

# 650W Interleaved Boost PFC Z-Rec™ (C3D) Demonstration Board

## 1. Introduction:

The 650W Z-Rec™ demonstration board is a 650-W, two phase interleaved, PFC pre-regulator that uses average current mode control techniques to achieve near unity power factor. The pre-regulator was designed to operate off a universal ac line input of 85 V to 265 V and provides a regulated 390-V dc output. This board demonstrates Cree's 600V Z-Rec™ SiC diode performance at more than 300W per phase. The 650W board is demonstrated with 2A SiC diodes for each phase.

## 2. Features:

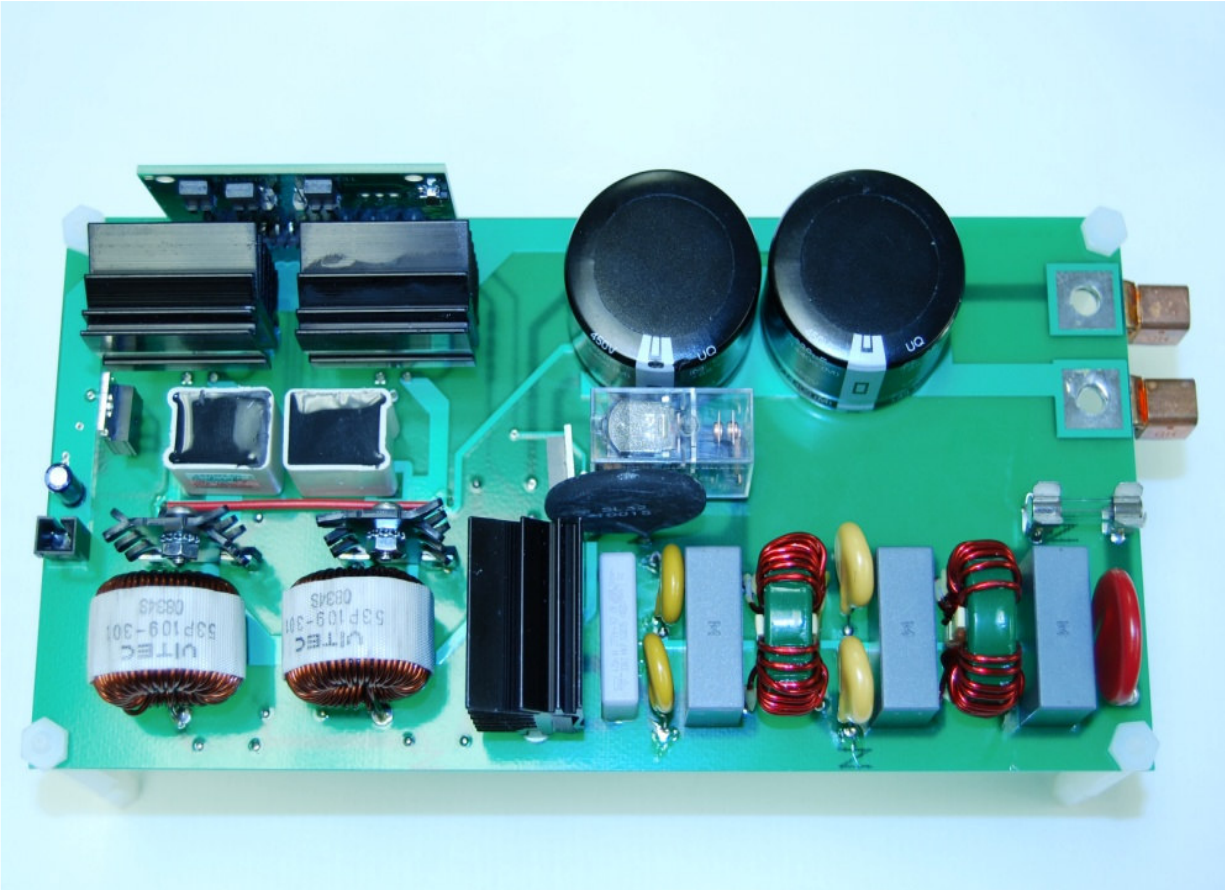
- Designed to meet IEC1000-3-2
- Universal line, 85Vac to 265Vac
- Regulated 390Vdc at 650W output
- Interleaved dual phase design
- Switching frequency 100kHz

