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User Guide for

# FEBFAN9673_B01H2500A

# Evaluation Board

# 2.5 kW Three-Channel CCM PFC with 12 $V_{SB}$ Module Evaluation Board

## Featured Fairchild Product:

## FAN9673

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

*Fairchild Semiconductor.com*

# Table of Contents

This user guide supports the 2500 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 | $P_O$ | 2.5 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 | $V_{BIBO}$ | 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

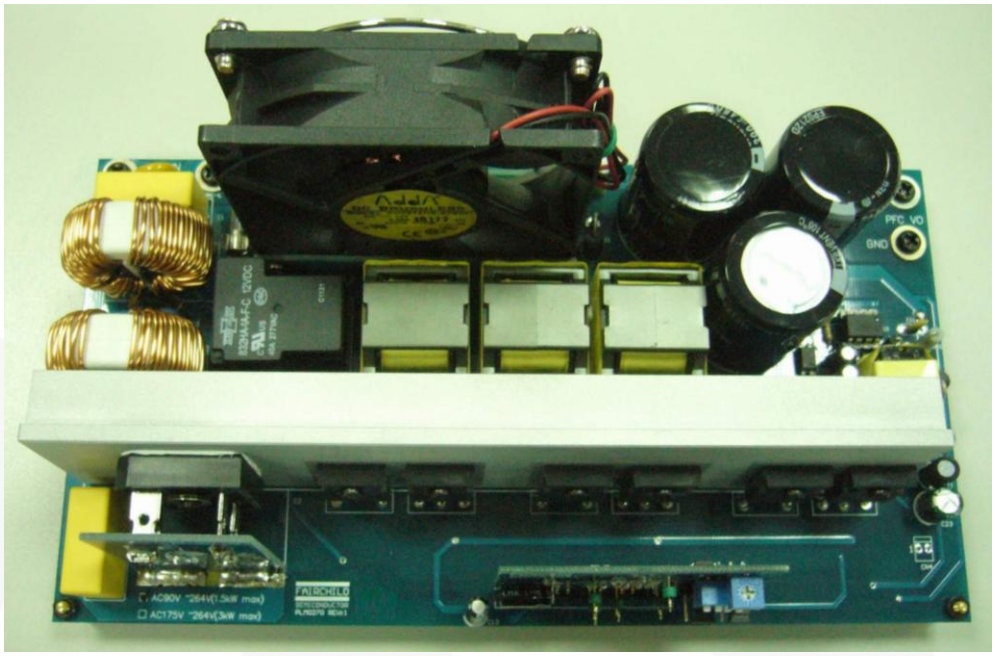



**Figure 1. Top View**

# 4. Printed Circuit Board

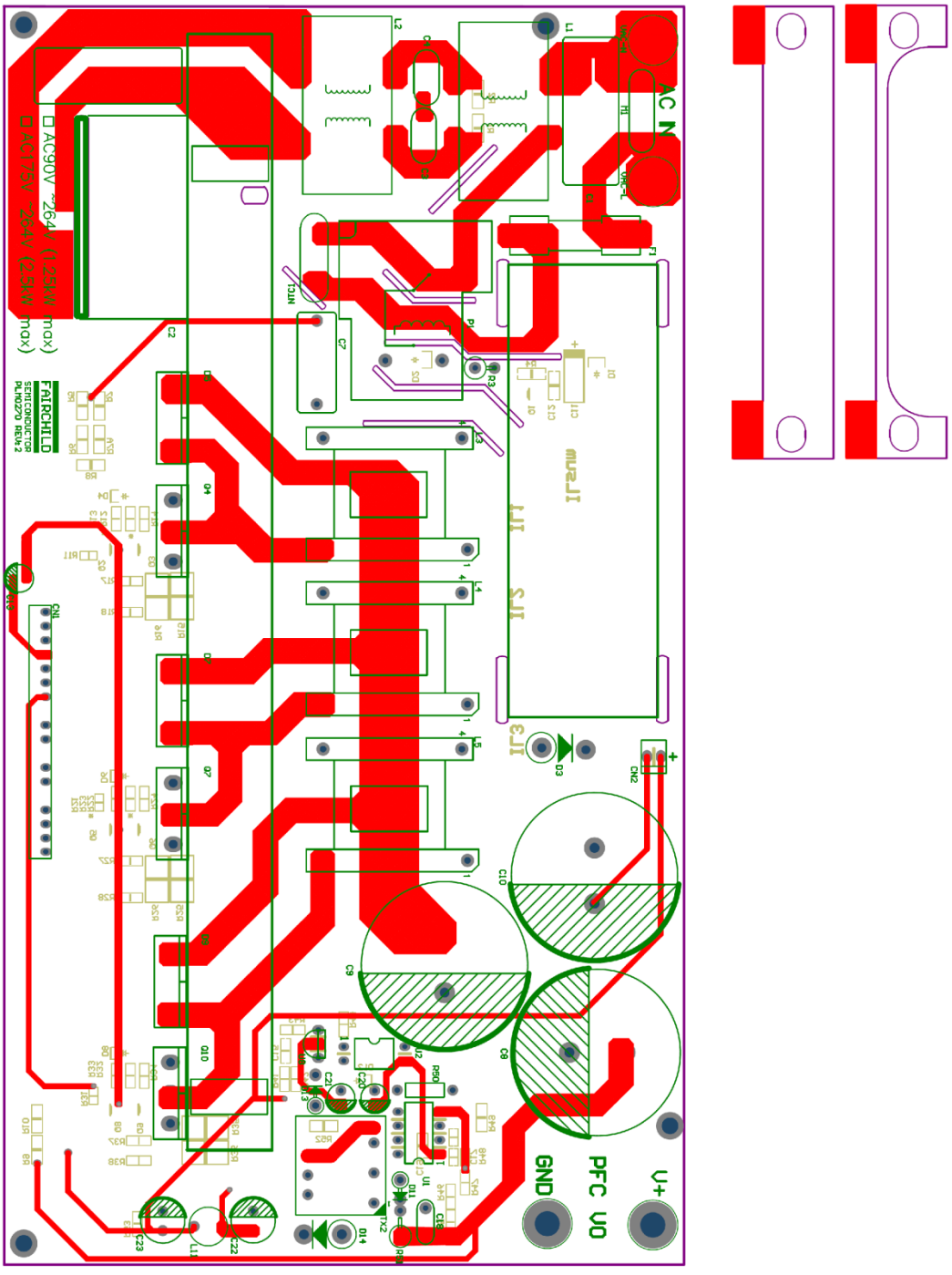



**Figure 2. Top Side of Evaluation Board**

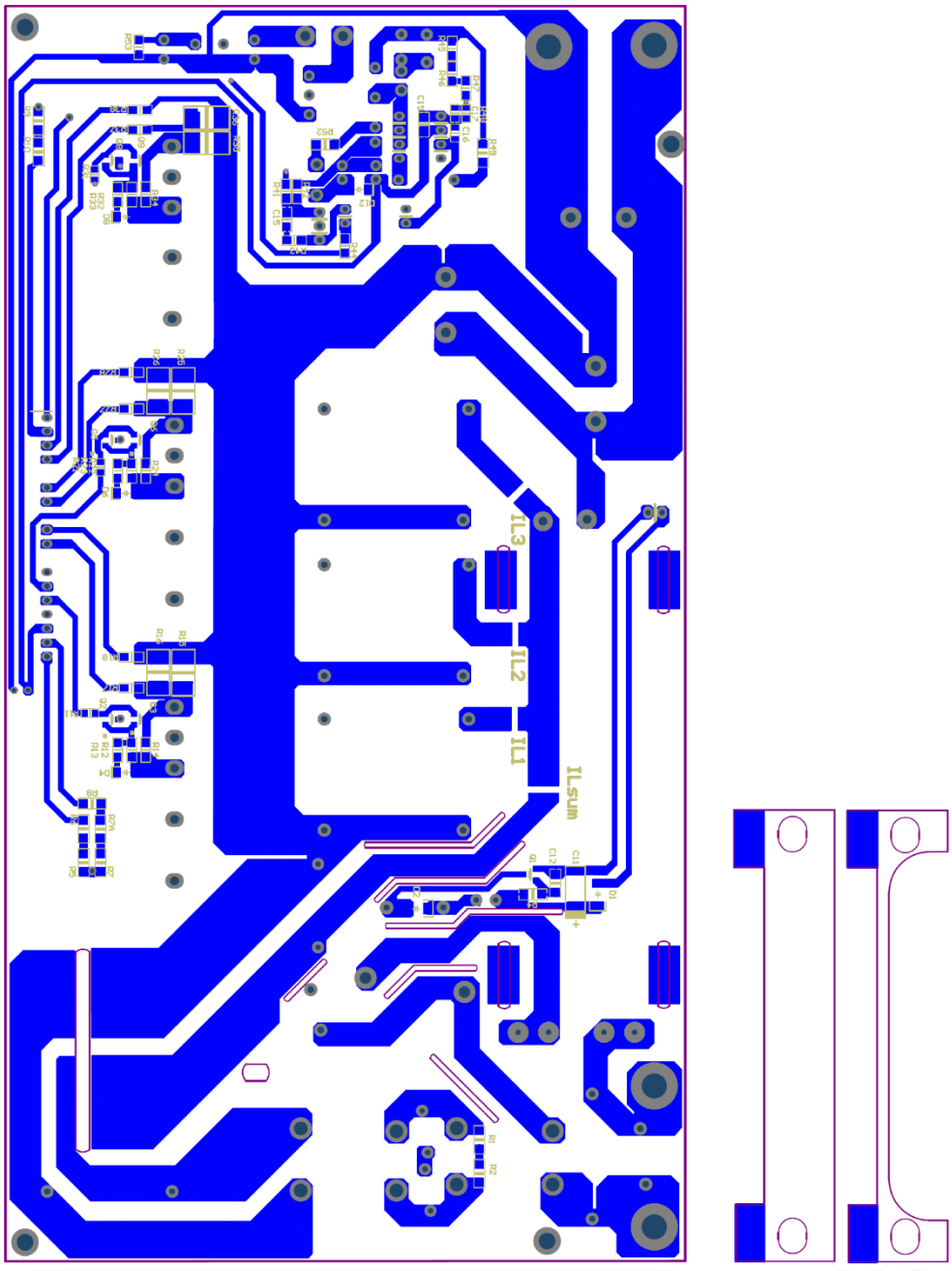



**Figure 3. Bottom Side of Evaluation Board**

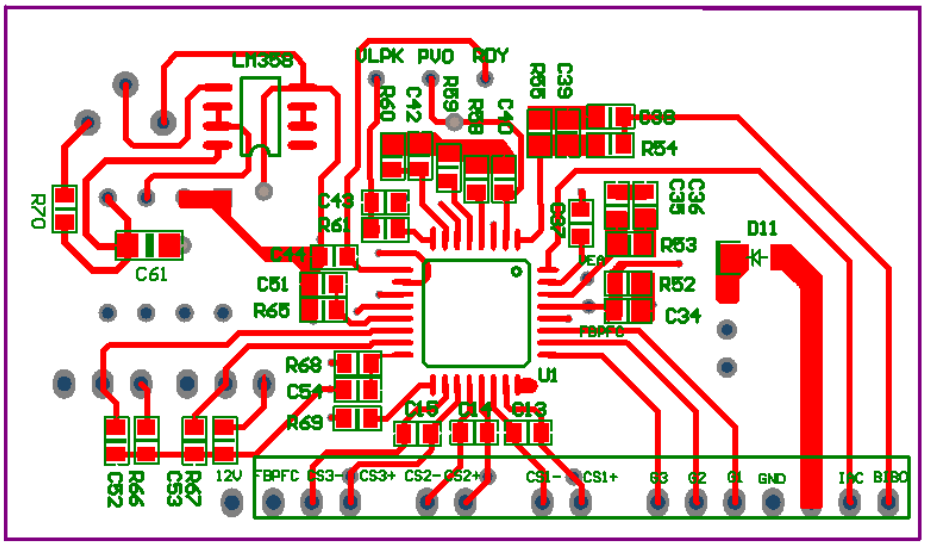



