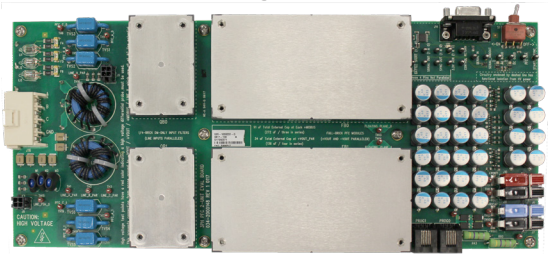
# EVAL-KIT-1000031-01

## Evaluation KIT for Paralleled 3-Phase PFC Converters




## Summary

SynQor has developed EVAL-KIT-1000031-01, an evaluation board to facilitate testing of our Paralleling 3-Phase PFC converters and its associated 3-Phase, differential mode AC line filters.


### Introduction

This application note is a guide to the features, schematic, component placement, and BOM for this evaluation board. The applicable modules are MACF-115-3PH-UNVD-QT 3-Phase differential AC Line Filters and MPFC-115-3PH-270P-FP 3-Phase PFC converters.

### Contents



This evaluation board and schematic are intended for demonstration purposes only and no guarantees are made for standards compliance.

**Shock Warning:** There are areas of this evaluation board that have exposed access to hazardous high voltage levels. These are non-isolated PFC modules with the output return voltage referenced to the input AC line. Exercise caution to avoid contact with those voltages. Also note that the evaluation board may retain high voltage for up to 1 second after input power has been removed. Exercise caution when handling.

**Thermal Considerations:** When testing converters on an evaluation board, ensure adequate cooling. Apply cooling air with a fan blowing across the converter or across a heatsink attached to the converter. Monitor the converter temperature to ensure it doesn't exceed the maximum rated per the datasheet specification.

