User Guide for

AN-8026: FAN9611 / FAN9612 400W 1-Layer Evaluation Board (FEB-301)

Featured Fairchild Product:
FAN9611 / FAN9612

Direct questions or comments about this Evaluation Board to: “Worldwide Direct Support”

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The following user guide supports the FAN9611 / FAN9612 400W evaluation board for interleaved boundary-conduction mode power factor corrected supply. The user guide should be used in conjunction with the FAN9611/FAN9611 / FAN9612 datasheet as well as the Fairchild application note *AN-6086 — Design Considerations for Interleaved Boundary-Conduction Mode PFC Using FAN9611 / FAN9612*. The user guide and the evaluation board can also be used to evaluate FAN9611 controller which has the lower turn-on threshold. Please visit Fairchild's website at www.fairchildsemi.com for information.

1. Overview of the Evaluation Board

The FAN9611 / FAN9612 interleaved dual Boundary-Conduction-Mode (BCM) Power-Factor-Correction (PFC) controller operates two parallel-connected boost power trains 180º out of phase. Interleaving extends the maximum practical power level of the control technique from about 300W to greater than 800W. Unlike the continuous conduction mode (CCM) technique often used at higher power levels, BCM offers inherent zero-current switching of the boost diodes (no reverse-recovery losses), which permits the use of less expensive diodes without sacrificing efficiency. Furthermore, the input and output filters can be smaller due to ripple current cancellation between the power trains and effectively doubling the switching frequency.

The advanced line feedforward with peak detection circuit minimizes the output voltage variation during line transients. To guarantee stable operation with less switching loss at light load, the maximum switching frequency is clamped at 600kHz. Synchronization is maintained under all operating conditions.

Built-in protection functions include output over-voltage, over-current, open-feedback, under-voltage lockout, brownout, and redundant latching over-voltage. The FAN9611 / FAN9612 is available in a lead-free 16-lead SOIC package.

Fairchild offers and evaluation board to aide in design and test of applications using the FAN9611 / FAN9612. The FAN9611 / FAN9612 evaluation board is a single-layer board designed for 400W (400V/1A) rated power. Thanks to the phase management, the efficiency is maintained above 95% at low-line and high-line, even down to 10% of the rated output power. The efficiencies for full-load condition are 96.3% and 98.0% at line voltages of 115V_{AC} and 230V_{AC}, respectively.

2. General Specification

Specification	Min.	Max.	Units
Input			
V_{IN} AC Voltage	90	264	V_{AC}
V_{IN} AC Frequency	47	63	Hz
V_{DD} Supply	13	16	V_{DC}
Output			
Output Voltage		400	V
Output Current		1	A
Total Output Power			
Maximum Load Output Power		400	W

3. Test Procedures

Before testing the board; DC voltage supply for VDD, AC voltage supply for line input, and DC electric load for output should be connected to the board properly.

1. Supply V_{DD} for the control chip first. It should be higher than 13V *(refer to the specification for V_{DD} turn-on threshold voltage).*
2. When V_{DD} is supplied, a "click" sound from the relay is heard. This is normal. Since the inrush current limit relay is turned on by 5V reference (pin #3), the relay turns on when FAN9611 / FAN9612 comes out of UVLO by supplying V_{DD} higher than 13V.
3. Connect the AC voltage (90~264V_{AC}) to start the FAN9611 / FAN9612. Since FAN9611 / FAN9612 has brownout protection and line OVP, any input voltages out of operation range trigger protections.
4. Change load current (0~1A) and check the operation. The board is designed to go into phase shedding for output power below around 55W. It goes back to two-channel interleaving operation for output power above around 110W.

Table 1. Test Equipment

Test Model	FEB301-001
Test Date	Sept.7, 2009
Test Temperature	Ambient
Test Equipment	AC Source: Chroma 61603 AC POWER SOURCE Electronic Load: Chroma 63108 Power Meter: WT210 Oscilloscope: Lecroy wavesurfer 24Xs DC Source: ABM 9306D
Test Items	Startup
	Normal Operation
	Normal Operation
	Line and Load Transient
	Brown in/out Protection
	Phase Management
	Efficiency
	Harmonic Distortion and Power Factor