## 3. Electrical Specifications:

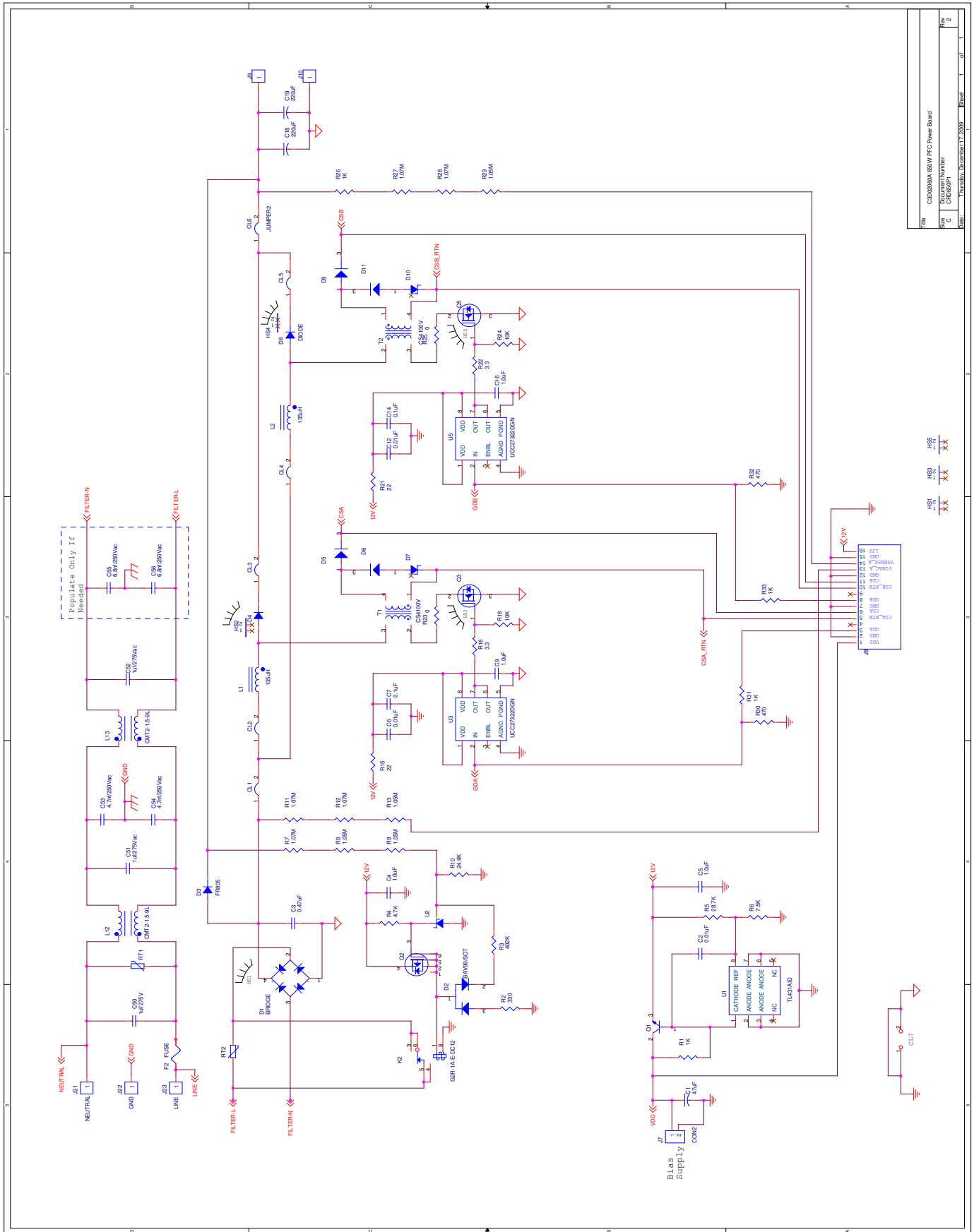
| Definition                         | Minimum   | Maximum     | Units     |
|------------------------------------|-----------|-------------|-----------|
| <b>RMS Input Voltage (AC line)</b> | <b>85</b> | <b>265</b>  | <b>V</b>  |
| <b>Output Voltage</b>              |           | <b>390</b>  | <b>V</b>  |
| <b>Line Frequency</b>              | <b>47</b> | <b>63</b>   | <b>Hz</b> |
| <b>Power Factor</b>                | <b>.9</b> | <b>0.99</b> |           |
| <b>Output Power</b>                |           | <b>650</b>  | <b>W</b>  |
| <b>Full Load Efficiency</b>        | <b>93</b> | <b>96.6</b> | <b>%</b>  |

### 4. Demonstration Board

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# 5. Schematics- Power Board



