iWatt
Intelligent AC-DC and LED Power™

iW1676-01 For 5V700mA Low-Cost Charger Design

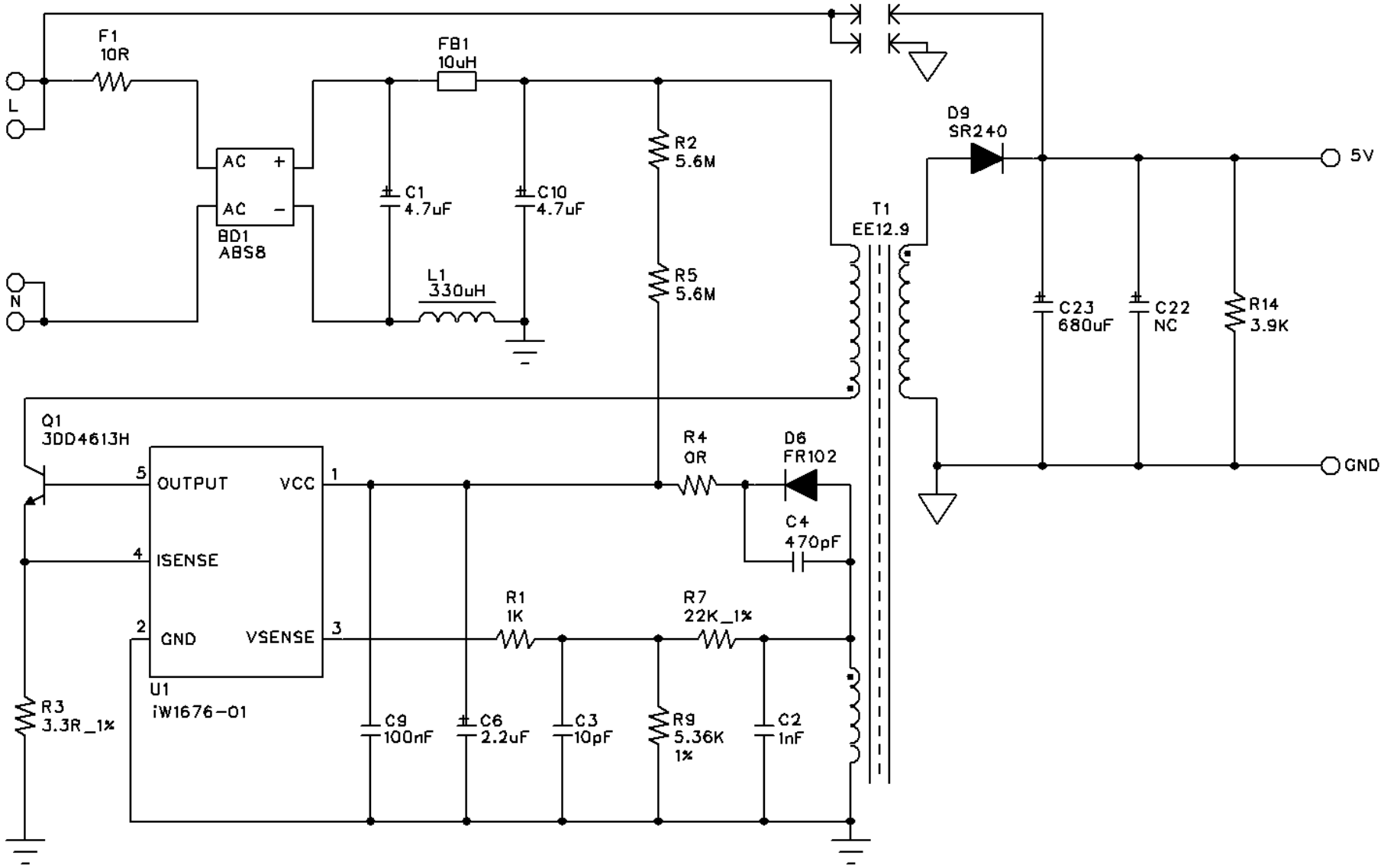
General Design Specification:

1. AC Input Range 90-264Vac
2. DC Output 5V, 700~900mA(CC)
3. Meet *"30mW"* No-Load standby Power Consumption Requirement
4. Meet *"EPA_2.0"* Requirement with end of USB
5. Meet "*USB3.0" Dynamic Load Response* Requirement
6. Meet "*MoU"* Requirement

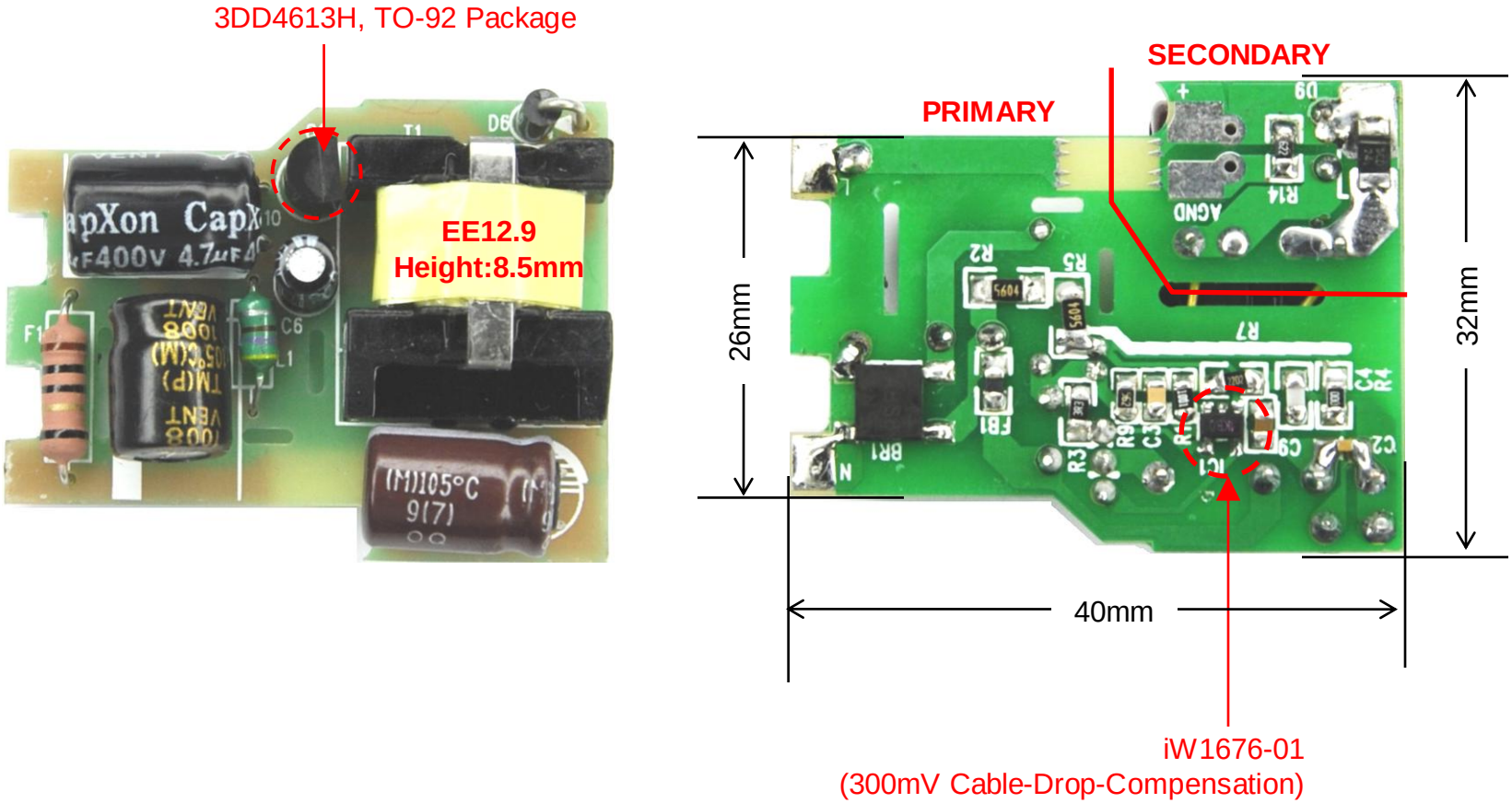
1. Specification

Description		Symbol	Min	Typ	Max	Units	Comment
Input							
Voltage		V_{IN}	90		264	V_{AC}	2 Wire
Frequency		f_{LINE}	47	50/60	63	Hz	
No-load Input Power (230V_{AC})					30	mW	
Output							
Constant Voltage	Output Voltage	V_{OUT_CV}	4.75	5.00	5.25	V	Measured at end of Output DC-Cable
	Output Current	I_{OUT_CV}	0		0.7	A	
Constant Current	Output Voltage	V_{OUT_CC}	< 2.5	Depending on battery voltage		V	Min V_{OUT} is dependence of V_{CC} supply voltage
	Output Current	I_{OUT_CC}	0.70		0.90	A	
Output Ripple Voltage		V_{RIPPLE}			150	mV_{P_P}	Measured at end of Output DC-Cable I_{OUT}=0.70A @T_A = 25 ℃ 20 MHz Bandwidth
Total Output Power							
Continuous Output Power		P_{OUT}		3.50		W	
Over Current Protection		I_{OUT_MAX}			0.9	A	Auto-restart
Active Mode Efficiency (Meet EPA2.0)		η	65.49			%	Measured at end of output DC-Cable, V_{IN} = 115VAC and 230VAC (T_{AMB} = 25 ℃).
Environmental							
Conducted EMI			Meets CISPR22B / EN55022B				
Safety			Designed to meet IEC950, UL1950 Class II				
Ambient Temperature		T_{AMB}	0		40	° C	Free convection, sea level

