User Guide for

FEBFAN9673Q_B1H5000A Evaluation Board

5 kW Three-Channel CCM PFC with 12 V_{SB} Module Evaluation Board

Featured Fairchild Product: FAN9673Q

Direct questions or comments about this evaluation board to: "Worldwide Direct Support"

Fairchild Semiconductor.com

Table of Contents

This user guide supports the 5000 W evaluation board for a three-channel CCM PFC using the FAN9673. It should be used in conjunction with the FAN9673 datasheet as well as Fairchild's application notes and technical support team. Please visit Fairchild's website at www.fairchildsemi.com/.

1. Introduction

The FAN9673 is a 32-pin, Continuous Conduction Mode (CCM) Power Factor Correction (PFC) controller IC intended for PFC pre-regulators. The FAN9673 includes average current and boost-type power factor correction, which results in a power supply that fully complies with the IEC1000-3-2 specification. A TriFault Detect™ function helps reduce external components and provides full protection for feedback loops, such as over voltage. An over-voltage comparator shuts down the PFC stage in the event of a sudden load decrease. The RDY signal can be used for power-on sequence control. The Channel Management (CM) function can enable / disable the each channel independently. The FAN9673 also includes PFC soft-start, peak current limiting, and input voltage brown-in/out protection.

1.1. Features

- Continuous Conduction Mode Control
- Maximum Three-Channel PFC Control
- Average Current Mode Control
- PFC Slave Channels External Signal / Channel Management Function Control
- Programmable Operation Frequency Range: 18 kHz~40 kHz or 55 kHz~75 kHz
- Programmable PFC Output Voltage
- Two Types of Current Limit
- TriFault Detect™ Protects Against Feedback Loop Failure
- SAG Protection
- Programmable Soft Start
- Under-Voltage Lockout (UVLO)
- Differential Current Sensing
- Available in 32-Pin LQFP Package

2. Evaluation Board Specifications

All data for this table was measured at an ambient temperature of 25°C.

Table 1. Summary of Features and Performance

Description	Symbol	Value	Comments
Output Power	P_O	5 kW	
Efficiency	Eff, η	>95%	
Input Voltage	V_{AC}	180~264 V	
Input Frequency		47~63 Hz	
Output Voltage	V_{OUT}, V_{PFC}	393 V	V_{PVO}=0 V
Brown In / Out Voltage	V_{AC}	170 V / 155 V	
PFC Frequency	f_{SW}	40 kHz	
PFC RDY	V_{RDY}	2.4 V / 1.55 V (96% / 62% of V_{PFC})	