## 6. Schematics- Daughter Card

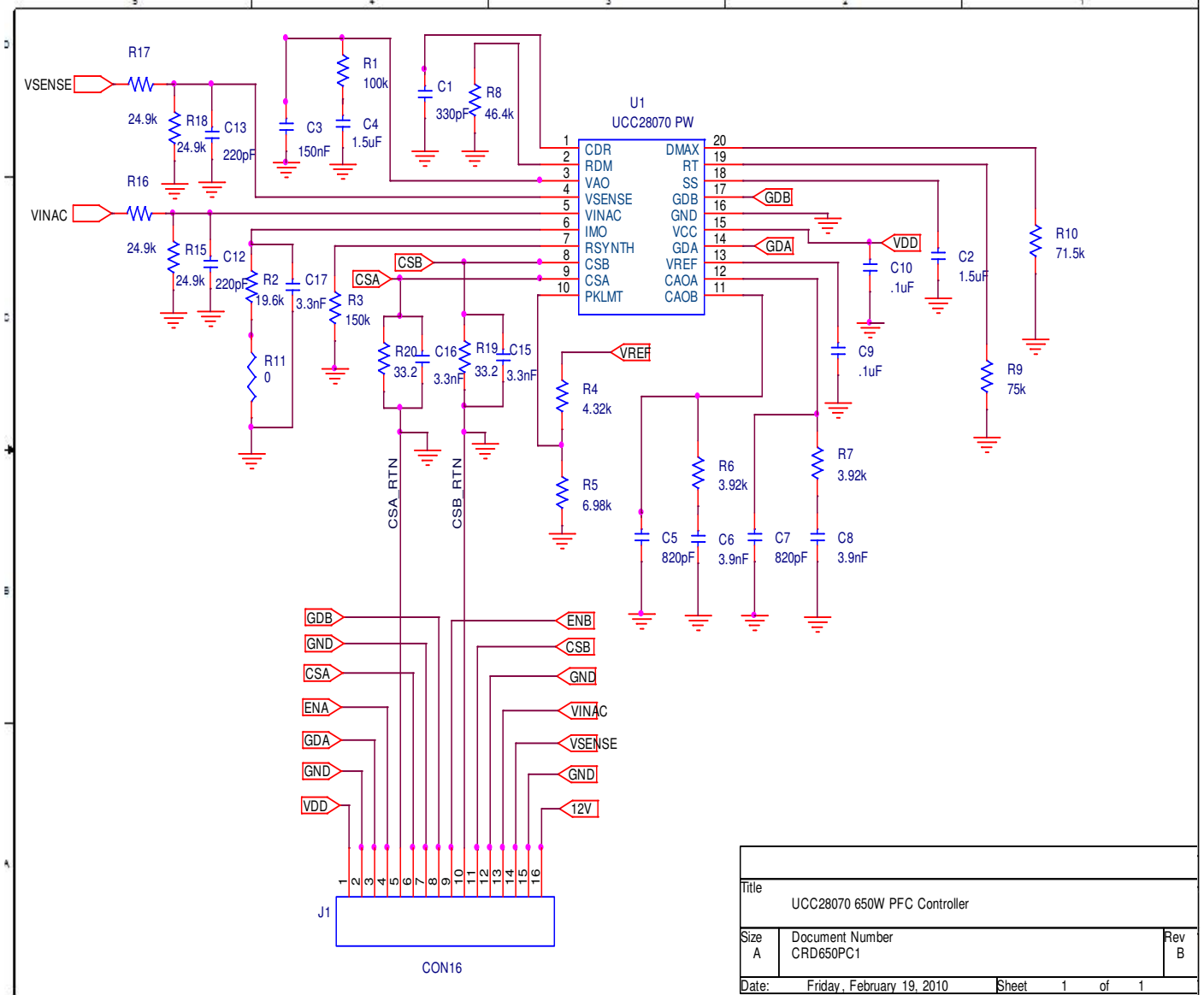
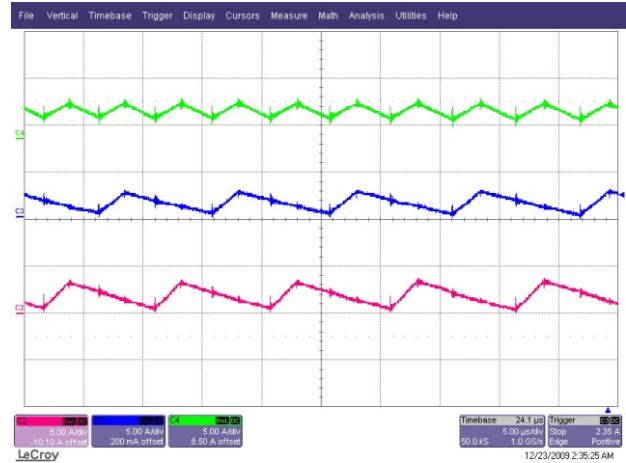