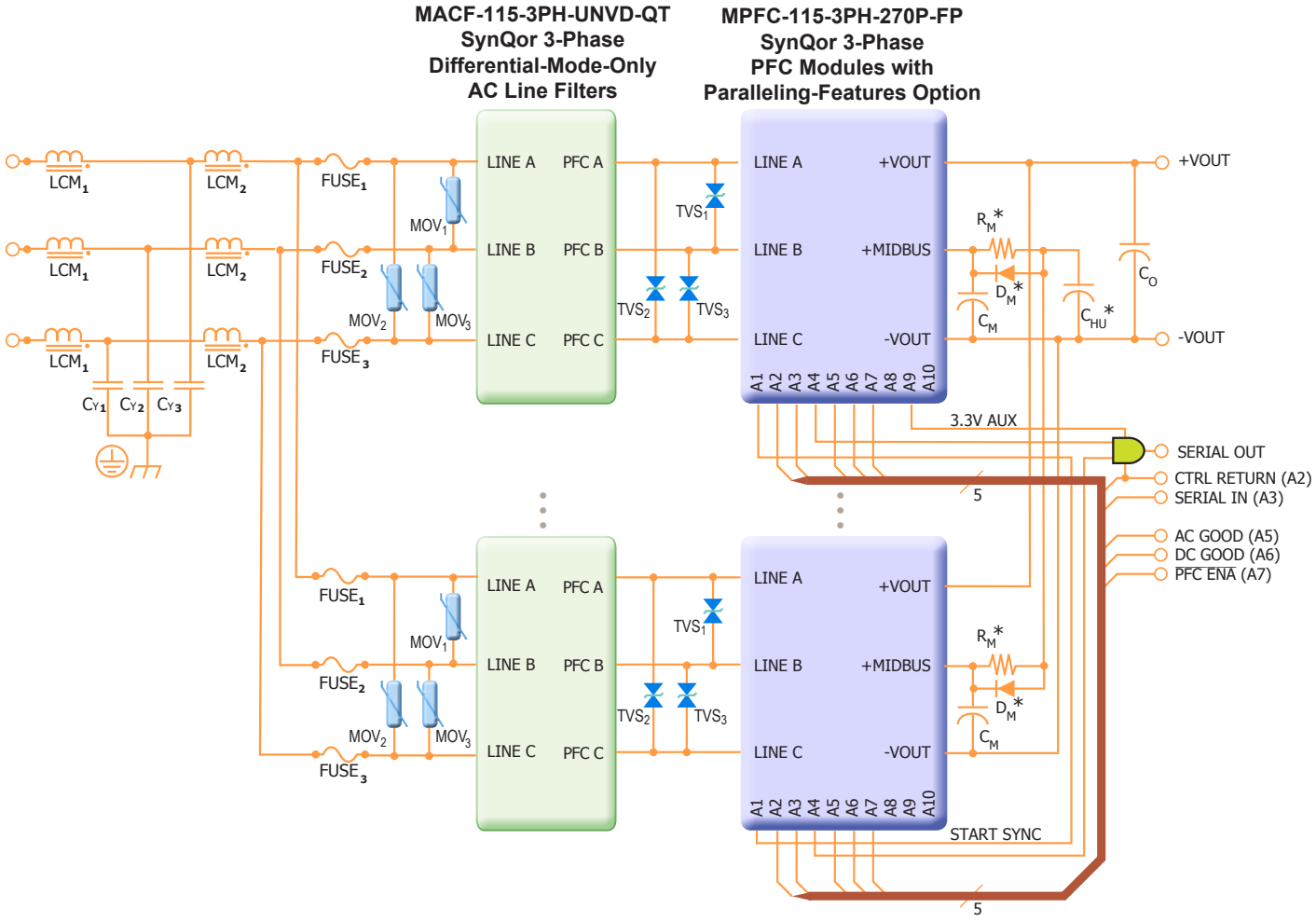
## Section 1 – Converter Description

The 3-Phase PFC converter has two stages. The input stage takes 3-Phase AC (115 Vrms L-N / 200 Vrms L-L) and shapes and balances the three AC input currents. Phase relation (A, B, C phases) are not connection specific. The PFC will work in any orientation. The output of the first stage is called +MIDBUS and it has an external capacitor on the evaluation board (see *Capacitor Bank on the Evaluation Board* section of the application note for more details). +MIDBUS voltage ranges from 160 Vdc to 220 Vdc over specified operating conditions. The +MIDBUS is then fed into a second stage that has a typical output voltage of 270 Vdc. The 3-Phase PFC will startup and operate under any valid load condition.

## Isolation Warning

Circuitry on this evaluation board is non-isolated with respect to the AC line inputs. This requires great care in making connections and taking measurements. Be aware that the output 270 Vdc and +MIDBUS 200 Vdc are non-isolated with respect to input AC lines. As such, take great care before taking any measurement with equipment that may make a connection to ground. The return line for either DC voltage is **NOT ground**. Connecting a scope probe to any power DC voltage on this board may result in damage to the board and/or the scope or scope probe. Use isolated differential probes or clamp on style current probes to avoid these issues. Note that the shield pin connects to a shield that lies between the converter and the baseplate and is meant to provide noise reduction in cases where the baseplate is connected to a heatsink that can become a noise radiator. For safety, **DO NOT CONNECT THE SHIELD TO THE BASEPLATE** as the shield is line referenced. In most applications, the output of the 3-Phase PFC is followed by an isolated DC-DC converter. The serial port and enable switch are isolated.

## Section 2 – Evaluation Block Diagram / Typical Application




**Suggested Parts:**
MOV 1-6 : 300 Vrms, 60 J ; EPCOS S10K300E2
TVS 1-3 : 430 Vpk, 20 J; Littelfuse AK3-430C or Bourns PTVS-430C-TH
Fuse 1-3 : 250 Vrms, 10 A; Littelfuse 0216010.XEP
CY 1-3 : 2 x 4.7 nF = 9.6 nF, X7R, 2220, Y2; Murata GA355DR7GF472KW01L
LCM 1-2 : For recommended construction see Table 1 in MPFC-115-3PH-270-FP datasheet

**Notes:**
Note 1: SHIELD pin must be left floating, but may be externally connected to the plane under the unit near the top of PCB to contain high frequency EMI.
Note 2: CB & RP are for stabilizing the system when DC-DC converters are used as the PFC module's load. Additional Hold-Up capacitance may be required for normal operation through interruptions in input power.

## Section 3 – Input and Output Connections

Input power is applied through connector J16, see Table 1. The mating connector for J16 is DF22-4S-7.92C (28) from Hirose Electric Company in Japan and is provided.

Output power is applied through connectors J10 and J11 or J6 and J7. See Table 2. The mating connectors are provided.

+MIDBUS is connected to J6, see Table 2.

### Table 1: Input Power Connector J16

| Connector Terminal # | Signal Name |
|---|---|
| J16-1 | AC Line A Input |
| J16-2 | AC Line B Input |
| J16-3 | AC Line C Input |
| J16-4 | Earth Ground |

### Table 2: Output Power Connectors

| Connector Terminal # | Signal Name |
|---|---|
| J10 | +VOUT |
| J6 | +MIDBUS |
| J7/J11 | -VOUT |

**Table 3: Test Points**

All high voltage test points have a red color indicating a High Voltage Differential Probe must be used. This prevents a connection between the scope ground and -VOUT/+VOUT/+MIDBUS/LINE_X which are all at AC line potential. All black colored test points are referenced to CTL_RETURN and are safe to use a standard scope probe.

| Black Test Points Signal Names |
|---|
| BATTLE SHORT (1 & 0) |
| SERIAL OUT (1 & 0) |
| SYNC OUT (1 & 0) |
| 3.3V AUX (1 & 0) |
| CTL RETURN (1 & 0) |
| SERIAL IN |
| SERIAL OUT |
| AC GOOD |
| DC GOOD |
| PFC ENABLE |
| START_SYNC |

| Red Test Points | Signal Name |
|---|---|
| TH1 | LINE_A_PAR |
| TH2 | LINE_B_PAR |
| TH3 | LINE_C_PAR |
| TH4 | PFC_A_0 |
| TH17 | PFC_A_1 |
| TH5 | PFC_B_0 |
| TH18 | PFC_B_1 |
| TH6 | PFC_C_0 |
| TH19 | PFC_C_1 |
| TH11<br>No Marking on PCB | +MIDBUS1<br>(Above PR0G0 Location) |
| TH7<br>No Marking on PCB | MIDBUS0<br>(Lower Right Corner, below J7) |
| TH9 | +VOUT |
| TH8 | -VOUT |
| TH10 | -VOUT |
| TH12 | +HUCAP |
| TH13 | FLOATING_PLANE_0 |
| TH14 | FLOATING_PLANE_1 |
| TH15 | PSEUDO-NEUTRAL<br>AT<br>LINE INPUT |
| TH16 | PSEUDO-NEUTRAL<br>AT<br>PFC INPUT |

***Note:*** *Please refer to the appropriate SynQor converter datasheet for descriptions of these features.*

## Section 4 – Switches, Lights, LEDs, External Transient Protection and BNC Connectors

### Description of Switches

#### Enable On/Off Switch

Toggling S1 switch to the ON position enables the 3-Phase PFC converter. Toggling S1 switch to the OFF position disables the 3-Phase PFC converter.