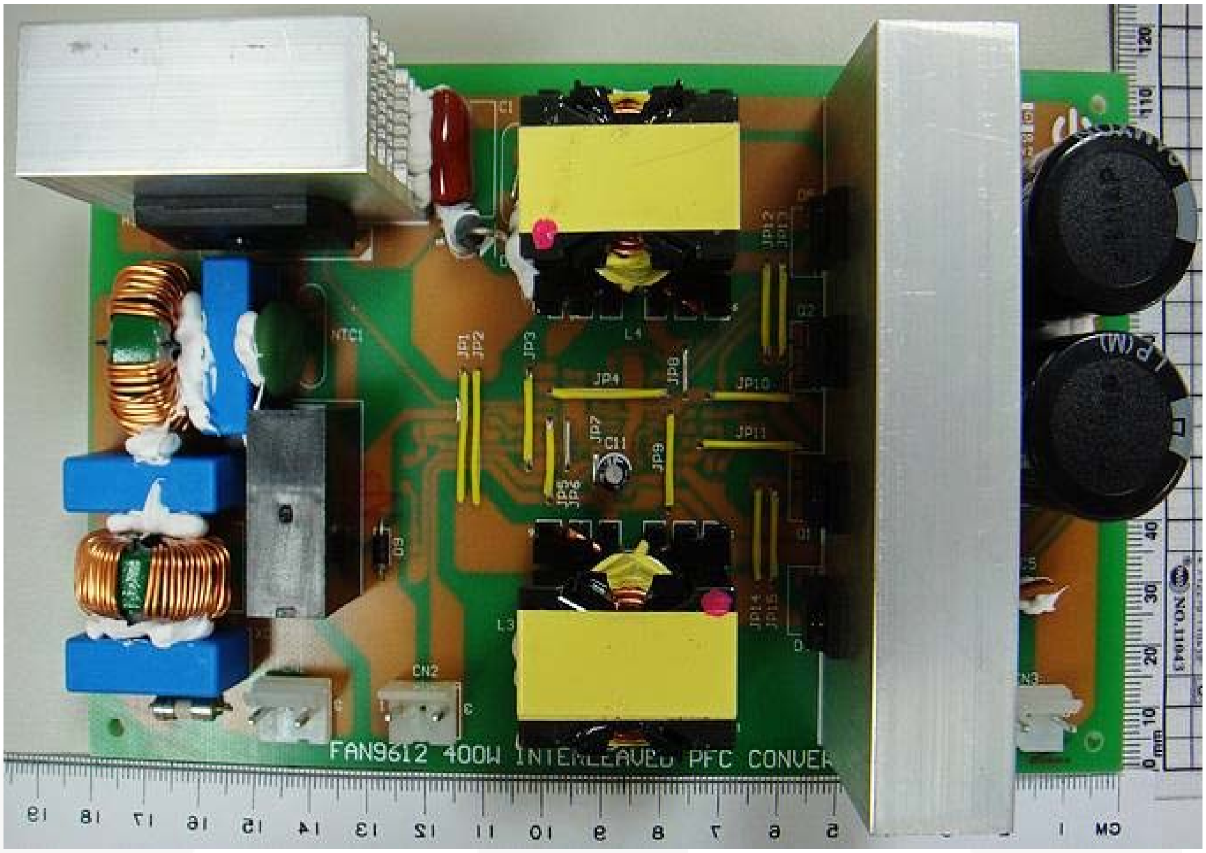


Figure 1. Photograph of Tested Board

4. Schematic

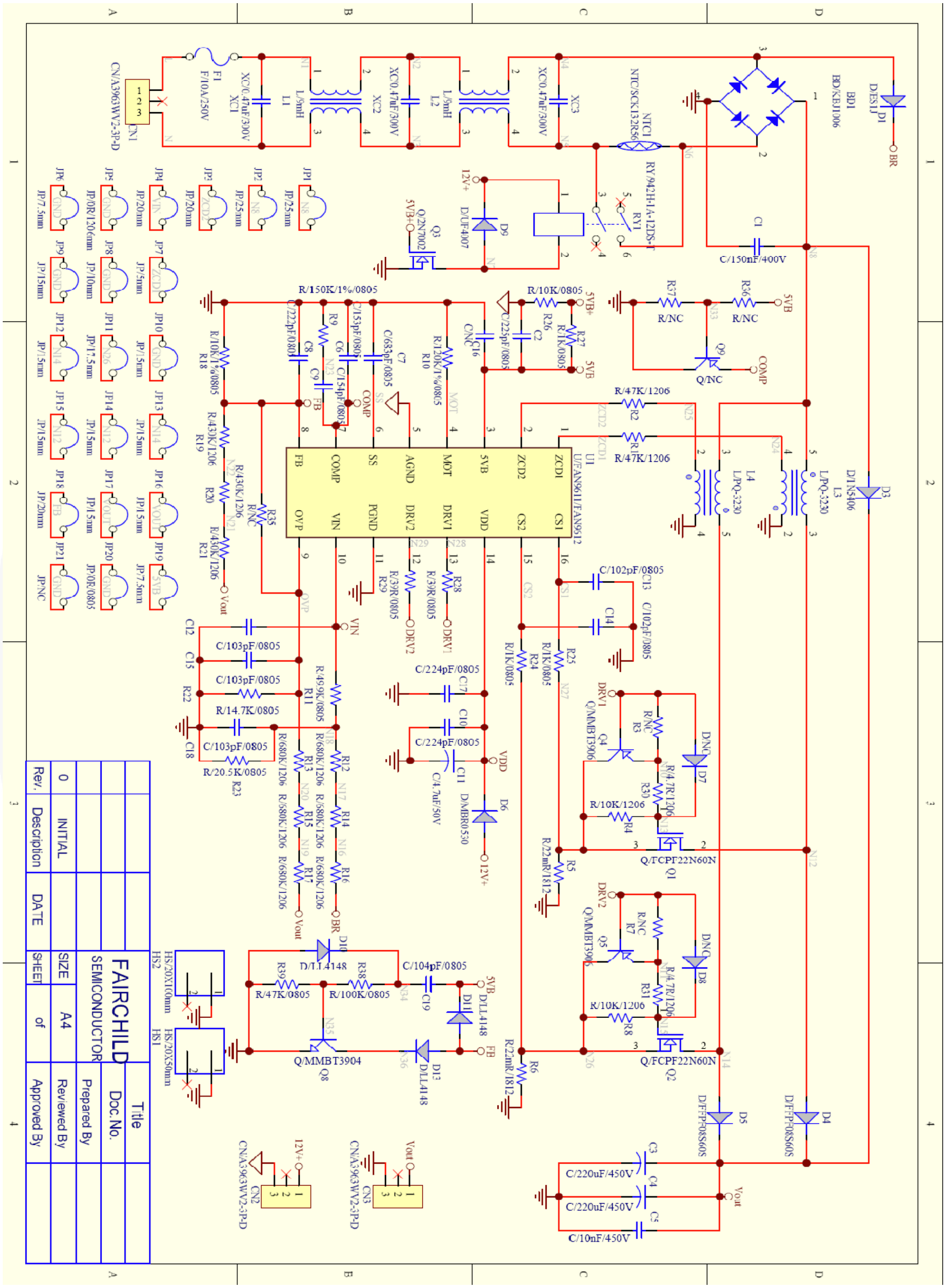
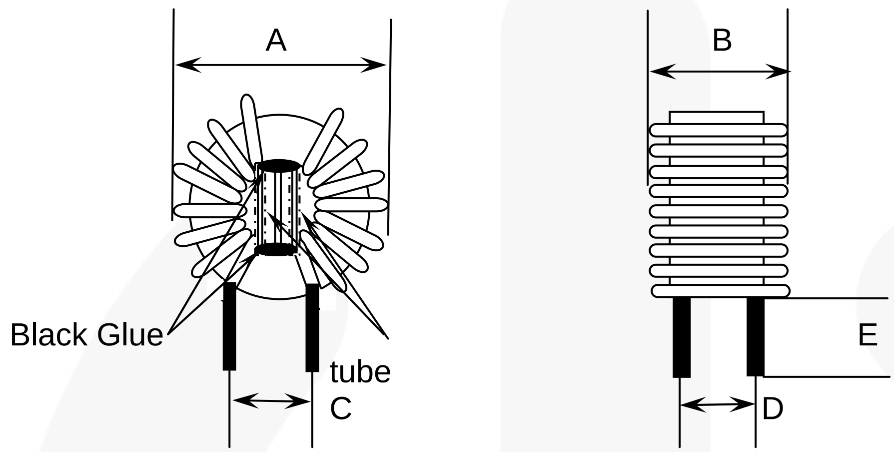


Figure 2. FAN9611 / FAN9612 400W Evaluation Board Schematic

5. Specification Approval

Customer	Fairchild Semiconductor			P/N:	TRN-0197
Date	08/04/2006	Version	A	Page	1/1

Dimension Unit: mm



A	30 max
B	5 max
C	11 ref
D	13 ref
E	15±1

Middle partition board thickness of 2mm
(Safety Regulation)

Electrical Specification: 1kHz, 1V

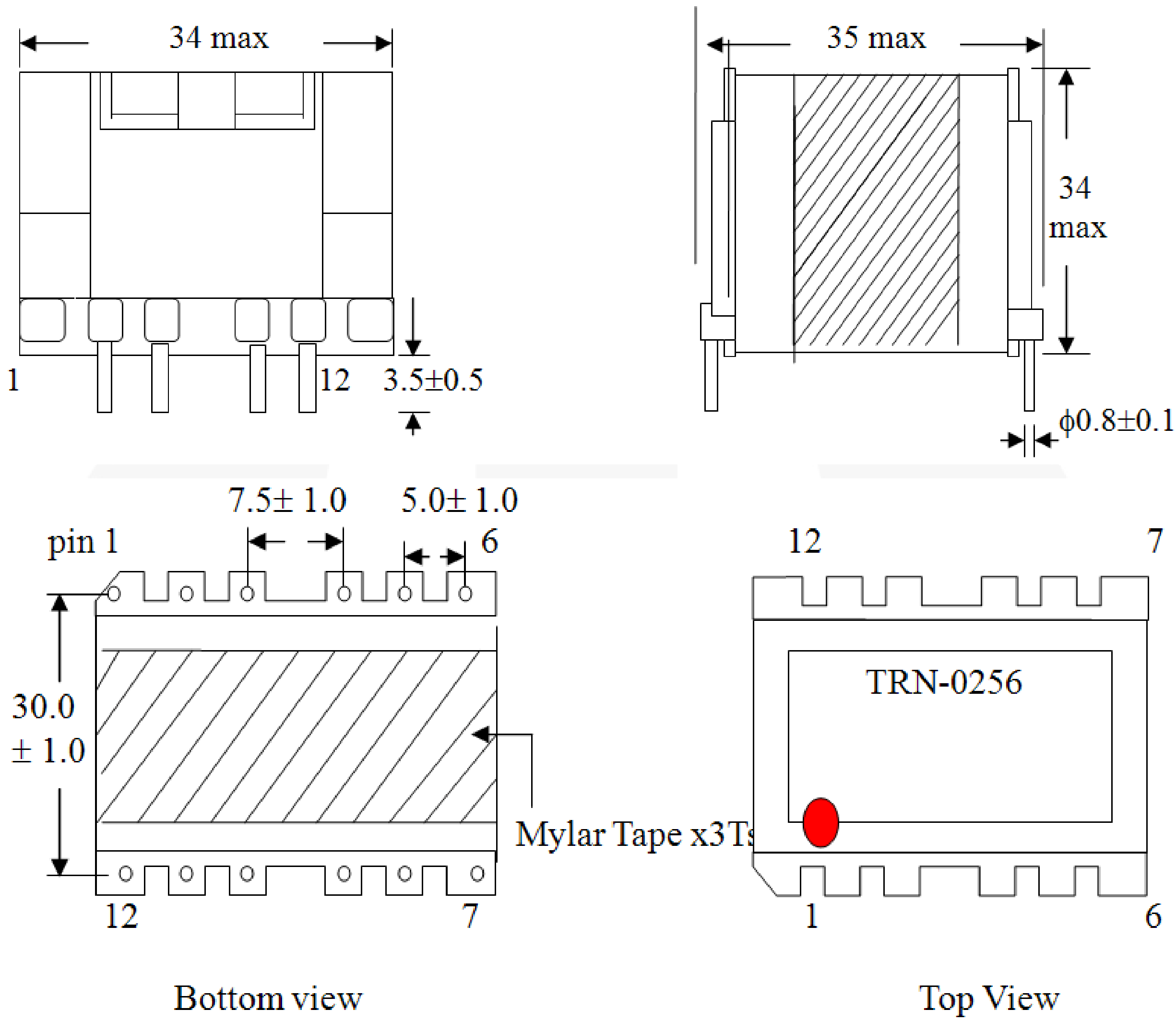
Inductance:L1=L2：9.0mH minimum
DC Resistance: L1=L2：0.05Ω maximum
Turn and Wire: L1=L2：ϕ0.9 x 30.5TSx2

Materials List:

Component	Material	Manufacturer	UL File #
1. CORE	T22x14x08	TOMITA	
2. WIRE	THFN-216	Ta Ya Electric Wire Co., Ltd.	E197768
	UEWN/U	PACIFIC Wire & Cable Co., Ltd.	E201757
	UEWE	Tai-I Electric Wire & Cable Co., Ltd.	E85640
	UWY	Jang Shing Wire Co., Ltd.	E174837
3. Solder	96.5% Sn,3% Ag,0.5% Cu,	Xin Yuan Co., Ltd.	

Unit	m/m	Drawn	Check	Title	
TEL	(02)29450588	Ci wun Chen	Guo long Huang	IDENT#.	TRN-0197
FAX	(02)29447647	SEN HUEI INDUSTRIAL CO.,LTD.		D W G#	I0060
No.26-1, Lane 128, Sec. 2, Singnan Rd., Jhonghe City, Taipei County 235, Taiwan (R.O.C.)					