3. Photograph

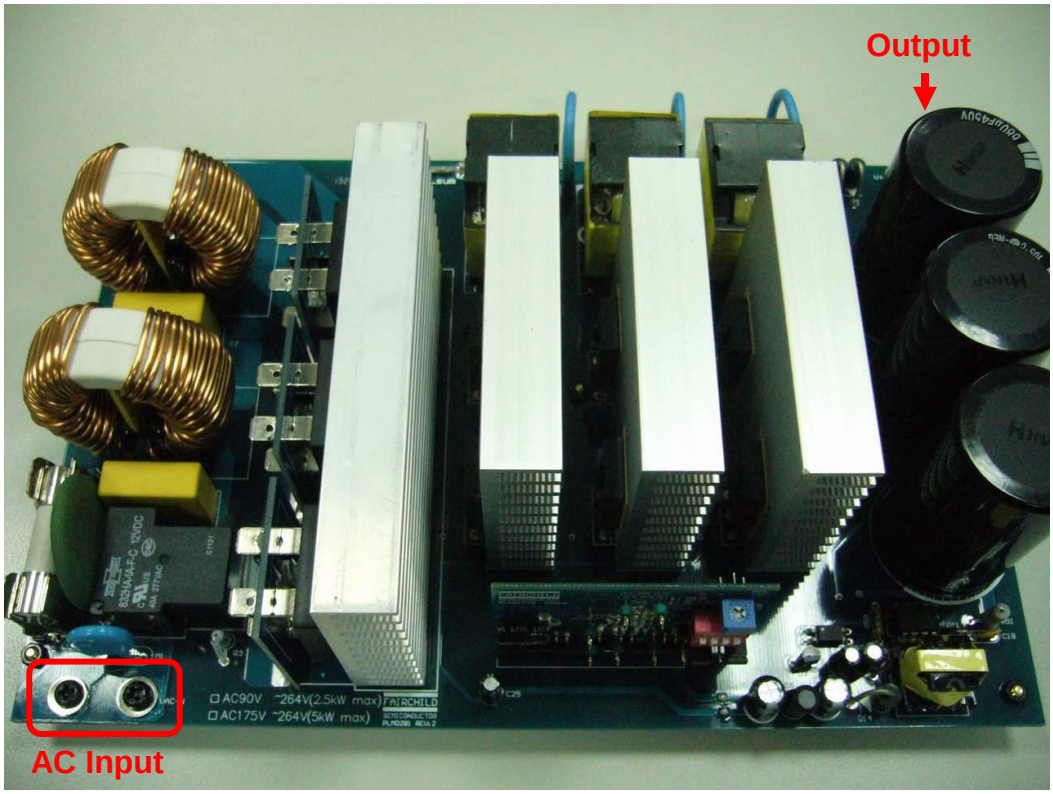


Figure 1. Top View of Evaluation Board

4. Printed Circuit Board

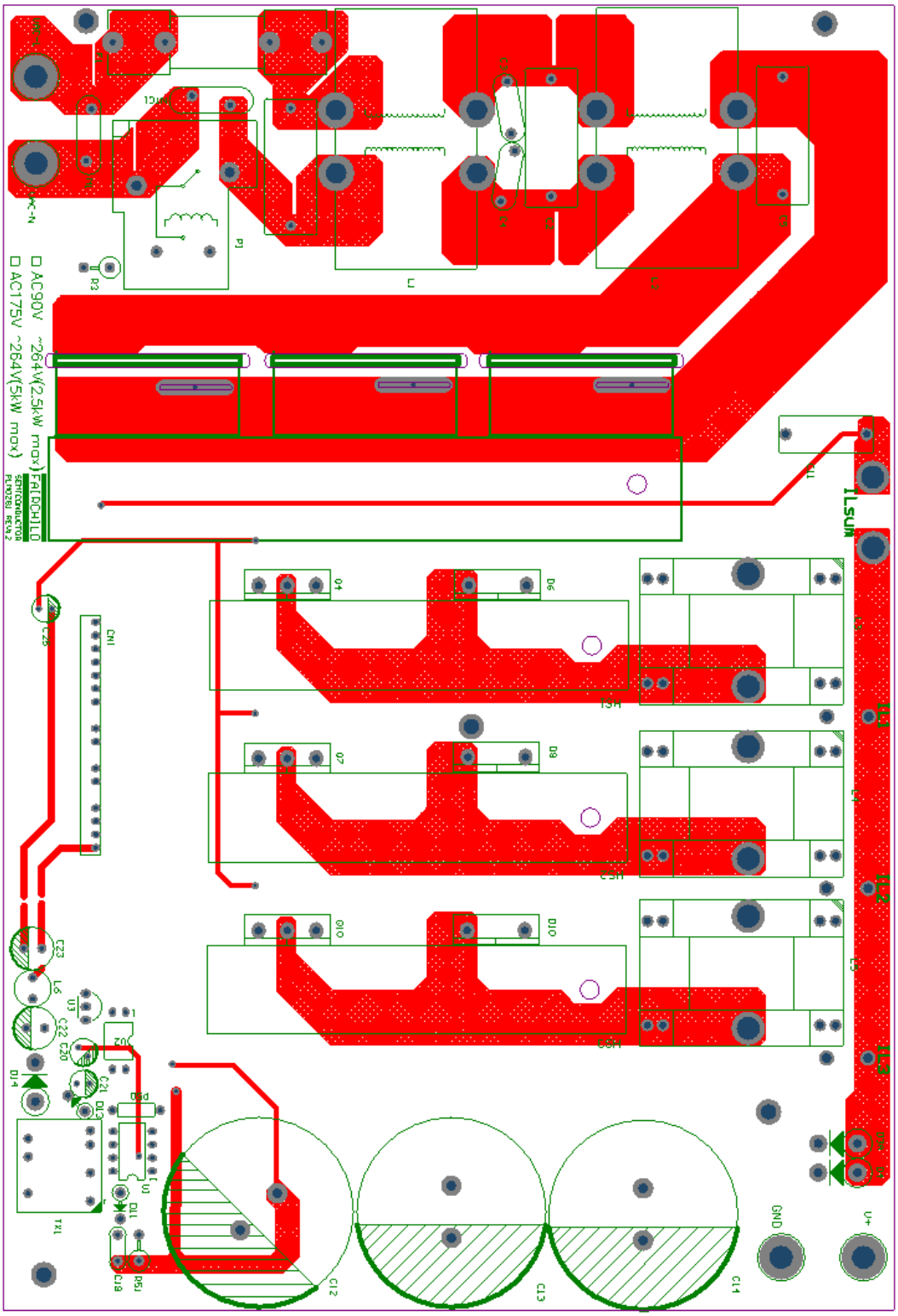


Figure 2. Top Side of Evaluation Board

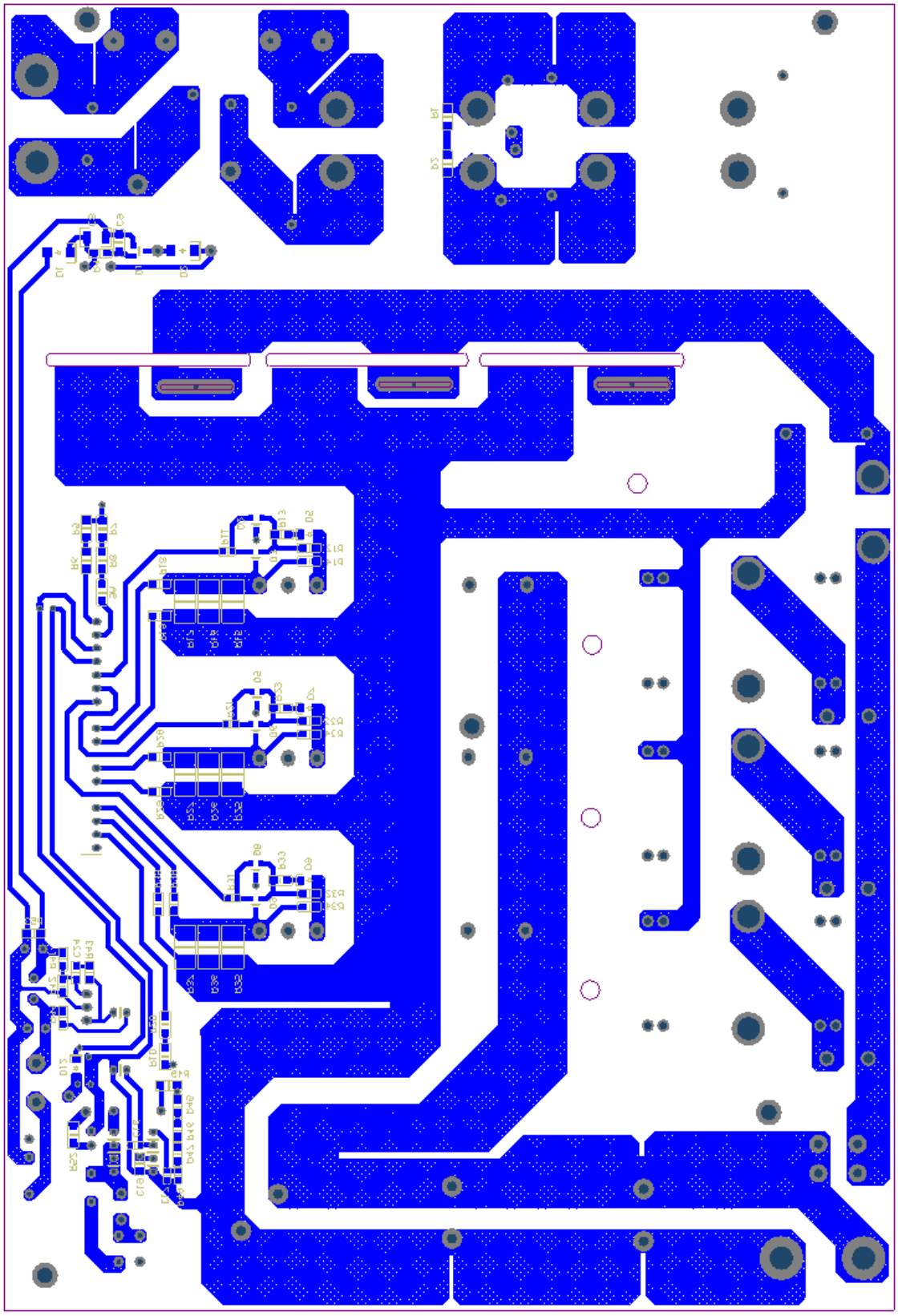


Figure 3. Bottom Side of Evaluation Board

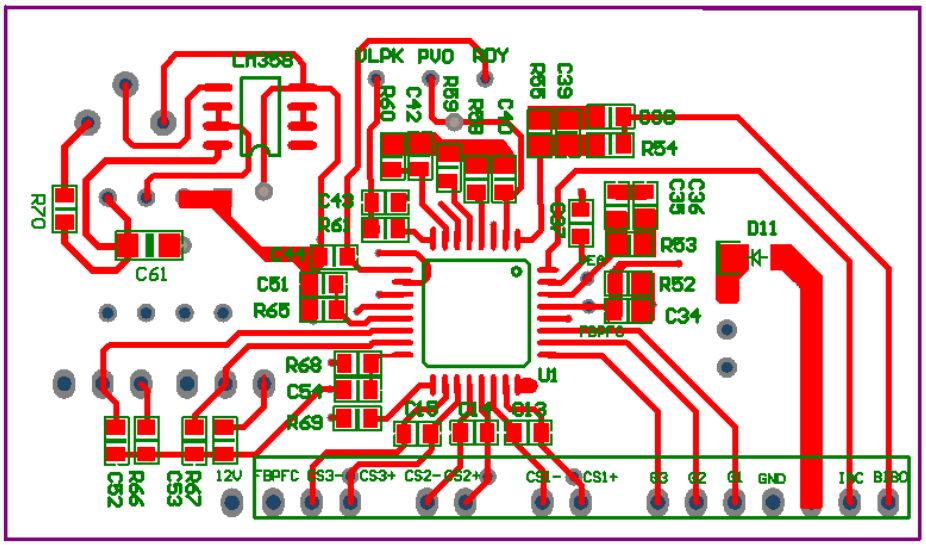


Figure 4. Top Side of Daughter Card

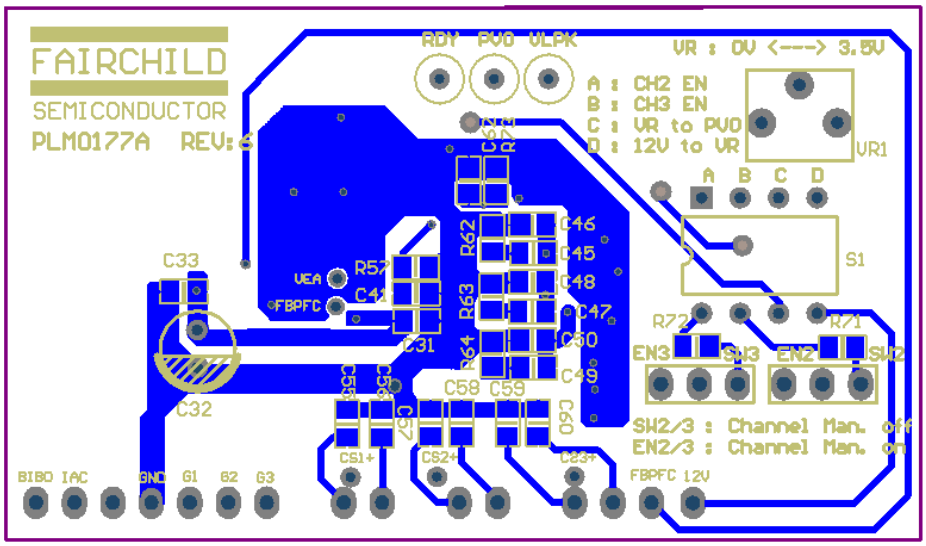


Figure 5. Bottom Side of Daughter Card

5. Schematic

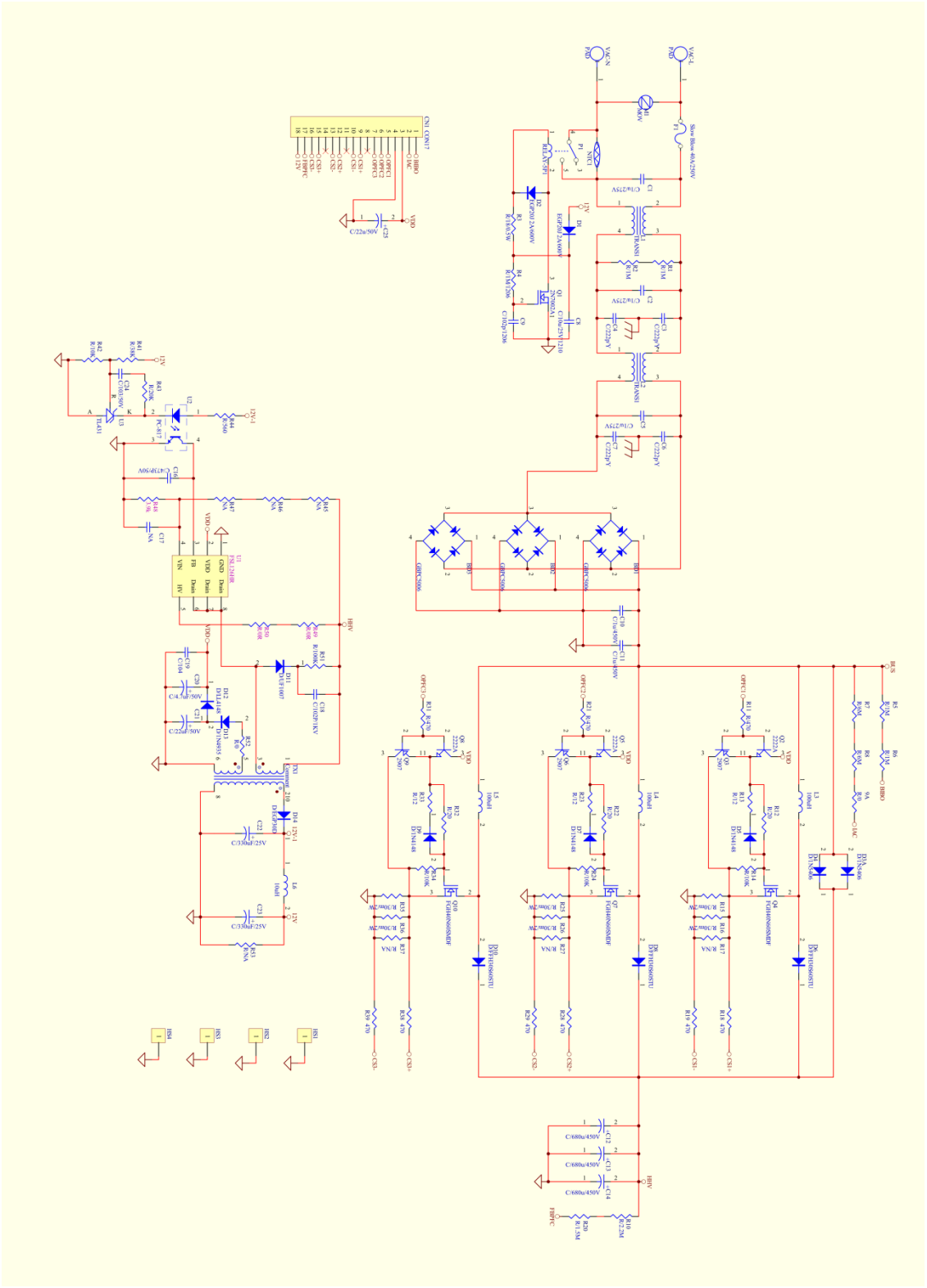


Figure 6. Evaluation Board Schematic

