High Power Factor Offline Flyback Controller
AL1788EV1User Guide

General Description

The AL1788 is a high performance high Power Factor Corrected (PFC) LED driver controller. It is a Primary Side controller designed for driving the Flyback converter. Based on Valley-ON Quasi-resonant mode, AL1788 is operating at Boundary Conduction Mode (BCM) which is good for EMI. It is universal Flyback solution with high PF and low THD.

The AL1788EV1 is designed to serve as an example for dual-CV (Constant Voltage) Output where main CV output requires high PFC and a secondary CV output is for wireless connectivity.

Key Features

Input Voltage Range: 8.0V to 25V

Primary Side Control or Secondary Side Control (No Opto Coupler required) AC-to-CV Regulation

Valley-on function to achieve low switching loss

High Power Factor (PF) and Low Total Harmonic Distortion (THD) for wide Loading range

High Efficiency

Low system BOM cost

Low Standby Power

Under Voltage Lockout (UVLO)

Over Voltage Protection (OVP)

Over Current Protection (OCP)

Output Short Protection (OSP)

Over-temperature protection (OTP): Thermal shutdown and auto thermal recovery

Application:

High PFC and low THD power supply

Smart Connected LED Light Bulbs

Smart Connected LED Tubes, Panel Lights, Troffers and Ceiling Lights

AL1788EV1 Board Specifications

Parameter	Value
Input Voltage	100Vac to 240V_{AC}
Power Rating	32Watt
Main output: (Vout / Io)	CV1: VO1 - 42V / 750mA
	CV2: 3V3 - 3.3V / 200mA
Standby Power	<500 mW (No Load on CV1, 15mA for CV2)
Protections	UVLO, OVP, OSP, OLP, OTP
Efficiency	>87% for Vo1 Full Load
XYZ Dimension	14.5 x 45 x 35 mm
Application	1-Channel Dimmable White 2-Channel Tunable White Smart Lightning dual CV-output power

Evaluation Board View:

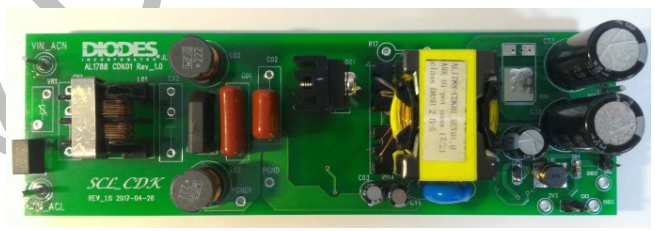


Figure 1: Top View

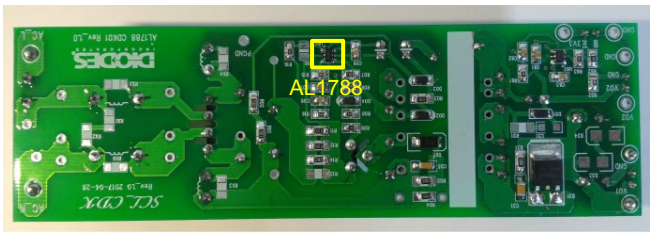
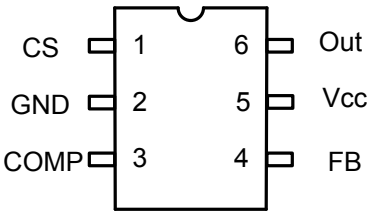


Figure 2: Bottom View

✧ AL1788 Pin Assignment



Top View (SOT26)

Pin Name	Pin Number	Descriptions
CS	1	Primary Current Sensing
GND	2	Ground
COMP	3	Loop Compensation Pin
FB	4	Voltage Sensing Feedback
VCC	5	Power Supply
OUT	6	Gate Driver Output