Customer	Fairchild Semiconductor			P/N:	TRN-0256
Date	09/02/2009	Version	A	Page	1/4



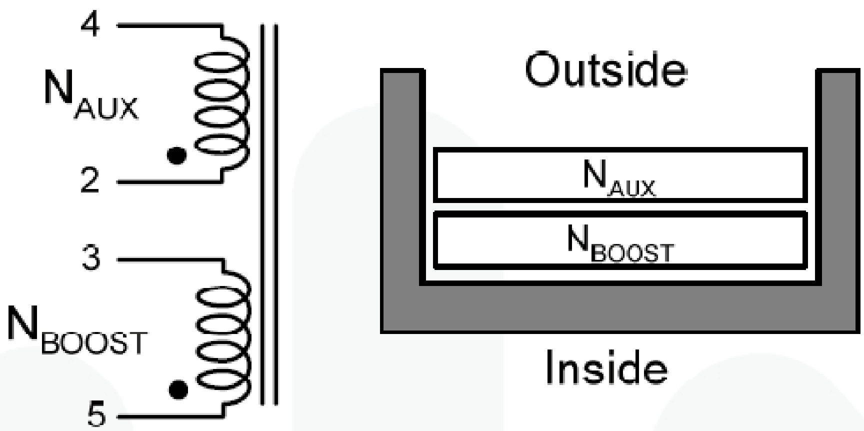
Notes:

1. Pin 1,6,7,8,10,11,12 removed.
2. Add insulation tape *3 turns to fix core and bobbin.
3. The red symbol indicates first pin.

Unit	m/m	Drawn	Check	Title	
TEL	(02)2945-0588	Ci wun Chen	Guo long Huang	IDENT#	TRN-0256
FAX	(02)2944-7647	SEN HUEI INDUSTRIAL CO.,LTD.		D W G#	I3205
No.26-1, Lane 128, Sec. 2, Singnan Rd., Jhonghe City, Taipei County 235, Taiwan (R.O.C.)					

Customer	Fairchild Semiconductor			P/N:	TRN-0256
Date	09/02/2009	Version	A	Page	3/4

6. Boost Inductor Specification



	Pin	Diameter / Thickness	Turns
N1	5 → 3	0.1 mm × 100 (Litz wire)	30
Insulation Tape		0.05 mm	3
N2	2 → 4	0.2 mm	3
Insulation Tape		0.05 mm	3

Core : PQ3230 (Ae=161 mm^2)
Bobbin: PQ3230
Inductance : 200μH

Figure 3. Boost Inductor in the FAN9611 / FAN9612 Evaluation Board

Note:

1. Pins 2, 4, 5 add tube.

Unit	m/m	Drawn	Check	Title	
TEL	(02)2945-0588	Ci wun Chen	Guo long Huang	IDENT#	TRN-0256
FAX	(02)2944-7647	SEN HUEI INDUSTRIAL CO.,LTD.		D W G#	I3205
No.26-1, Lane 128, Sec. 2, Singnan Rd., Jhonghe City, Taipei County 235, Taiwan (R.O.C.)					

6.1. Electrical Specification

Inductance Test: at 1kHz, 1V

- P(5-3): 200µH ±5%
- DC Resistance test at T_A = 25°C
- P(5-3): 62.44mΩ maximum
- P(2-4): 196.7mΩ maximum

Hi-Pot Test:

- AC 1000V / 60Hz / 0.5mA hi-pot for one minute between pri to sec
- AC 500V / 60Hz/ 0.5mA hi-pot for one minute between pri to core

Insulation Test:

- The insulation resistance is between pri to sec and windings to core measured by DC 500V
- Must be over 100MΩ

Terminal Strength:

- Kg on terminals for 30 seconds, test the breakdown

UNIT	m/m	DRAWN	CHECK	TITLE	
TEL	(02)2945-0588	Ci wun Chen	Guo long Huang	IDENT#	TRN-0256
FAX	(02)2944-7647	SEN HUEI INDUSTRIAL CO.,LTD.		D W G#	I3205
No.26-1, Lane 128, Sec. 2, Singnan Rd., Jhonghe City, Taipei County 235, Taiwan (R.O.C.)					

Customer	Fairchild Semiconductor			P/N:	TRN-0256
Date	09/02/2009	Version	A	Page	3/4

Materials List:

Component	Material	Manufacturer	File#
1.Bobbin	Phenolic 94v-0,T373J,150°C	PQ3230 Chang Chun Plastics Co., Ltd.	E59481(S)
2.Core	MB4	Ferrite Core PQ3230	
3.Wire	UEWE 130°C	Tai-I Electric Wire & Cable Co., Ltd.	E85640（S）
	UEW-2 130°C	Jung Shing Wire Co., Ltd.	E174837
	UEW-B 130°C	Chuen Yih wire co., Ltd.	E154709（S）
4.Varnish	BC-346A 180°C	John C Dolph Co., Ltd.	E51047（M）
	468-2FC 130°C	Ripley Resin Engineering Co., Inc.	E81777（N）
5.Tape 0.025tmm	Polyester 3M #1350 130°C	Minnesota mining ＆MFG Co., Ltd.	E17385（N）
	#31CT 130°C	Nitto Denko Corp.	E34833（M）
6.Tube	Teflon tube TFS 600V,200°C	Great Holding Industrial Co., Ltd.	E156256（S）
7.Terminals	Tin coated- Copper wire	Will Fore Special Wire Corp.	

Unit	m/m	Drawn	Check	Title	
TEL	(02)2945-0588	Ci wun Chen	Guo long Huang	IDENT#	TRN-0256
FAX	(02)2944-7647	SEN HUEI INDUSTRIAL CO.,LTD.		D W G#	I3205
No.26-1, Lane 128, Sec. 2, Singnan Rd., Jhonghe City, Taipei County 235, Taiwan (R.O.C.)					

7. Bill of Materials

Component	Qty.	Part #	Reference
JUMPER WIRE 0.8ψ(mm)	18		JP1~ JP4 JP6~JP19
Resistor 0805 0Ω+/-5%	1		JP20
Resistor 0805 39Ω+/-5%	2		R28 R29
Resistor 0805 1KΩ+/-5%	3		R24 R25 R27
Resistor 0805 14K7Ω +/-1%	1		R22
Resistor 0805 10KΩ+/-1%	2		R18 R26
Resistor 0805 20K5Ω +/-1%	1		R23
Resistor 0805 47KΩ+/-5%	1		R39
Resistor 0805 49K9Ω +/-1%	1		R11
Resistor 0805 100KΩ+/-5%	1		R38
Resistor 0805 120KΩ+/-1%	1		R10
Resistor 0805 150KΩ+/-1%	1		R9
Resistor 1206 0Ω+/-5%	1		JP5
Resistor 1206 4Ω7+/-5%	2		R30 R31
Resistor 1206 10KΩ+/-5%	2		R4 R8
Resistor 1206 47KΩ+/-5%	2		R1 R2
Resistor 1206 430KΩ+/-5%	3		R19 R20 R21
Resistor 1206 680KΩ+/-5%	6		R12~R17
NTC13ψ 2Ω SCK132	1		NTC1
Resistor 1812 0Ω022 +/-5%	2		R5 R6
0805 MLCC X7R +/-10% 102P 50V	2		C13 C14
0805 MLCC X7R +/-10% 103P 50V	3		C12 C15 C18
0805 MLCC X7R +/-10% 473P 50V	1		C19
0805 MLCC X7R +/-10% 104P 50V	1		C6
0805 MLCC X7R +/-10% 154P 25V	1		C9
0805 MLCC X7R +/-10% 222P 50V	1		C8
0805 MLCC X7R +/-10% 224P 50V	2		C10 C17
0805 MLCC X7R +/-10% 225P 25V	1		C2
0805 MLCC X7R +/-10% 683P 50V	1		C7

Bill of Materials (Continued)

Component	Qty.	Part #	Manufacturer	Reference
Ceramic Capacitor 103P 500V +80/-20%	1			C5
Electrolytic Capacitor 47µ 50V 105°C	1	LHK	JACKCON	C11
Electrolytic Capacitor 220µF 450V 105°C	2	LKP	JACKCON	C3 C4
MPP Capacitor 0.15µF 400V ±5%	1	MPP154J2G15	ALL-RISE	C1
X1 Capacitor 0.47µ 300V +/-10%	3	SX1-S474-1K300S1	SHINY	XC1 XC2 XC3
Common Mode Choke	2	TRN0197	SEN HUEI	L1 L2
Custom Inductor PQ3230 L=200µH	2	TRN0256	SEN HUEI	L3 L4
Rectifier 3A/600V DO-201AD	1	1N5406	Fairchild Semiconductor	D3
Ultra Fast Recovery Rectifier 1A/600V	1	ES1J	Fairchild Semiconductor	D1
Ultra Fast Diode 1A/1000V DO-41	1	UF 4007	Fairchild Semiconductor	D9
SMD Diode LL4148	4			D7 D8 D10 D13
Bridge 10A/600V	1	KBJ1006	CP	BD1
SMD Schottky Rectifiers 0.5A/30V SOD-123	1	MBR0530	Fairchild Semiconductor	D6
Rectifier 8A/600V TO-220F	2	FFPF08S60S	Fairchild Semiconductor	D4 D5
MOSFET N-CH 300mA/60V	1	2N7002	Fairchild Semiconductor	Q3
SMD NPN Amplifier	1	MMBT3904	Fairchild Semiconductor	Q8
SMD PNP Amplifier	2	MMBT3906	Fairchild Semiconductor	Q4 Q5
MOS 18A/500V TO-220F	2	FDPF18N50	Fairchild Semiconductor	Q1 Q2
FUSE CERAMIC 250V10A SLOW	1	37SG	SLEEK	F1
RELAY 942H-1A-12DS-T	1		BRIGHT TOWARD	RY1
WAFER(8639HS) 3-1P 3.96mm180°	3			CN1 CN2 CN3
HS 50(L)*50(H)*20(W)mm	1	MCH0597	SHUN TEH	HS1
HS 100(L)*50(H)*20(W)mm	1	MCH0598	SHUN TEH	HS2
IC FAN9611 / FAN9612 SMD	1	SOIC-16	Fairchild Semiconductor	U1
PCB FCS0390 REV 4	1		Fairchild Semiconductor	

