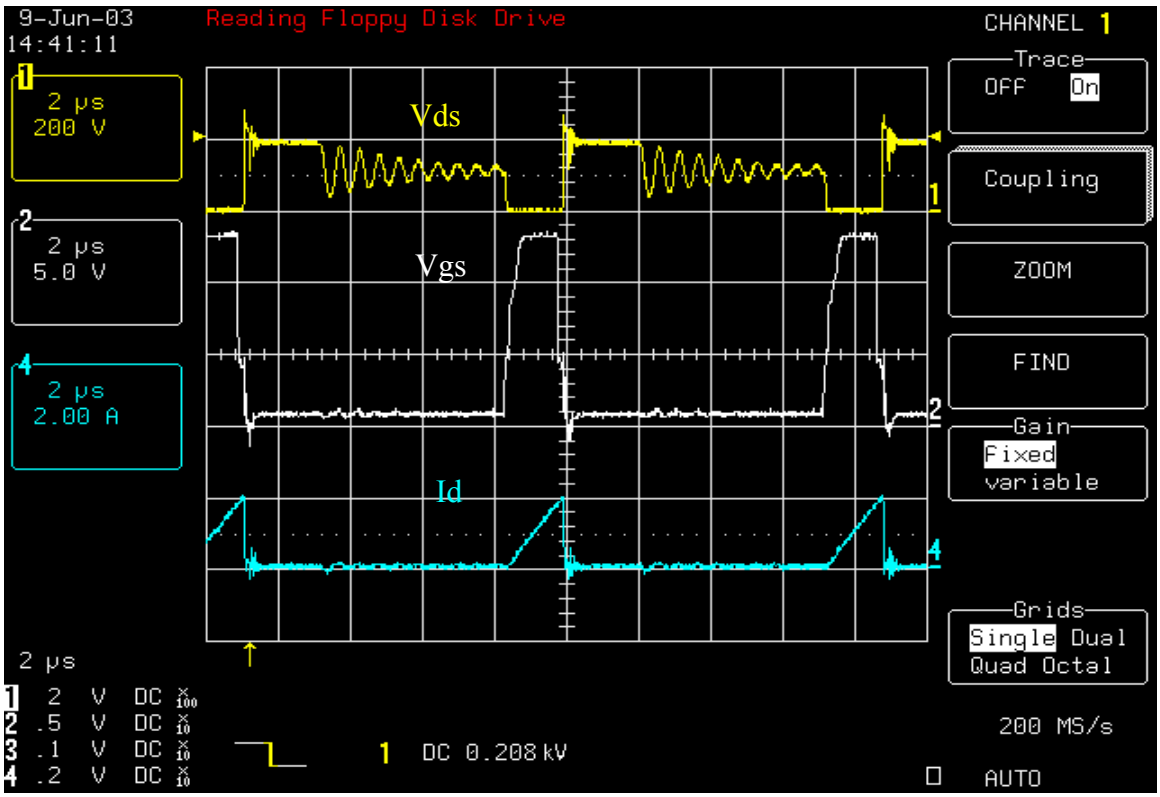

DEMO 60W SMPS WITH ICE3DS01

Bill of Materials
60W SMPS Demo Board with ICE3QS01

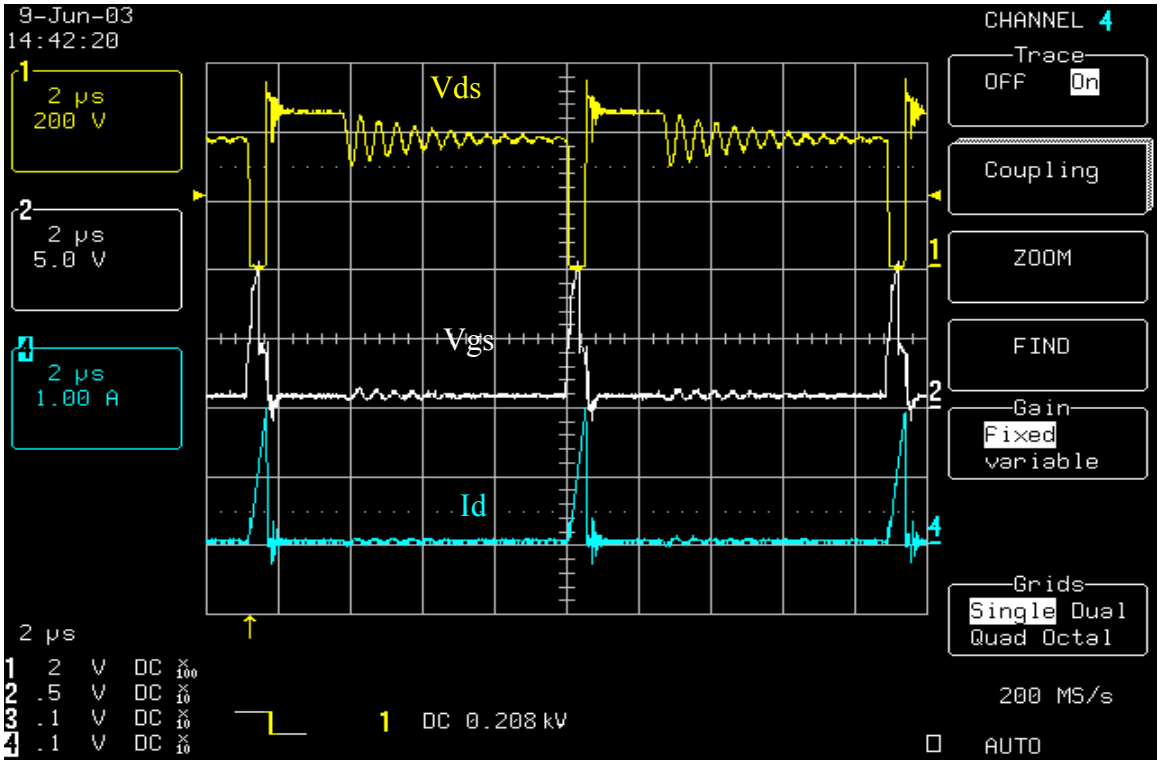
Item No	Designator	Part Type	Quantity
1	BR1	SKB2/04L5A	1
2	C1	0.22uF 275V, X2 Capacitor	1
3	C2	0.22uF 275V, X2 Capacitor	1
4	C3	150uF/400V	1
5	C4	10nF/630V	1
6	C5	2.2nF 250V, Y1 Capacitor	1
7	C6	1000uF/35V	1
8	C7	1000uF/35V	1
9	C8	220uF/25V	1
10	C9	680nF/50V	1
11	C10	2.7nF/50V	1
12	C11	47uF/35V	1
13	C12	1uF/50V	1
14	C13	470nF/50V	1
15	C14 (Optional)	470pF/1KV	1
16	Cds (Optional)	220pF/1KV	1
17	Con1	Connector	1
18	Con2	Connector	1
19	D1	UF4006	1
20	D2	MUR1520	1
21	D3	1N4148	1
22	FUSE1	2A/250V	1
23		Fuse Holder	2
24	HS1	HS34, heat sink for Q1	1