2. Schematic


F1
10R
L
N
AC +
AC –
BD1
ABS8
FB1
10uH
C1
4.7uF
C10
4.7uF
L1
330uH
R2
5.6M
R5
5.6M
T1
EE12.9
D9
SR240
5V
GND
C23
680uF
C22
NC
R14
3.9K
Q1
3DD4613H
OUTPUT
VCC
ISENSE
GND
VSENSE
U1
iW1676-01
R4
0R
D6
FR102
C4
470pF
R1
1K
R7
22K_1%
R3
3.3R_1%
C9
100nF
C6
2.2uF
C3
10pF
R9
5.36K
1%
C2
1nF

3. Circuit Board Photograph

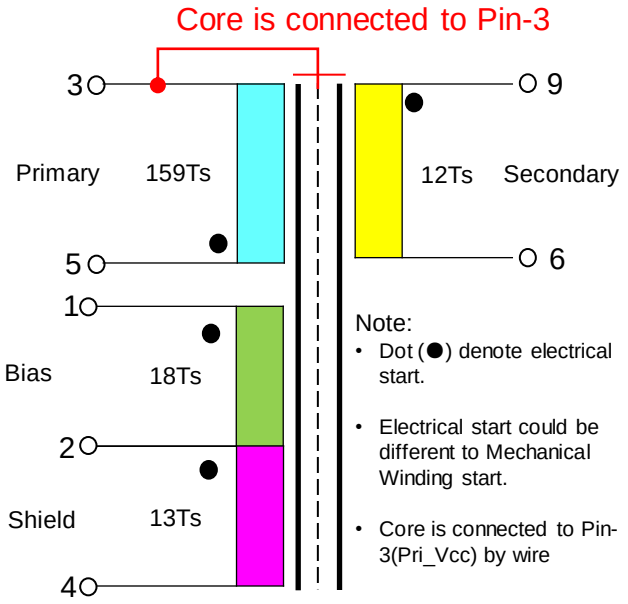


4. Bill of Material

Item	Qty	Reference	Description
1	1	U1	iW1676-01, Off-line Digital PSR & PWM & VMS Controller, SOT23-5
2	1	C1	4.7uF, 400V, E-Cap,Φ8mmx10mm
3	1	C2	1nF, 50V, X7R, SMD-0805
4	1	C3	10pF, 50V, X7R, SMD-0603
5	1	C4	470pF, 50V, X7R, SMD-0603
6	1	C6	2.2uF, 50V, Low ESR E-Cap,Φ4mmX7mm
7	1	C9	100nF, 50V, X7R, SMD-0805
8	1	C10	4.7uF, 400V, E-Cap,Φ8mmx12mm
10	1	C23	680uF, 10V, Low ESR E-Cap, Φ8mmx12mm
11	1	BR1	ABS8, 1A1000V, BRIDGE RECTIFIER, ABS
12	1	D6	FR102,1A100V, Fast Recovery Rectifier (Trr=150nS), DO-41
13	1	D9	SCD24, 2A40V, Schottky Diode, SMD-2010
14	1	F1	10Ω, Fusible Resistor, 1W
15	1	L1	470uH, Color Ring Inductor, 0410
16	1	FB1	10UH, Chip Inductor(P/N:LQM21FN100M80L), SMD-0805
17	1	Q1	3DD4613H, 1.5A800V, NPN Transistor, TO-92
18	1	R1	1KΩ±5%, SMD-0603
19	2	R2,R5	5.6MΩ ±5%, SMD-1206
20	1	R3	3.3Ω ±1%, SMD-0805
21	1	R4	0Ω, SMD-0805
22	1	R7	22KΩ ±1%, SMD-0805
23	1	R9	5.36kΩ ±1%, SMD-0603
24	1	R14	3.9KΩ ±5%, SMD-0805
25	1	T1	EE12.9, Horizontal Type
26	1	PCB	Single Side Board, 94V0

5. Transformer Design

SCHEMATIC



ELECTRICAL SPECIFICATIONS:

1. Primary Inductance (Lp) = 1.7mH±7%@10KHz
2. Primary Leakage Inductance <5% * L_P, Short pin1,2,4 7,8
3. Electrical Strength = 3KV, 50/60Hz,1Min

MATERIALS:

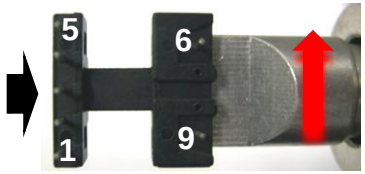
1. Core : EE12.9 (Ferrite Material TDK PC40 or equivalent)
2. Bobbin : EE12.9 Horizontal.
3. Magnet Wires (Pri) : Type 2-UEW
4. Magnet Wire (Sec) : Triple Insulated Wires
5. Layer Insulation Tape :3M1298 or equivalent.

FINISHED :

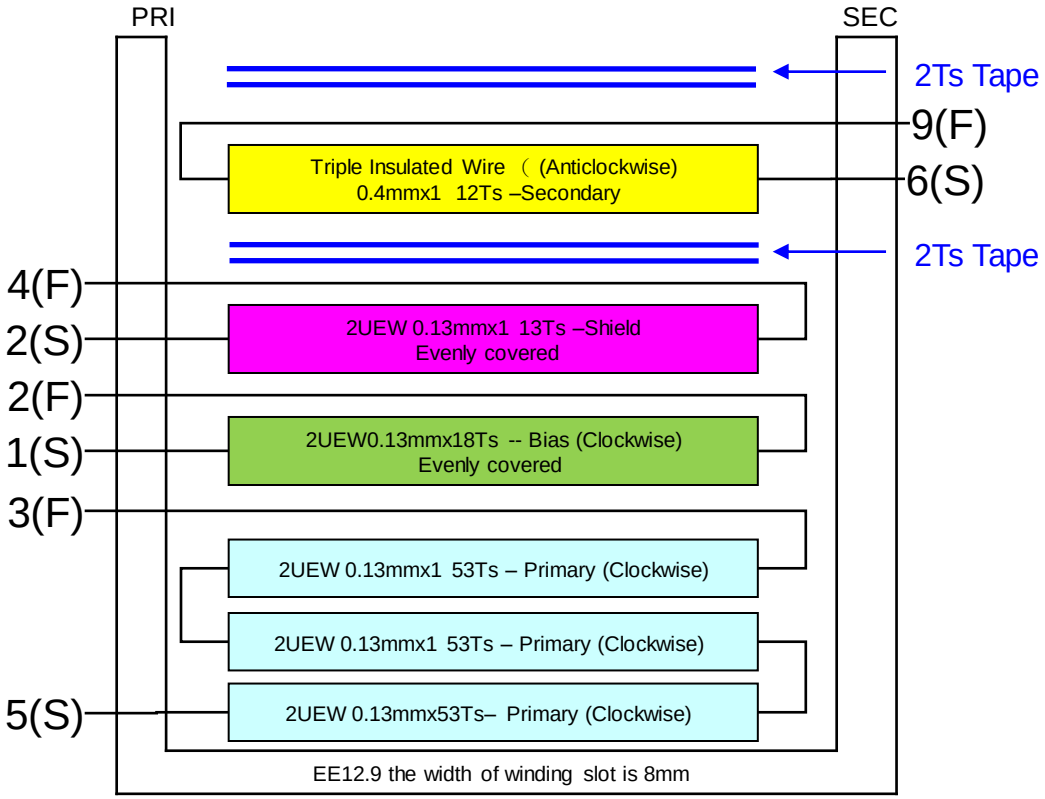
1. Varnish the complete assembly

Instruction for start of first winding…

Winding Start pin-5 & End pin-3 in "Clockwise" direction – looking from Pin 1/5 side of the Bobbin.



Rotating direction of winding machine



6. Regulation, Ripple and Efficiency Measurement

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*** Note: Output voltage is measured at end of PCB**

V_{IN} (V_{AC})	P_{IN} (W)	V_{OUT} (V)	I_{OUT} (mA)	V_{RIPPLE} (mV_{P-P})	P_{OUT} (W)	η (%)	OCP (mA)	Average η(%)
90	0.011	5.015	**0**	**22**			760	75.43
	1.150	4.981	175	50	0.87	75.80		
	2.321	5.065	350	53	1.77	76.38		
	3.625	5.190	525	75	2.72	75.17		
	4.962	5.271	700	100	3.69	74.36		
115	0.012	5.019	0	22			760	76.76
	1.149	4.982	175	50	0.87	75.88		
	2.291	5.059	350	61	1.77	77.29		
	3.530	5.186	525	69	2.72	77.13		
	4.808	5.270	700	90	3.69	76.73		
230	0.025	5.005	0	20			750	74.91
	1.210	4.997	175	62	0.87	72.27		
	2.379	5.051	350	57	1.77	74.31		
	3.580	5.192	525	71	2.73	76.14		
	4.794	5.267	700	92	3.69	76.91		
264	0.035	5.024	0	22			745	73.49
	1.237	4.978	175	60	0.87	70.42		
	2.422	5.042	350	57	1.76	72.86		
	3.642	5.186	525	75	2.72	74.76		
	4.854	5.264	700	95	3.68	75.91		

7. EPA_2.0 Requirement

Table 1: Energy-Efficiency Criteria for Ac-Ac and Ac-Dc External Power Supplies in Active Mode: Standard Models

Nameplate Output Power (P_{no})	Minimum Average Efficiency in Active Mode (expressed as a decimal) [2]
0 to ≤ 1 watt	≥ 0.480 * P_{no} + 0.140
> 1 to ≤ 49 watts	≥ [0.0626 * Ln (P_{no})] + 0.622
> 49 watts	≥ 0.870

Table 2: Energy-Efficiency Criteria for Ac-Ac and Ac-Dc External Power Supplies in Active Mode: Low Voltage Models