**Figure 4. Top Side of Daughter Card**

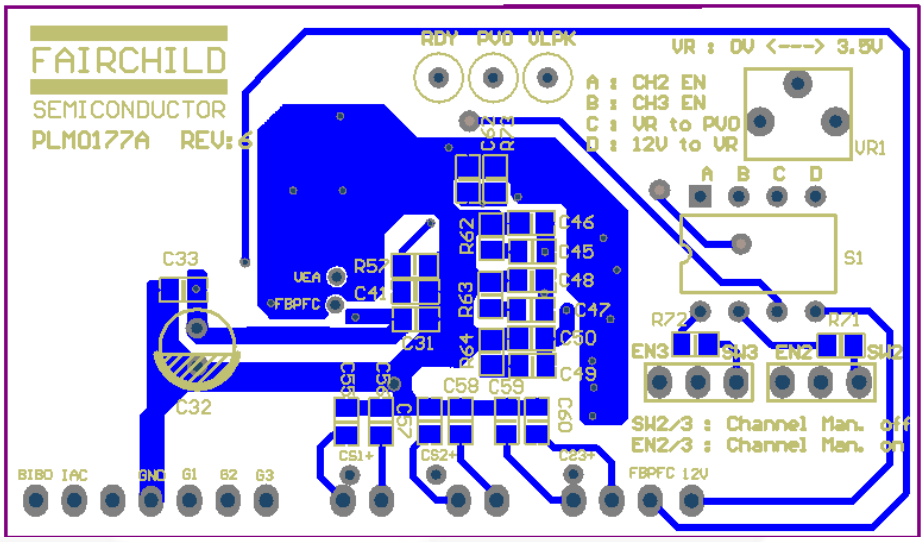



**Figure 5. Bottom Side of Daughter Card**

# 5. Schematic

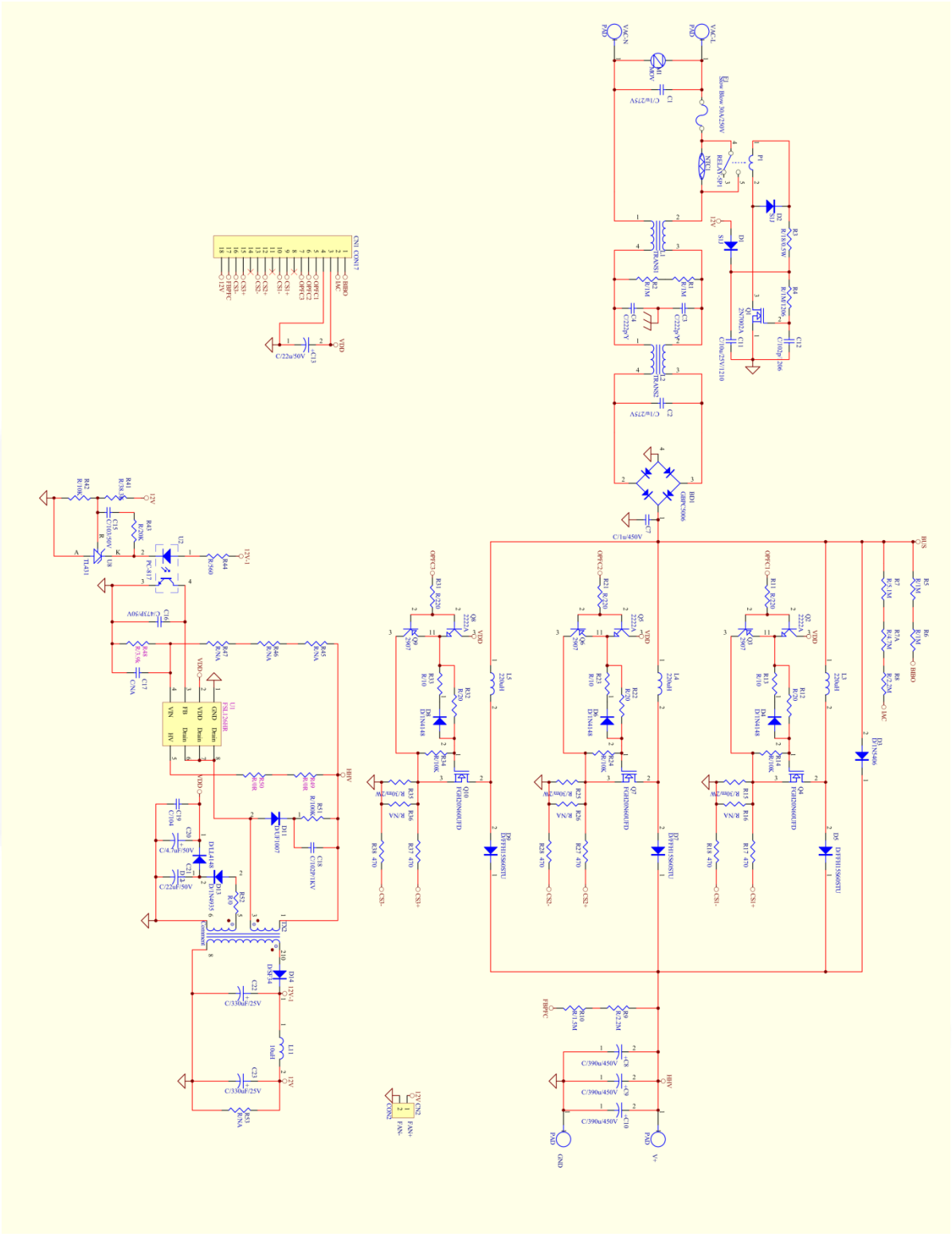


**Figure 6. Evaluation Board Schematic**

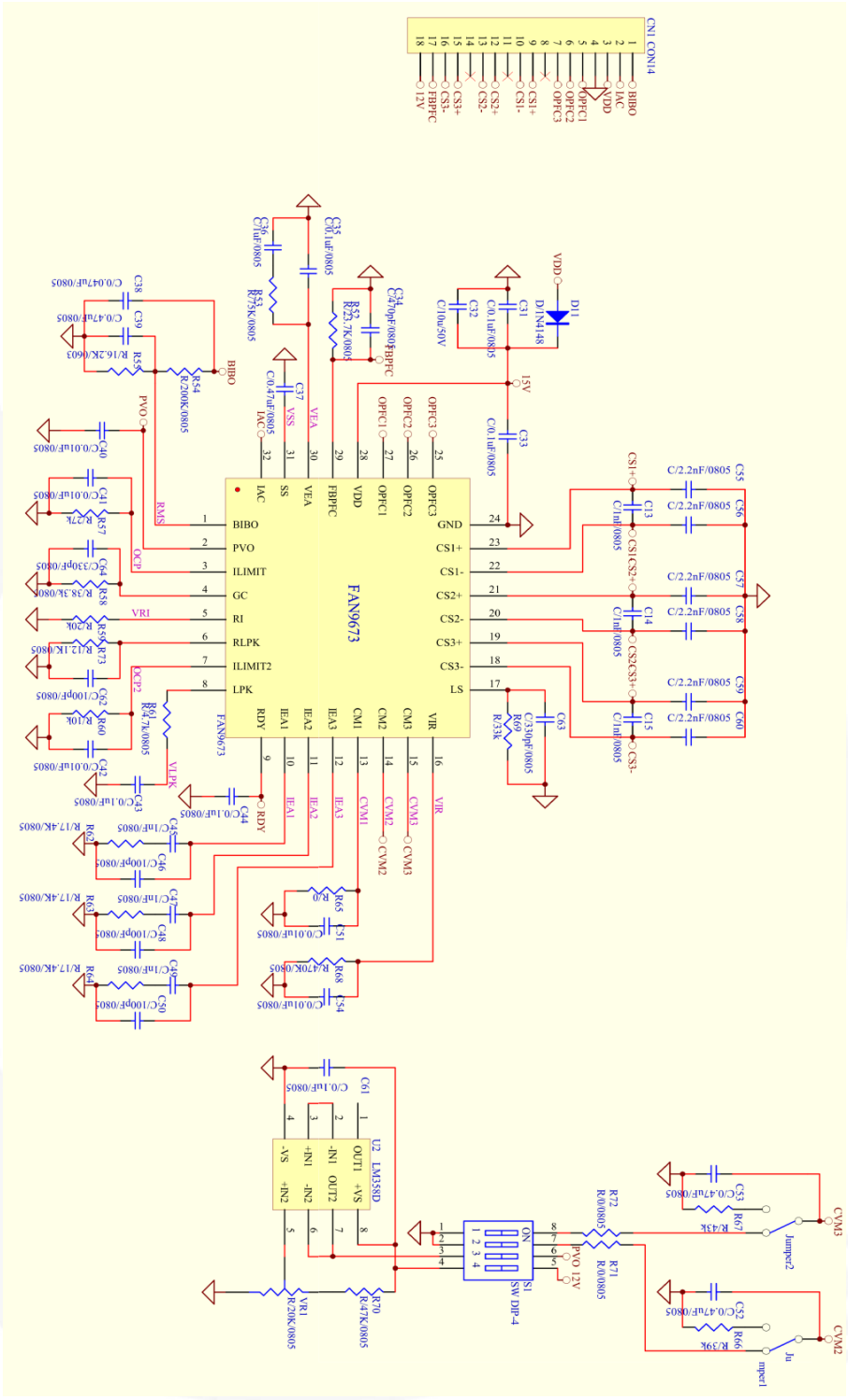



**Figure 7. Daughter Card Schematic**

# 6. Bill of Materials

| Main Board (PLM270 REV.1) | | | | | |
|---|---|---|---|---|---|
| **Reference** | **Qty.** | **Part Number** | **Value** | **Description** | **Manufacturer** |
| BD1 | 1 | GBPC5006 | | | |
| PLM0276BV0 | 1 | | | Transfer Card for Bridge | |
| C1, C2 | 2 | | 1 µF / 275 V | X Capacitor | |
| C11 | 1 | | 10 µF / 25 V | | |
| C12 | 1 | | 1 nF / 1 kV | | |
| C13, C21 | 2 | | 22 µF / 50 V | | |
| C15 | 1 | | 10 nF / 50 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 | | |