✧ Evaluation Board Schematic

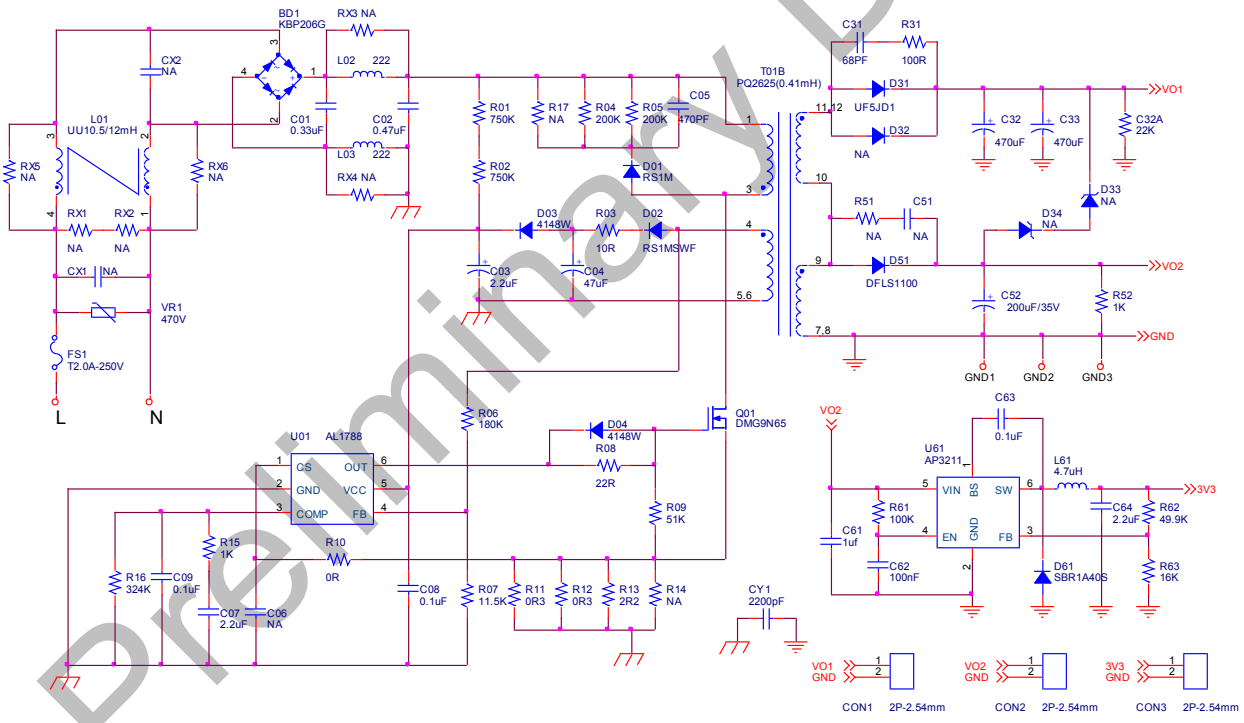


Figure 3: Evaluation Board Schematic

✧ Evaluation Board Layout

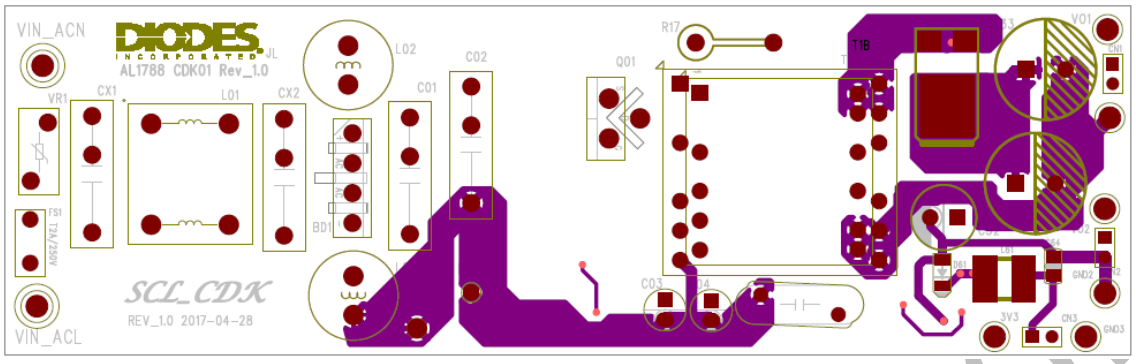


Figure 4: PCB Board Layout Top View

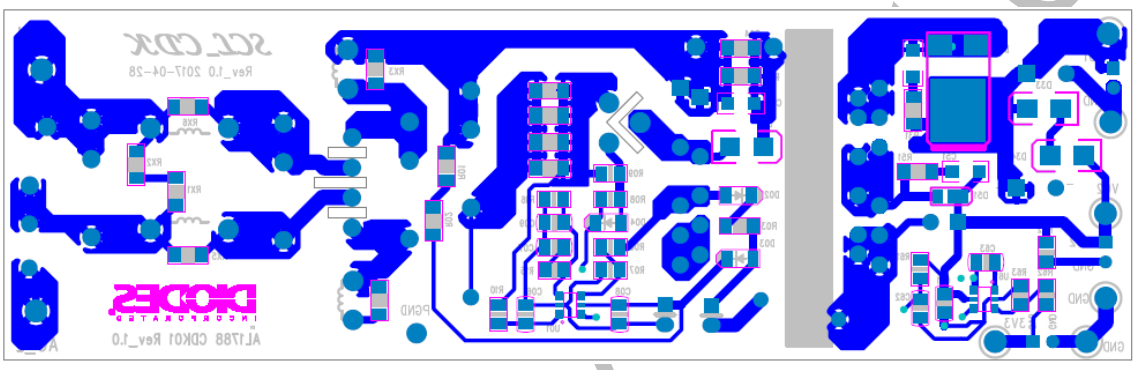


Figure5: PCB Board Layout Bottom View

✧ Bill of Material (BOM)

#	Name	QTY	Part Number	Description	Note
1	U01	1	AL1788W6-7	Single-Stage Flyback and PFC controller for CV regulation (SOT236)	Diodes, Inc.
2	U61	1	AP3211	1.4MHz, 1.5A Asynchronous DC-DC buck converter (SOT236)	Diodes, Inc.
3	D01	1	RS1M	1.0A surface mount fast recovery rectifier (SMA)	Diodes, Inc.
4	D02	1	RS1MSWF	1.0A surface mount fast recovery rectifier (SOD123F)	Diodes, Inc.
5	D03,D04	2	1N4148W	Surface mount fast switching diode (SOD123)	Diodes, Inc.
6	D31	1	UF5JD1	5A ULTRA-FAST rectifier (TO252)	Diodes, Inc.
7	D51	1	DFLS1100	1.0A High voltage schottky barrier rectifier (POWERDI@123)	Diodes, Inc.
8	D61	1	SBR1A40S1	1.0A SBR Super Barrier Rectifier (SOD123)	Diodes, Inc.
9	D33,D34	2	NA	Not fitted (for Regulation)	Diodes, Inc.
10	BD1	1	KBP206G	2.0A Glass passivated bridge rectifier (KBP)	Diodes, Inc.
11	Q01	1	DMG9N65CTI	N-Channel Enhancement Mode MOSFET (ITO-220AB)	Diodes, Inc.
12	C01	1	0.33uF/400V	EMI filter and Storage capacitor	
13	C02	1	0.47uF/400V	EMI filter and Storage capacitor	
14	C03	1	2.2uF/50V	Storage capacitor for startup (5*11)	
15	C04	1	47uF/35V	VCC hold-up capacitor (5*11)	
16	C05	1	470PF/1KV	Snubber capacitor (1206)	
17	C06	0	NA	Not fitted (0805 for CS filter)	
18	C07	1	2.2uF/16V	Compensation capacitor	
19	C08	1	0.1uF	VCC Filter	
20	C09	1	0.1uF	Compensation capacitor	
21	C31	1	68pF/1KV	Snubber capacitor (1206)	
22	C33,C32	2	470uF/63V	42V output filter capacitor	
23	C32A	1	22K	42V dummy load (1206)	
24	C52	1	220uF/35V	7.5V output filter capacitor	

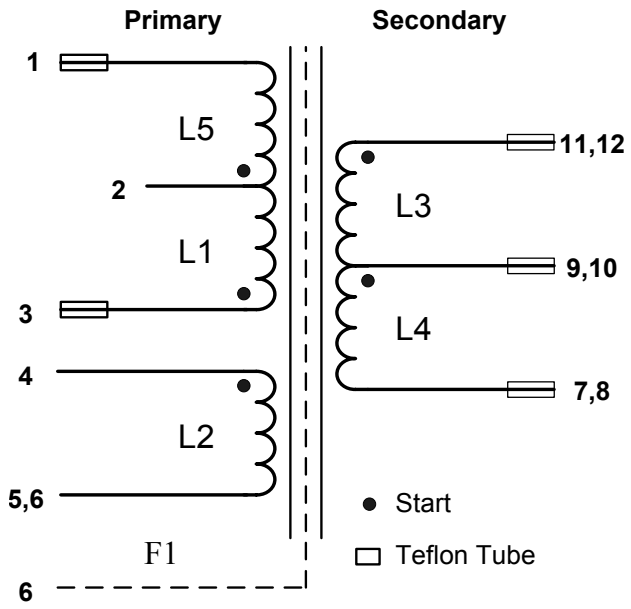
25	C61	1	1.0uf	3.3V buck converter input filter	
26	C62	1	100nF	3.3V buck converter push-pull capacitor	
27	C63	1	0.1uF	Bootstrap capacitor for 3.3V converter	
28	C64	1	2.2uF/16V	3.3V buck converter output filter	
29	CX1,CX2	0	NA	Not fitted (for EMI filter)	
30	CY1	1	2200pF-Y1	EMI filter	
31	FS1	1	T2.0A-250V	Fuse	LittleFuse
32	L01	1	10mH	EMI filter (UU10.5)	
33	L02,L03	2	2.2mH	EMI filter (DR10*14)	
34	L61	1	4.7uH	3.3V buck converter inductor (PCMB053T-4R7MS)	Cyntec (Fortron Co.,Ltd.)
35	R02,R01	2	750K	Startup resistor (startup time<1000ms)	
		--	545K	Startup resistor (startup time<500ms)	
		--	375K	Startup resistor (startup time<400ms)	
36	R03	1	10R	VCC filter resistor	
37	R05,R04	2	200K	Snubber resistor (1206)	
38	R06	1	180K	Feedback resistor	
39	R07	1	11.5K	Feedback resistor	
40	R08	1	22R	Gate Resistor	
41	R09	1	51K	Discharge resistor for to avoid capacitive coupling driving the MOSFET	
42	R10	1	0R	Jumper (for CS filter)	
43	R12,R11	2	0R3	MOSFET Drain current sense resistor	
44	R13	1	2R2	MOSFET Drain current sense resistor	
45	R15	1	1K	Compensation resistor	
46	R52	1	1K	7.5V dummy load (1206)	
47	R16	1	324K	Compensation resistor	
48	R31	1	100R	Snubber resistor (1206)	
49	R61	1	100K	RC delay of 3.3V converter EN	
50	R62	1	49.9K	3.3V converter voltage feedback resistor	

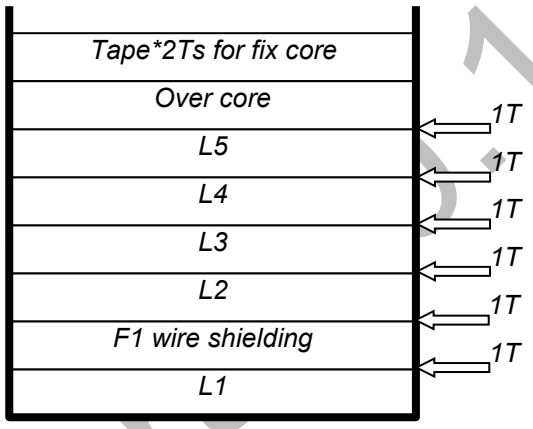
51	R63	1	16K	3.3V converter voltage feedback resistor	
52	R17	0	NA (1pcs)	Not fitted (sunnber)	
53	RX1,RX2,RX3, RX4,RX5,RX6, R14,R51,C51	0	NA (9pcs)	Not fitted	
54	T01B	1	PQ2625_0.41mH	Transformer	
55	VR1	1	471K	Varistor for EMC	
56	CON1	1	2P-2.54mm	VO1 (42V)output connector	
57	CON2	1	2P-2.54mm	VO2 (7.5V) output connector	
58	CON3	1	2P-2.54mm	3V3 output connector	