Nameplate Output Power (P_{no})	Minimum Average Efficiency in Active Mode (expressed as a decimal) [2]
0 to ≤ 1 watt	≥ 0.497 * P_{no} + 0.067
> 1 to ≤ 49 watts	≥ [0.0750 * Ln (P_{no})] + 0.561
> 49 watts	≥ 0.860

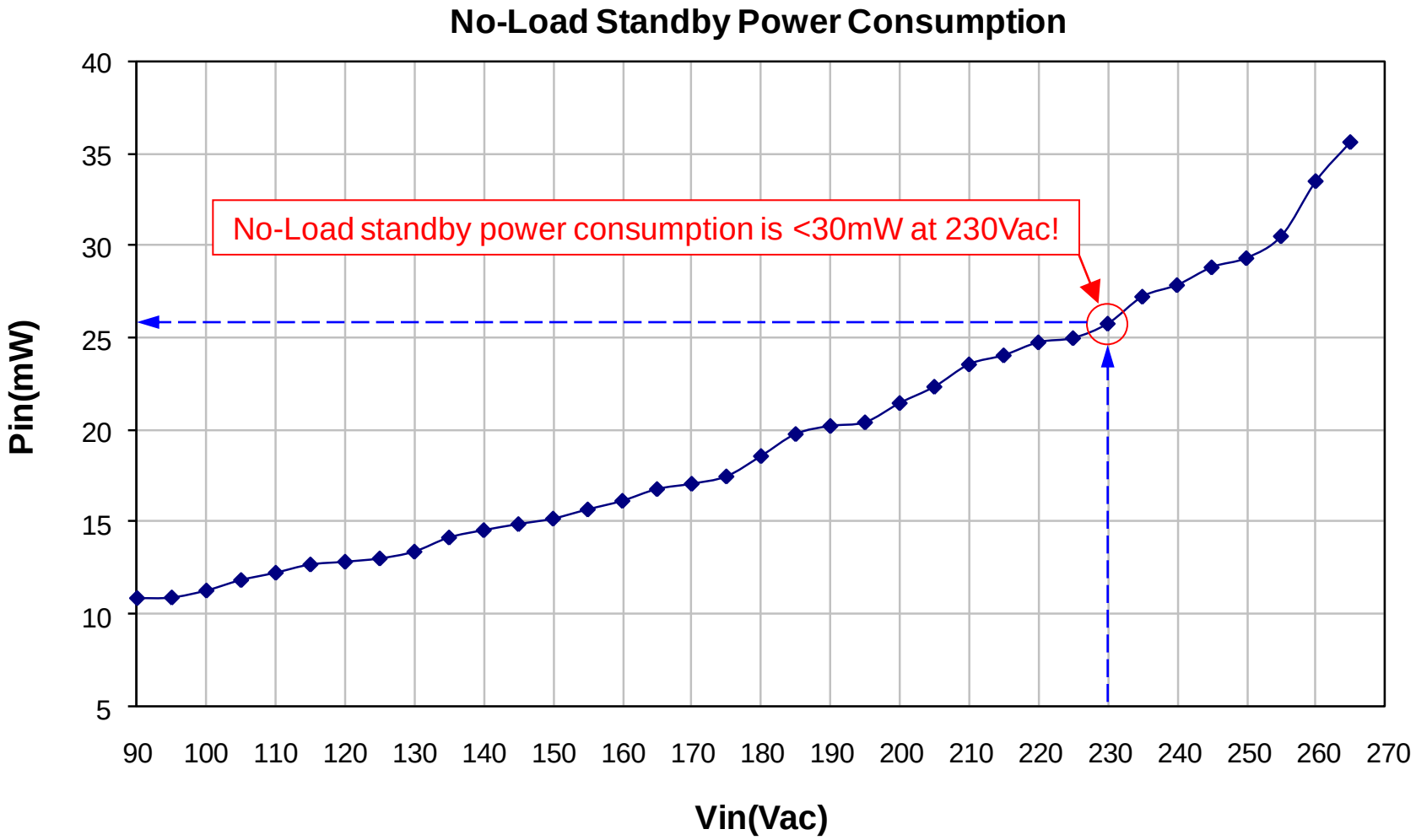
EPA2.0 (Final) for Low Voltage Model (P_{no}=3.50W)

$$0.075 \times Ln(3.5W) + 0.561 = 66.0\%$$

Meet EPA2.0 with lots of Margin!

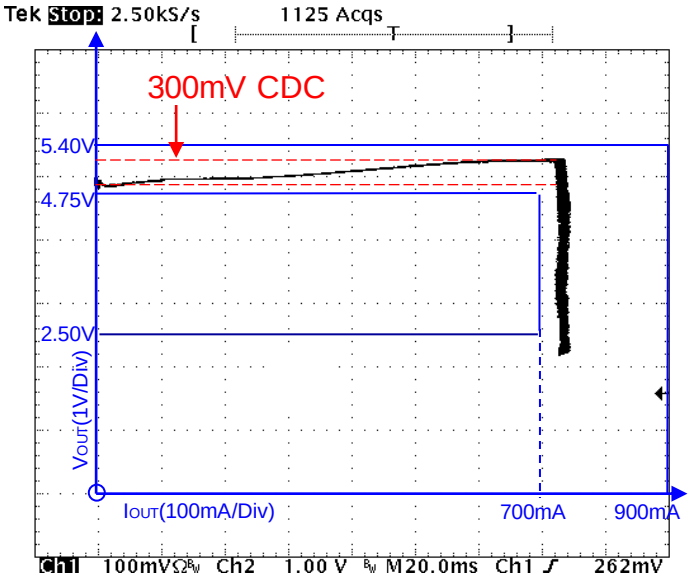
V_{IN} (VAC)	I_{OUT} (mA)	P_{IN} (W)	Measure at end of PCB				Measure at end of Cable 26AWG/1.8m, R_{Cable}=0.51Ω			
			$V_{OUT\ PCB}$ (V)	$P_{OUT\ PCB}$ (W)	EFF_{PCB} (%)	$AV\text{-}EFF_{PCB}$ (%)	$V_{OUT\ Cable}$ (V)	$P_{OUT\ Cable}$ (W)	EFF_{Cable} (%)	$AV\text{-}EFF_{Cable}$ (%)
115	175	1.149	4.982	0.87	75.88	76.76	4.89	0.86	74.52	73.44
	350	2.291	5.059	1.77	77.29		4.88	1.71	74.56	
	525	3.530	5.186	2.72	77.13		4.92	2.58	73.15	
	700	4.808	5.270	3.69	76.73		4.91	3.44	71.53	
230	175	1.210	4.997	0.87	72.27	74.91	4.91	0.86	70.98	71.64
	350	2.379	5.051	1.77	74.31		4.87	1.71	71.68	
	525	3.580	5.192	2.73	76.14		4.92	2.59	72.21	
	700	4.794	5.267	3.69	76.91		4.91	3.44	71.69	