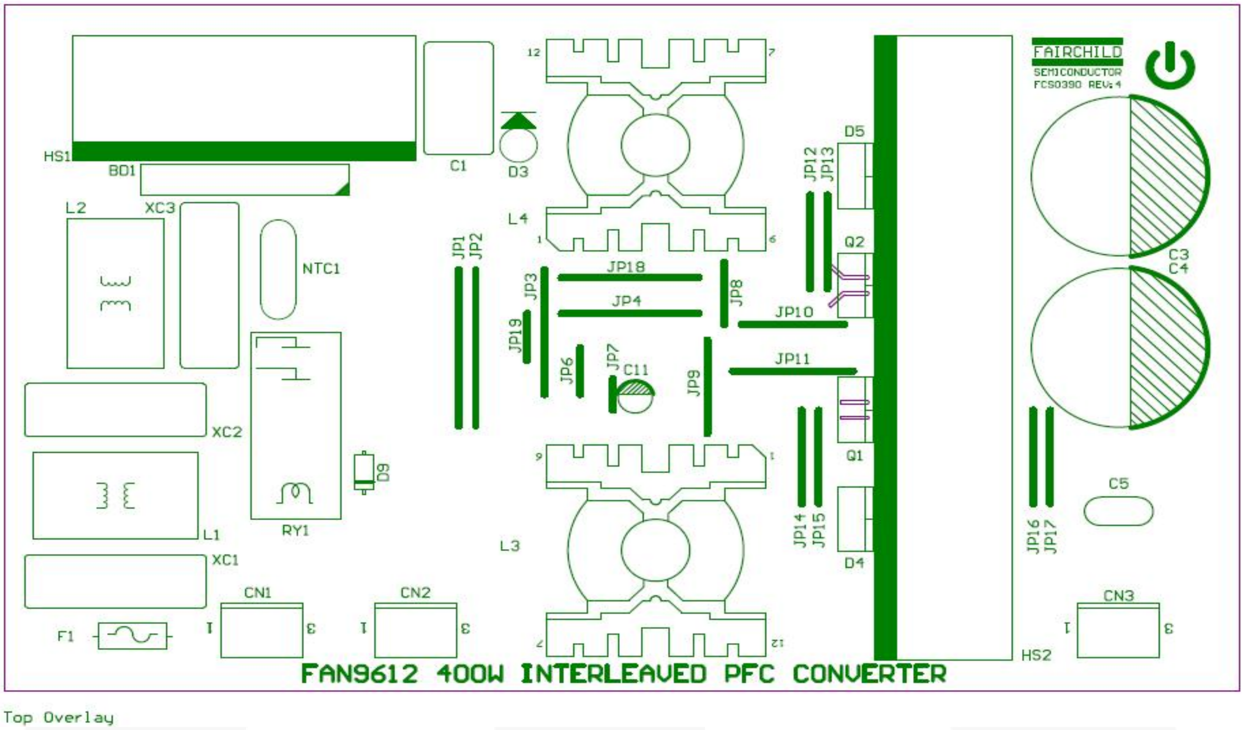


Figure 4. PCB Layout Top Overlay

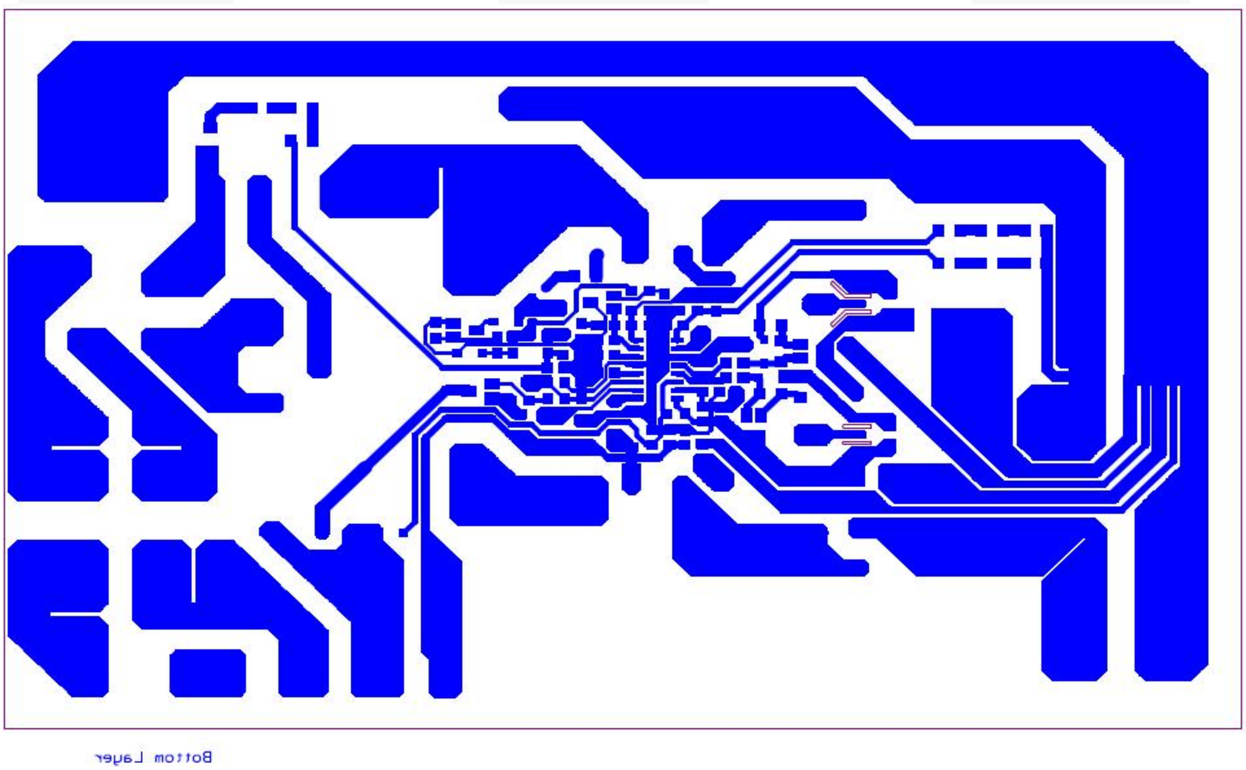


Figure 5. PCB Layout Bottom Layer

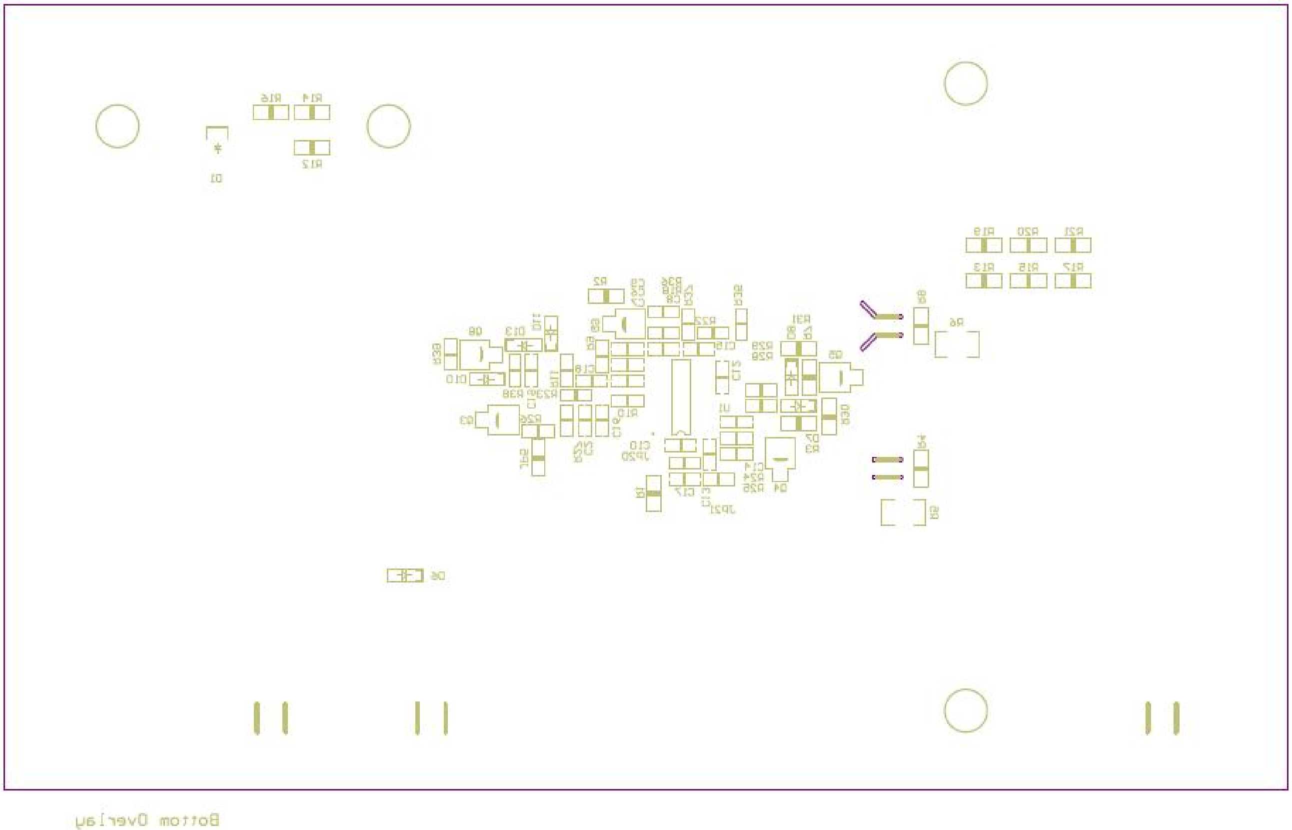


Figure 6. PCB Layout Bottom Overlay

8. Test Results

8.1. Startup

Test Condition: 115V_{AC} / 60Hz, 230V_{AC} / 50Hz, no load and full load.

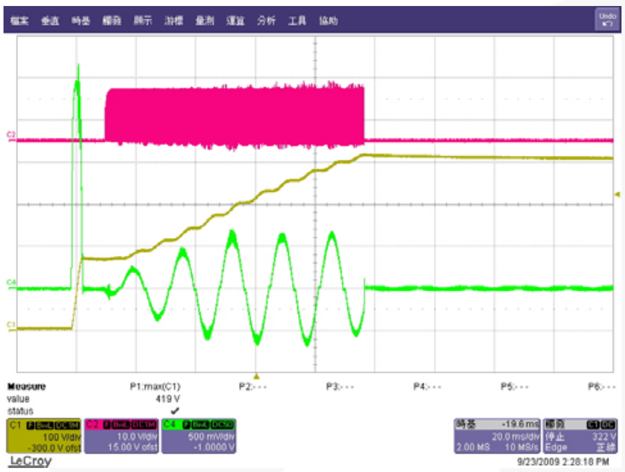


Figure 7. 115V_{AC} / 60Hz No Load

Figure 8. 115V_{AC} / 60Hz Full Load

Note:

2. Only 29V overshoot is observed (7.44% of nominal output voltage) for no-load startup and only 18V (4.62% of normal output voltage) overshoot is observed for full-load startup.

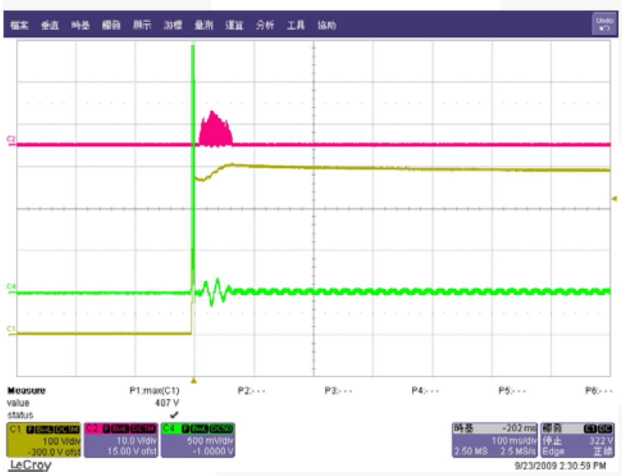


Figure 9. 230V_{AC}/50Hz No Load

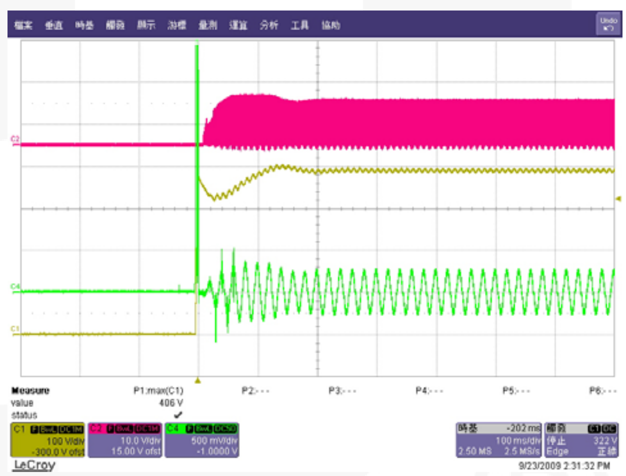


Figure 10. 230V_{AC}/50Hz Full Load

Note:

3. Only 17V overshoot is observed (4.36% of nominal output voltage) for no-load startup and only 18V (4.62% of normal output voltage) overshoot is observed for full-load startup.