25	HS2	HS34, heat sink for D2	1
26	IC1	ICE3DS01G	1
27	IC2	SFH617A-3	1
28	IC3	TL431	1
29	J	20mm Jumper	1
30	J1	10mm Jumper	1
31	J2	10mm Jumper	1
32	J3	12.5mm Jumper	1
33	J4	10mm Jumper	1
34	L1	80mH, 4A common Choke	1
35	L2	1uH, 5A	1
36	Q1	SPP07N60C3	1
37		T0220 Isolation Pad	2
38		Isolation Bush	2
39	R1	33k, 2W, 5%	1
40	R2	22k, 0.25W, 1%	1

41	R3	1.2k, 0.25W, 1%	1
42	R4	4.3k, 0.25W, 1%	1
43	R5	10k, 0.25W, 1%	1
44	R6	1k, 0.25W, 1%	1
45	R7	750, 0.25W, 1%	1
46	R8	0.56, 0.5W, 5%	1
47	R8A	0.56, 0.5W, 5%	1
48	R9	27, 0.25W, 1%	1
49	R10	470, 0.25W, 1%	1
50	R11	100, 0.25W, 1%	1
51	R12 (Optional)	100, 2W, 5%	1
52	RT1	236/2.5	1
53	T1	ER28L/N72, 12pin	1
54	VAR1	S07K275	1
55	ZD1	18V, 0.5W	1
56		3mm Screw	2
57		3mm Nut	2
58		Ferrite Bead	2