Figure 2: UCC28070 Daughter Card Schematics

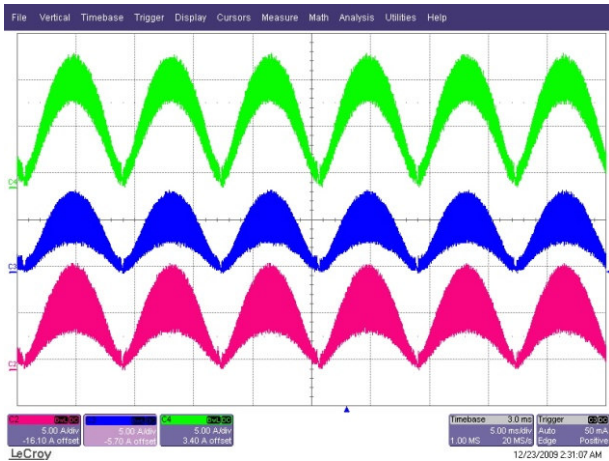
## 7. Input Ripple Cancellation Waveforms



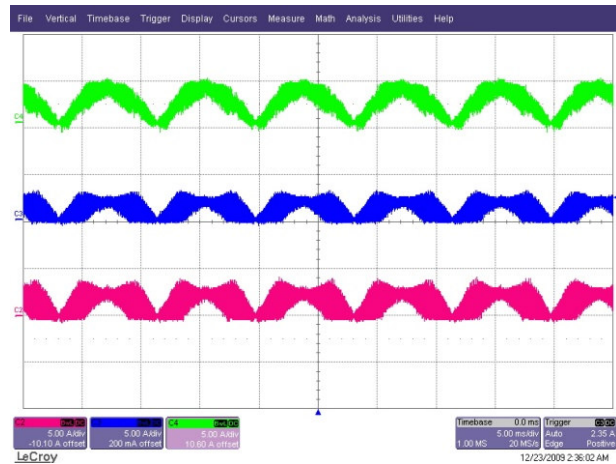
**Figure 3: Input and Inductor Current Ripple at  $V_{in}=85V$  RMS and  $P_{out}=650W$**