### Description of Lights

#### Neon Lamp Indicators

LI1: AC Line A power present
LI2: AC Line B power present
LI3: AC Line C power present

#### LED Indicators

LED1: AC GOOD
(Green – Near AC GOOD Test Point, below switch S1)
LED2: DC GOOD
(Red – Near DC GOOD Test Point, below switch S1)
LED3: Bias On
(Orange – Near 3.3V AUX Test Points, below switch J14)

### Description of Transient Protection Devices

The evaluation board includes protective MOV devices on all three input lines. These are in place to absorb energy from potential transients that may be present on your line. Transient voltage suppressors (TVS) are included after each filter to clamp the peak line-line voltage seen by the PFC module, when stimulated by an input transient.

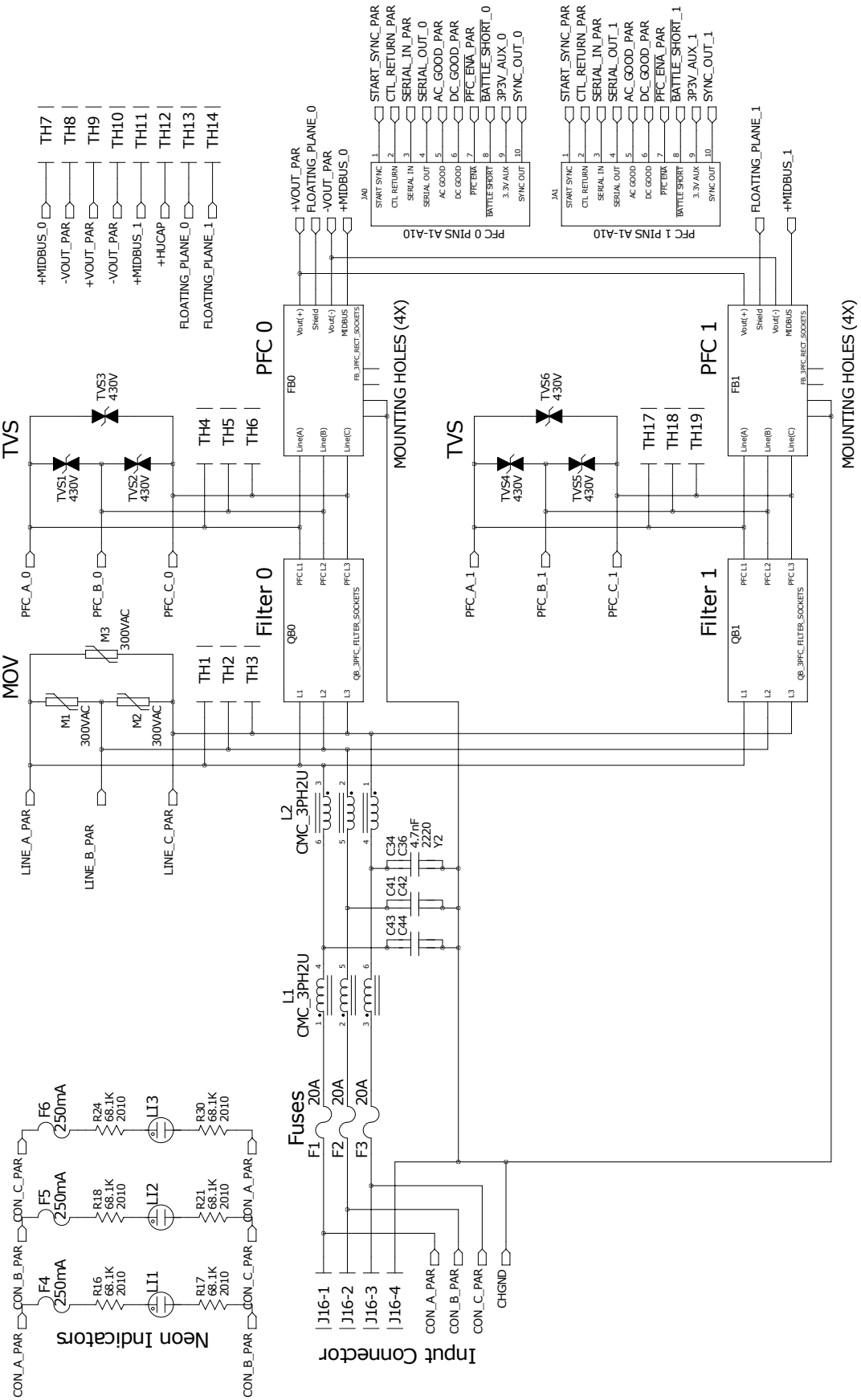
#### MOV Devices

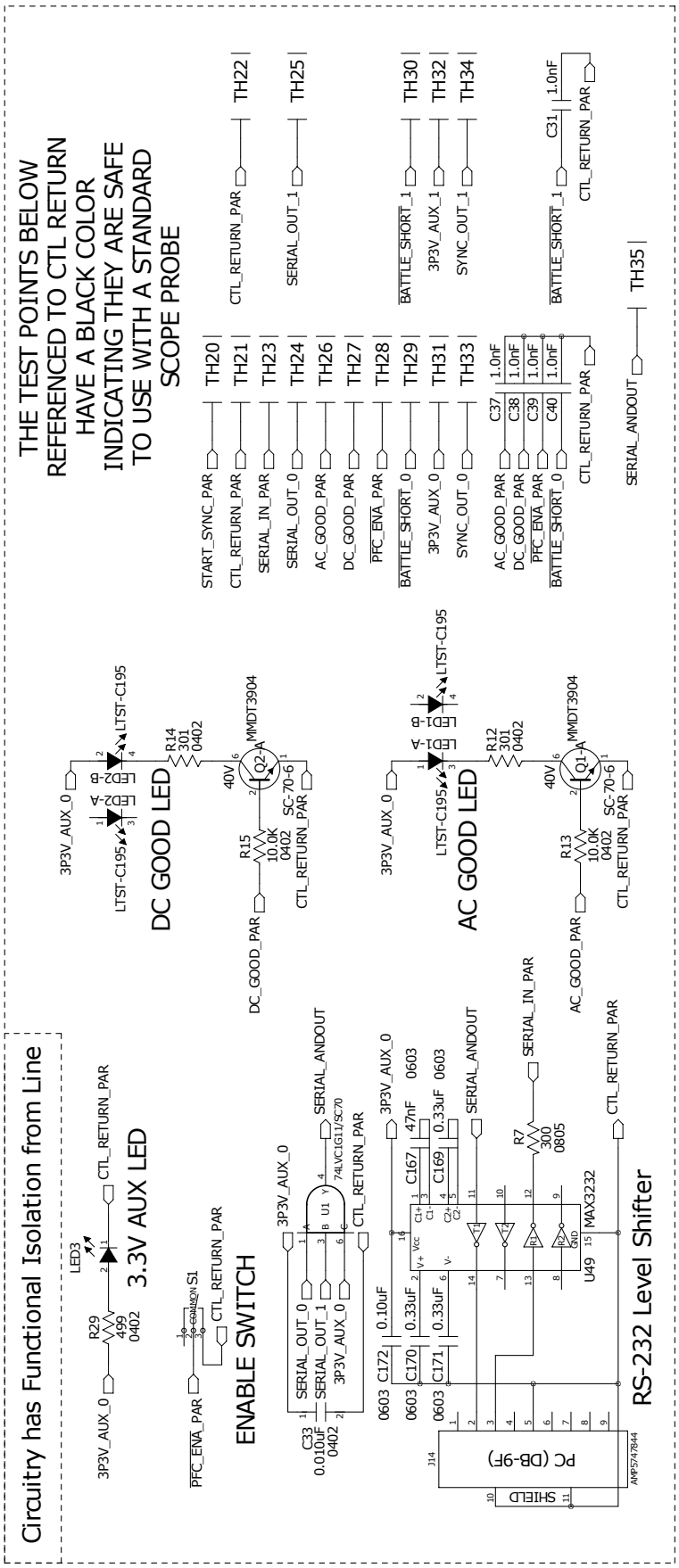
PAin to PBin: M1
PBin to PCin: M2