✧ Transformer Design:

- Transformer Pin & Wire Description:

Circuit：	Cross sectional view：





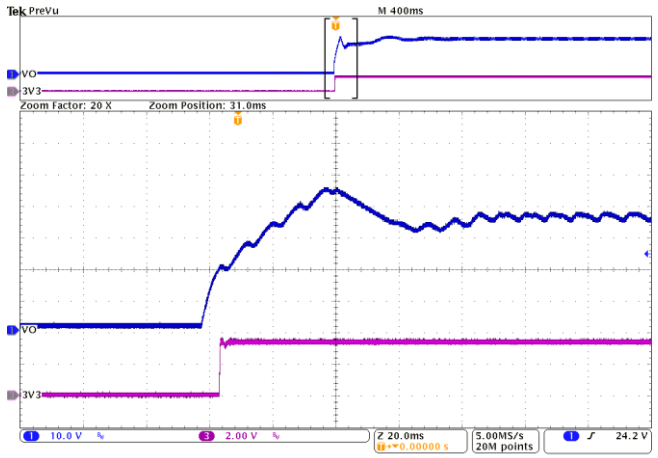
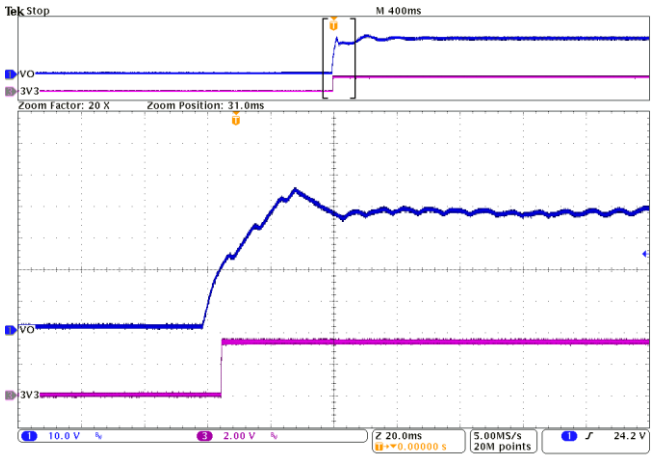
Name	Start		Finish	Wire Specification (φ)	Turns(Ts)	Method	Layer(s)	Tape Layer(s)
L1	3	➔	2	2UEW-B 0.25mm x 2P	21	Close	1	1T
F1	6	➔		2UEW-B 0.2mm x 1P	54	Close	1	1T
L2	4	➔	6	2UEW-B 0.2mm x 1P	12	Space	1	1T
L3	12	➔	10	Triple wire-B 0.4mm x 2P	21	Close	2	1T
L4	9	➔	7	Triple wire-B 0.4mm x 2P	6	Space	1	1T
L5	2	➔	1	2UEW-B 0.25mm x 2P	18	Close	1	1T
	OVER CORE							2Ts

- Electrical Characteristic:

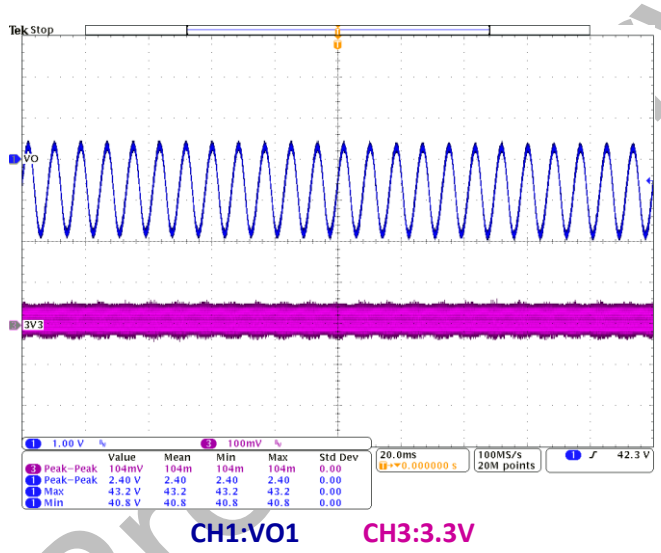
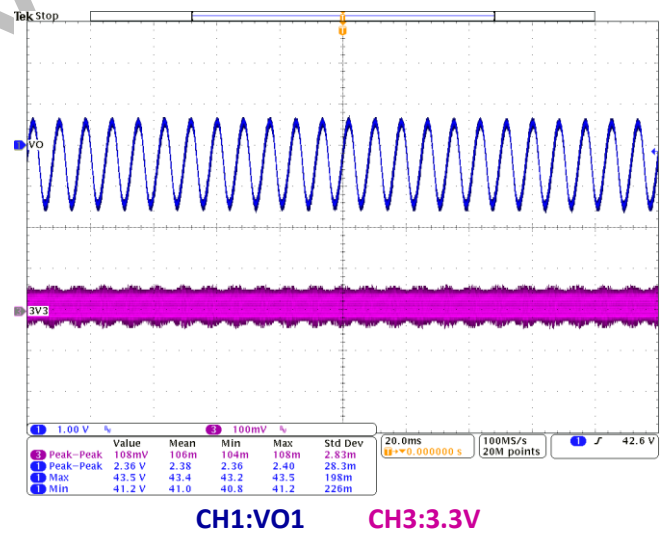
#	Test Item	Winding	Pin	Rating	Unit	Tolerance	Remark
2.1	Inductance	L1 and L5	3 → 1	0.41	mH	+/-5%	@ 100KHz / 1V

✧ Demo Board Performance Test

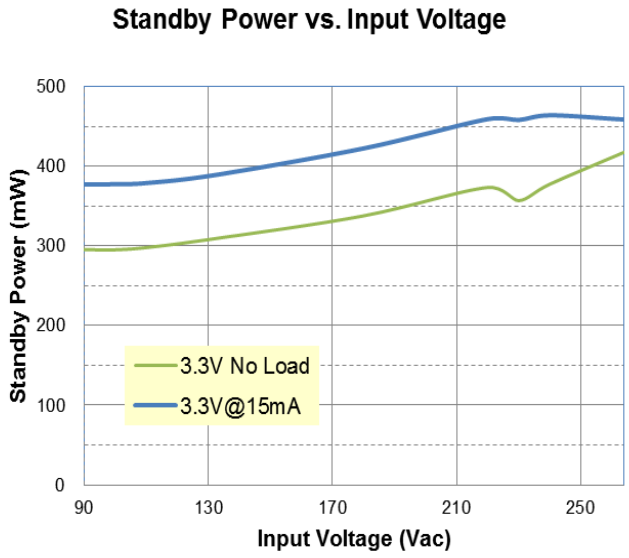
- Output Turn ON Waveform:

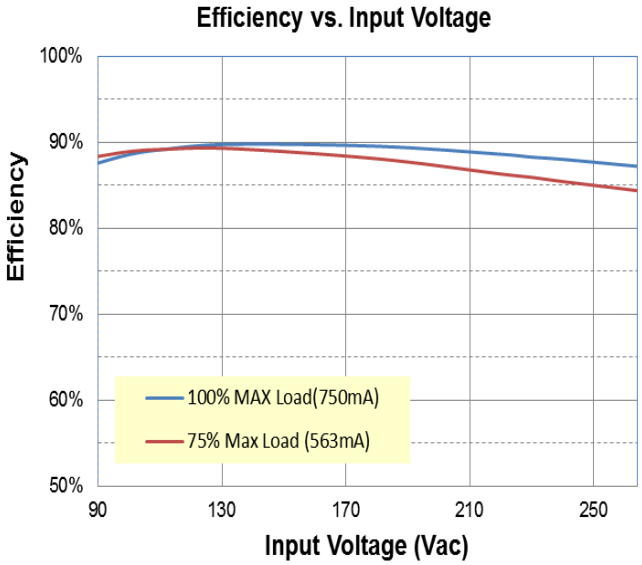
110V VO1/500mA, 3V3/200mA Turn ON Waveform	230V VO1/500mA, 3V3/200mA Turn ON Waveform
	