8. No-Load Standby Power Consumption

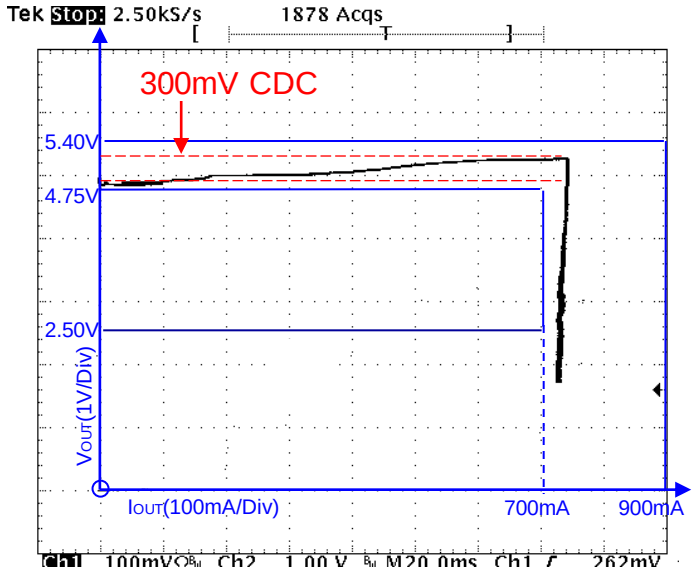


9. Output VI Characteristics

V_{IN}=90Vac/50Hz

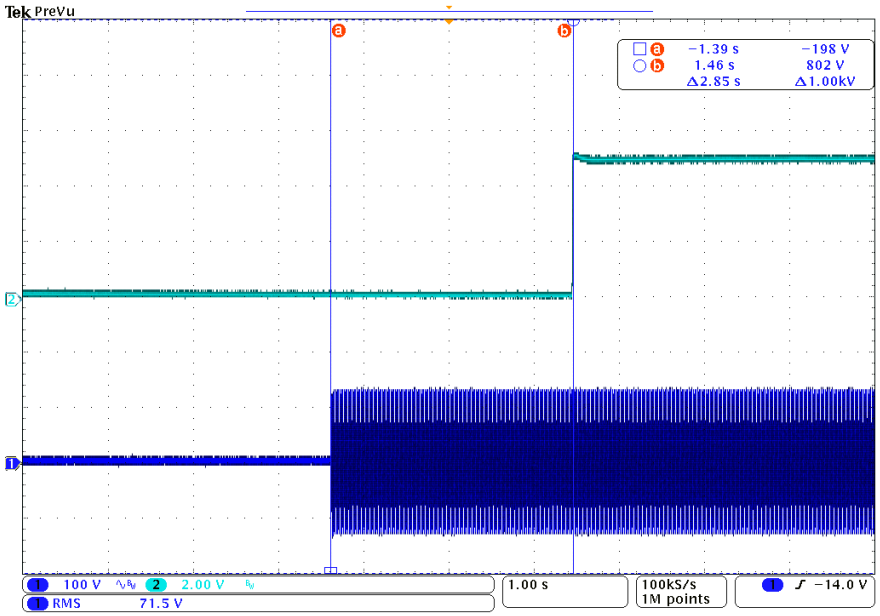


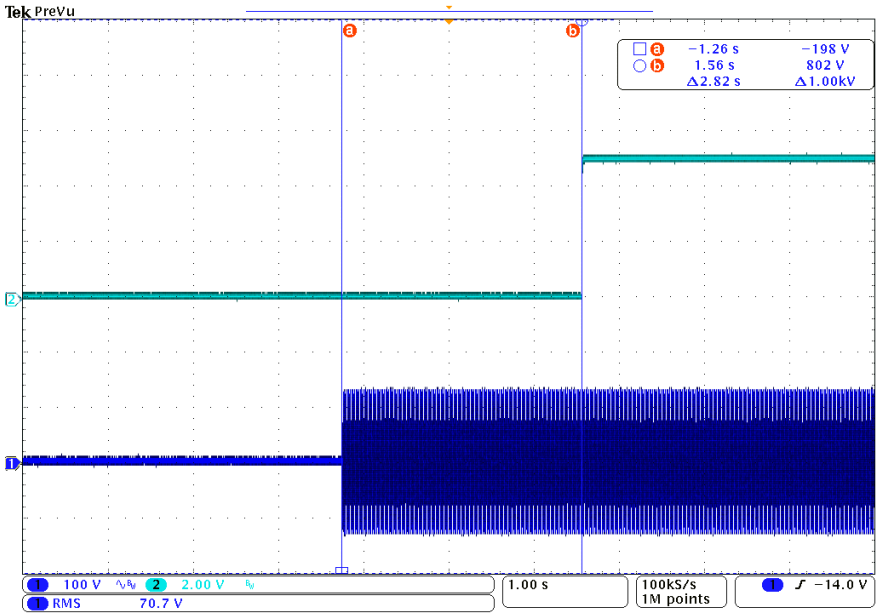
V_{IN}=264Vac/50Hz



*** Note: Output voltage is monitored at end of PCB**

10. Turn-On Delay Time





90Vac, No Load

T_{ST_DELAY}=2.85s

90Vac, Full Load =700mA

T_{ST_DELAY}=2.83s

11. Dynamic Load Response

Frequency: *50Hz* , Duty-Cycle: *50%* , Slew-Rate*: 0.05A/us,* Iout:*0mA-700mA-0A*

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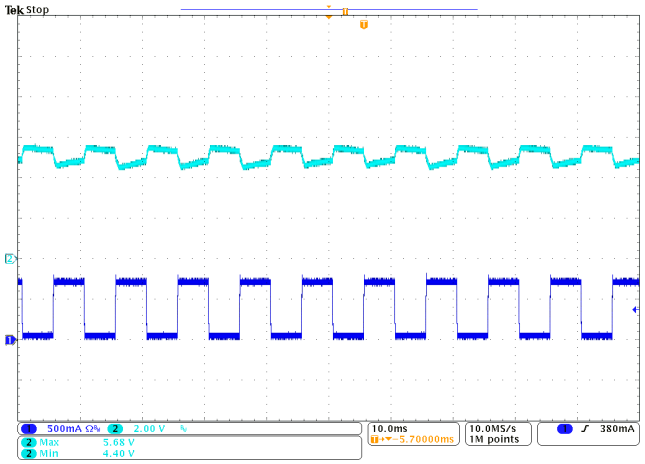
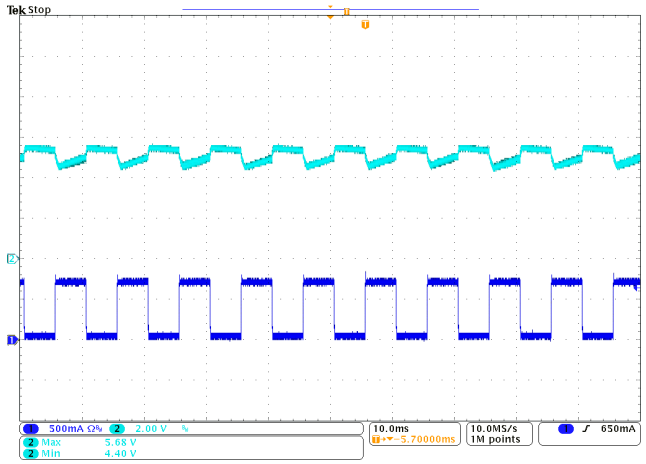
Vin=90Vac/60Hz



V_{OUT_MAX}=5.68V

V_{OUT_MIN}=4.40V

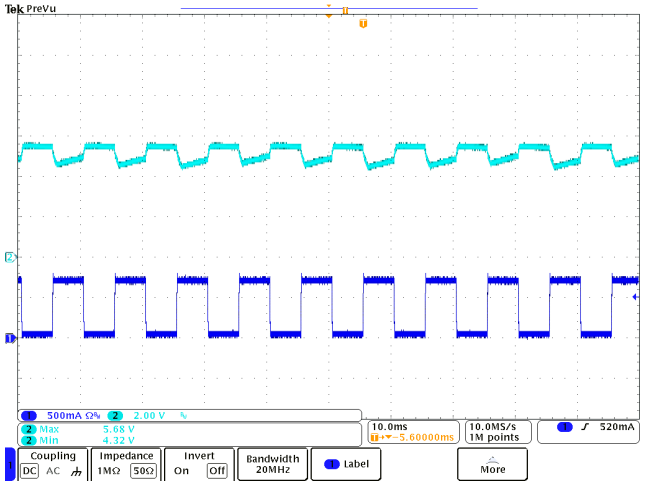
Vin=115Vac/60Hz



V_{OUT_MAX}=5.68V

V_{OUT_MIN}=4.40V

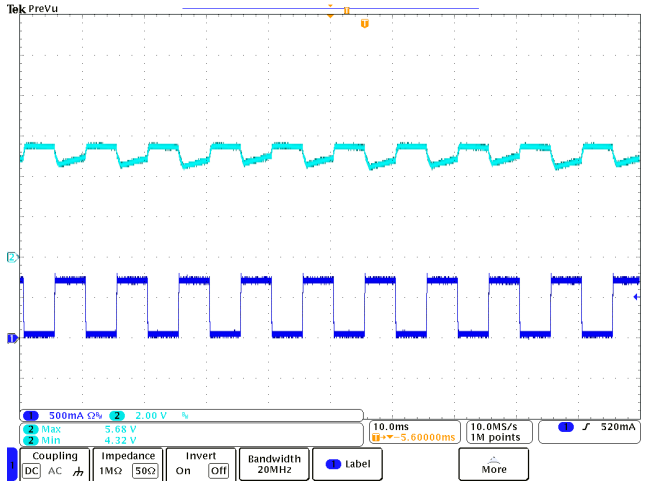
Vin=230Vac/50Hz



V_{OUT_MAX}=5.68V

V_{OUT_MIN}=4.32V

Vin=264Vac/50Hz



V_{OUT_MAX}=5.68V

V_{OUT_MIN}=4.32V

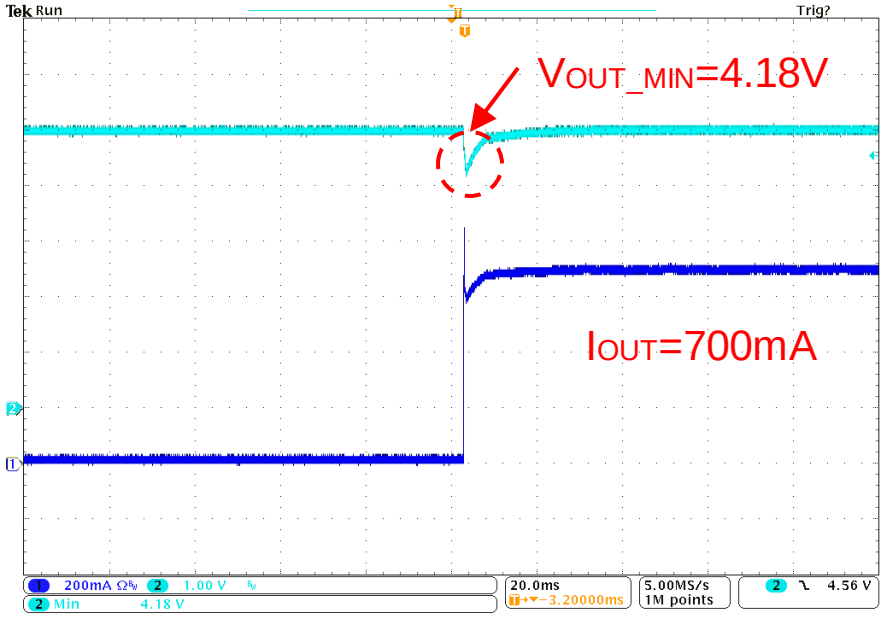
CH1: Output Current, 0.5A/Div ;CH2: Output Voltage, 2V/Div;
V_{OUT} is monitored at end of output DC-cable (26AWG/1.8m, R_{CABLE}=0.51Ω)