PAin to PCin: M3

#### TVS Devices

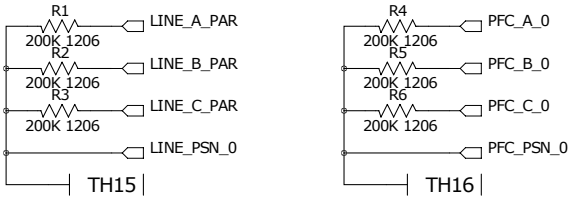
PA0MID to PB0MID: TVS1
PB0MID to PC0MID: TVS2
PA0MID to PC0MID: TVS3
PA1MID to PB1MID: TVS4
PB1MID to PC1MID: TVS5
PA1MID to PC1MID: TVS6

## Section 5 – Schematic

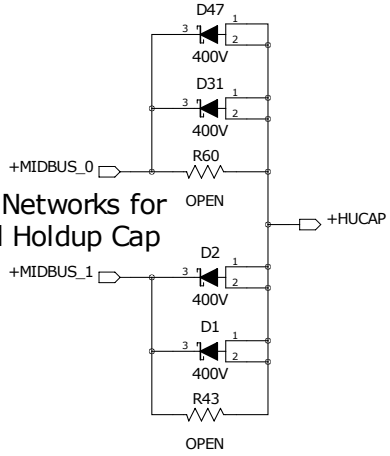


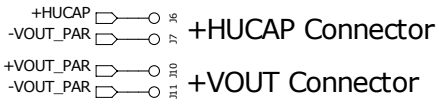

Circuitry has Functional Isolation from Line
THE TEST POINTS BELOW
REFERENCED TO CTL RETURN
HAVE A BLACK COLOR
INDICATING THEY ARE SAFE
TO USE WITH A STANDARD
SCOPE PROBE
3.3V AUX LED
ENABLE SWITCH
DC GOOD LED
AC GOOD LED
RS-232 Level Shifter
PC (DB-9F)
MAX3232
74LVC1G11/SC70
MMDT3904
LTST-C195
START_SYNC_PAR
CTL_RETURN_PAR
SERIAL_IN_PAR
SERIAL_OUT_0
SERIAL_OUT_1
AC_GOOD_PAR
DC_GOOD_PAR
PFC_ENA_PAR
BATTLE_SHORT_0
BATTLE_SHORT_1
3P3V_AUX_0
3P3V_AUX_1
SYNC_OUT_0
SYNC_OUT_1
SERIAL_ANDOUT
TH20
TH21
TH22
TH23
TH24
TH25
TH26
TH27
TH28
TH29
TH30
TH31
TH32
TH33
TH34
TH35