**Figure 4: Input and Inductor Current Ripple at  $V_{in}=265V$  RMS and  $P_{out}=650W$**



**Figure 5: Input and Inductor Current Ripple at  $V_{in}=85V$  RMS and  $P_{out}=650W$**



**Figure 6: Input and Inductor Current Ripple at  $V_{in}=265V$  RMS and  $P_{out}=650W$**

## 8. Performance Data with C3D02060 (with Cooling)

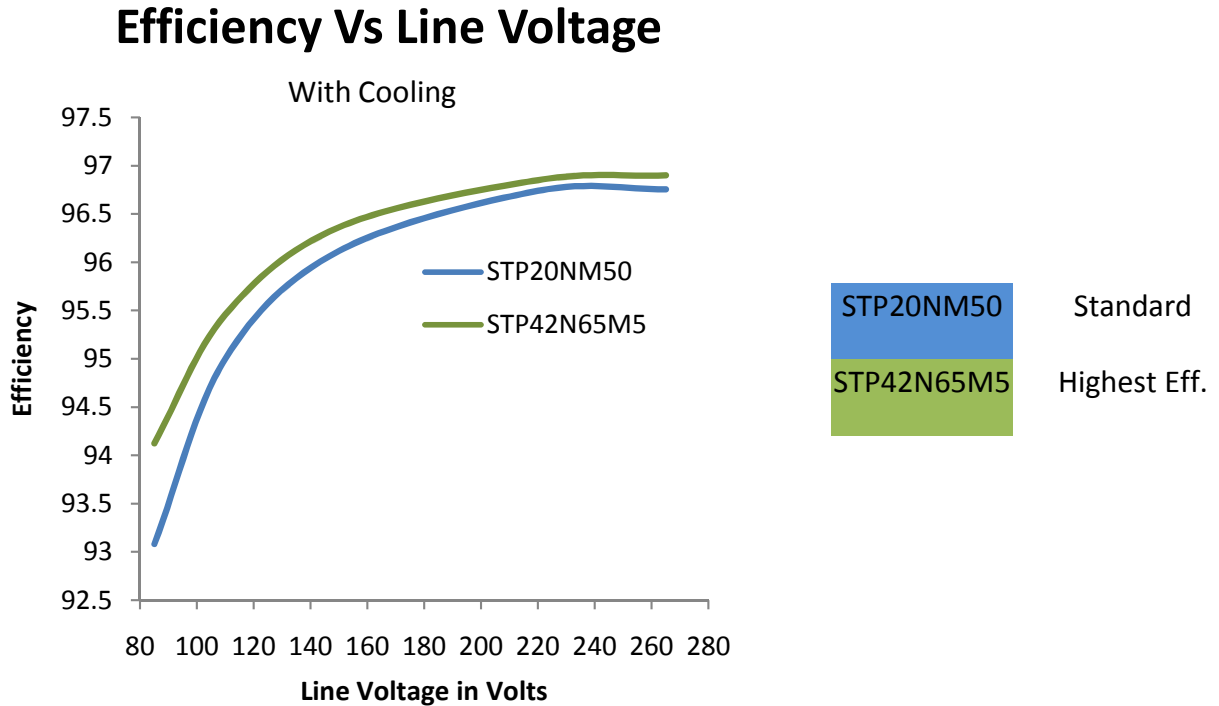


Figure 7: Efficiency Data at Pout=650W for various line voltages

## 9. Performance Data with C3D02060 –STP42N65M5(without Cooling)

| Vin (V) | Iin(V) | PF    | Eff (%) | Q1 (deg C) | Q2 (deg C) | D1 (deg C) | D2 (deg C) |
|---------|--------|-------|---------|------------|------------|------------|------------|
| 265     | 2.5    | 0.988 | 96.64   | 58.4       | 58.1       | 56.8       | 62.2       |
| 220     | 3.1    | 0.994 | 96.62   | 60.6       | 59.4       | 61.5       | 66.6       |
| 150     | 4.5    | 0.999 | 96.20   | 70.3       | 68.6       | 69.8       | 74.2       |
| 110     | 6.2    | 0.999 | 95.37   | 82.1       | 79.6       | 78.6       | 83.7       |
| 85      | 8.2    | 0.999 | 93.73   | 97.4       | 93.2       | 90.5       | 94.7       |