12. Load Transition (0mA → 700mA, Single Pulse)

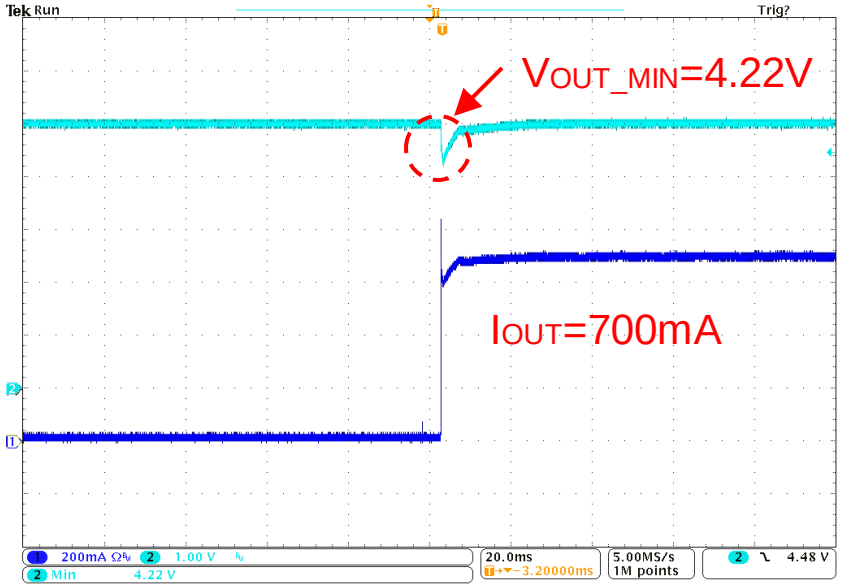
Test conditions :

1. Load Mode: *CR Mode*
2. Output Filtering Capacitor (C23): *680uF*
3. V_{OUT} is monitored at end of cable (AWG26/1.8M, R_{CABLE}=0.51Ω)
4. Equipment: E-Load-"Kikusui PLZ 72W", AC Source-"Kikusui PCR500L", Digital Oscilloscope-"Tek DPO4034"

Vin=90Vac

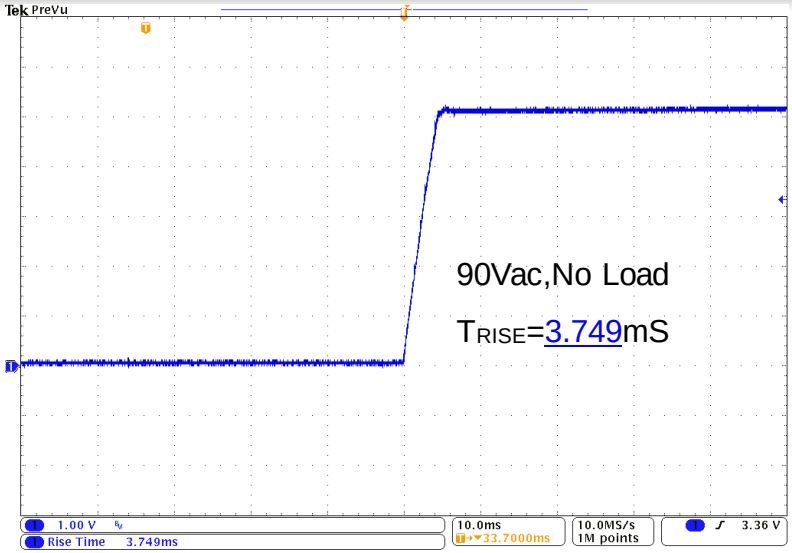


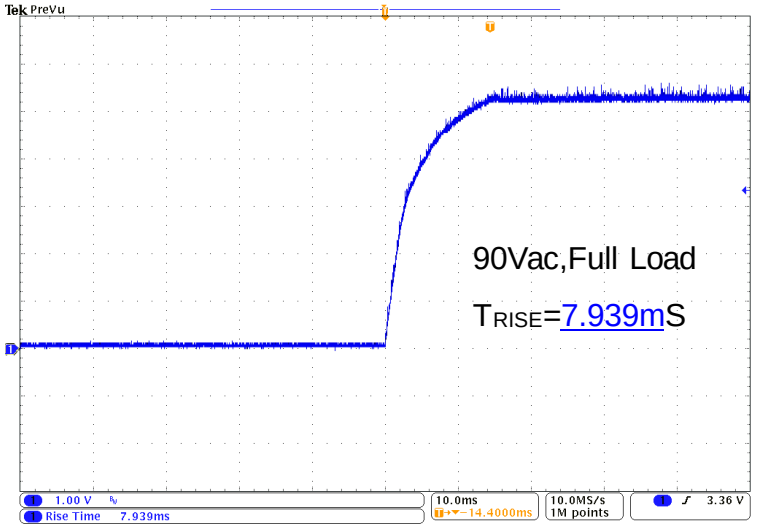
Vin=264Vac

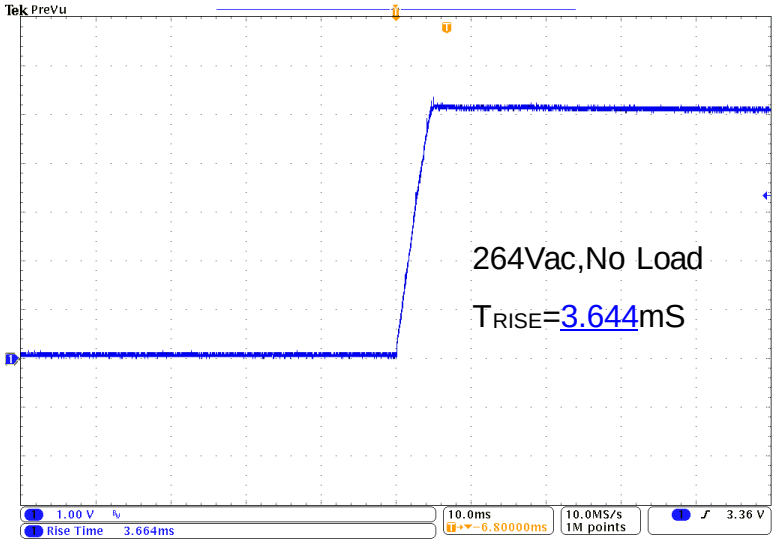


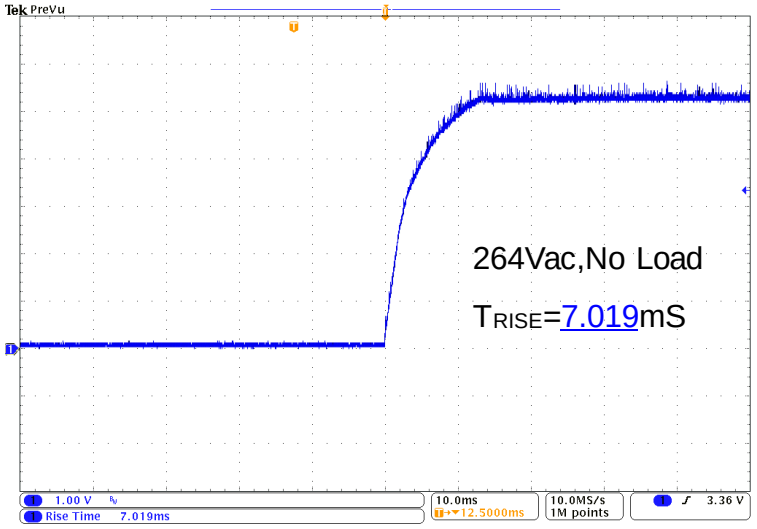
CH1: Output Current, 0.2A/Div; CH2: Output Voltage, 1V/Div