## Resistor Networks to Generate Pseudo-Neutral Potential

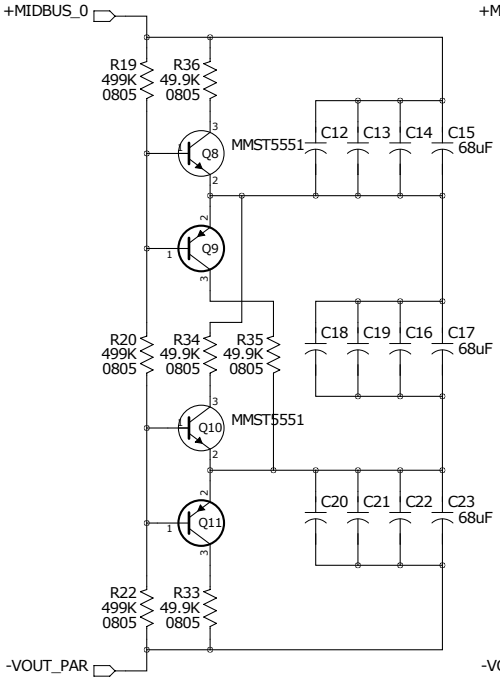



## R || D Networks for Shared Holdup Cap

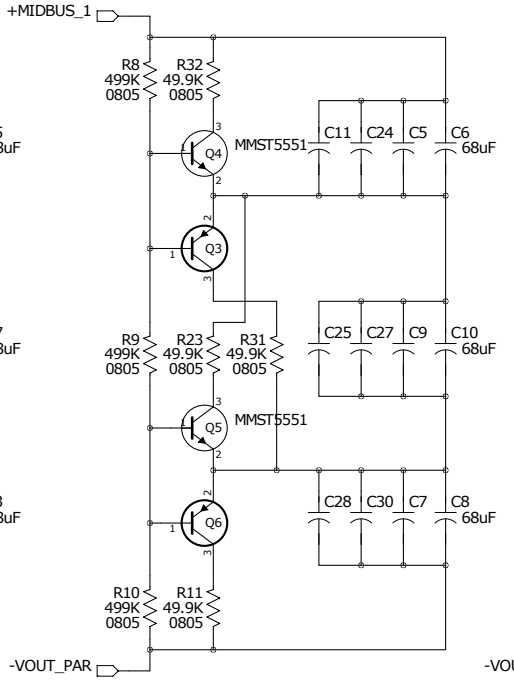


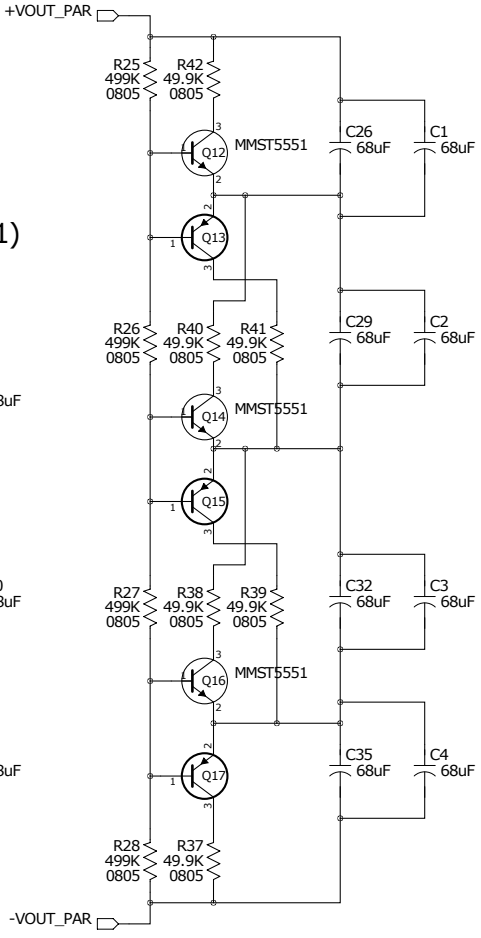

## Total 91uF @ +MIDBUS (Unit 0)




## Total 91uF @ +MIDBUS (Unit 1)

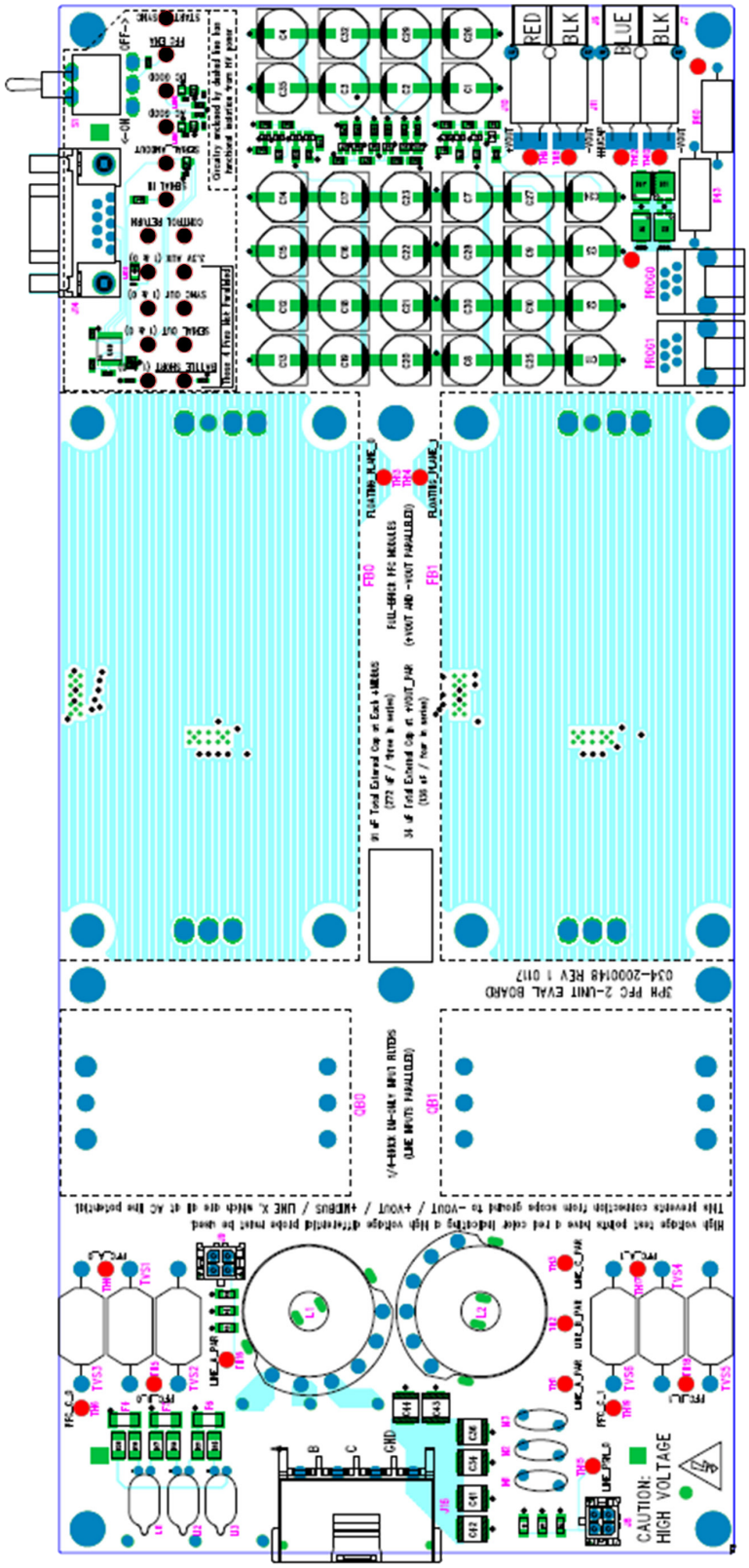



## Total 34uF @ +VOUT (shared)



## Section 6 – Component Placement

**All high voltage test points have a red color indicating a High Voltage Differential Probe must be used.** This prevents a connection between the scope ground and -VOUT/+VOUT/+MIDBUS/LINE_X which are all at AC line potential. All black colored test points are referenced to CTL_RETURN and are safe to use a standard scope probe.



## Section 7 – Basic Operating Instructions

Apply the 3-Phase input, 115 Vrms (L-N) at J16 on left, using the provided cable assembly. Earth ground, and Phases A, B, and C are labeled. There is no neutral connection, and phase rotation (A, B, C) does not matter to the device. Lamps LI1, LI2, LI3 indicate the presence of hazardous voltages at the input.

Connect the loads at:

+MIDBUS for loosely regulated 200 V

and/or

+VOUT for regulated 270 V

Use Switch S1 in lower right for enable / disable control.

Be aware that the output 270 Vdc and +MIDBUS 200 Vdc are non-isolated with respect to input AC lines. As such, take great care before taking any measurement with equipment that may make a connection to ground. The return line for either DC voltage is **NOT ground**. Connecting a scope probe to any power DC voltage on this board may result in damage to the board and/or the scope or scope probe. Use isolated differential probes or clamp on style current probes to avoid these issues.

All high voltage test points have a red color indicating a High Voltage Differential Probe must be used. This prevents a connection between the scope ground and -VOUT/+VOUT/+MIDBUS/LINE X which are all at AC line potential. All black colored test points are referenced to CTL RETURN and are safe to use a standard scope probe.

Measurements may be taken or a downstream converter added to test the PFC in an evaluation system.

### Capacitor Bank on the Evaluation Board

The test board includes a small amount of output capacitance on the MAIN OUTPUT (270 Vdc). Although no large bulk hold-up capacitance is required for operation, the device will require a nominal amount of capacitance at the +MIDBUS node for normal operation. The capacitors selected are rated from -55 °C to 125 °C, and arranged in groups in series strings due to their voltage rating. A single larger value electrolytic capacitor would also be acceptable. Capacitors on the output nodes serve to stabilize the input system both for this converter and downstream power converters.