| C22, C23 | 2 | | 330 µF / 25 V | | |
| C3, C4 | 2 | | 2.2 pF / 250 V | Y Capacitor | |
| C7 | 1 | | 1 µF / 450 V | MPE | |
| C8, C9, C10 | 3 | | 390 µF / 450 V | | |
| CN1 | 1 | | CON18 | | |
| CN2 | 1 | | CON2 | | |
| D1, D2 | 2 | | S1J | | |
| D11 | 1 | UF1007 | | | |
| D13 | 1 | 1N4935 | | | Fairchild |
| D14 | 1 | SF34 | | | |
| D3 | 1 | 1N5406 | | | Fairchild |
| D4, D6, D8, D12 | 4 | 1N4148 | | | |
| D5, D7, D9 | 3 | FFH15S60STU | | | Fairchild |
| F1 | 1 | Slow Blow Fuse | 30 A / 250 V | | |
| L1, L2 | 2 | FS3010H-1LB | | EMI | FORMOSA SHING GA ENTERPRISE CO., LTE. |
| L11 | 1 | | 10 µH | | |
| L3, L4, L5 | 3 | Core Type: QP2925H | 220 µH | | |
| M1 | 1 | | MOV | | |
| Q1 | 1 | 2N7002A | | | |
| Q2, Q5, Q8 | 3 | 2222A | | | |
| Q3, Q6, Q9 | 3 | 2907 | | | |
| Q4, Q7, Q10 | 3 | FGH20N60UFD | | | Fairchild |
| R1, R2, R4, R5, R6 | 5 | SMD 1206 | 1 MΩ | | |