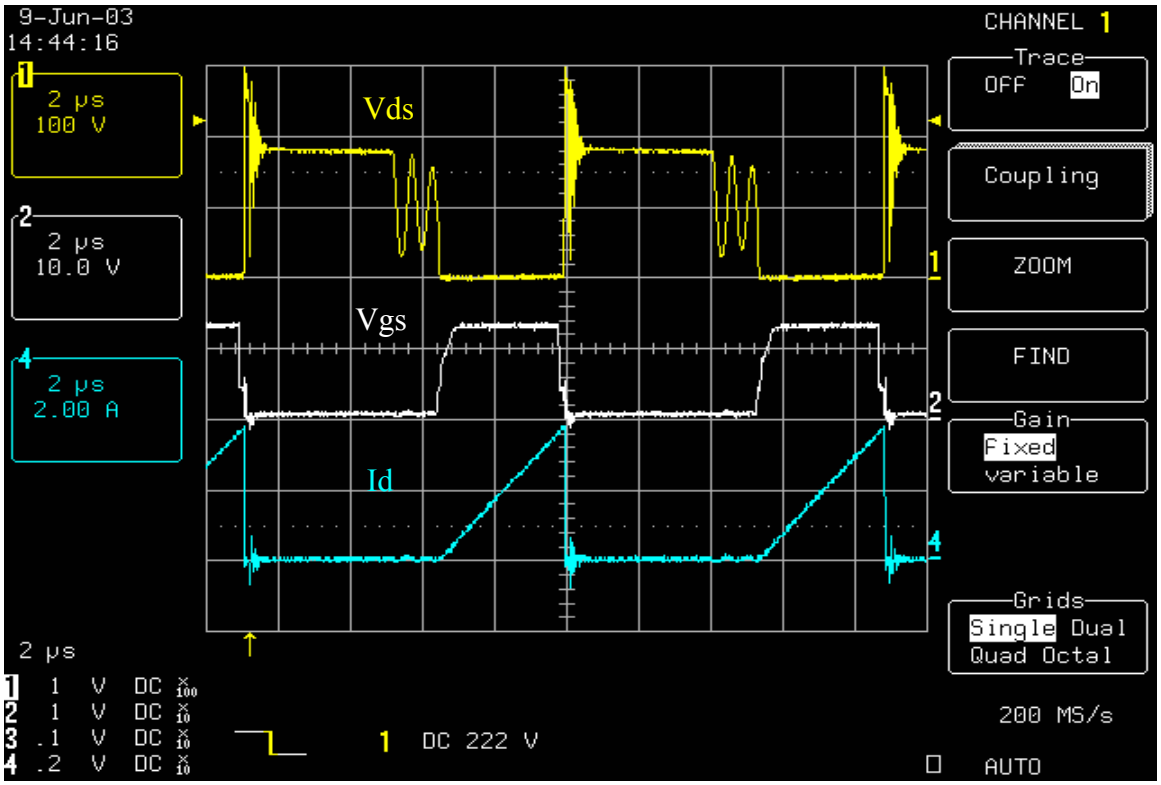
Waveforms



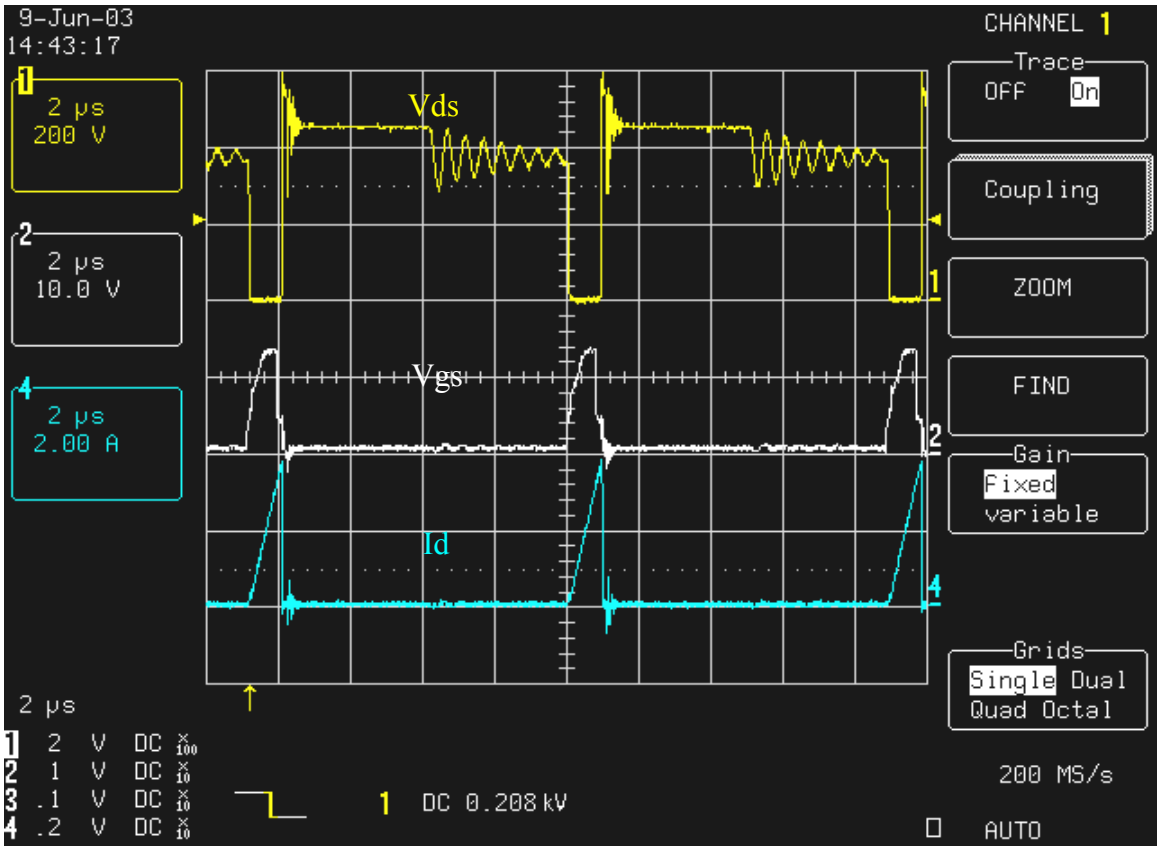
Normal Mode with 1A