## 10. EMI Performance:

### 2 Common modes 1.5 mH with one Y2 caps 6.8n and X2 Caps= 1uF



Figure 8: Frequency sweep from 150kHz to 1MHz  
Vin=208V RMS and Pout=650W

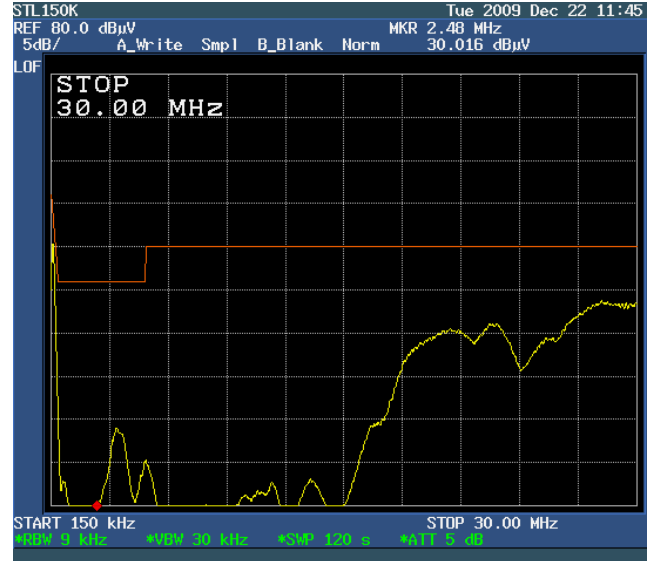


Figure 9: Frequency sweep from 150kHz to 30MHz  
Vin=208V RMS and Pout=650W

### 2 Common modes 1.5 mH with both with Y2 caps (4.7n and 6.8n) X2 Caps= 1uF



Figure 10: Frequency sweep from 150kHz to 1MHz  
Vin=208V RMS and Pout=650W



Figure 11: Frequency sweep from 150kHz to 30MHz  
Vin=208V RMS and Pout=650W

## 11.1 Bill of Materials - Power Board

| Quantity | Reference           | Value           | Description  | Size               | Part Number    | Mfr           |
|----------|---------------------|-----------------|--|--------------------|----------------|---------------|
| 5        | CL1,CL2,CL4,CL5,CL6 | N/A             | Jumper, 0.400 inch length, PVC Insulation, AWG 22, | 0.060 x 0.400 inch | 923345-04-C    | 3M            |
| 2        | CL7,CL2             | N/A             | Jumper, 2.000 inch length, PVC Insulation, AWG 18  | 0.035 inch Dia.    | 923345-20-C    | 3M            |
| 1        | C1                  | 47uF            | Capacitor, Aluminum Electrolytic, 35V              | 0.197 inch         | ECA-1VM470     | Panasonic     |
| 3        | C2,C6,C12           | 0.01uF          | Capacitor, Ceramic, 25V, X7R, ±10%                 | 0603               | Std            | Std           |
| 1        | C3                  | 0.47uF          | Capacitor, 0.47UF, 305VAC, EMI SUPPRESSN           | 0.336 x 1.043 inch | BFC233820474   | Vishay        |
| 4        | C4,C5,C9,C16        | 1.0uF           | Capacitor, Ceramic, 25V, X5R, ±10%                 | 0603               | Std            | Std           |
| 2        | C14,C7              | 0.1uF           | Capacitor, Ceramic, 25V, X7R, ±10%                 | 0603               | Std            | Std           |
| 2        | C19,C18             | 220uF           | Capacitor, Aluminum, 450V, 20%, -40C° to 105C°     | 35mm Dia           | EETUQ2W221LJ   | Panasonic     |
| 1        | D1                  | BRIDGE          | RECT BRIDGE GPP 25A 600V GBJ                       | 1.190 x 0.190 inch | GBJ1506-BP     | Diodes        |
| 1        | D2                  | BAV99/SOT       | DIODE SW DUAL 75V 350MW SOT23                      | SOT23              | BAV99-7-F      | Diodes        |
| 1        | D3                  | FR805           | RECT FAST REC 600V 8A TO-220A                      | TO220AC            | FR805          | Diodes        |
| 2        | D4,D8               | C3D02060A       | Diode Zero Recovery SiC 600V-2A                    | TO220AC            | C3D02060A      | CREE          |
| 4        | D5,D6,D9,D11        | BAS16/SOT       | Diode, Switching, 150-mA, 75-V, 350mW              | SOT23              | BAS16-V-GS08   | Vishay-Liteon |
| 2        | D10,D7              | 33V             | Diode, Zener, 33-V @ 3.8-mA, 225-mW, 5%            | SOT23              | MMBZ5257BLT1   | Motorola      |
| 1        | F2                  | 15A             | Fuse, Fast-Acting, 5x20mm 217 Series               | 5x20mm             | 0217015.HXP    | Littelfuse    |
| 2        | FB2                 | 10A             | Fuseholder, 5x20mm fuses, board mount (Qty: 2)     | 6x12mm             | 0751.0062      | Shurter       |
| 2        | HS1, HS3, HS5       | 780653B1180     | Heatsink, Vertical-mount                           | 1.180 x 0.764 inch | 780653B1180    | Aavid         |
| 2        | HS2,HS4             | 592502          | Heatsink, TO-220, Vertical-mount, 30°C/W           | 0.88 x 0.25 inch   | 592502B03400G  | Thermalloy    |
| 1        | J8                  | PPTC161LF BN-RC | Header, 16-pin, 100mil spacing, Female             | 0.100 inch x 16    | PPTC361LFBN-RC | Sullins       |
| 1        | K2                  | G2R-1A-E-DC12   | Relay, Reed, DPST, 16A, 250VAC                     | 0.210 x 0.810 inch | G2R-1A-E-DC12  | Omron         |