CH1:VO1 CH3:3.3V	CH1:VO1 CH3:3.3V

- Output Ripple Voltage Waveform:

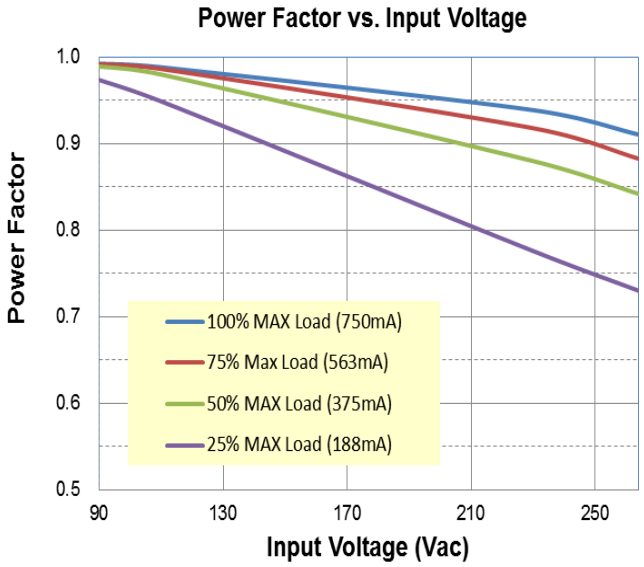
110Vac VO1/750mA, 3V3/200mA Output Ripple	230Vac VO1/750mA, 3V3/200mA Output Ripple
	
CH1:VO1 CH3:3.3V	CH1:VO1 CH3:3.3V

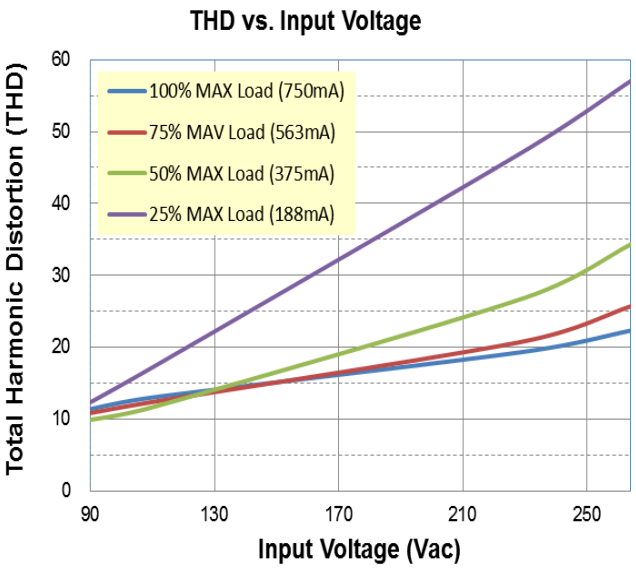
- Standby Power and Efficiency Performance:
  Startup Resistor: R01=R02=750Kohm



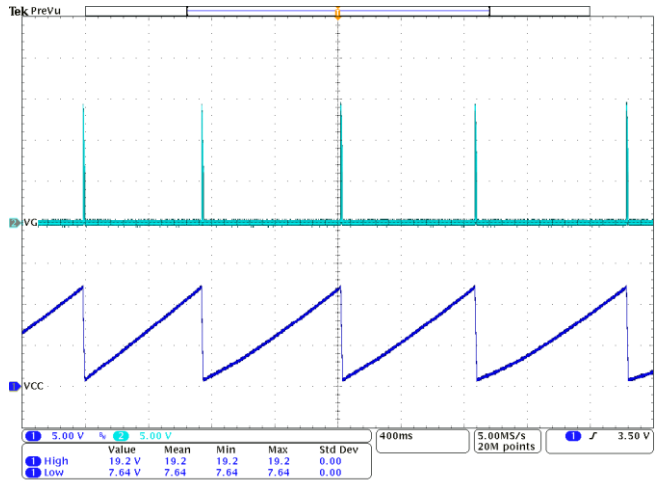
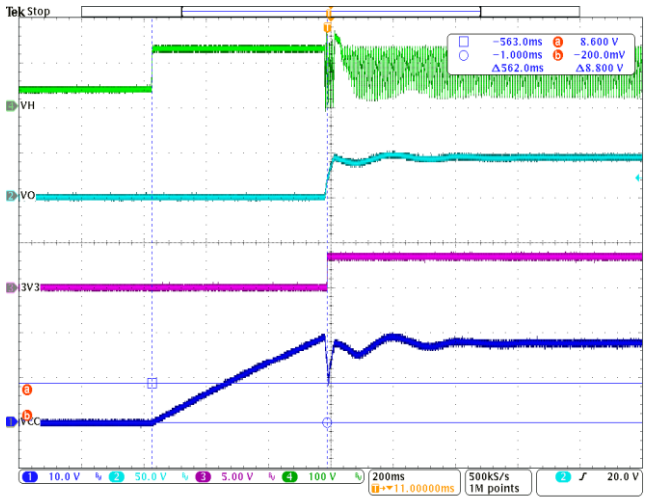


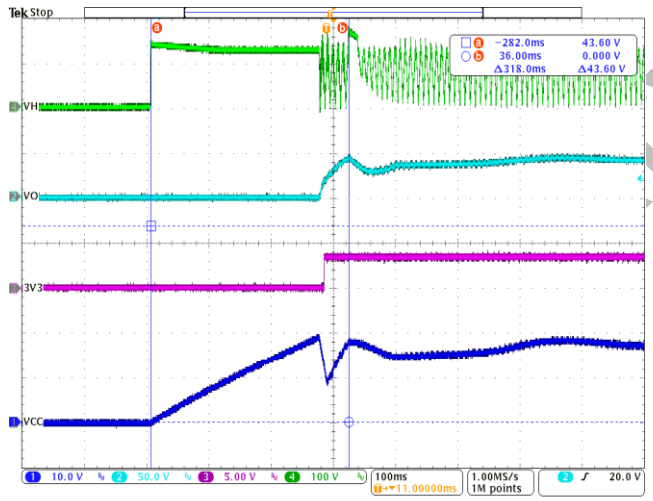
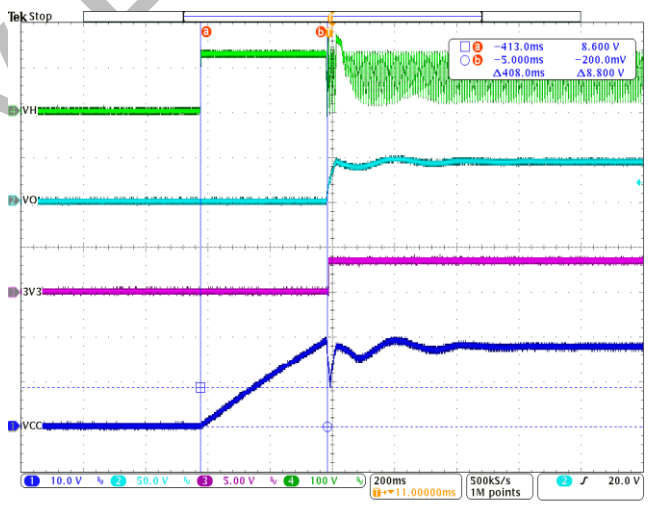
- Power Factor and Total Harmonic Distortion Performance:





- UVLO, Startup Time and Standby Power :

UVLO-ON and UVLO-OFF	R01=R02=750K, Startup time=562ms
	
CH1:VCC CH2:Vgate	CH1:VCC CH2:VO1 CH3:3.3V CH4:VH

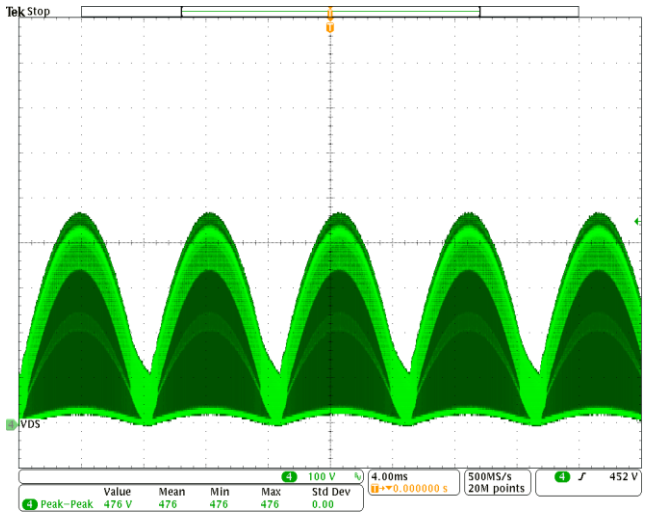
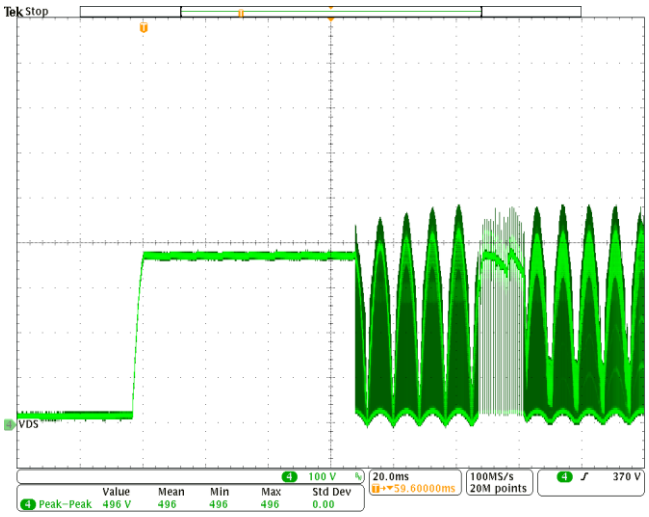
R01=R02=375K, Startup time=318ms	R01=R02=545K, Startup time=408ms
	
CH1:VCC CH2:VO1 CH3:3.3V CH4:VH	CH1:VCC CH2:VO1 CH3:3.3V CH4:VH

✓ Startup Time and Standby Power vs. Startup Resistor

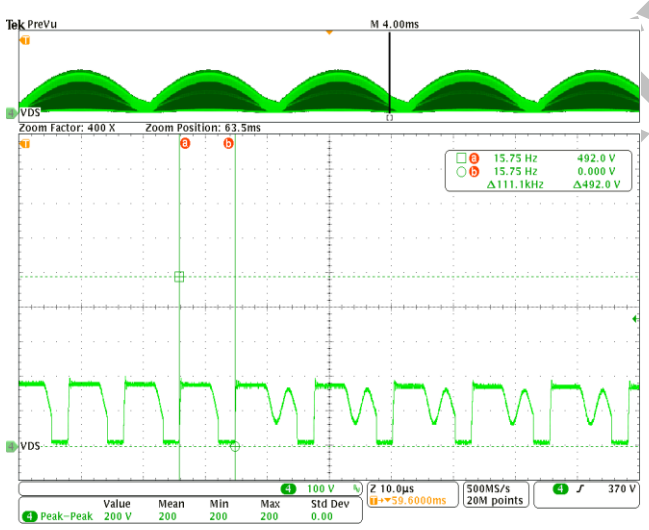
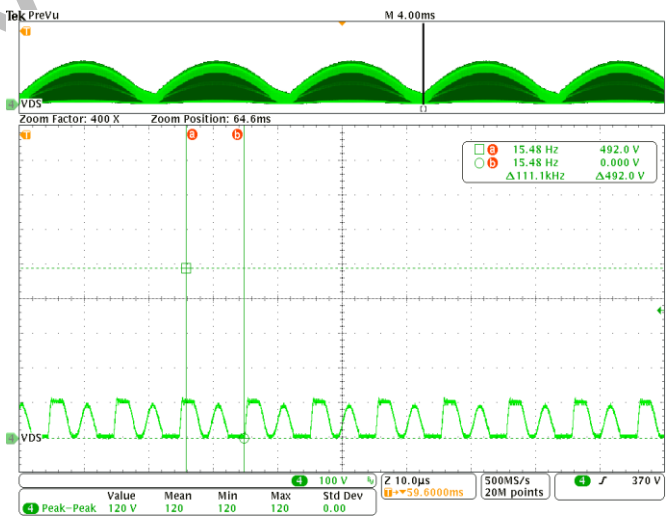
Startup Resistor	1500Kom	1090Kohm	750Kohm
Startup Time	562ms	408ms	318ms
Standby Power	390.2mW	417.5mW	471.6mW

Note:
Low startup resistors reduce the startup time, but will increase standby power.

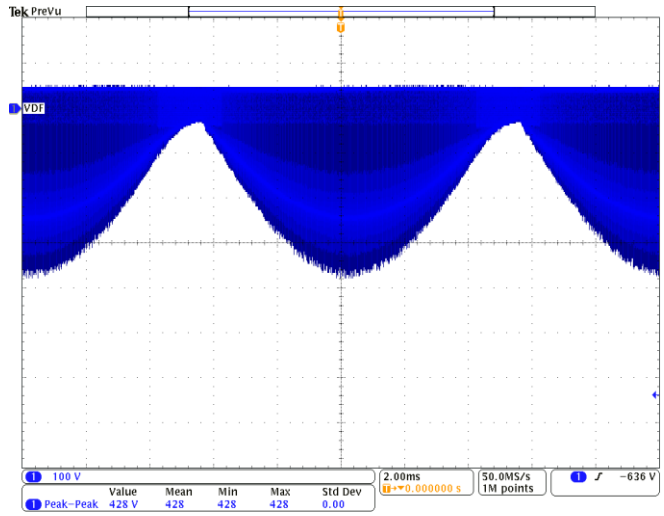
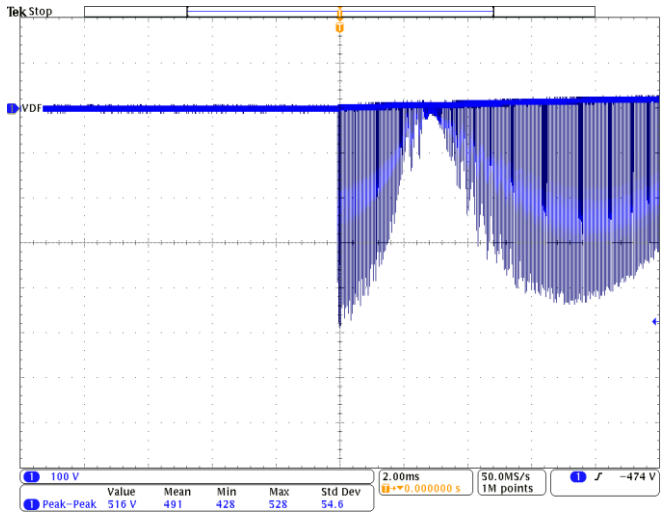
- MOSFET (Q01) Voltage Waveform:

264Vac Full Load normal Waveform	264Vac Full Load turn on waveform
	
VDS_max=476V	VDS_max=496V

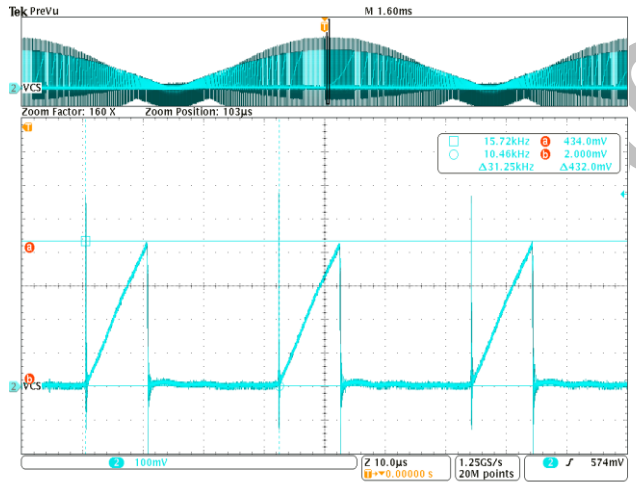
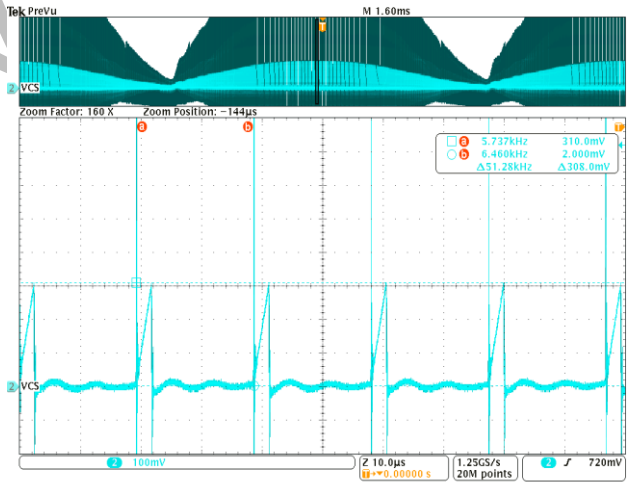
- Valley Switching Performance:

264Vac Full Load MOSFET VDS Waveform	264Vac Full Load Output Ripple Waveform
	
VO1Full Load VCS_90V=0.434V	Full Load VCS_264V=0.310V

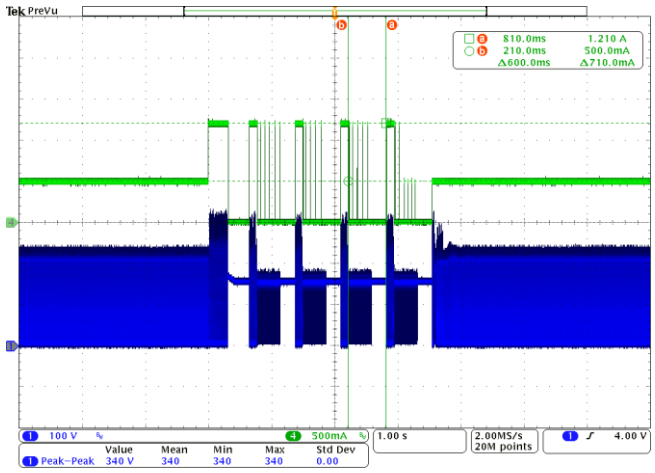
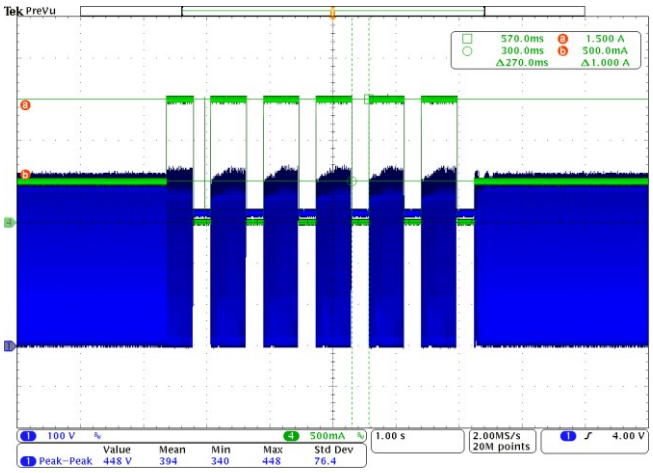
- Output Rectifier Diode (D31) Voltage Waveform:

264Vac Full Load normal Waveform	264Vac Full Load turn on waveform
	
VDF_max=428V	VDF_max=516V

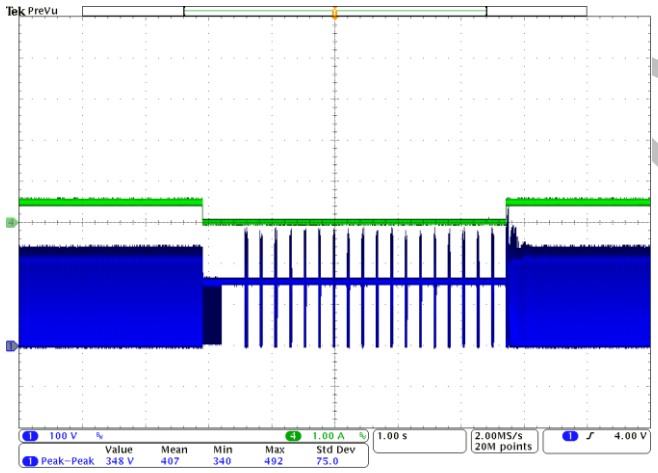
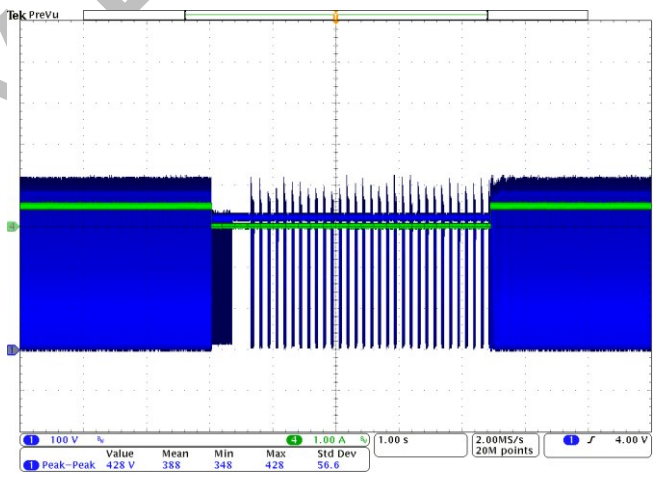
- Current Sense Voltage Waveform:

90Vac Full Load normal Waveform	264Vac Full Load normal Waveform
	
Full Load VCS_90V=0.434V	Full Load VCS_264V=0.310V

- Over Current Protection:

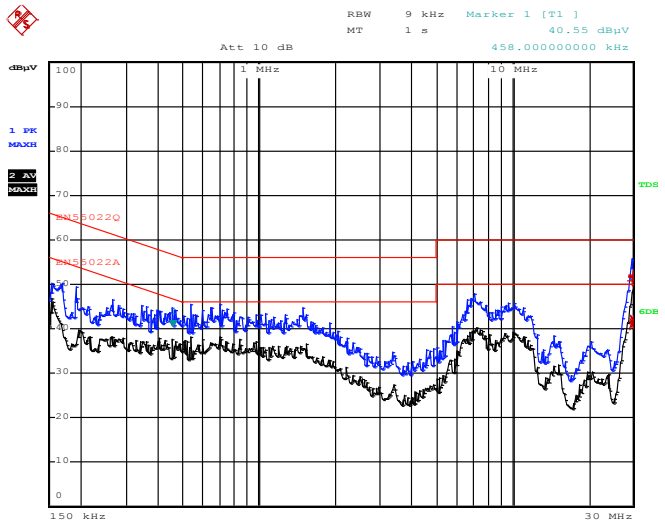
110Vac; OCP current: 1.2A	230Vac; OCP current: 1.5A
	
CH1:VDS CH4:IO	CH1:VDS CH4:IO

- Short Circuit Protection:

110Vac; Output Short and Auto Recover	230Vac; Output Short and Auto Recover
	
CH1:VDS CH4:IO	CH1:VDS CH4:IO

- Conducted EMI Test:
  Load Condition: VO1 add 54ohm Resistor (750mA).