Load at Input Voltage 85V



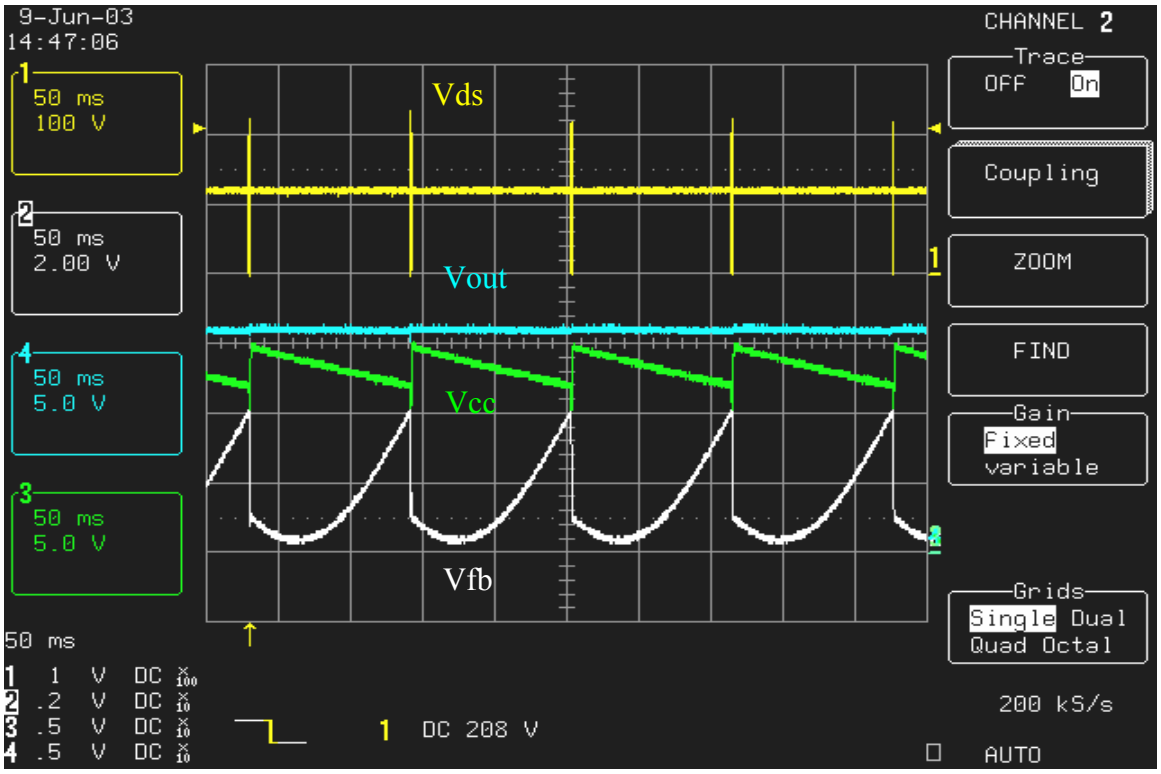
Normal Mode with 1A Load at Input Voltage 265V