8.2. Normal Operation

Test Condition: Inductor current of 115V_{AC} / 60Hz, 230V_{AC} / 50Hz full load.

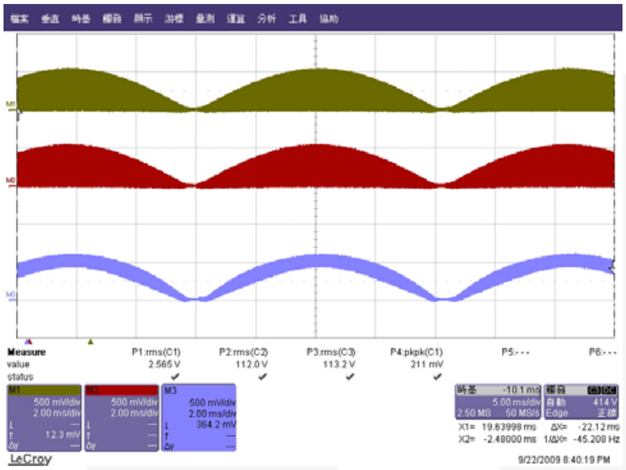


Figure 11.115V_{AC} / 60Hz Full Load

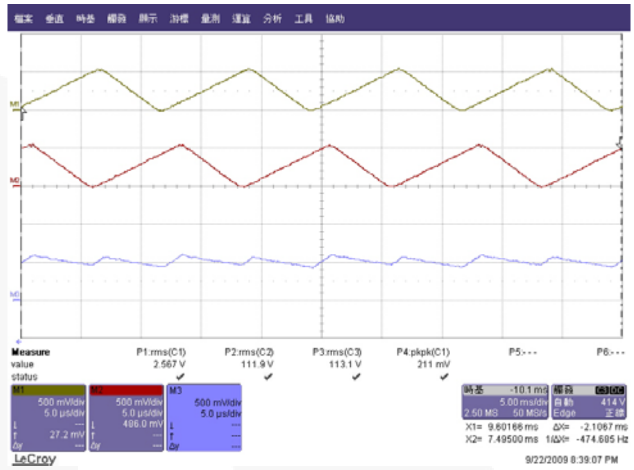


Figure 12.115V_{AC} / 60Hz Full Load

Note:

4. Figure 11 and Figure 12 show the two inductor currents and the sum of two inductor currents at 115V_{AC} line voltage and full-load conditions. The sum of the inductor currents has relatively small ripple due to the ripple cancellation of interleaving operation.

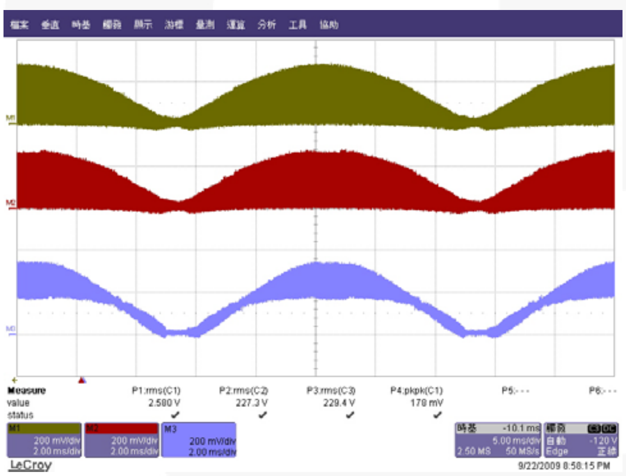


Figure 13.230V_{AC} / 50Hz Full Load

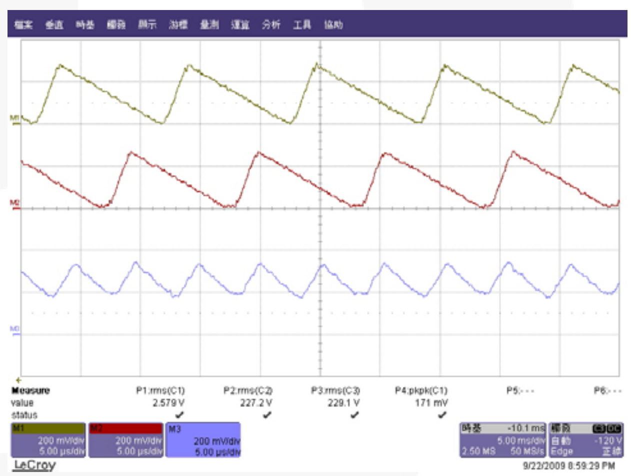


Figure 14.230V_{AC} / 50Hz Full Load

Note:

5. Figure 13 and Figure 14 show the two inductor currents and the sum of two inductor currents at 230V_{AC} line voltage and full-load conditions. The sum of the inductor currents has relatively small ripple due to the ripple cancellation of interleaving operation.