| R10 | 1 | SMD 1206 | 1.5 MΩ | | |
| R11, R21, R31 | 3 | | 220 Ω | | |
| R12, R22, R32 | 3 | | 20 Ω | | |
| R13, R23, R33 | 3 | | 10 Ω | | |
| R14, R24, R34, R42 | 4 | | 10 kΩ | | |
| R15, R25, R35 | 3 | SMD 2512 | 30 mΩ / 2 W | | |

| Main Board (PLM270 REV.1) | | | | | |
|---|---|---|---|---|---|
| **Reference** | **Qty.** | **Part Number** | **Value** | **Description** | **Manufacturer** |
| R17, R18, R27, R28, R37, R38 | 6 | | 470 Ω | | |
| R3 | 1 | | 20 Ω / 350 V / 0.5 W | | |
| 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 | SMD 1206 | 5.1 MΩ | | |
| R7A | 1 | SMD 1206 | 4.7 MΩ | | |
| R9, R8 | 1 | SMD 1206 | 2.2 MΩ | | |
| Relay1 | 1 | Power Relay | 40 A | | |
| TX2 | 1 | 750342371 | | 12 $V_{SB}$ Transformer | Würth Elektronik |
| U1 | 1 | FSL126HR | | Controller | Fairchild |
| U2 | 1 | PC-817 | | | |
| U8 | 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 | 4 | 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 | | |
| C63, C64 | 2 | SMD 0805 | 330 pF | | |
| C32 | 1 | | 10 µ/50 V | | |
| C13, C14, C15 | 2 | SMD 0805 | 1 nF | | |
| C55, C56, C57, C58, C59, C60 | 6 | SMD 0805 | 2.2 nF | | |
| C34 | 1 | SMD 0805 | 470 pF | | |
| CN1 | 1 | | | CON14 | |
| D11 | 1 | | 1N4148 | | |
| 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 | | |
| R57 | 1 | SMD 0805 | 27 kΩ | | |
| R55 | 1 | SMD 0603 | 16.2 kΩ | | |
| R62, R63, R64 | 3 | SMD 0805 | 17.4 kΩ | | |

| Daughter Card (PLM0177A REV.6) | | | | | |
|---|---|---|---|---|---|
| **Reference** | **Qty** | **Part Number** | **Value** | **Description** | **Manufacturer** |
| 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 | | |
| 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