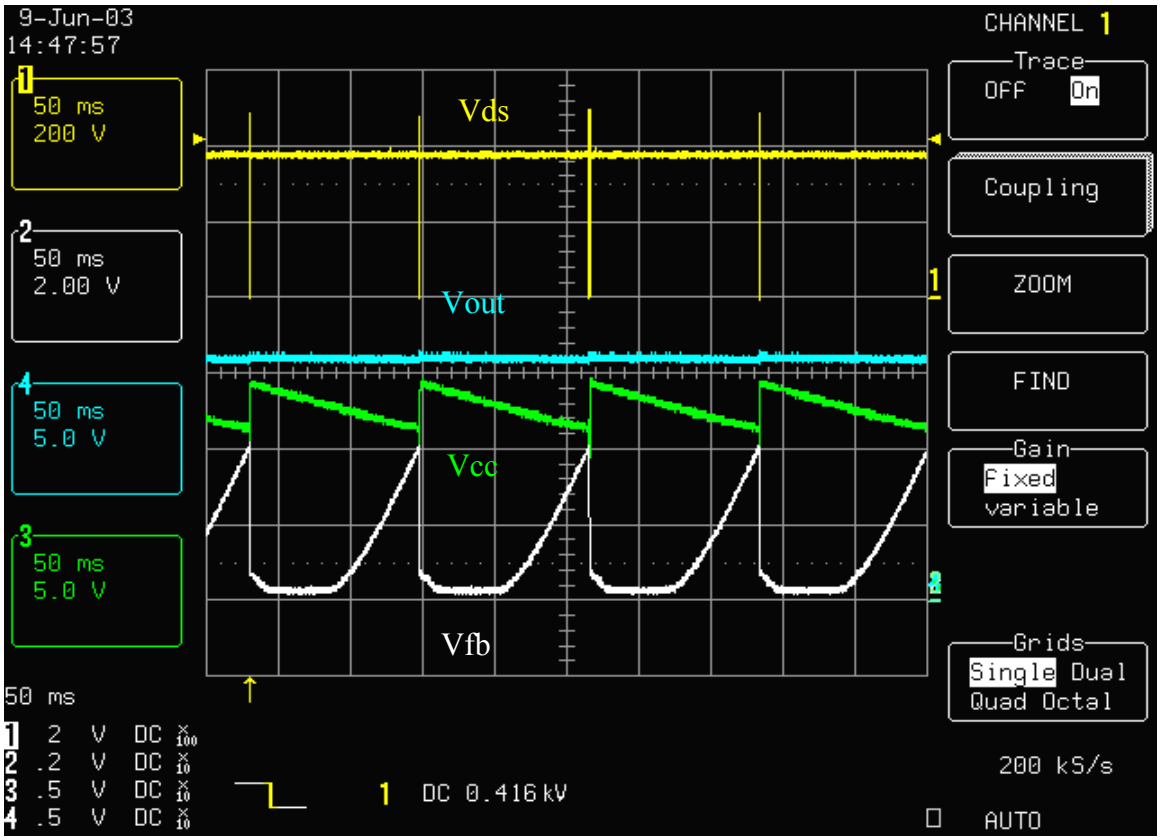
Normal Mode with Full Load 3.75A at Input Voltage 85V