8.3. Line and Load Transient

Test Condition: 115V_{AC} to 230V_{AC} full load transient and 230V_{AC} load transient.

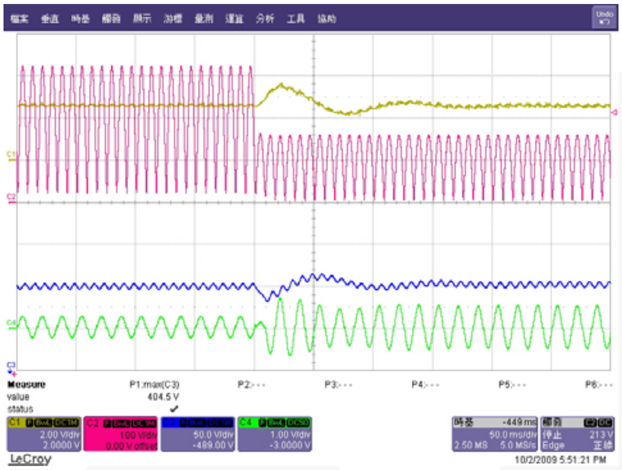


Figure 15.230V_{AC} to 115V_{AC} Line Transient

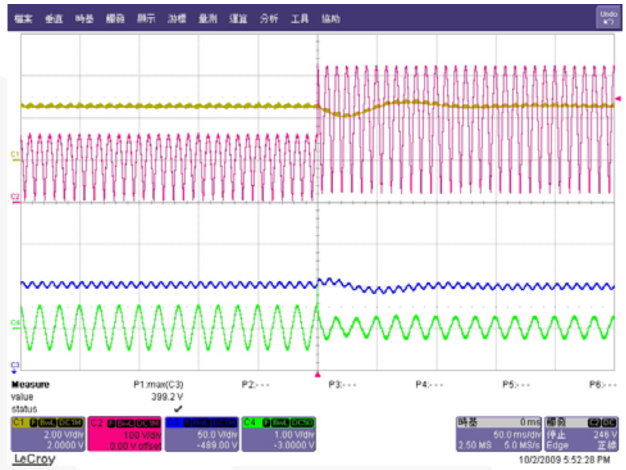


Figure 16.115V_{AC} to 230V_{AC} Line Transient

Note:

6. Figure 15 and Figure 16 show the line transient operation and minimal effect on the output voltage due to the line feed forward function. When the line voltage changes from 230V_{AC} to 115V_{AC}, 14.5V (3.72% of nominal output voltage) voltage undershoot is observed. When the line voltage changes from 115V_{AC} to 230V_{AC}, almost no voltage undershoot is observed.

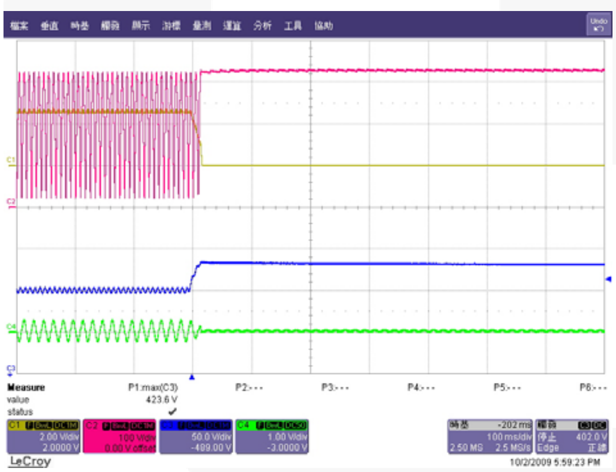


Figure 17.230V_{AC} 100% to 0% Line Transient

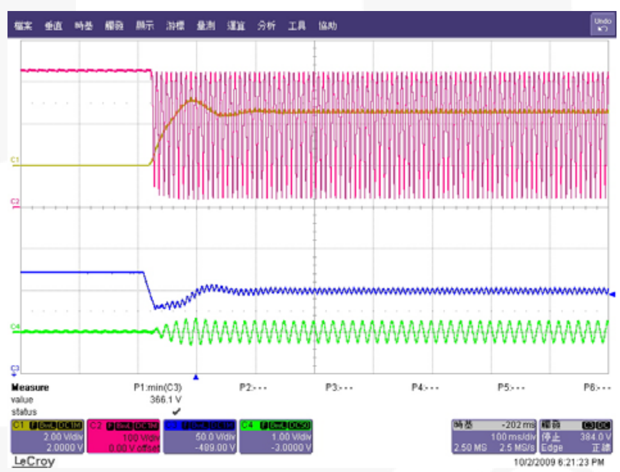


Figure 18.230V_{AC} 0% to 100% Line Transient

Note:

7. Figure 17 and Figure 18 show the load-transient operation. When the output load changes from 100% to 0%, 23.6V (6.1% of nominal output voltage) voltage overshoot is observed. When the output load changes from 0% to 100%, 23.9V (6.13% of nominal output voltage) voltage undershoot is observed.

8.4. Brown in/out Protection

Test Condition: startup and shutdown when slowly increasing and decreasing the line voltage.

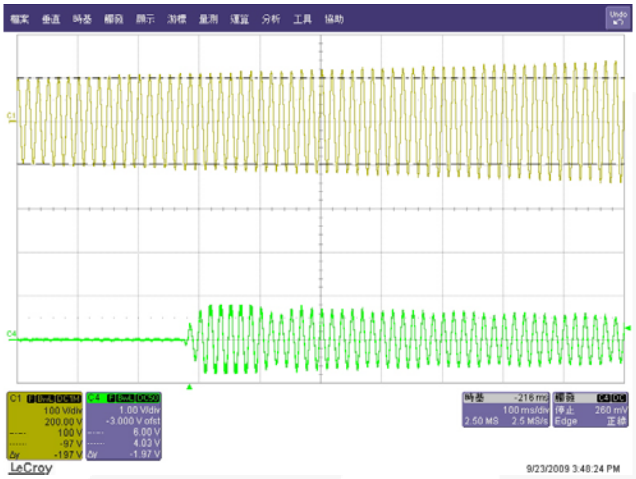


Figure 19.Brownin

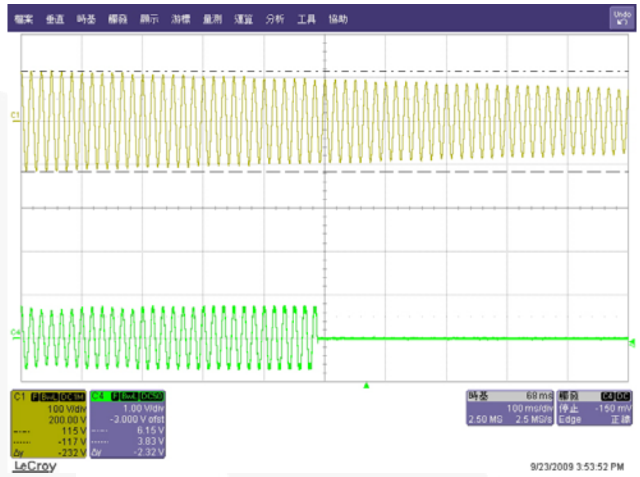


Figure 20.Brownout

Note:

8. Figure 19 and Figure 20 show the startup and shutdown operation at slowly increasing and decreasing line voltage, respectively. The power supply starts when the line voltage reaches around 80V_{AC} and shuts down when line voltage drops below 70V_{AC}.

8.5. Phase Management

Test Condition: Change the output load to observe the phase shedding and adding.