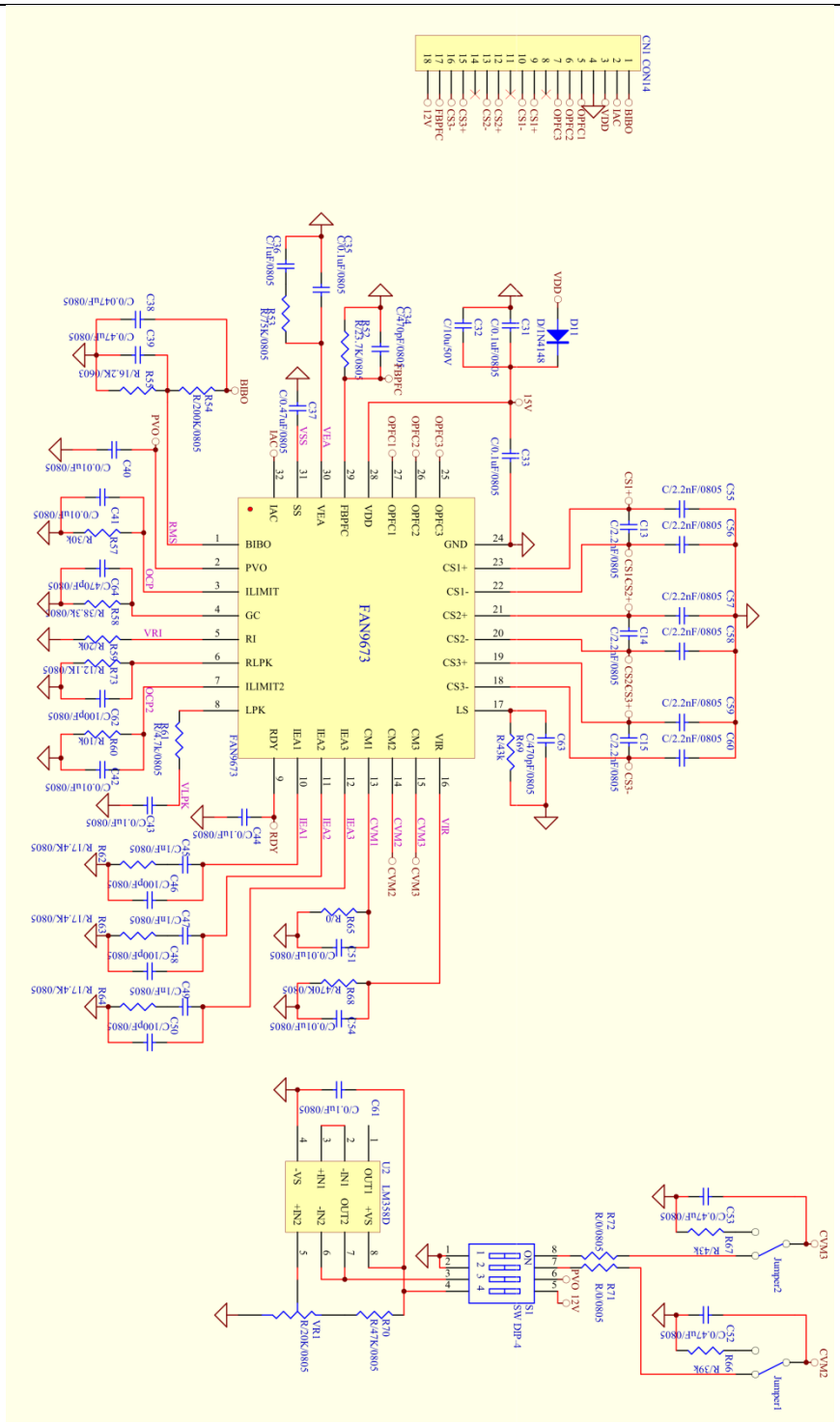


Figure 7. Daughter Card Schematic

6. Bill of Materials

Main Board (PLM281 REV.2)					
Reference	**Qty.**	**Part Number**	**Value**	**Description**	**Manufacturer**
BD1, BD2, BD3	3	GBPC5006			
PLM0276AV0 x3	3			Transfer Card for Bridge	
C1, C2, C5	3		1 µF / 275 V		
C10	1		1 µF / 450 V		
C12, C13, C14	3		680 µF / 450 V		
C16	1		47 nF / 50 V		
C18	1		1 nF / 1 kV		
C19	1		0.1 µF		
C20	1		4.7 µF / 50 V		
C21, C25	2		22 µF/ 50 V		
C22, C23	2		330 µF / 25 V		
C24	1		10 nF / 50 V		
C3, C4	2		2.2 pF / 250 V		
C8	1		10 µF / 25 V		
C9	1		1 nF / 1 kV		
CN1	1			CON18	
D1, D2	2	S1J			
D11	1	UF1007			
D13	1	1N4935			Fairchild
D14	1	EGP30D			
D3, D4	2	1N5406			Fairchild
D5, D7, D9, D12	4	1N4148			
D6, D8, D10	3	FFH30S60STU			Fairchild
F1	1	Slow Blow Fuse	40 A / 250 V		
HS1	1	H-sink			
HS2, HS3, HS4	3	H-sink			
L1, L2	2	FS4015H-2LB		EMI	FORMOSA SHING GA ENTERPRISE CO., LTE.
L3, L4, L5	3	Core Type: QP3925H	100 µH		
L6	1		10 µH		
M1	1		MOV		
Q1	1	2N7002A			
Q2, Q5, Q8	3	2222A			
Q3, Q6, Q9	3	2907			
Q4, Q7, Q10	3	FGH40N60SMDF			Fairchild
R1, R2, R4, R5, R6	5		1 MΩ		
R11, R21, R31	3		470 Ω		
R12, R22, R32	3		20 Ω		