Normal Mode with Full Load 3.75A at Input Voltage 265V



Burst Mode with No Load at Input Voltage 85V



Burst Mode with No Load at Input Voltage 265V

Test Report

Normal Mode

Vin	Iin	Pin	Pout	Efficiency	Vo	Io
(V)	(A)	(W)	(W)	(%)	(V)	(A)
85	0.52	24.14	19.96	82.69	15.97	1.25
	0.96	49.07	39.90	81.31	15.96	2.5
	1.34	73	59.85	81.99	15.96	3.75
100	0.47	24	19.96	83.18	15.97	1.25
	0.85	48.4	39.90	82.44	15.96	2.5
	1.20	73	59.85	81.99	15.96	3.75
110	0.43	24.06	19.96	82.97	15.97	1.25
	0.78	48.5	39.90	82.27	15.96	2.5
	1.13	74.14	59.85	80.73	15.96	3.75
220	0.27	24.01	19.96	83.14	15.97	1.25
	0.48	47.71	39.90	83.63	15.96	2.5
	0.68	72.2	59.85	82.89	15.96	3.75
265	0.23	24.4	19.96	81.81	15.97	1.25
	0.42	48.45	39.93	82.40	15.97	2.5
	0.60	72	59.85	83.13	15.96	3.75

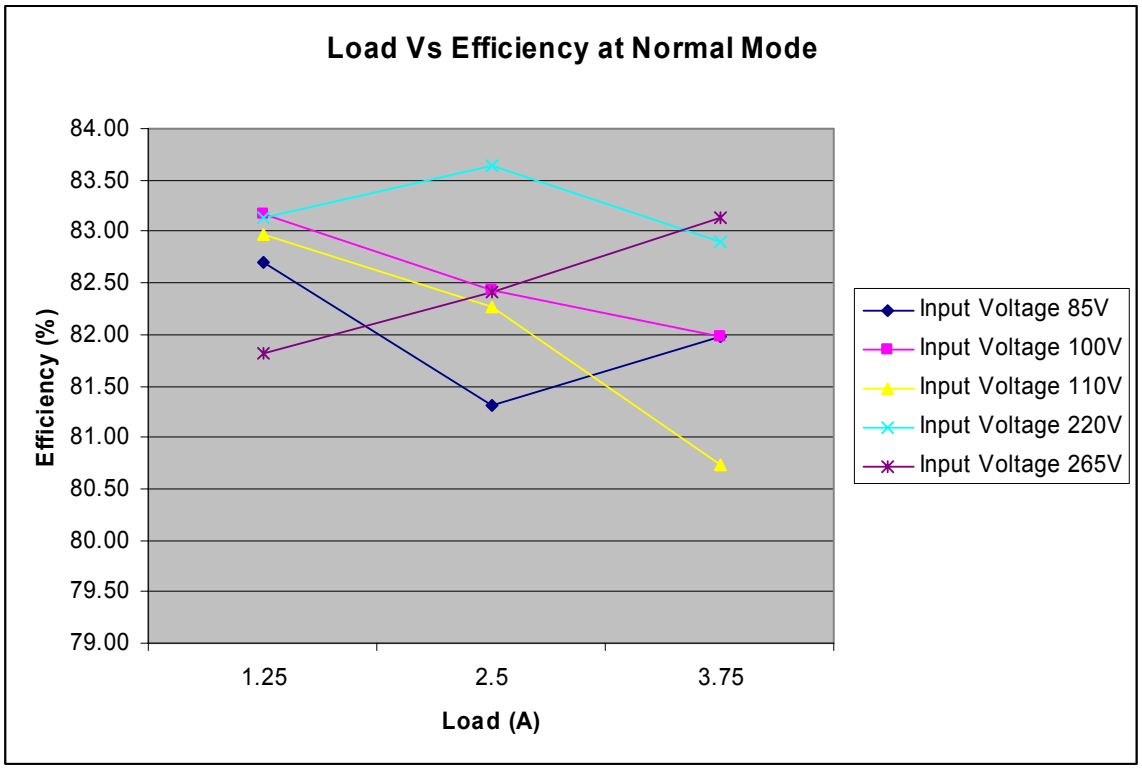
Burst Mode

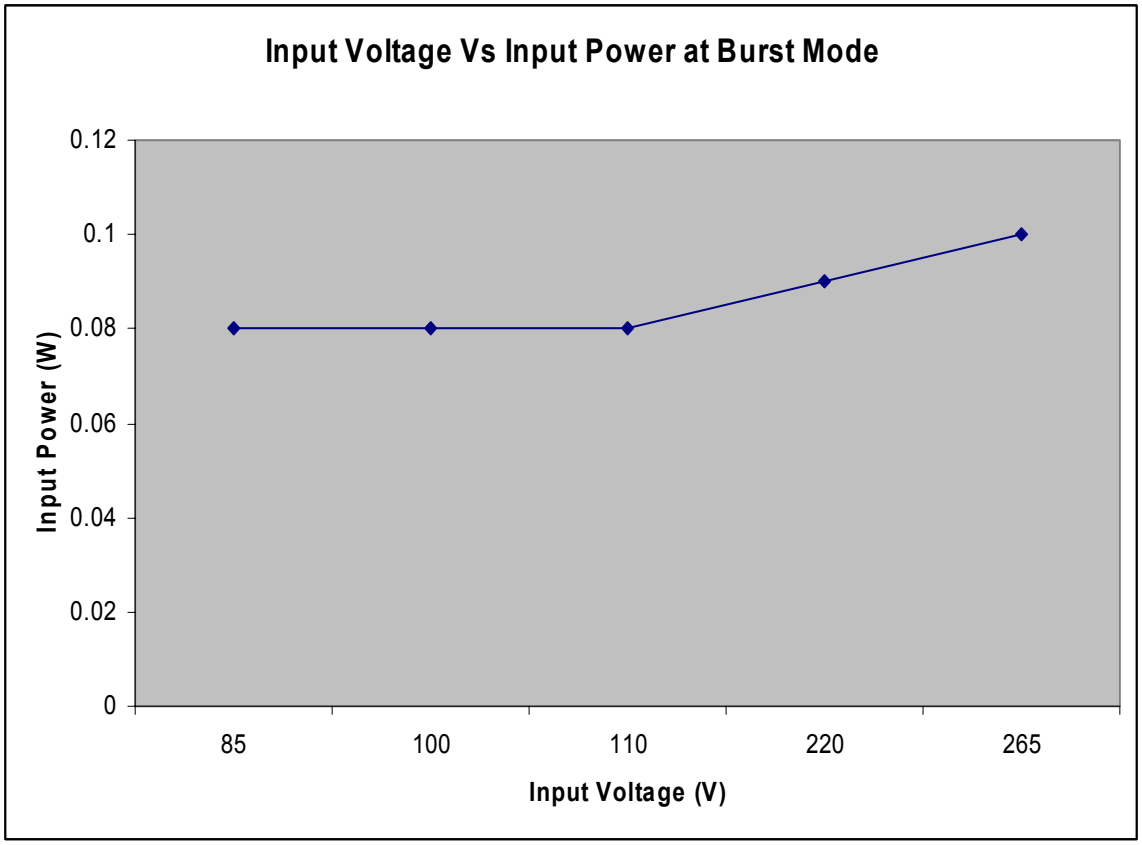
Vin	Pin	Vo	Io
(V)	(W)	(V)	(A)
85	0.08	15.97	0
100	0.08	15.97	0
110	0.08	15.97	0
220	0.09	15.97	0
265	0.1	15.97	0