Two-Wires Input 110Vac/L Full Load (750mA)

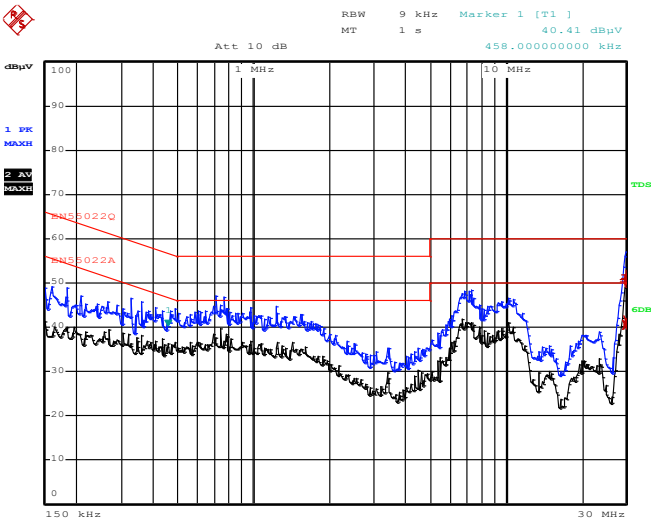


EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55022Q
Trace2: EN55022A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1	Quasi Peak	29.69 MHz	50.79	-9.20
2	Average	29.758 MHz	41.24	-8.75
2	Average	29.802 MHz	40.90	-9.09
1	Quasi Peak	29.83 MHz	51.69	-8.30
2	Average	29.878 MHz	42.04	-7.95
1	Quasi Peak	29.922 MHz	51.72	-8.27
1	Quasi Peak	29.938 MHz	51.84	-8.15
2	Average	29.938 MHz	41.95	-8.04
1	Quasi Peak	29.962 MHz	51.99	-8.00
2	Average	29.962 MHz	41.87	-8.12

Two-Wires Input 110Vac/N Full Load (750mA)

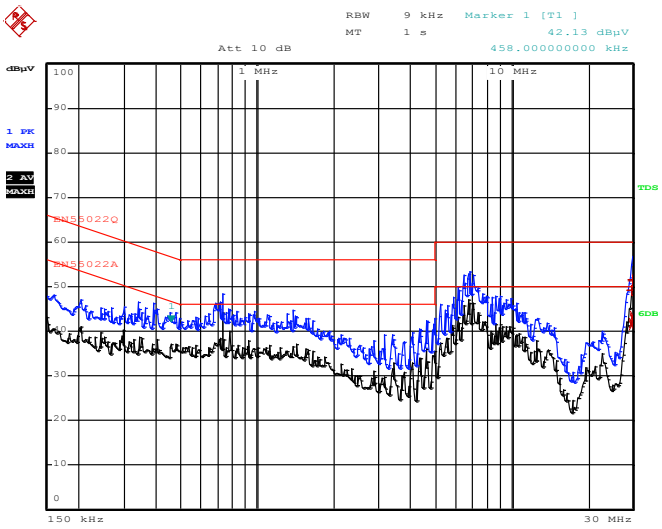


EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55022Q
Trace2: EN55022A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1	Quasi Peak	29.702 MHz	50.37	-9.62
1	Quasi Peak	29.794 MHz	50.77	-9.22
1	Quasi Peak	29.814 MHz	50.76	-9.23
2	Average	29.814 MHz	40.61	-9.38
2	Average	29.862 MHz	40.66	-9.33
2	Average	29.926 MHz	40.55	-9.44
1	Quasi Peak	29.95 MHz	51.08	-8.91
2	Average	29.95 MHz	41.20	-8.79
2	Average	29.974 MHz	41.58	-8.41
1	Quasi Peak	29.998 MHz	51.71	-8.28

Two-Wires Input 230Vac/L Full Load (750mA)

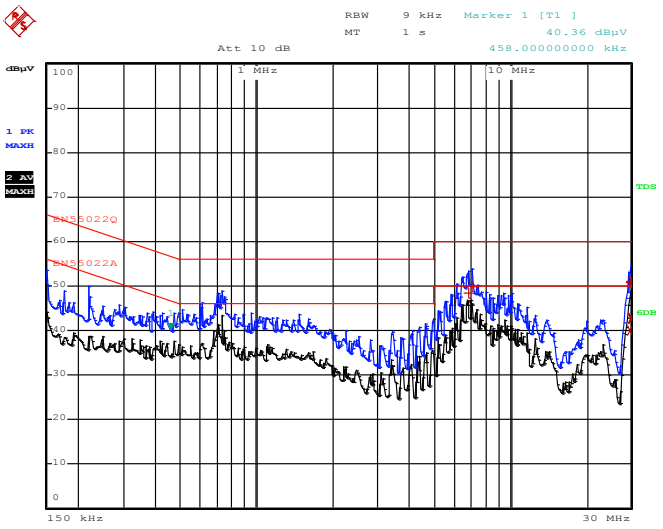


EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55022Q
Trace2: EN55022A
Trace3: ---

TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
2	Average	29.606 MHz	41.80	-8.19
2	Average	29.67 MHz	41.40	-8.59
1	Quasi Peak	29.738 MHz	49.24	-10.75
1	Quasi Peak	29.762 MHz	49.34	-10.65
1	Quasi Peak	29.882 MHz	51.40	-8.59
2	Average	29.906 MHz	43.38	-6.61
1	Quasi Peak	29.95 MHz	51.57	-8.42
2	Average	29.95 MHz	42.93	-7.06
1	Quasi Peak	29.966 MHz	51.55	-8.44
2	Average	29.974 MHz	42.53	-7.46

Two-Wires Input 230Vac/N Full Load (750mA)