Main Board (PLM281 REV.2)					
Reference	**Qty.**	**Part Number**	**Value**	**Description**	**Manufacturer**
R13, R23, R33	3		12 Ω		
R14, R24, R34, R42	4		10 kΩ		
R15, R16, R25, R26, R35, R36	6		30 mΩ / 2 W		
R18, R19, R28, R29, R38, R39	6		470 Ω		
R20	1		1.5 MΩ		
R3	1		20 Ω		
R41	1		38.3 kΩ		
R43	1		20 kΩ		
R44	1		560 Ω		
R48	1		3.9 kΩ		
R49, R50, R52	3		0 Ω		
R51	1		100 kΩ		
R7	1		5.1 MΩ		
R8	1		4.7 MΩ		
R9A, R10	2		2.2 MΩ		
Relay1	1	Power Relay	40 A		
TX1	1	750342371		12 V_{SB} Transformer	Würth Elektronik
U1	1	FSL126HR		Controller	Fairchild
U2	1	PC-817			
U3	1	TL431			

Daughter Card (PLM0177A REV.6)					
Reference	**Qty.**	**Part Number**	**Value**	**Description**	**Manufacturer**
C35, C40, C41, C42, C51, C54	6	SMD 0805	0.01 µF		
C38	1	SMD 0805	0.047 µF		
C31, C33, C43, C44, C61	5	SMD 0805	0.1 µF		
C36, C37, C39, C52, C53	5	SMD 0805	0.47 µF		
C45, C47, C49	3	SMD 0805	1.2 nF		
C46, C48, C50, C62	4	SMD 0805	100 pF		
C32	1		10 µ / 50 V		
C13, C14, C15	3	SMD 0805	2.2 nF		
C55, C56, C57, C58, C59, C60	6	SMD 0805	2.2 nF		
C34, C63, C64	1	SMD 0805	470 pF		
CN1	1			CON14	
D11	1		1N4148		

Daughter Card (PLM0177A REV.6)					
Reference	**Qty.**	**Part Number**	**Value**	**Description**	**Manufacturer**
U1	1	FAN9673		Controller	Fairchild
U2	1	LM358D			Fairchild
R56, R65, R72, R71	4	SMD 0805	0 Ω		
R60	1	SMD 0805	10 kΩ		
R73	1	SMD 0805	12.1 kΩ		
R55	1	SMD 0603	16.2 kΩ		
R62, R63, R64	3	SMD 0805	17.4 kΩ		
R69	1	SMD 0805	43 kΩ		
R54	1	SMD 0805	200 kΩ		
R59	1	SMD 0805	20 kΩ		
VR1	1	SMD 0805	20 kΩ		
R52	1	SMD 0805	23.7 kΩ		
R57	1	SMD 0805	30 kΩ		
R58	1	SMD 0805	38.3 kΩ		
R61	1	SMD 0805	4.7 kΩ		
R68	1	SMD 0805	470 kΩ		
R66, R67, R70	3	SMD 0805	47 kΩ		
R53	1	SMD 0805	75 kΩ		
S1	1	DIP-4		Switch	

7. Transformer and Winding Specifications

7.1. TX2 Specification

- Core: EE-16 (3C94)
- Bobbin: 10 Pins

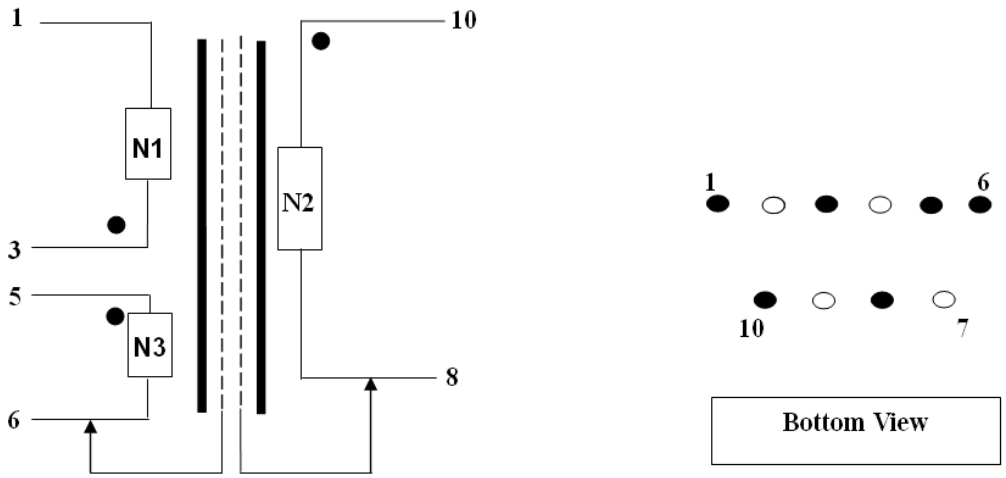


Figure 8. Transformer Specifications & Construction

Table 2. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	N1	3 → 2	0.29φ×1	36	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
3	N2	10 → 8	0.35φ×3	10	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
5	N1	2 → 1	0.29φ×1	18	Solenoid Winding
6	Insulation: Polyester Tape t = 0.025 mm, 6-Layer				
7	N3	5 → 6	0.15φ×1	13	Solenoid Winding
8	Insulation: Polyester Tape t = 0.025 mm, 3-Layer				
9	Copper-Foil 1.2T to PIN6				

Table 3. Electrical Characteristics

	Pins	Specifications
Inductance	3 - 1	800 μH ±5%

7.2. L1 & L2 Specification

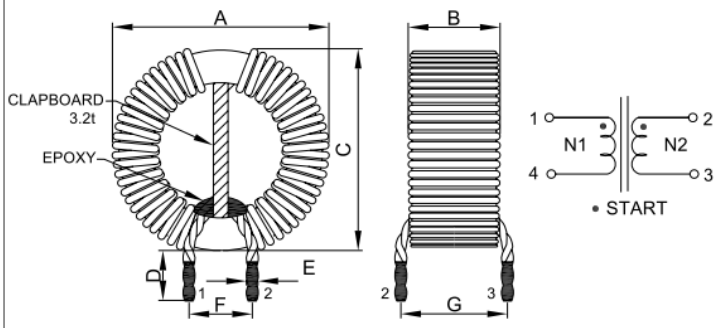
FORMOSA SHING GA ENTERPRISE CO., LTD.