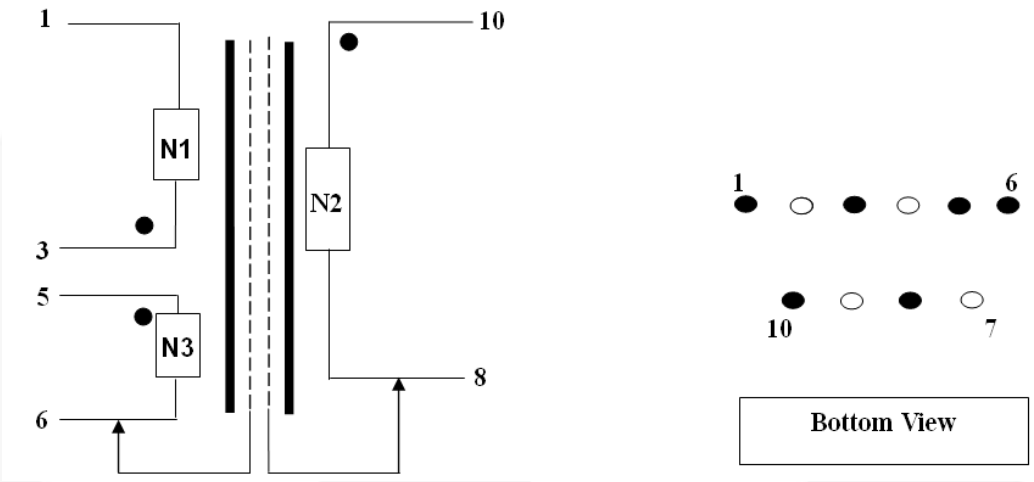



**Figure 8. Transformer Specifications & Construction**

**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 | N2 | N2 | N2 | N2 |
| 4 | Insulation: Polyester Tape t = 0.025 mm, 3-Layer | | | | |
| 5 | N1 | N1 | N1 | N1 | N1 |
| 6 | Insulation: Polyester Tape t = 0.025 mm, 6-Layer | | | | |
| 7 | N3 | N3 | N3 | N3 | N3 |
| 8 | Insulation: Polyester Tape t = 0.025 mm, 3-Layer | | | | |
| 9 | Copper-Foil 1.2T to PIN6 | | | | |

**Table 3. Electrical Characteristics**

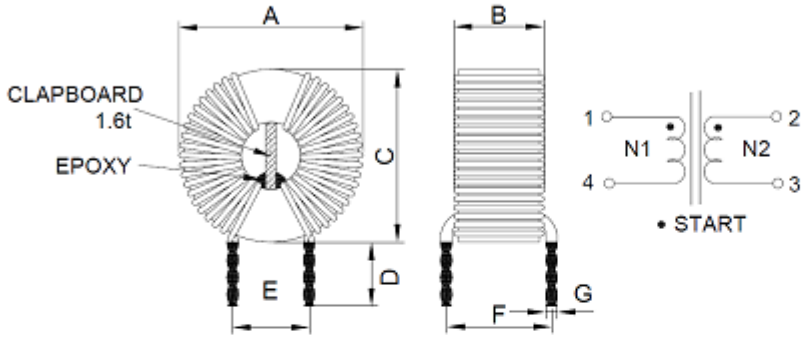
| | Pins | Specifications |
|---|---|---|
| Inductance | 3 - 1 | 800 μH ±5% |

## 7.2. L1 & L2 Specification

**SPECIFICATION FOR PRODUCTS**

| | | | |
|---|---|---|---|
| CUST | Fairchild | OUT DWG NO. | FS-XJ077AR |
| ITEM | FS3010H-1LB | DATE | 07/22/2011 |
| PART NO. | | REV:A/0 | |

1.OUT LINE DIMENSION:




| SPEC.(mm) | |
|---|---|
| A | 40.0 MAX |
| B | 20.0 MAX |
| C | 38.0 MAX |
| D | 10.0±1.0 |
| E | 10.0REF |
| F | 18.0REF |
| G | 2.8MAX |

2.WINDING & ELECTRONICS: （10kHz /0.1V）25℃

| ITEM | START | FINISH | MATERIAL | TURNS | COLOR | INDUCTANCE | DCR(mΩ) |
|---|---|---|---|---|---|---|---|
| N1 | 1 | 4 | 2UEW Φ1.2*2P | 15.5TS | N | 8.0mH MIN | / |
| N2 | 2 | 3 | 2UEW Φ1.2*2P | 15.5TS | N | 8.0mH MIN | / |

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

4.MATERIAL LIST:

| NO | ITEM | MATERIAL | SUPPLIER | UL NO. | CLASS |
|---|---|---|---|---|---|
| 1 | CORE | FS3010H-1LB | FRIENDSHIP ELECTRONICS CO.,LTD | | |
| 2 | WIRE | 2UEW | PACIFIC ELECTRIC WIRE&CABLE CO.,LTD. | E201757 | 130℃ |
| 3 | EPOXY | 3300HL | DONGGUAN EATTO ELECTRONIC MATERIAL CO.,LTD | E218090 | 90℃ |
| 4 | CLAPBOARD | FR-4 | HUIZHOU JIANYONG INSULATED PRODUCT CO.,LTD | E123995 | 130℃ |
| | | | | | |