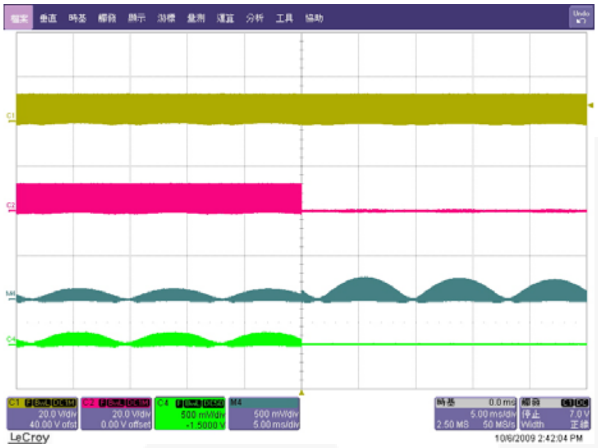


Figure 21. Phase-Shedding

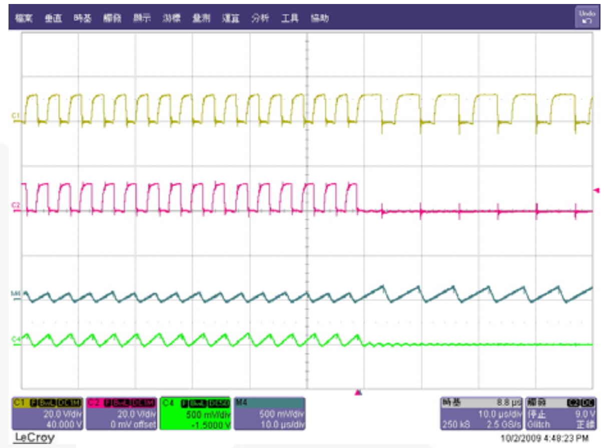


Figure 22. Zoom-In

Note:

9. Figure 21 and Figure 22 show the phase-shedding waveforms. The duty cycle of the channel 1 gate drive signal is doubled when the other channel gate drive signal is disabled to minimize the line current glitch.

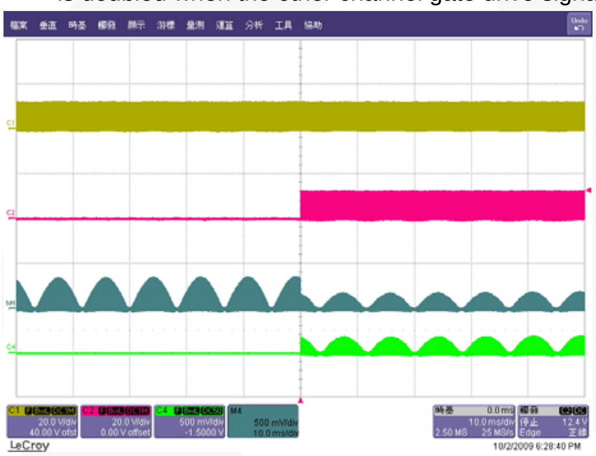


Figure 23. Phase-Adding

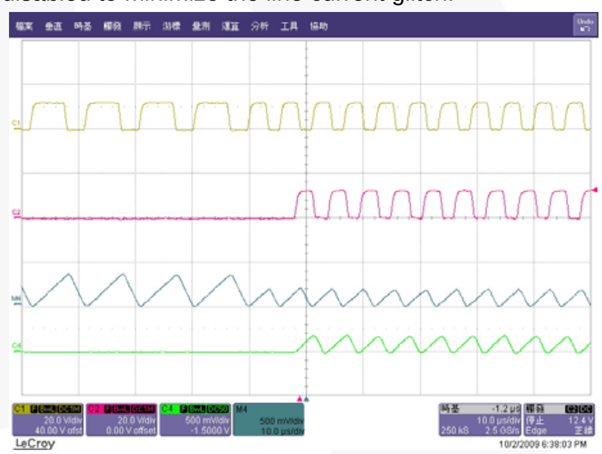


Figure 24. Zoom-In

Note:

10. Figure 23 and Figure 24 show the phase-adding waveforms. The duty cycle of Channel 1 gate drive signal becomes half just before the other channel gate drive signal is enabled to minimize the line current glitch.

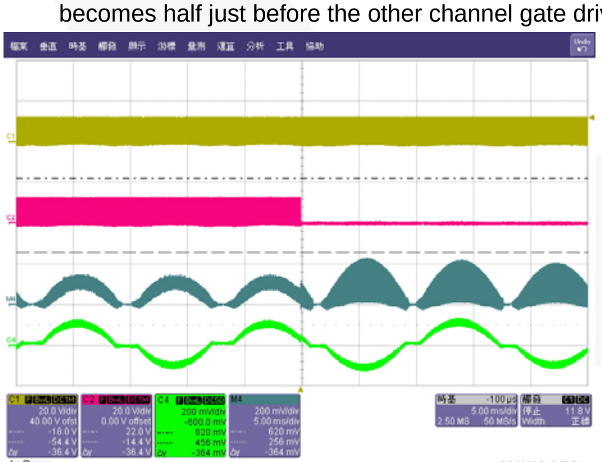


Figure 25. Phase-Shedding and Line Current

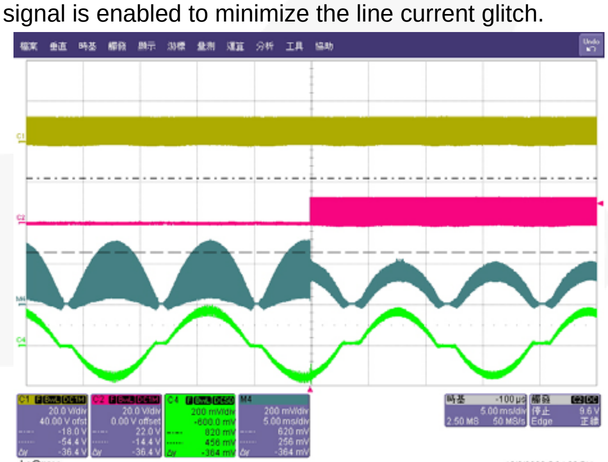


Figure 26. Phase-Adding and Line Current

Note:

11. Figure 25 and Figure 26 show the sum of two-inductor current and line current for phase shedding and adding, respectively. As shown, the phase management causes no visible change in the line current waveforms.

8.6. Efficiency

Test Condition: 115V$_{AC}$ / 60Hz and 230V$_{AC}$ / 50Hz efficiency.