Capacitors are solid polymer electrolytic for good ESR at low temperature and lifetime at high temperature. The highest voltage rating for Nichicon PCR is 80 V continuous so capacitors are wired in series with active balancing.

On-Board Capacitance:

91 µF @ +MIDBUS_0
91 µF @ +MIDBUS_1
34 µF @ +VOUT

Each +MIDBUS, 0 and 1, has 4 sets of 3 series capacitors in parallel for a total of 24 capacitors
+VOUT has 2 set of 4 series capacitors in parallel for a total of 8 capacitors

Please refer to the applications section of the datasheet for more detailed information on additional capacitance.

http://www.synqor.com/Datasheets/MPFC-115-3P-270-FP_Datasheet.pdf

## Additional Information

Two LEDs below the AC GOOD (Green) and DC GOOD (Red) test points (Below S1) indicate the status of the AC GOOD and DC GOOD signals. An Orange LED below J14 indicates that 3.3V AUX from PFC_0 is on.

The PCB and PFC modules have means in place for shield layers on both the PCB itself, under the module and between the baseplate and module, as part of the 3-Phase PFC full brick. The baseplate retains electrical isolation. These layers are in place to reduce EMI radiation. The evaluation board and PFC modules properly connect these shields.

## Serial Interface Communications

To communicate with adaptor board kit, a DB9 Male to DB9 Female and USB RS232 adaptor are required.

| Manufacturer | Part Number | Description |
|---|---|---|
| Future Technology Devices Intl. | UC232R-10 | Cable USB RS232 Embedded 10CM |
| Assmann WSW Components | AK131-2 | Cable DB9M-DB9F 2M |

Please refer to application note “MPFC-115-3PH-270-FP Serial Interface” for information regarding the communications standards and parameters available for monitoring.

## Appendix A – Bill of Materials (BOM)

### Table 4: EVAL-1000031

| Ref Des | Value | Package | Description |
|---|---|---|---|
| A1 | | ANDERSON_HOUSING | Black PP15-45 Anderson Housing; Anderson Power 1327G6FP |
| A2 | | ANDERSON_HOUSING | Red PP15-45 Anderson Housing; Anderson Power 1327FP |
| A3 | | ANDERSON_HOUSING | Black PP15-45 Anderson Housing; Anderson Power 1327G6FP |
| A4 | | ANDERSON_HOUSING | Red PP15-45 Anderson Housing; Anderson Power 1327FP |
| C1-C30, C32, C35 | 68µF | Radial | Solid Polymer Electrolytic SMT, 80V; Nichicon PCR1K680MCL1GS |
| C31, C37-C40 | 1.0nF | 0603 | X7R, 50V |
| C34,C36, C41-C44 | 4.7nF | 2220 | Y2 |
| C33 | 0.010µF | 0402 | X7R, 25V |
| C167 | 47nF | 0603 | X7R, 16V |
| C169 – C171 | 0.33uF | 0603 | X7R, 16V |
| C172 | 0.10µF | 0603 | X7R, 16V |
| D1, D2, D31, D47 | 400V | PowerDI 5 | Ultrafast Recovery Rectifier, 5A Diodes, Inc, PDU540-1 |
| F1 - F3 | 20A | Axial | 20A Fuse; Littelfuse 0505020.MXEP |
| F4 - F6 | 1A | 1206 | 1A Fuse; Littelfuse 0437001.WR |
| J6 | | Anderson40RA | Right Angle 40A CRIMP Pin for Anderson Connectors; 1336G1 |
| J7 | | Anderson40RA | Right Angle 40A CRIMP Pin for Anderson Connectors; 1336G1 |
| J8 | | | 3mm Header, Surface Mount Compatible, Dual Row, Vertical, with PCB Polarizing Peg, 4 Circuits, Tin (Sn) Plating, with Kinked PC Tails; Molex 43045-0412, Wurth 662 004 211 22 |
| J9 | | | 3mm Header, Surface Mount Compatible, Dual Row, Vertical, with PCB Polarizing Peg, 4 Circuits, Tin (Sn) Plating, with Kinked PC Tails; Molex 43045-0412, Wurth 662 004 211 22 |
| J10 | | Anderson40RA | Right Angle 40A CRIMP Pin for Anderson Connectors; 1336G1 |
| J11 | | Anderson40RA | Right Angle 40A CRIMP Pin for Anderson Connectors; 1336G1 |
| J14 | | | RIGHT-ANGLE FEMALE DB9 CONNECTOR, TH HOLE; Tyco 574844-6 |
| J16 | 4 PIN | 4PINRASRTH | 4-Pin RA Header; Hirose EI DF22-4P-7.92DS(05) |
| J19 | | STAPLE | Anderson Connector PCB Mount Staple Spanning 2 Modules; Anderson Power Products 114555P2 |
| J21 | | STAPLE | Anderson Connector PCB Mount Staple Spanning 2 Modules; Anderson Power Products 114555P2 |
| LED1 | | LTST-C195 | BI-COLOR GREEN/YELLOW LED |
| LED2 | | LTST-C195 | BI-COLOR GREEN/YELLOW LED |
| LED3 | | 1206 | Orange LED Top-View |
| L1 | 170 µH | Horiz Toroid Thru-Hole | 3-Phase Common Mode Choke with Insulated Wire *See Note 1 |
| L2 | 170 µH | Horiz Toroid Thru-Hole | 3-Phase Common Mode Choke with Insulated Wire *See Note 1 |
| LI1 | | Radial | Neon Lamp; Visual Communications A1C |
| LI2 | | Radial | Neon Lamp; Visual Communications A1C |
| LI3 | | Radial | Neon Lamp; Visual Communications A1C |