|   |                    |                  |   |                       |                |                  |
|---|--------------------|------------------|---|-----------------------|----------------|------------------|
| 2 | L1,L2              | 78uH             | Power Inductor (78uH @ 10.7ADC Bias & 309uH @0ADC)  | 0.913 X 1.165<br>inch | 53P109-301     | Vitec            |
| 2 | L1,L2              | 95uH             | Power Inductor (67 Turns, 95uH@8.5ADC & 390uH@0ADC) | 1.794 X .691<br>inch  | 77076-A7,16AWG | Magnetics        |
| 1 | Q1                 | TIP29            | Transistor, NPN 1A, 40V                             | TO-220V               | TIP29-BP       | Micro Commercial |
| 1 | Q2                 | ZXMP6A17<br>E6TA | MOSFET P-CH 60V 3A SOT-23-6                         | SOT23-6               | ZXMP6A17E6TA   | Zetex            |
| 2 | Q3,Q5              | STP20NM5<br>0    | MOSFET, N-ch, 500V-V, 20-A, 200-<br>milliOhms       | TO-220V               | STP20NM50      | ST               |
| 2 | Q3,Q5              | STP42N65<br>M5   | MOSFET, N-ch, 650V-V, 33-A, 79-<br>milliOhms        | TO-220V               | STP42N65M5     | ST               |
| 1 | RT1                | V275LA40A<br>P   | Varistor, Disk, 275V                                | 0.220 x 1.043<br>inch | V275LA40AP     | Littelfuse       |
| 1 | RT2                | 7 Ohm            | Varistor, Disk, 265V max., 15A @ 65C°               | 0.200 x 1.180<br>inch | SL32 10015     | Amethern         |
| 3 | R1,R31,R33         | 1K               | Resistor, Chip, 1/16W, ±1%                          | 0603                  | Std            | STD              |
| 1 | R26                | 1k               | Resistor, Chip, 1/16W, ±1%                          | 0805                  | Std            | STD              |
| 1 | R2                 | 330              | Resistor, Chip, 1/16W, ±1%                          | 0603                  | Std            | STD              |
| 1 | R3                 | 402K             | Resistor, Chip, 1/16W, ±1%                          | 0603                  | Std            | STD              |
| 1 | R4                 | 4.7K             | Resistor, Chip, 1/16W, ±1%                          | 0603                  | Std            | STD              |
| 1 | R5                 | 28.7K            | Resistor, Chip, 1/16W, ±1%                          | 0603                  | Std            | STD              |
| 1 | R6                 | 7.5K             | Resistor, Chip, 1/16W, ±1%                          | 0603                  | Std            | STD              |
| 5 | R7,R11,R12,R27,R28 | 1.07M            | Resistor, Chip, 1/16W, ±1%                          | 0805                  | Std            | STD              |
| 4 | R8,R9,R13,R29      | 1.05M            | Resistor, Chip, 1/16W, ±1%                          | 0805                  | Std            | STD              |
| 1 | R10                | 24.9K            | Resistor, Chip, 1/16W, ±1%                          | 0805                  | Std            | STD              |
| 2 | R21,R15            | 22               | Resistor, Chip, 1/16W, ±1%                          | 0603                  | Std            | STD              |
| 2 | R16,R22            | 3.3              | Resistor, Chip, 1/16W, ±1%                          | 0805                  | Std            | STD              |
| 2 | R18,R24            | 10K              | Resistor, Chip, 1/16W, ±1%                          | 0603                  | Std            | STD              |
| 2 | R25,R23            | 0                | Resistor, Chip, 1/16W, ±1%                          | 0805                  | Std            | STD              |
| 2 | R30,R32            | 470              | Resistor, Chip, 1/16W, ±1%                          | 0603                  | Std            | STD              |
| 2 | T1,T2              | CS4100V          | Transformer, Current Sense, 100:1                   | 0.570 x 0.770<br>inch | CS4100V-01L    | Coilcraft        |
| 1 | U1                 | TL431AID         | IC, Adj Shunt Regulator, 100-mA, 36-V               | SO8                   | TL431AID       | TI               |

|   |                                |                 |   |                     |                 |                      |
|---|--------------------------------|-----------------|---|---------------------|-----------------|----------------------|
| 1 | U2                             | TL431AIDBZR     | IC PREC SHUNT REG ADJ SOT23-3                           | SOT23-3             | TL431AIDBZR     | TI                   |
| 2 | U5,U3                          | UCC27322DGN     | IC, Single 9-A High Speed Low-Side MOSFET Driver        | MSOP-8              | UCC27322DGN     | TI                   |
| 3 | C50,C51,C52                    | 1uF             | Capacitor, 1uF, 275VAC, 560VDC X2 Cap                   | 10x18.5x26.5 mm     | R46KN410000N2   | Arcotronics          |
| 2 | C55,C56                        | 6.8nF           | Capacitor, 6.8nF, 300V, Ceramic, Y2-VY2 series          | 14.5mm Dia.         | VY2682M59Y5US63 | Vishay               |
| 2 | C53,C54                        | 4.7nF           | Capacitor, 4.7nF, 300V, Ceramic, Y2-VY2 series          | 12.5mm Dia.         | VY2472M49Y5US6* | Vishay               |
| 2 | L12,L13                        | 1.5mH           | Common Mode Choke, 1.5mH, 9A, 17uH Leakage              | 1.23x1.25x.825 inch | CMT2-1.5-9L     | Coilcraft            |
| 6 | 2x @ HS1, HS3,HS5              | Spacers         | Board Spacers, Standoffs, 0.125" (3.2mm) 1/8", Nylon #4 | 0.125 x 0.250       | 875             | Keystone Electronics |
| 4 | 2x @ HS1, HS3, HS5             | Screw           | Pan Head Screw M3 (steel) 0.236" (6.00mm)               | 0.236" (6.00mm)     | Std             | STD                  |
| 4 | 1x @ HS3, HS5<br>1x @ HS2, HS4 | Insulator       | Thermal Pad Silicon TO220                               |                     | 3223-07FR-51    | Berquist             |
| 2 | 1x @HS2, HS4                   | Nut             | Std #4/40 Steel Nut                                     |                     | Std             | STD                  |
| 2 | 1x @ HS2, HS4                  | Screw           | Pan Head Screw #4/40 Steel 0.5"                         |                     | Std             | STD                  |
| 2 | 1x @HS2, HS4                   | Shoulder Washer | Washer/Bushing #4 0.031"L Nylon                         |                     | 3049            | Keystone Electronics |
|   |                                |                 | Highest Efficiency                                      |                     |                 |                      |
|   |                                |                 | Standard  |                     |                 |                      |