## 7.3. L3, L4, & L5 Specification

- Core: QP2925H (3C94)
- Bobbin: 4 Pins

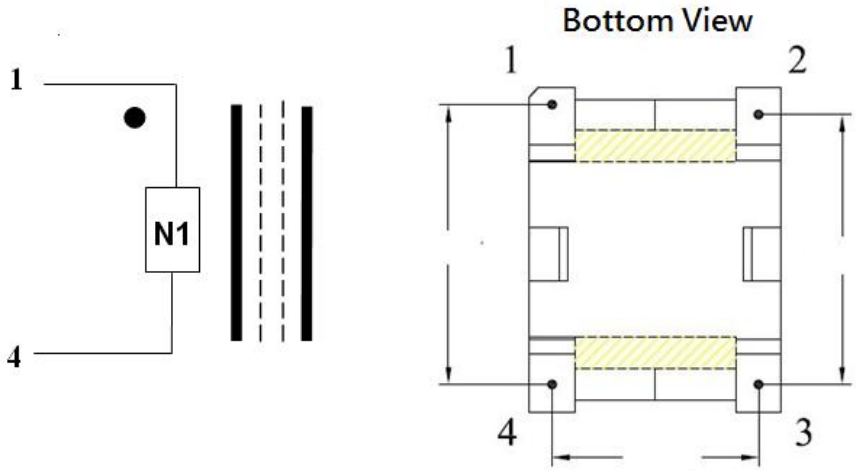



**Figure 9. Transformer Specifications & Construction**

**Table 4. Winding Specifications**

| No. | Winding | Pin (S → F) | Wire | Turns | Winding Method |
|---|---|---|---|---|---|
| 1 | N1 | 1 → 4 | 0.1φ×40 *2 | 46 | Solenoid Winding |
| 2 | Insulation: Polyester Tape t = 0.025 mm, 2-Layer | | | | |
| 3 | Copper-Foil 1.2T to PIN3 | | | | |

**Table 5. Electrical Characteristics**

| | Pin | Specifications |
|---|---|---|
| Inductance | 1 - 4 | 220 μH ± 5% |

## 7.4. L11 Specification

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

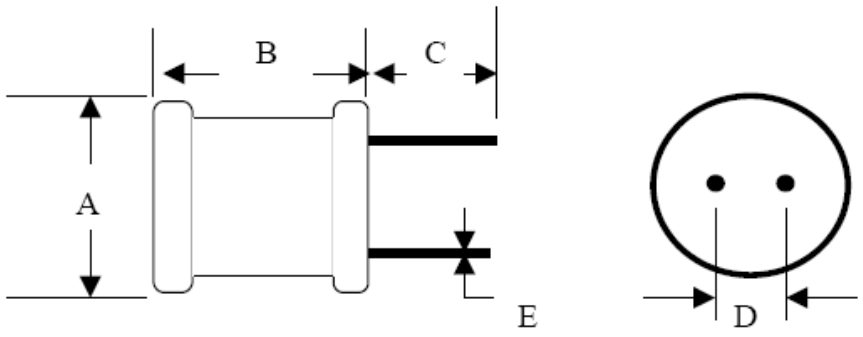



**Figure 10. Transformer Specifications & Construction**

**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** | FEBFAN9673_B01H2500A |
| **Test Date** | Nov.4, 2013 |
| **Test Temperature** | Ambient 25ºC |
| **Test Equipment** | AC Source: EXTECH 6220<br>AC/DC Electronic load: Chroma 63020<br>Power Meter: HIOKI 3390<br>Oscilloscope: Lecroy Wavesurfer 424 |
| **Test Items** | 1. AC Trim Up & Trim Down<br>2. PFC ON/OFF & RDY<br>3. Ripple & Noise<br>4. Efficiency<br>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: $V_{Bridge+}$