MAGNETIC CORES SINCE 1987.

SPECIFICATION FOR PRODUCTS

CUST	FAIRCHILD	OUT DWG NO.	
ITEM	SN-403215-A	DATE	2014/06/16
PART NO.		REV:A2	

1.SCHEMATIC DIMENSION:



SPEC.(mm)	
A	53.0 MAX
B	27.0 MAX
C	49.0 MAX
D	10.0±1.0
E	4.0 MAX
F	10.0 REF
G	24.0 REF

***Vacuum Varnish Processed**

2.WINDING & ELECTRONICS: (150kHz 0.1V)30℃

ITEM	START	FINISH	MATERIAL	TURNS	COLOR	INDUCTANCE	DCR(mΩ)
N1	1	4	2UEW Φ1.6*2P	16TS	N	1.0mH MIN	/
N2	2	3	2UEW Φ1.6*2P	16TS	N	1.0mH MIN	/

3.TEST INSTRUMENTS: L.C.R.CH-1062;502B

4.MATERIAL LIST:

NO	ITEM	MATERIAL	SUPPLIER	UL NO.	CLASS
1	CORE	SN403215-A	FORMOSA SHING GA ENTERPRISE CO., LTD.		
2	WIRE	2UEW	PACIFIC ELECTRIC WIRE&CABLE CO.,LTD.	E201757	130℃
3	EPOXY	G-9008	GUDAK CHEMISTRY TECH.(D.G)LTD	E218090	90℃
4	CLAPBOARD	FR-4	HUIZHOU JIANYONG INSULATED PRODUCT CO.,LTD	E123995	130℃
5	MYLAR TAPE	CT-280	HUIZHOU YAHUA STICKING TAPE CO.,LTD	E165111	
6	VARNISH	V1630FS	ELANTAS ELECTRICAL INSULATION ELANTAS PDG INC	E75225	

CUSTOMER	APPROVAL	CHECKED	DRAWN
	AI-PING	STEVEN CHANG	SANDY CHEN

■TEL：886-2-87875958 ■FAX：886-2-87875969 ■E-MAIL：philip01@ms2.hinet.net

7.3. L3, L4, & L5 Specification

- Core: QP3925H (3C94)
- Bobbin: 7 Pins

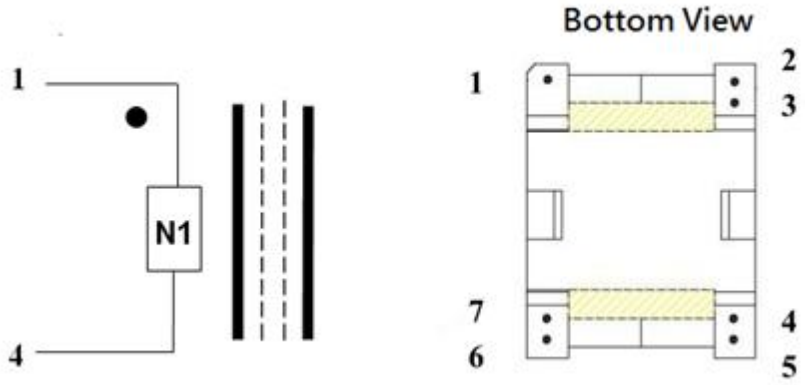


Figure 9. Transformer Specifications & Construction

Table 4. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	N1	1 → 6, 7	0.2φ×35 *1	25	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025 mm, 2-Layer				
3	Copper-Foil 1.2T to PIN4, 5				

Table 5. Electrical Characteristics

	Pin	Specifications
Inductance	1 → 6, 7	100 μH ± 5%

7.4. L11 Specification

- Core: Ferrite core DRWW 6x10(6ψ*10 mm)
- Bobbin: 2 Pins

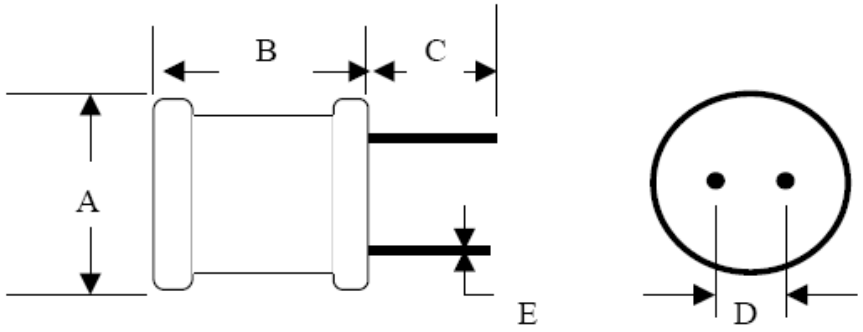


Figure 10. Transformer Specifications & Construction

Table 6. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	N1	1 → 2	0.55 mm	18	Solenoid Winding
2	Ferrite core DRWW 6x10 (6ψ*10 mm)				

Table 7. Electrical Characteristics

	Pin	Specifications
Inductance	1 - 2	10 μH ± 5%

8. Test Conditions & Test Equipment

8.1. Features

Table 8. Test Conditions & Test Equipment

Test Mode	FEBFAN9673Q_B1H5000A
Test Date	Nov.4, 2013
Test Temperature	Ambient 25°C
Test Equipment	AC Source: EXTECH 6220 AC/DC Electronic Load: Chroma 63020 Power Meter: HIOKI 3390 Oscilloscope: Lecroy Wavesurfer 424
Test Items	1. AC Trim Up & Trim Down 2. PFC ON/OFF & RDY 3. Ripple & Noise 4. Efficiency 5. Current Harmonic

8.2. Test Procedure

Before powering up the board, verify that the AC voltage source is connected to line input terminals on the evaluation board and the AC-DC electronic load is connected to the PFC output.