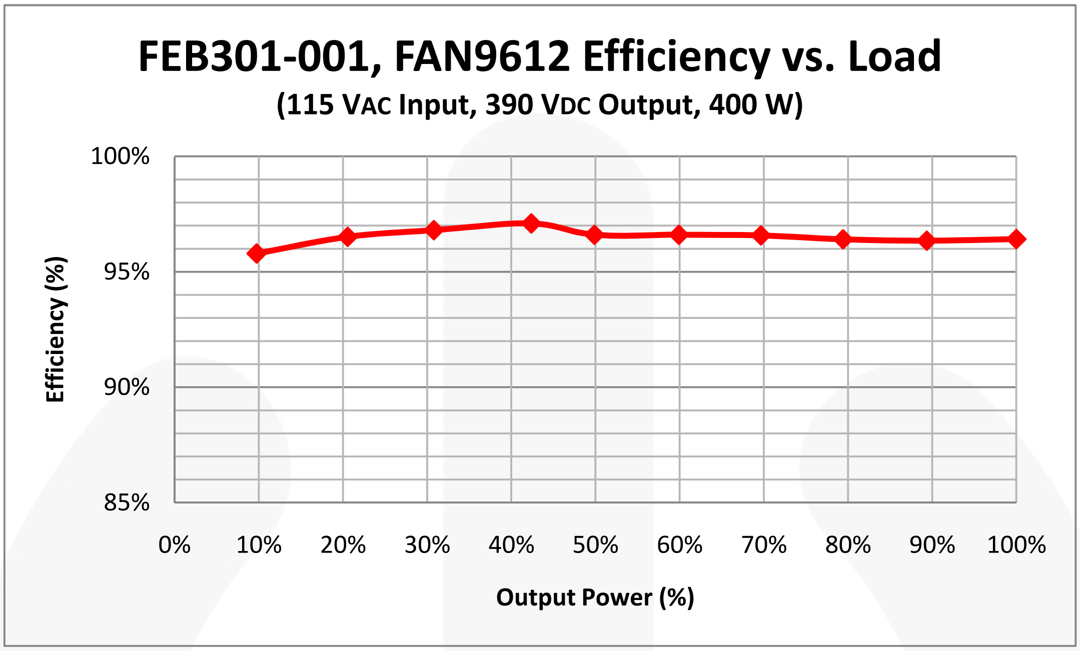


Figure 27.115V$_{AC}$ / 60Hz Efficiency vs. Load

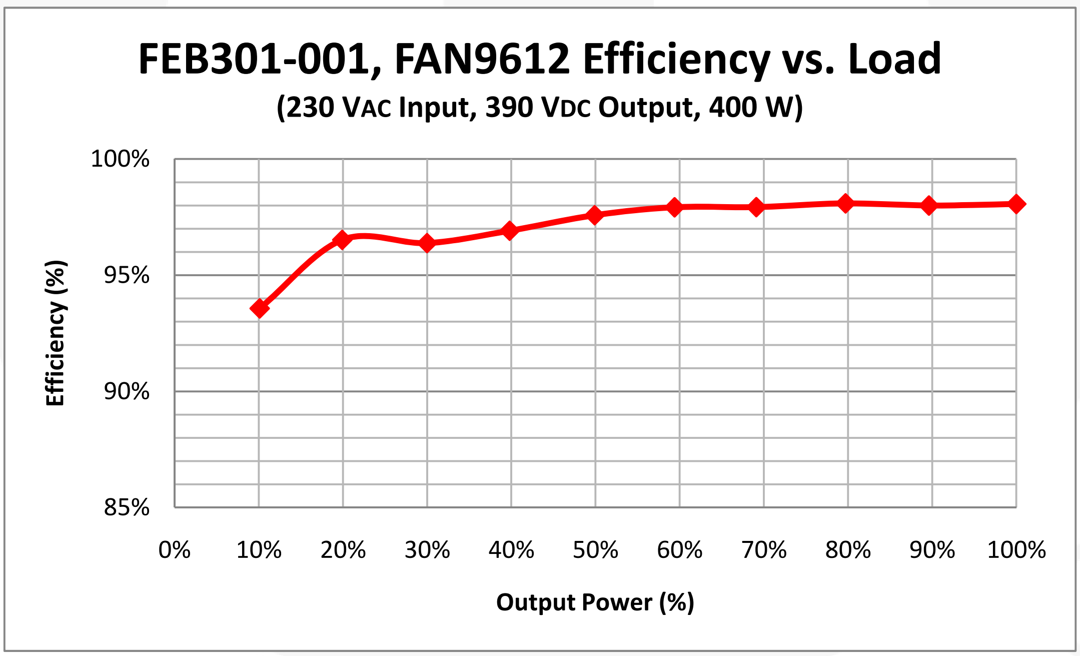


Figure 28.230V$_{AC}$ / 50Hz Efficiency vs. Load

Note:

12. Figure 27 and Figure 28 show the measured efficiency of the evaluation board at input voltages of 115V$_{AC}$ and 230V, respectively. Since phase shedding reduces the switching loss by effectively decreasing the switching frequency at light-load, a greater efficiency improvement is achieved at high line where switching losses are greater. Relatively less improvement is obtained for low line since the MOSFET is turned on with zero voltage and switching losses are negligible.

8.7. Harmonic Distortion and Power Factor

Test Condition: Measure the harmonic and power factor at 115V_{AC} / 60Hz and 230V_{AC} / 50Hz output full load.

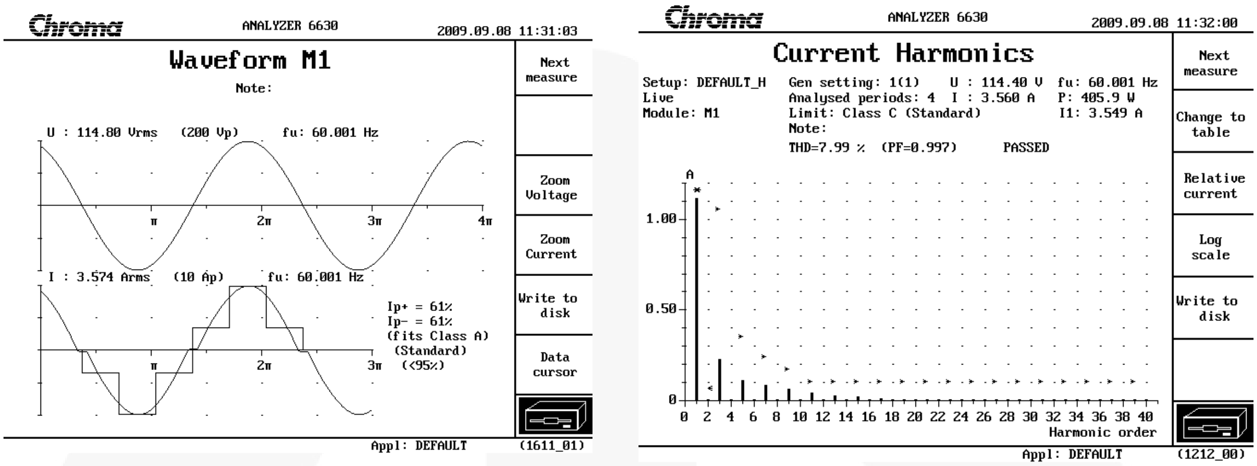


Figure 29. 115V_{AC}/60Hz, Output Full Load

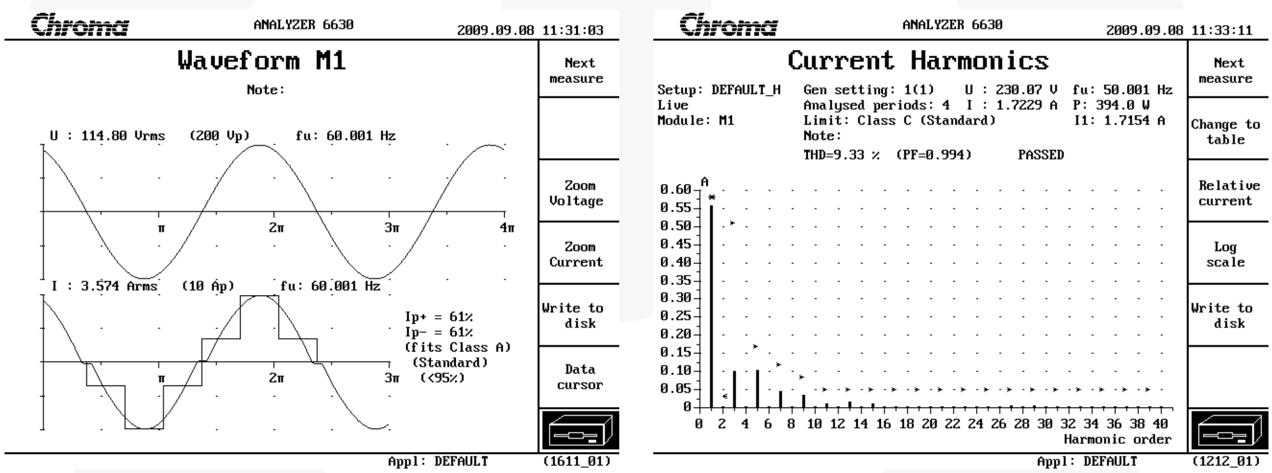


Figure 30.230V_{AC} / 50Hz, Output Full Load

Note:

13. To compare the measured harmonic current with EN61000 class D and C, respectively, at input voltage of 115V_{AC} and 230V_{AC}. Class D is applied to TV and PC power, while Class C is applied to lighting applications. As can be observed, both regulations are met with sufficient margin.

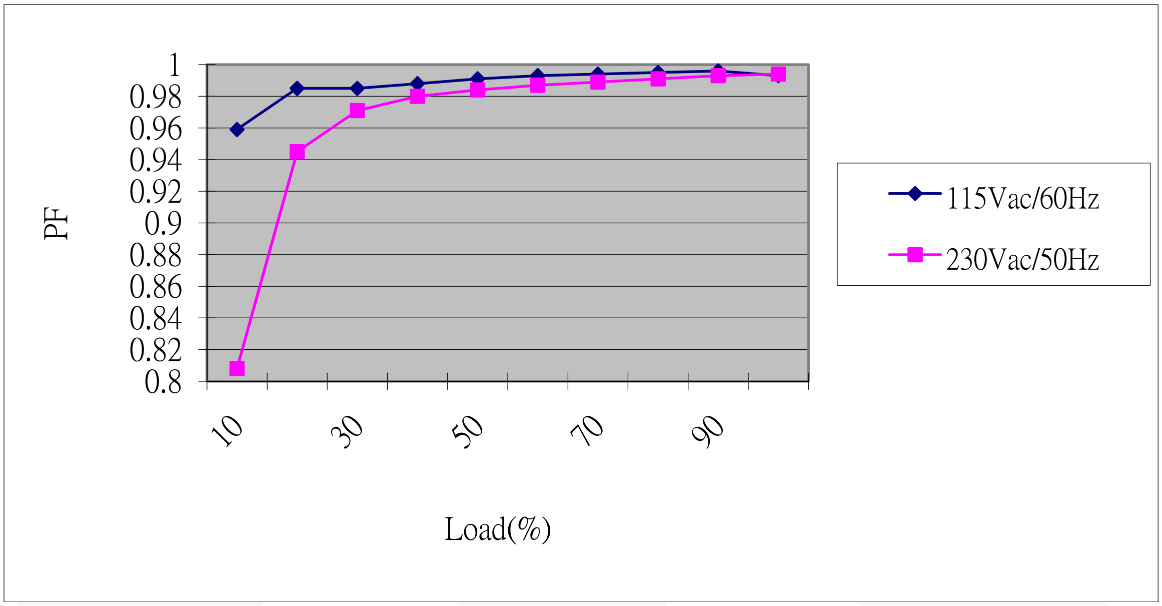


Figure 31. Measured Power Factor

Table 2. Total Harmonic Distortion at Input Voltage of 115V$_{AC}$ and 230V$_{AC}$

	50%	75%	100%
115V$_{AC}$ / 60Hz	12.88	9.91	7.99
230V$_{AC}$ / 50Hz	13.06	11.47	9.33

9. References

FAN9611 / FAN9612 — Interleaved Dual BCM PFC Controller

AN-6086 — Design Consideration for Interleaved Boundary Conduction Mode (BCM) PFC Using FAN9611 / FAN9612

AN-8018 — FAN9611 / FAN9612 400W Interleaved Dual-BCM PFC Controller Evaluation Board User Guide