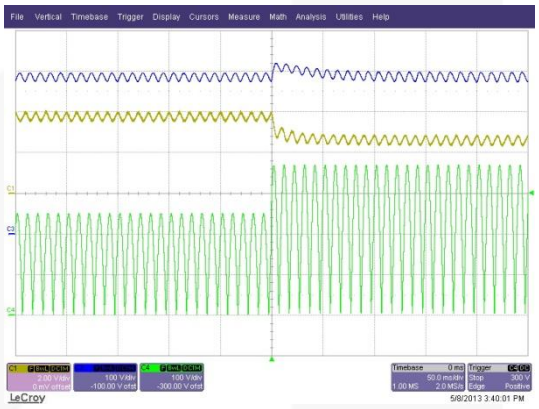


Figure 11. 180 V→264 V 2500 W Load

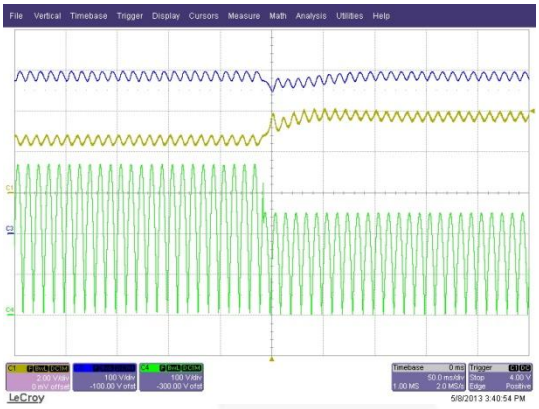


Figure 12. 264 V→180 V 2500 W Load

## 9.2. 5.4 PFC ON / OFF & RDY

### Test Result:

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

Figure 13. PFC ON

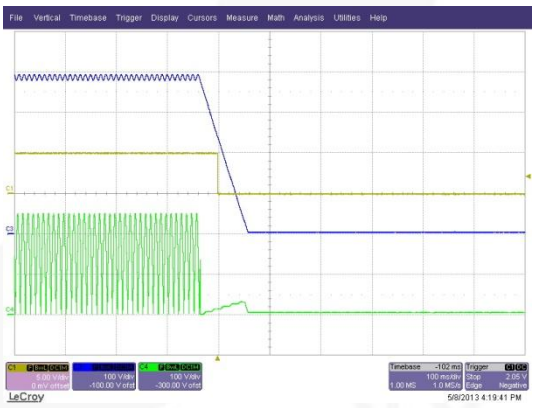


Figure 14. PFC OFF

## 9.3. Ripple & Noise

### Test Result:

CH3: $V_{PFC}$

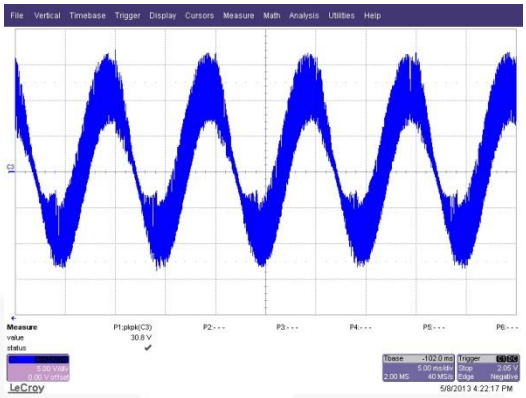


Figure 15. 180 V / 50 Hz

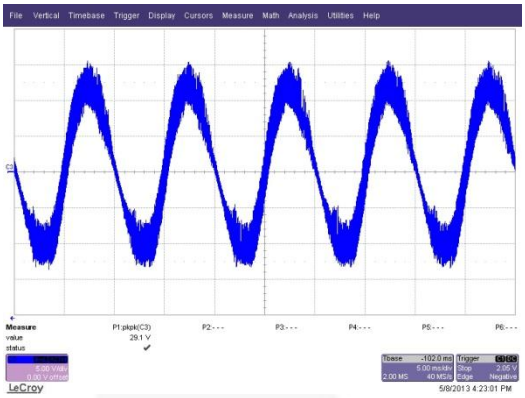


Figure 16. 264 V / 50 Hz

## 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 | 653 | 627 | 96.02% |
| B. $V_{IN}$=180 V at 50% Load | 1298 | 1256 | 96.76% |
| C. $V_{IN}$=180 V at 75% Load | 1943 | 1877 | 96.60% |
| D. $V_{IN}$=180 V at 100% Load | 2594 | 2503 | 96.49% |
| E. $V_{IN}$=220 V at 25% Load | 650 | 628 | 96.62% |
| F. $V_{IN}$=220 V at 50% Load | 1292 | 1256 | 97.21% |
| G. $V_{IN}$=220 V at 75% Load | 1923 | 1872 | 97.35% |
| H. $V_{IN}$=220 V at 100% Load | 2573 | 2503 | 97.28% |
| I. $V_{IN}$=264 V at 25% Load | 646 | 628 | 97.21% |
| J. $V_{IN}$=264 V at 50% Load | 1286 | 1256 | 97.67% |
| K. $V_{IN}$=264 V at 75% Load | 1915 | 1873 | 97.81% |
| L. $V_{IN}$=264 V at 100% Load | 2561 | 2505 | 97.81% |

## 9.5. Current Harmonic

**Test Results:**

| FAN9673 | | | |
|---|---|---|---|
| **Input Voltage** | **Condition** | **PF** | **THD (%)** |
| **180 V / 50 Hz** | 25% Load | 0.989 | 13.58 |
| | 50% Load | 0.993 | 10.81 |
| | 75% Load | 0.995 | 9.10 |
| | 100% Load | 0.997 | 7.39 |
| **220 V / 50 Hz** | 25% Load | 0.986 | 12.21 |
| | 50% Load | 0.992 | 11.65 |
| | 75% Load | 0.994 | 10.04 |
| | 100% Load | 0.995 | 9.46 |
| **264 V / 50 Hz** | 25% Load | 0.958 | 22.33 |
| | 50% Load | 0.972 | 21.87 |
| | 75% Load | 0.973 | 22.46 |
| | 100% Load | 0.974 | 22.37 |

## 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. Safety Precautions


Before applying power to the FEBFAN9673_B01H2500A evaluation board, it is imperative that all involved personnel read and understand the safety precautions and understand the power on/off procedures.

The FEBFAN9673_B01H2500A 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:**

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.

# 11. Revision History

| Rev. | Date | Description |
|---|---|---|
| 1.0.0 | Jan 2014 | Initial release |
| 1.0.1 | July | BOM updated |
| 1.2 | Jan. 2015 | BOM updated |
| | | |

## WARNING AND DISCLAIMER

Replace components on the Evaluation Board only with those parts shown on the parts list (or Bill of Materials) in the Users' Guide. Contact an authorized Fairchild representative with any questions.

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