1. Set the electronic load to no-load or light-load condition and apply the AC voltage across the input of the evaluation board.
2. When the AC voltage (180~264 V_{AC}) is supplied to the board, the FAN9673 begins normal operation and the on-board flyback converter provides the 12 V_{SB} output. The Flyback transformer's auxiliary winding supplies the V_{DD} voltage for the FAN9673 to power up the PFC stage.
3. PFC startup is controlled by the V_{EA} level. Prior to the soft-start voltage reaching 6 V, the V_{EA} level is limited by soft start.
4. After the bulk capacitor or PFC output voltage reaches the steady-state value, 392 V, the load condition of the electronic load can be changed to test system performance.

Hint:

1. It is recommended that an external fan be added to help dissipate the heat on the NTC, IGBT, diode, and bridge on the evaluation board.

9. Performance of Evaluation Board

9.1. AC Trim Up & Trim Down

Test Condition:

Switch the input voltage from 180 V to 264 V or from 264 V to 180 V, the output voltages should be normal and the output of PFC bus should be less than 450 V.

Test Result:

CH1: V_{VEA} CH3: V_{PFC} CH4: $V_{Bridge+}$

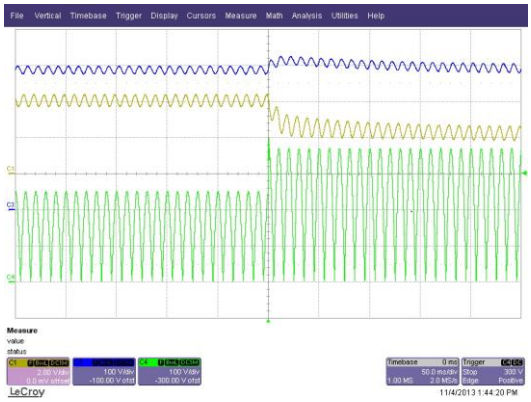


Figure 11. 180 V→264 V 5000 W Load

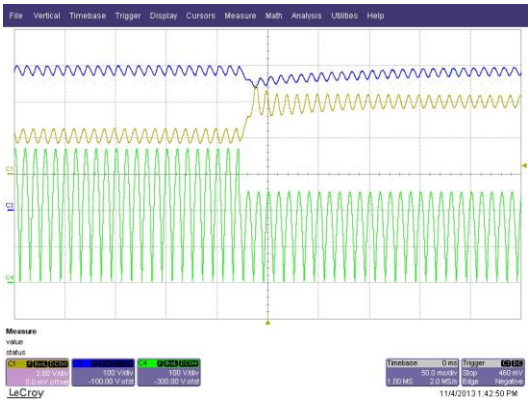


Figure 12. 264 V→180 V 5000 W Load

9.2. PFC ON / OFF & RDY

Test Result:

CH1: V_{RDY} CH3: V_{PFC} CH4: $V_{Bridge+}$

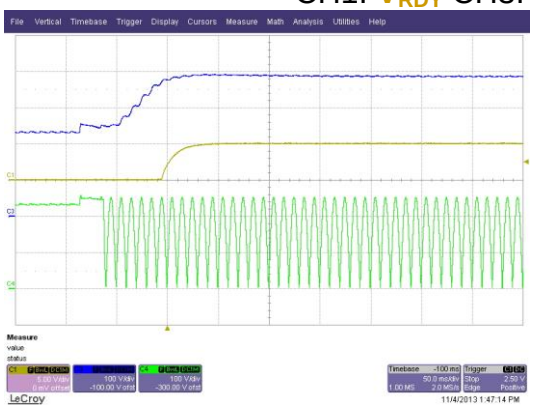


Figure 13. PFC ON

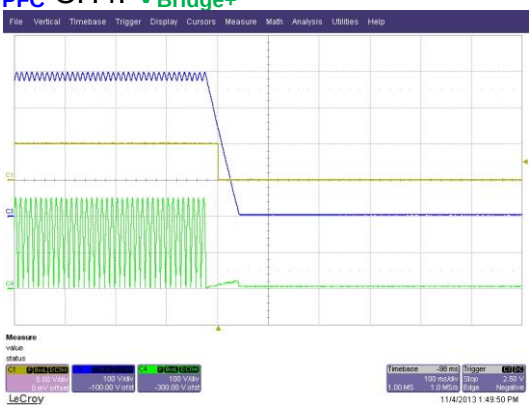


Figure 14. PFC OFF

9.3. Ripple & Noise

Test Result:

CH3: V_{PFC}

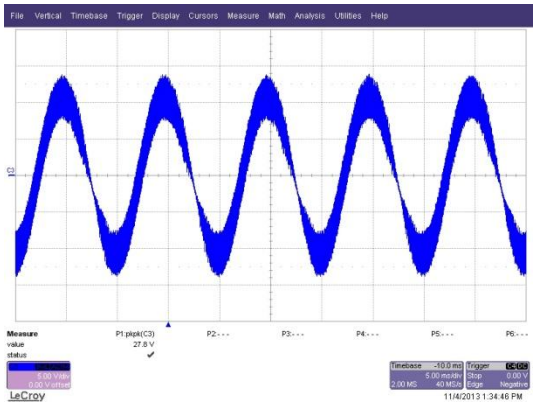


Figure 15. 180 V / 50 Hz

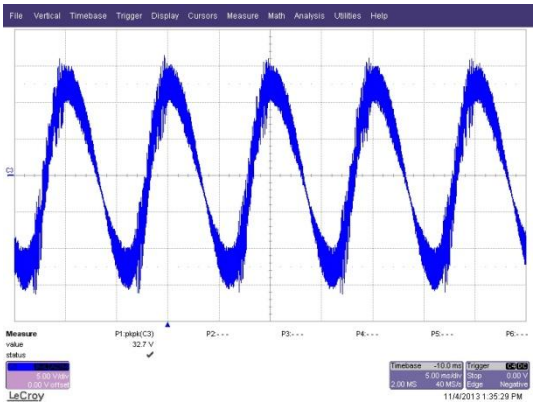


Figure 16. 264 V / 50 Hz

9.4. Efficiency

Test Condition:

Measure efficiency at min., mid., and max. loading.