13. Output Rise Time

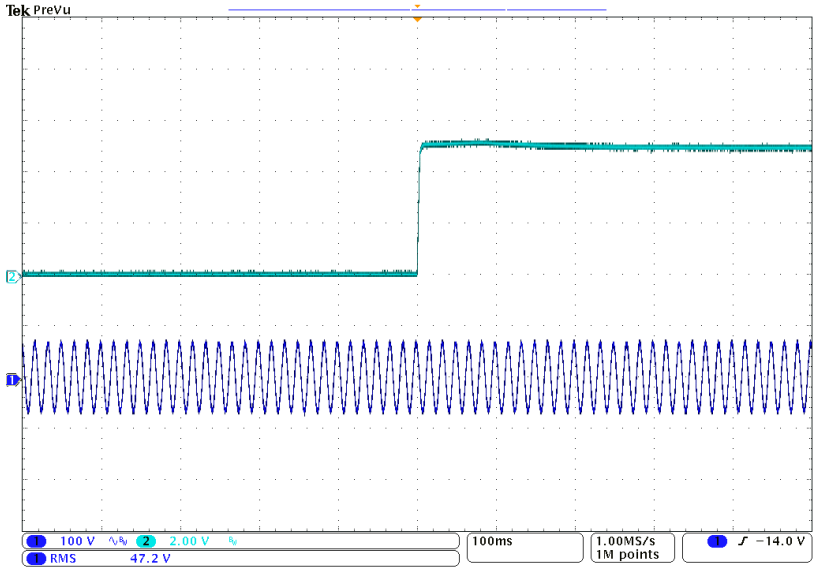


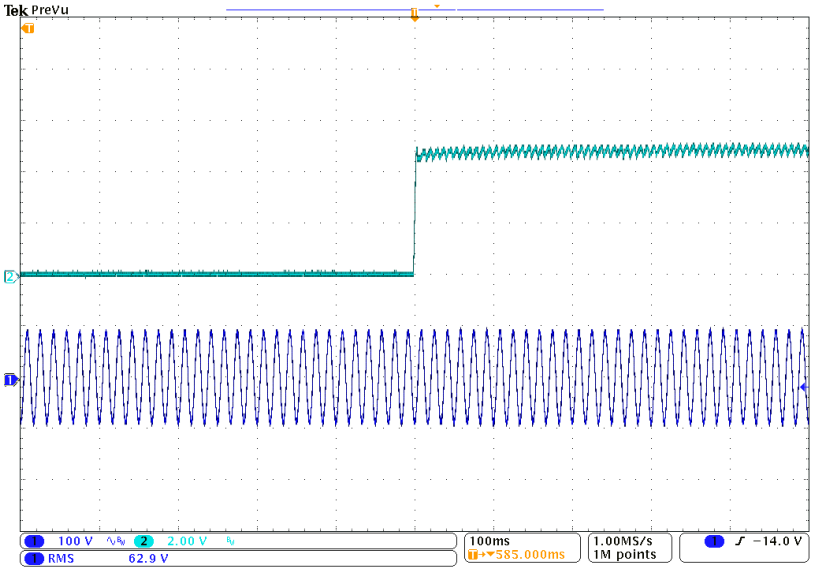






14. AC Startup Voltage Characteristic





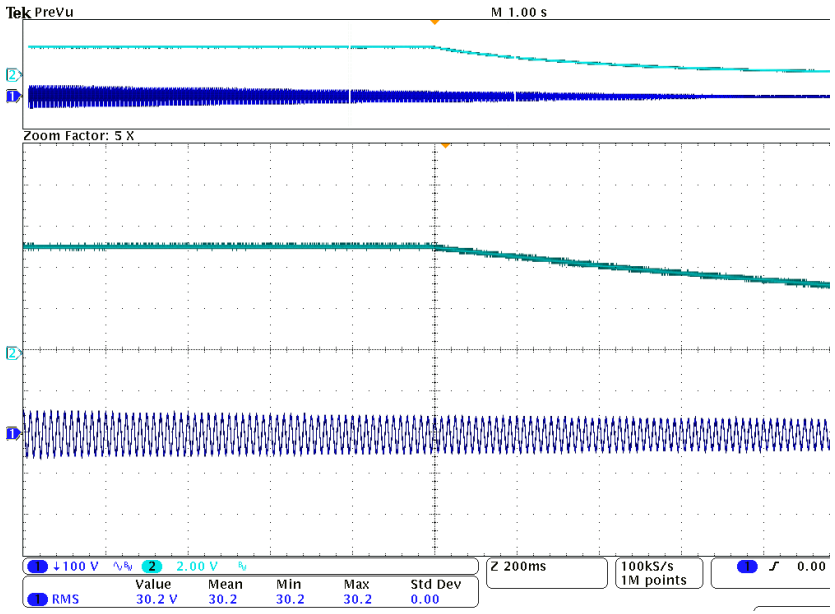
No Load

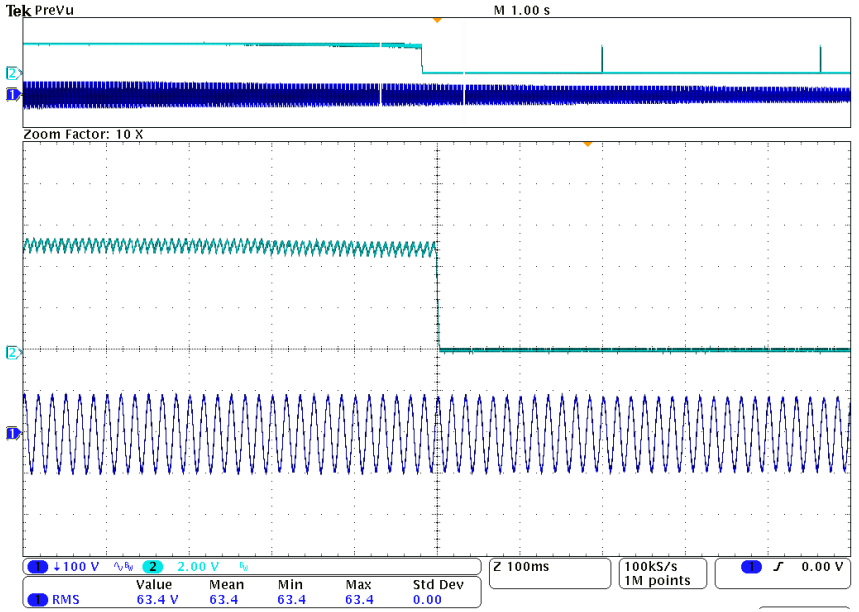
$V_{IN\_STARTUP}$ =47.2Vac

Full Load

$V_{IN\_STARTUP}$=62.9Vac

15. AC Brownout Voltage Characteristic





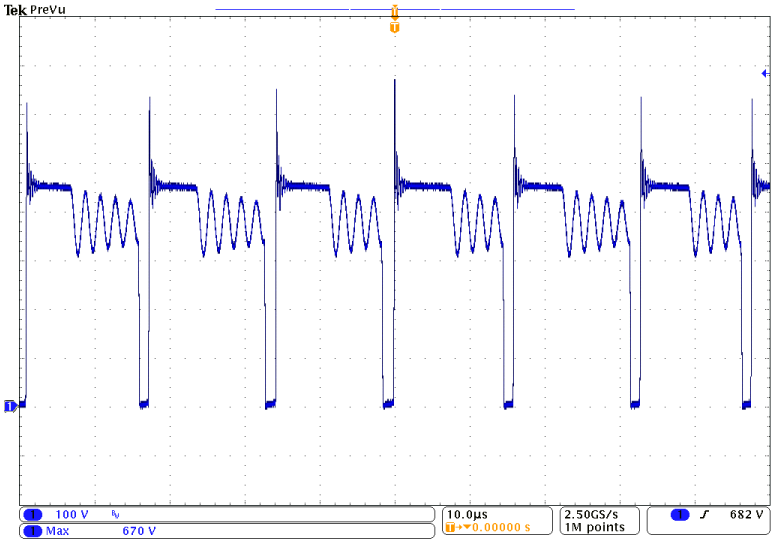
No Load

$V_{IN\_BROWNOUT}$ =30.2Vac

Full Load

$V_{IN\_BROWNOUT}$=61.4Vac

16. V_{CE} Waveform



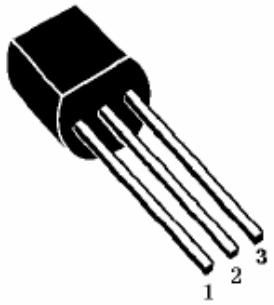
Test Condition:

V_{IN}=264Vac, I_{OUT}=0.75A

Result:

V_{CE_MAX}=**670V**

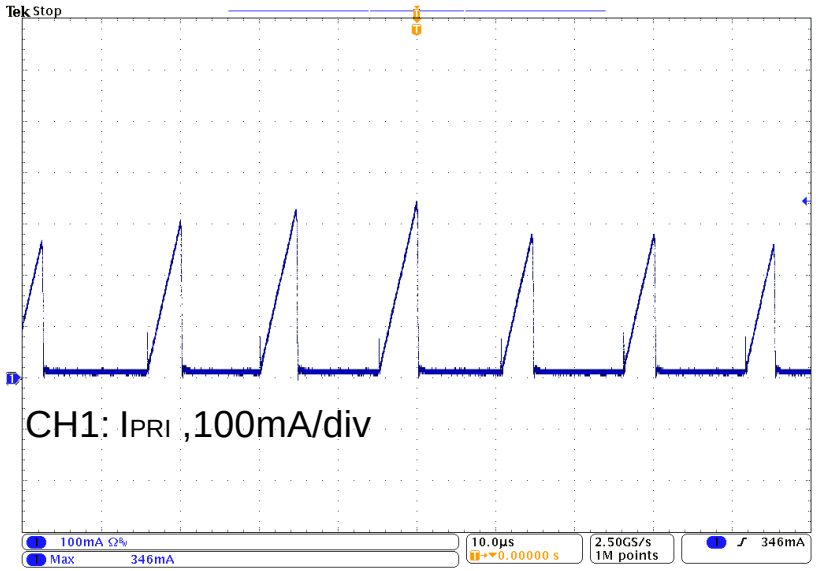
Appendix – Simple Specification for used transistor (3DD4613H)

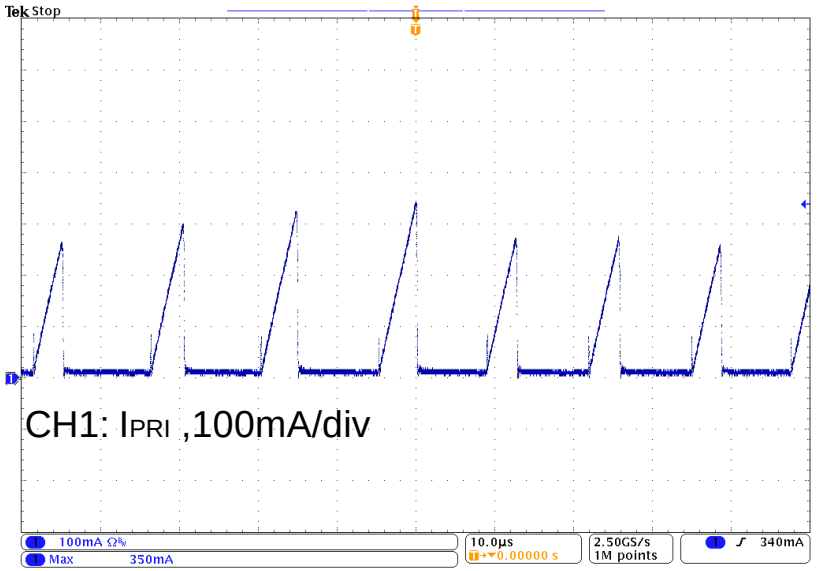


项　目 Parameter		符　号 Symbol	数　值 Value	单　位 Unit
集电极—发射极直流电压	Collector- Emitter Voltage（V_{BE}=0）	V_{CES}	900	V
集电极—发射极直流电压	Collector- Emitter Voltage（I_B=0）	V_{CEO}	500	V
发射极—基极直流电压	Emitter-Base Voltage	V_{EBO}	9	V
最大集电极直流电流	Collector Current（DC）	I_C	1.5	A
最大集电极脉冲电流	Collector Current（pulse）	I_{CP}	3.0	A
最大集电极耗散功率	Total Dissipation (TO-92)	P_C	1	W
最高结温	Junction Temperature	T_j	150	℃
贮存温度	Storage Temperature	T_{stg}	-55~+150	℃

17. Transformer Flux Density

(Np=159Ts, Lm_max=1.82mH, Ae=12.4mm^2-EE12.9)





I_{PRI} is monitored at 90Vac and *0.7A* load

I_{PRI}=346mA

B_{MAX} =(I_{PRI}* L_{PRI}) / (N_P*A_e)

=(346*1.82)/(159*12.4)

=0.319Tesla

I_{PRI} is monitored at 90Vac and *0.78A* load (Max Output Power).