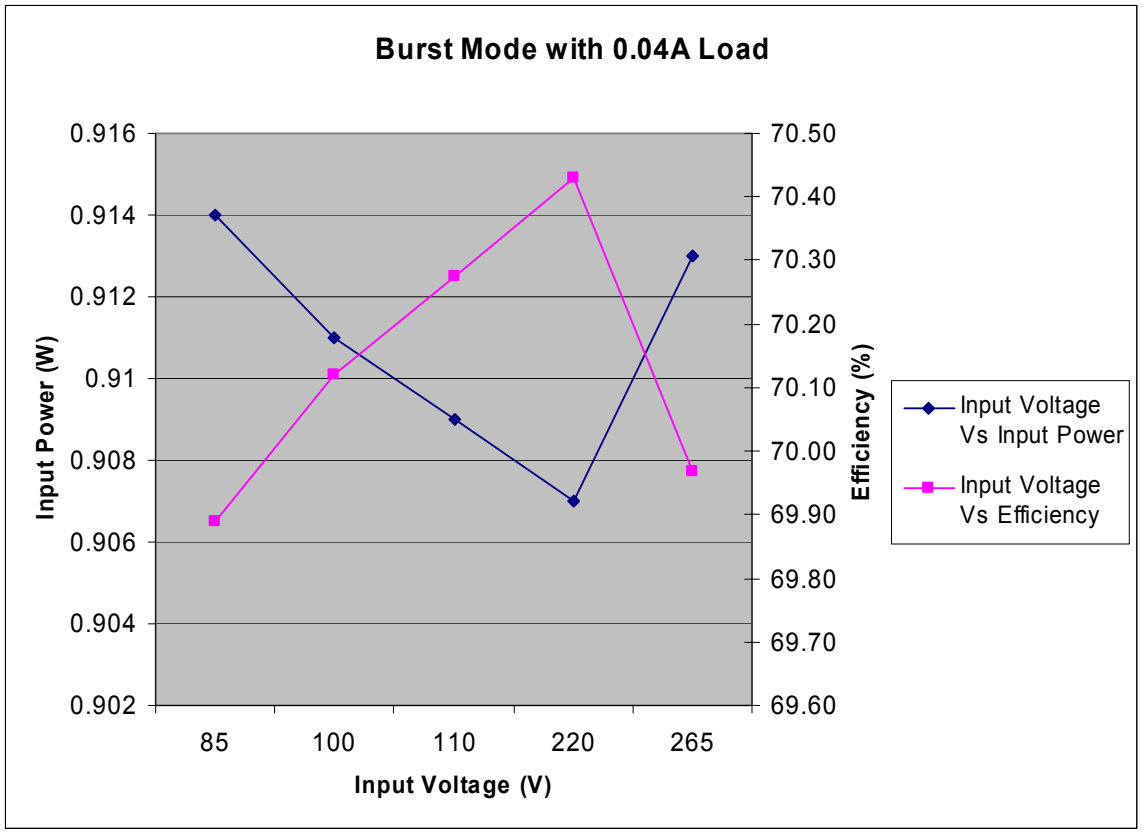
Burst Mode with 0.04A Load

Vin	Iin	Pin	Pout	Efficiency	Vo	Io
(V)	(A)	(W)	(W)	(%)	(V)	(A)
85	0.038	0.914	0.64	69.89	15.97	0.04
100	0.036	0.911	0.64	70.12	15.97	0.04
110	0.035	0.909	0.64	70.28	15.97	0.04
220	0.04	0.907	0.64	70.43	15.97	0.04
265	0.045	0.913	0.64	69.97	15.97	0.04

Graphs


Load Vs Efficiency at Normal Mode
84.00
83.50
83.00
82.50
82.00
81.50
81.00
80.50
80.00
79.50
79.00
Efficiency (%)
1.25
2.5
3.75
Load (A)
Input Voltage 85V
Input Voltage 100V
Input Voltage 110V
Input Voltage 220V
Input Voltage 265V


Input Voltage Vs Input Power at Burst Mode
0.12
0.1
0.08
0.06
0.04
0.02
0
Input Power (W)
85
100
110
220
265
Input Voltage (V)


Burst Mode with 0.04A Load
0.916
0.914
0.912
0.91
0.908
0.906
0.904
0.902
Input Power (W)
70.50
70.40
70.30
70.20
70.10
70.00
69.90
69.80
69.70
69.60
Efficiency (%)
85
100
110
220
265
Input Voltage (V)
Input Voltage Vs Input Power
Input Voltage Vs Efficiency

References

[1] F3 ICE3DSO1/G Off-Line SMPS Current Mode Controller with Integrated 500V Startup Cell, Infineon Technologies.