***Note 1:** Refer to the MACF-115-3PH-270P-FP Datasheet, page 11, for CM Choke construction based on the desired number of PFC modules to be placed in parallel

## Appendix A – Bill of Materials (BOM)

### Table 4: EVAL-1000031

| Ref Des | Value | Package | Description |
|---|---|---|---|
| M1 | 300VAC | Radial | Metal Oxide Varistor, 300V AC, 10mm disc; E pcos S10K300E2, Epcos B72210S2301K101 |
| M2 | 300VAC | Radial | Metal Oxide Varistor, 300V AC, 10mm disc; E pcos S10K300E2, Epcos B72210S2301K101 |
| M3 | 300VAC | Radial | Metal Oxide Varistor, 300V AC, 10mm disc; E pcos S10K300E2, Epcos B72210S2301K101 |
| Q1 | 40V | SC-70-6 | Dual NPN Transistor; Diodes, Inc. 118-0DT3904 |
| Q2 | 40V | SC-70-6 | Dual NPN Transistor; Diodes, Inc. 118-0DT3904 |
| Q3 | -150V | SC-70-3 | PNP Transistor; Diodes, Inc. MMST5401-7-F |
| Q4 | 160V | SC-70-3 | NPN Transistor; Diodes, Inc. MMST5551-7, Philips PMST5551 TR |
| Q5 | 160V | SC-70-3 | NPN Transistor; Diodes, Inc. MMST5551-7, Philips PMST5551 TR |
| Q6 | -150V | SC-70-3 | PNP Transistor; Diodes, Inc. MMST5401-7-F |
| Q8 | 160V | SC-70-3 | NPN Transistor; Diodes, Inc. MMST5551-7, Philips PMST5551 TR |
| Q9 | -150V | SC-70-3 | PNP Transistor; Diodes, Inc. MMST5401-7-F |
| Q10 | 160V | SC-70-3 | NPN Transistor; Diodes, Inc. MMST5551-7, Philips PMST5551 TR |
| Q11 | -150V | SC-70-3 | PNP Transistor; Diodes, Inc. MMST5401-7-F |
| Q12 | 160V | SC-70-3 | NPN Transistor; Diodes, Inc. MMST5551-7, Philips PMST5551 TR |
| Q13 | -150V | SC-70-3 | PNP Transistor; Diodes, Inc. MMST5401-7-F |
| Q14 | 160V | SC-70-3 | NPN Transistor; Diodes, Inc. MMST5551-7, Philips PMST5551 TR |
| Q15 | -150V | SC-70-3 | PNP Transistor; Diodes, Inc. MMST5401-7-F |
| Q16 | 160V | SC-70-3 | NPN Transistor; Diodes, Inc. MMST5551-7, Philips PMST5551 TR |
| Q17 | -150V | SC-70-3 | PNP Transistor; Diodes, Inc. MMST5401-7-F |
| R1 – R6 | 200K | 1206 | Resistor, High Voltage; Stackpole Electronics RVC1206FT200K, Yageo RV1206FR-07200KL |
| R8, R9, R10,R19, R20,R22, R25-28 | 499K | 0805 | Resistor - Special High Voltage, 499K, 0.5%, 0805 KOA, HV732ATTD4993D |
| R11,R23, R31-39, R40-42 | 49.9K | 0805 | Resistor 49.9K 1% 0805 Yageo, RC0805FR-0749K9L |
| R16-R18, R21,R24, R30 | 68.0K | 2010 | Resistor, High Voltage Rohm, KTR25JZPF6802 |
| R12, R14 | 301 | 0402 | Resistor 301 1% 0402 Yageo, RC0402FR-07301RL |
| R13,R15 | 10K | 0402 | Resistor 10K 1% 0402 Yageo, RC0402FR-0710K0L |
| R29 | 499 | 0402 | Resistor 4991% 0402 Yageo, RC0402FR-07499RL |
| R7 | 300 | 0805 | Resistor 300 5% 0805 Surge Panasonic, ERJ-P06J301V |
| R43, R60 | 4.7 | Axial | NPN Transistor; Diodes, Inc. MMST5551-7, Philips PMST5551 TR |
| R60 | 4.7 | Axial | Resistor, Pulse Rated Ceramic Composition Ohmite, OX47GKE |
| S1 | SPST | RA | SPDT-T series Subminiature toggle switch C&K Comps, E101MD1ABE |
| TVS1 – TVS6 | 430V | Axial | High Energy Bidirectional TVS Littelfuse, AK3-430C |
| U1 | | SC-70-6 | 3-Input AND Gate, SC-70-6 TI, SN74LVC1G11DCKR |
| U49 | | TSSOP-16 | RS-232, 3.3/5.0V Transceiver, TSSOP-16 TI, MAX3232EIPWR |