I_{PRI}=350mA

B_{MAX} =(I_{PRI}* L_{PRI})/ (N_P * A_e)

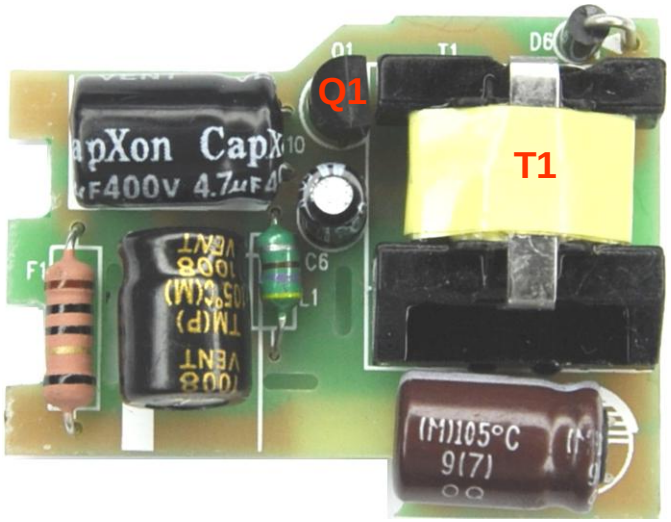
=(350*1.82)/(159*12.4)

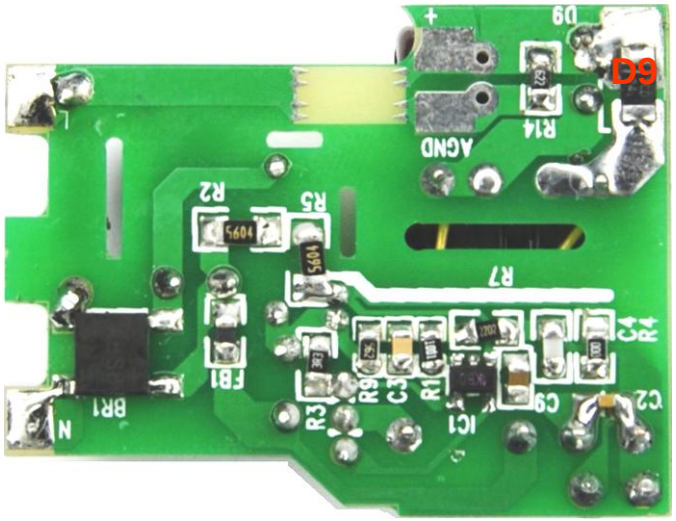
=0.323Tesla

18. Thermal Test for Critical Component

Note: The UUT is assembled with case and placed in a temperature chamber

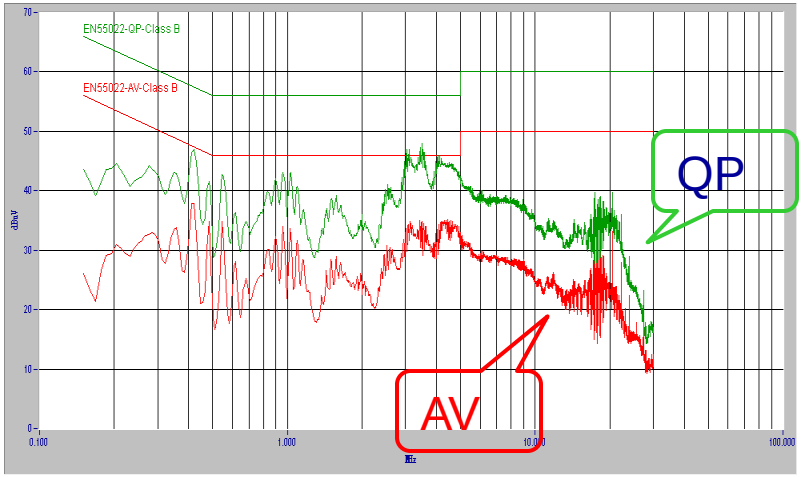
Item	V_{IN}=90V_{AC}, Iout=700mA		V_{IN}=264V_{AC}, Iout=700mA	
	Temp.(℃)	Rising Temp. (℃)	Temp.(℃)	Rising Temp. (℃)
Transistor (Q1,D4613)	88	48	99	59
Transformer(T1, EE12.9)	87	47	85	45
Output SK-Diode(D9, SCD34)	85	45	85	45
Ambient Temperature	40		40	



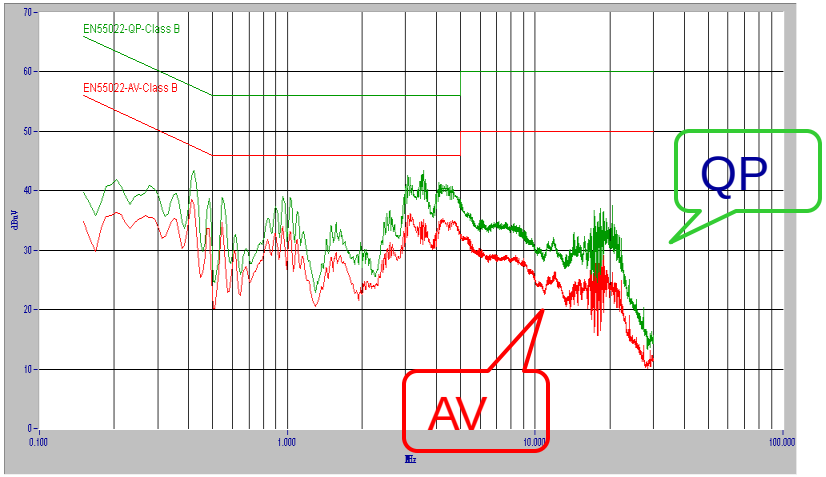


19. Conducted EMI

Vin=230Vac/50Hz, Live



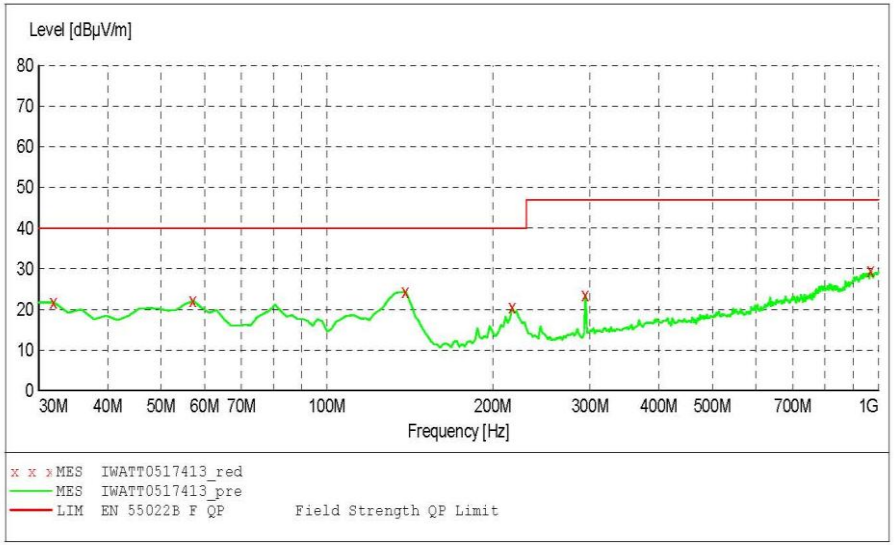
Vin=230Vac/50Hz, Neutral



Note: Resistive & Full load; output (-) is floating.

20. Radiated EMI

Vin=230Vac/50Hz, HORIZONTAL

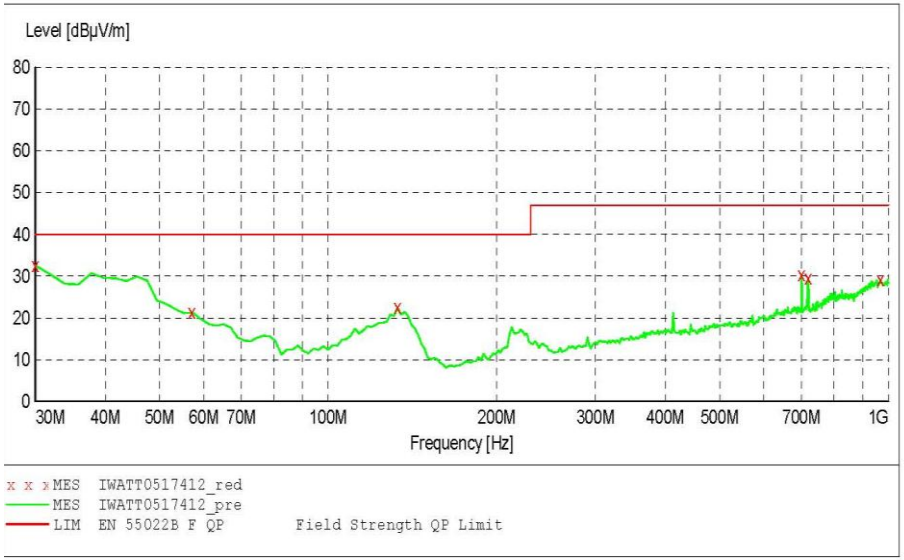


MEASUREMENT RESULT: "IWATT0517413_red"