## 11.2 Bill of Materials - Control Card

| Quantity | Reference       | Value       | Description                                    | Size            | Part Number | Mfr     |
|----------|-----------------|-------------|--|-----------------|-------------|---------|
| 1        | C1              | 330pF       | Capacitor, Ceramic, 50V, C0G, ±5%              | 0603            | STD         | STD     |
| 2        | C2,C4           | 1.5uF       | Capacitor, Ceramic, 16V, X5R, ±10%             | 0603            | STD         | STD     |
| 1        | C3              | 150nF       | Capacitor, Ceramic, 25V, X7R, ±10%             | 0603            | STD         | STD     |
| 2        | C5,C7           | 820pF       | Capacitor, Ceramic, 50V, C0G, ±5%              | 0603            | STD         | STD     |
| 2        | C6,C8           | 3.9nF       | Capacitor, Ceramic, 50V, X7R, ±10%             | 0603            | STD         | STD     |
| 2        | C9,C10          | .1uF        | Capacitor, Ceramic, 25V, X7R, ±10%             | 0603            | STD         | STD     |
| 2        | C12,C13         | 220pF       | Capacitor, Ceramic, 50V, C0G, ±5%              | 0603            | STD         | STD     |
| 3        | C15,C16,C17     | 3.3nF       | Capacitor, Ceramic, 50V, X7R, ±10%             | 0603            | STD         | STD     |
| 1        | J1              | PBC16SBAN   | CONN, HEADER, .100, SINGL, R/A, 16POS          | 0.100 inch x 16 | PBC36SBAN   | Sullins |
| 1        | R1              | 100k        | Resistor, Chip, 1/16W, ±1%                     | 0603            | STD         | STD     |
| 1        | R2              | 19.6k       | Resistor, Chip, 1/16W, ±1%                     | 0603            | STD         | STD     |
| 1        | R3              | 63.4k       | Resistor, Chip, 1/16W, ±1%                     | 0603            | STD         | STD     |
| 1        | R4              | 4.32k       | Resistor, Chip, 1/16W, ±1%                     | 0603            | STD         | STD     |
| 1        | R5              | 6.98k       | Resistor, Chip, 1/16W, ±1%                     | 0603            | STD         | STD     |
| 2        | R6,R7           | 3.92k       | Resistor, Chip, 1/16W, ±1%                     | 0603            | STD         | STD     |
| 1        | R8              | 46.4k       | Resistor, Chip, 1/16W, ±1%                     | 0603            | STD         | STD     |
| 1        | R9              | 75k         | Resistor, Chip, 1/16W, ±1%                     | 0603            | STD         | STD     |
| 1        | R10             | 71.5k       | Resistor, Chip, 1/16W, ±1%                     | 0603            | STD         | STD     |
| 1        | R11             | 0           | Resistor, Chip, 1/16W, ±1%                     | 0603            | STD         | STD     |
| 4        | R15,R16,R17,R18 | 24.9k       | Resistor, Chip, 1/16W, ±1%                     | 0603            | STD         | STD     |
| 2        | R19,R20         | 33.2        | Resistor, Chip, 1/10W, ±1%                     | 0805            | STD         | STD     |
| 1        | U1              | UCC28070 PW | IC, Two- Phases Interleaved CCM PFC Controller | TSSOP-20        | UCC28070PW  | TI      |