Test Result:

FAN9673	Input Watts (W)	Output Watts (W)	Efficiency
A. V_{IN}=180 V at 25% Load	1295	1250	96.5%
B. V_{IN}=180 V at 50% Load	2590	2500	96.5%
C. V_{IN}=180 V at 75% Load	3885	3750	96.5%
D. V_{IN}=180 V at 100% Load	5195	5000	96.2%
E. V_{IN}=220 V at 25% Load	1288	1250	97.0%
F. V_{IN}=220 V at 50% Load	2573	2500	97.1%
G. V_{IN}=220 V at 75% Load	3856	3750	97.2%
H. V_{IN}=220 V at 100% Load	5149	5000	97.1%
I. V_{IN}=264 V at 25% Load	1280	1250	97.6%
J. V_{IN}=264 V at 50% Load	2553	2500	97.9%
K. V_{IN}=264 V at 75% Load	3836	3750	97.7%
L. V_{IN}=264 V at 100% Load	5122	5000	97.6%

9.5. Current Harmonic

Test Results:

FAN9673			
Input Voltage	**Condition**	**PF**	**THD (%)**
180 V / 50 Hz	25% Load	0.9912	10.55
	50% Load	0.9947	9.17
	75% Load	0.9971	6.62
	100% Load	0.9974	6.40
220 V / 50 Hz	25% Load	0.9800	14.32
	50% Load	0.9868	14.36
	75% Load	0.9905	12.55
	100% Load	0.9924	11.26
264 V / 50 Hz	25% Load	0.9365	25.85
	50% Load	0.9369	33.22
	75% Load	0.9526	29.59
	100% Load	0.9600	27.29

180 V / 50 Hz Input Current Waveform & Harmonic

Figure 17. 25% Load

Figure 18. 50% Load

Figure 19. 75% Load

Figure 20. 100% Load

220 V / 50 Hz Input Current Waveform & Harmonic

Figure 21. 25% Load

Figure 22. 50% Load

Figure 23. 75% Load

Figure 24. 100% Load

264 V / 50 Hz Input Current Waveform & Harmonic

Figure 25. 25% Load

Figure 26. 50% Load

Figure 27. 75% Load

Figure 28. 100% Load

10. Notice Letter

To properly operate the high-power interleaved CCM PFC evaluation board, cooling fans must be enabled to remove the heat from switching IGBTs and diodes. The fans are usually set up as shown in the following picture.

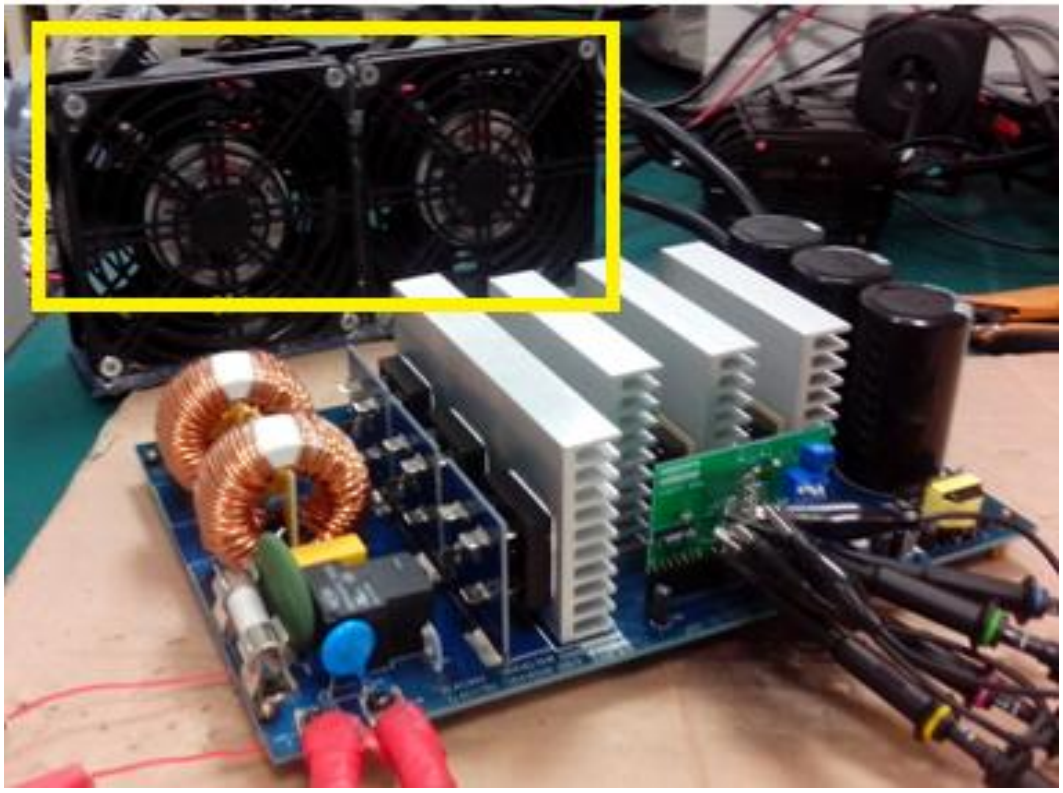


Figure 29. Recommended Fan Setup

Note:

2. Fans are not provided with the evaluation board. Supply fans for testing.

11. Safety Precautions

Before applying power to the FEBFAN9673Q_B1H5000A evaluation board, it is imperative that all involved personnel read and understand the safety precautions and understand the power on/off procedures.

The FEBFAN9673Q_B1H5000A evaluation board operates at lethal voltages and has bulk capacitors that store significant charge. Accidental contact can lead to lab equipment damage, personnel injury, and may be fatal. Be exceptionally careful when probing and handling this board. Always observe normal laboratory precautions, including:

A. All connected computers and measurement equipment MUST be isolated from the AC mains before operating voltages are applied to the board. Alternatively, AC/DC power to the board may be isolated.

B. When using an oscilloscope with this board, it must be isolated from the AC line. Alternatively, high-voltage (700 V+) isolated probes may be utilized.

C. Start with a clean working surface, clear of any conductive material.

D. Be careful while turning on the power switch to the AC source.

E. Never probe or move a probe on the board while the AC line voltage is present.

F. Ensure the bulk capacitors are discharged before disconnecting the high power load.

Note:

3. Even when a computer is isolated from AC mains through external supply, a connection to earth-potential may exist through LAN, VGA, or other connections to peripherals.

12. Revision History

Rev.	Date	Description
1.0.0	Jan 2014	Initial release
1.0.1	April 2014	Update to BOM
1.0.2	July 2014	Update to BOM
1.3	March 2014	Updated Part number to FEBFAN9673Q_B1H5000A

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