3/17/2011 10:29PM

Frequency MHz	Level dBµV/m	Transd dB	Limit dBµV/m	Margin dB	Det.	Height cm	Azimuth deg	Polarization
31.943888	21.70	-11.2	40.0	18.3	---	300.0	100.00	HORIZONTAL
57.214429	22.10	-24.1	40.0	17.9	---	300.0	294.00	HORIZONTAL
138.857715	24.40	-21.0	40.0	15.6	---	300.0	1.00	HORIZONTAL
216.613226	20.60	-20.9	40.0	19.4	---	100.0	0.00	HORIZONTAL
294.368737	23.60	-18.6	47.0	23.4	---	100.0	55.00	HORIZONTAL
968.897796	29.60	-5.4	47.0	17.4	---	100.0	224.00	HORIZONTAL

Vin=230Vac/50Hz, VERTICAL



MEASUREMENT RESULT: "IWATT0517412_red"

3/17/2011 10:27PM

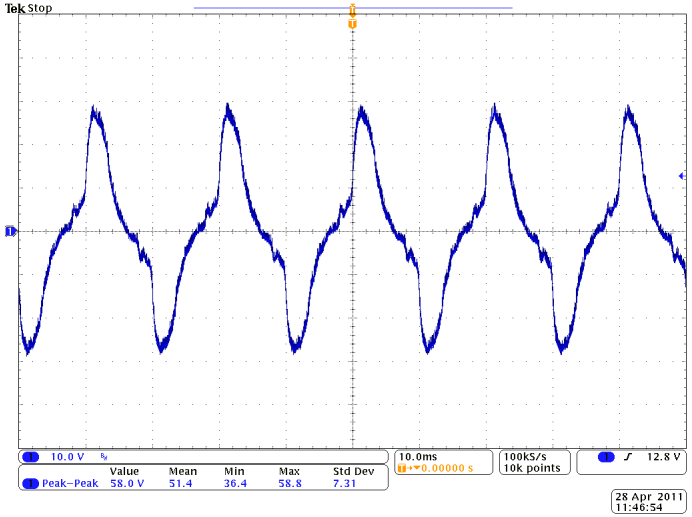
Frequency MHz	Level dBµV/m	Transd dB	Limit dBµV/m	Margin dB	Det.	Height cm	Azimuth deg	Polarization
30.000000	32.60	-10.2	40.0	7.4	---	100.0	335.00	VERTICAL
57.214429	21.30	-24.1	40.0	18.7	---	100.0	14.00	VERTICAL
133.026052	22.50	-20.0	40.0	17.5	---	100.0	197.00	VERTICAL
700.641283	30.40	-10.5	47.0	16.6	---	100.0	3.00	VERTICAL
720.080160	29.50	-10.6	47.0	17.5	---	100.0	3.00	VERTICAL
968.897796	29.20	-5.4	47.0	17.8	---	100.0	294.00	VERTICAL

Note: Resistive & Full load; output (-) is floating.

21. MoU

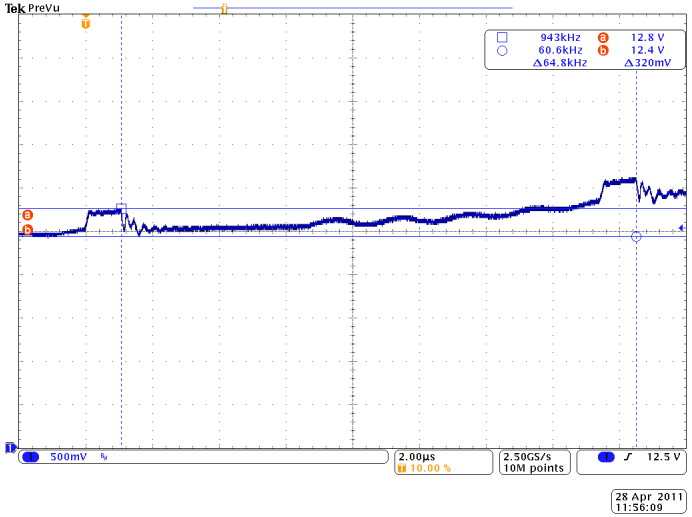
Test condition:

1) Vin=264Vac/50Hz
2) Load: 10Ω resistive Load
3) The length of output DC cable: 1 Meter
3) Connect 170pF cap from load to line under EPS switching frequency component



AC frequency component

V_pp=58.0V



EPS switching frequency component

V_pp=320mV

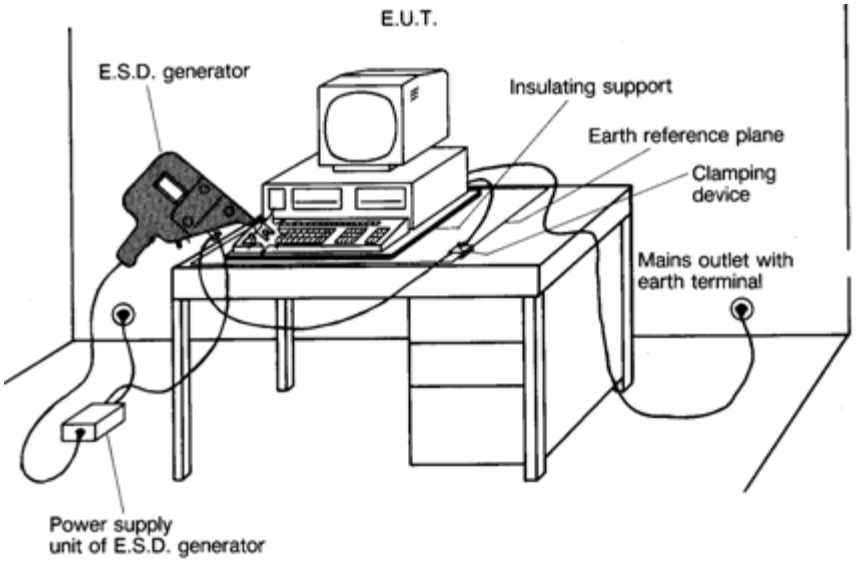
22. ESD (IEC 61000-4-2)

iWatt
Intelligent AC-DC and LED Power™

Test condition:

V_{IN}=230VAC/50Hz, No_Load and Full_Load (Resistive Load)

Air-Discharge		Result (no-load)	Result (full-load)
12KV	+	PASS	PASS
	-	PASS	PASS
14KV	+	PASS	PASS
	-	PASS	PASS
15KV	+	PASS	PASS
	-	PASS	PASS
16KV	+	PASS	PASS
	-	PASS	PASS
18KV	+	PASS	PASS
	-	PASS	PASS
19KV	+	PASS	PASS
	-	PASS	PASS
20KV	+	PASS	PASS
	-	PASS	PASS



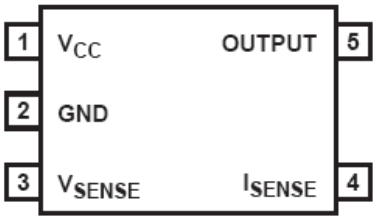
Appendix-1. V_{CC} Supply Voltage

The purpose of this test is to verify operating range of Vcc voltage under various loading conditions.

Item	Vcc range [Max: 16V, Min: 4.2V]			
Input Vac	Vin=90Vac	Vin=115Vac	Vin=230Vac	Vin=264Vac
Output No-load	7.32V	7.32V	7.48V	7.48V
Output Full-load (700mA)	11.4V	12V	13.90V	14.4V
Max load (CC/CV corner)	11.5V	12.2V	14.2V	14.6V

Above test result show all voltage measuring points is within normal operating range.

iW1676



SOT23 Package

V_{CC} SECTION (Pin 1)						
Maximum operating voltage (Note 1)	$V_{CC(MAX)}$				16	V
Start-up threshold	$V_{CC(ST)}$	V_{CC} rising	10.0	11.0	12.0	V
Undervoltage lockout threshold	$V_{CC(UVL)}$	V_{CC} falling	3.8	4.0	4.2	V
Start-up Current	$I_{IN(ST)}$	V_{CC} = 10 V	1.0	1.7	3.0	µA
Quiescent current	I_{CCQ}	No I_B current		2.7	4.0	mA
Zener breakdown voltage	V_{ZB}	Zener current = 5 mA T_A=25°C	18.5	19.5	20.5	V

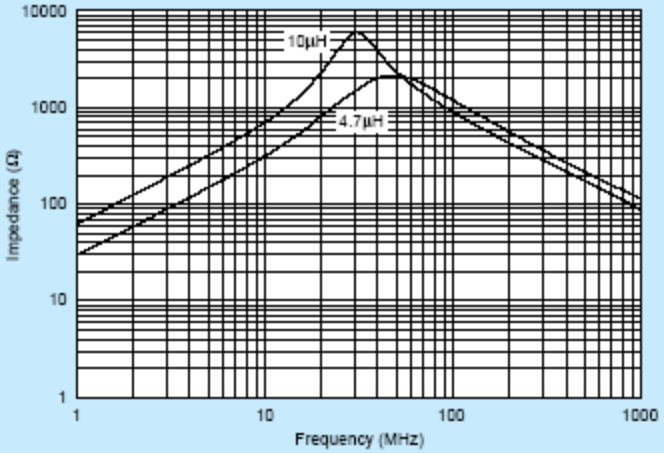
Appendix-2. Chip Inductor (FB1)

■ Rated Value (☐: packaging code)

Part Number	Inductance	Test Frequency	Rated Current	DC Resistance	Self Resonance Frequency (min.)	
LQM21FN4R7M80☐	4.7µH±20%	1MHz	120mA	0.18ohm±30%	25MHz	Kit
LQM21FN100M80☐	10µH±20%	1MHz	100mA	0.30ohm±30%	15MHz	Kit

Class of Magnetic Shield: Magnetic shield of ferrite Operating Temperature Range: -55°C to +125°C

■ Impedance-Frequency Characteristics (Typ.)



■ Inductance-Current Characteristics (Typ.)