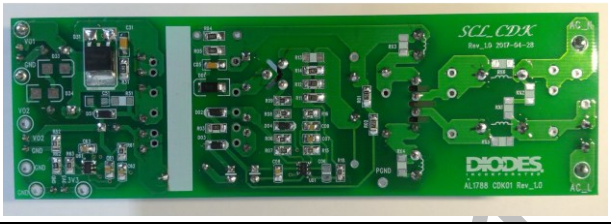
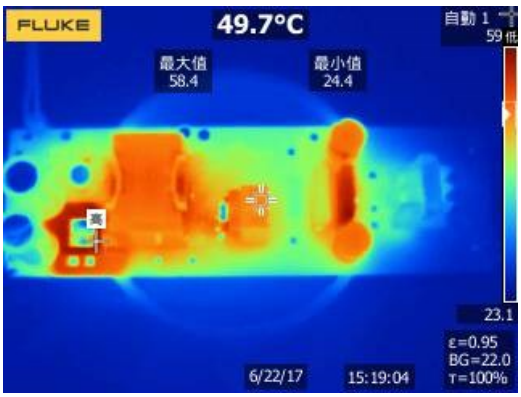
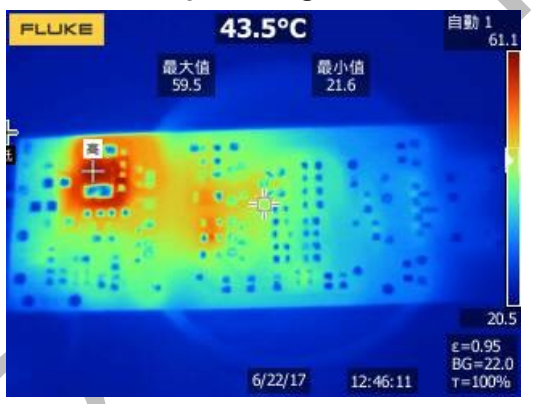
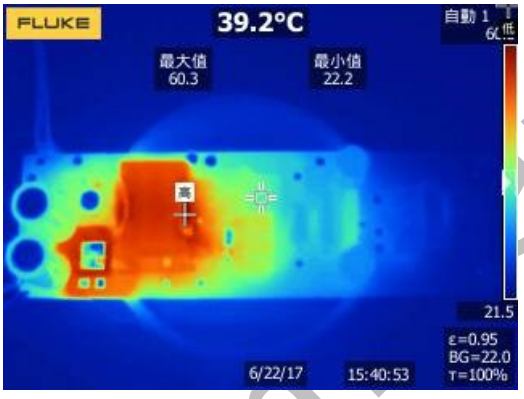
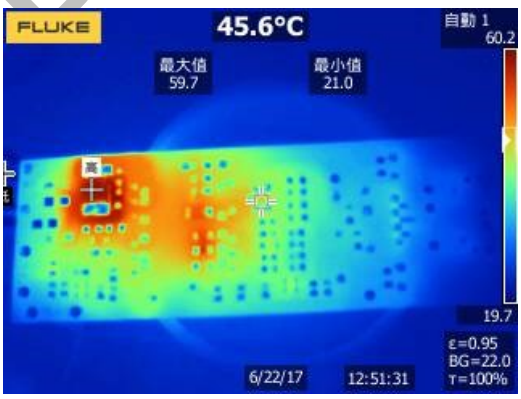
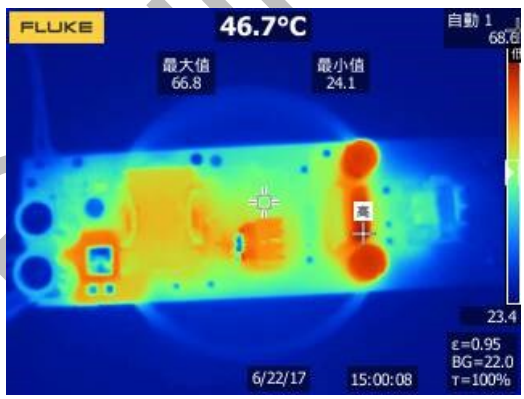
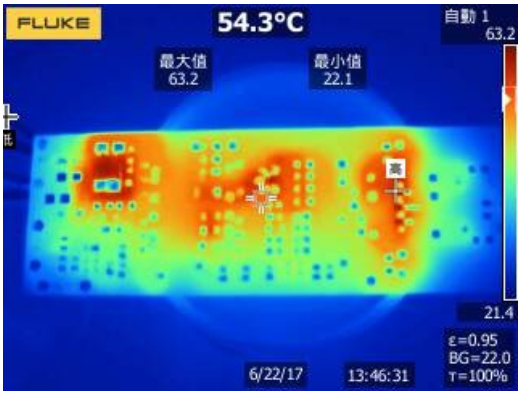


EDIT PEAK LIST (Final Measurement Results)

Trace1: EN55022Q
Trace2: EN55022A
Trace3: ---

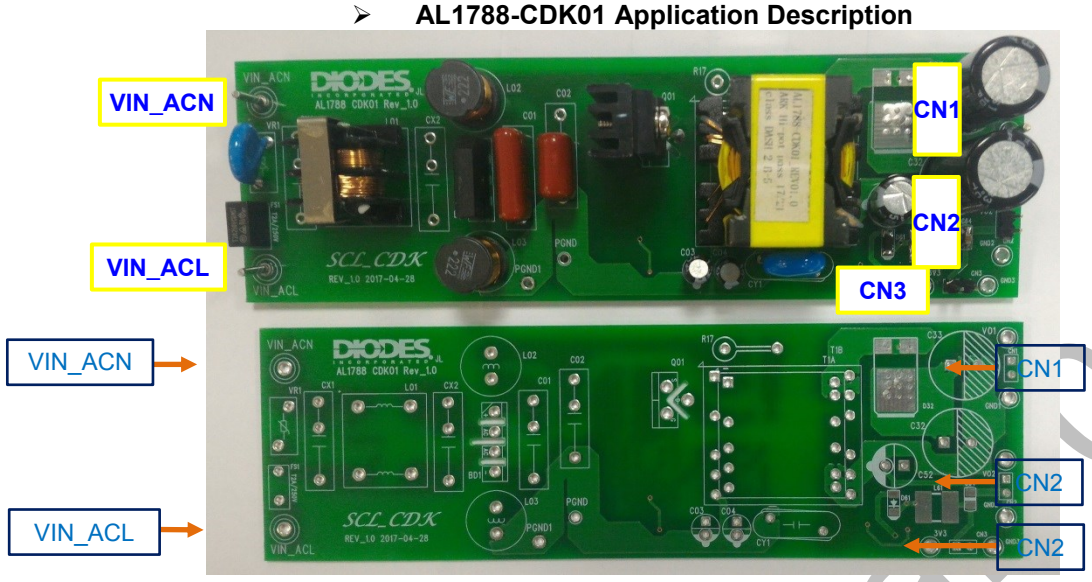
TRACE		FREQUENCY	LEVEL dBµV	DELTA LIMIT dB
1	Quasi Peak	6.878 MHz	48.37	-11.63
1	Quasi Peak	7.13 MHz	50.10	-9.89
2	Average	29.762 MHz	40.04	-9.95
1	Quasi Peak	29.886 MHz	50.75	-9.24
2	Average	29.886 MHz	42.59	-7.40
1	Quasi Peak	29.906 MHz	50.82	-9.17
2	Average	29.906 MHz	42.77	-7.22
2	Average	29.926 MHz	42.85	-7.15
1	Quasi Peak	29.93 MHz	50.94	-9.05
2	Average	29.95 MHz	42.58	-7.41

- Thermal Test Result

Two-Wires Input 110Vac/L Full Load (750mA)	Two-Wires Input 110Vac/N Full Load (750mA)
	
TOP- Input Voltage=264Vac	**BOT- Input Voltage=264Vac**
	
TOP- Input Voltage=230Vac	**BOT-Input Voltage=230Vac**
	
TOP- Input Voltage=90Vac	**BOT-Input Voltage=90Vac**
	

✧ Input / Output Application Description:

➢ **AL1788-CDK01 Application Description**



■ Input Pin Functions:

Connector	PIN#	Name	Function Description
VIN_ACL	1	VIN_ACL	Connect to AC (L) Input
VIN_ACN	1	VIN_ACN	Connect to AC (N) Input

■ Output Pin Functions:

Connector	PIN#	Name	Function Description
VO1	1	VO1	42V Output for CV 750mA_max output
CN1	1	VO1	42V Output for CV
	2	GND	GND
GND1	1	GND	GND
VO2	1	VO2	7.5V Output for CV 150mA_max output
CN2	1	VO2	7.5V Output for CV 150mA_max output
	2	GND	GND
GND2	1	GND	GND
3V3	1	3V3	3.3V Output for MCU 200mA_Max output
CN3	1	3V3	3.3V Output for MCU 200mA_Max output
	2	GND	GND
GND3	1	GND	GND

✧ Quick Start Guide

- The evaluation board is preset at 42V (VO1) and 3.3V (3V3) for universal voltage input 100V < V_{ac} < 240V
- Ensure that the AC source is switched OFF or disconnected.
- Connect the AC line wires of power supply to “L and N” on the board.
- Turn on the AC main switch.
- Measure CVout to check VO1 and 3V3 to ensure proper output voltages (42V and 3.3V)

✧ Use Case examples for smart light bulb development

- AL1788DCK01 + AL1794EV1 (30V DC-to-CC Linear CCR)
- AL1788CDK01 + AL8860EV1 (40V DC-to-CC Switching Buck)

✧ Reference web site:

- AL1794EV1 - http://www.diodes.com/_files/evbd/AL1794EV1UserGuide.pdf
- AL8860EV1 - http://www.diodes.com/_files/evbd/AL8860EV1UserGuide.pdf

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