# 240 W USB PD3.1 Solution

# TND6412/D

## SPECIFICATION

| onsemi's Devices | Applications | Input Voltage | Output Power | Topology | I/O Isolation |
|---|---|---|---|---|---|
| NCP1680<br>NCP13994<br>2*NCP51530BMNTWG<br>2*NCP4306DAHZZAA<br>FAN65004C<br>4*NCP58921<br>2*NTMT064N65<br>2*FDMS4D0N12C | PD3.1 adapter for computer and smart phone, Industrial and lighting power supply, other applications | 90 Vac to 264 Vac | 240 W | TPPFC + LLC + DC−DC | Isolated |

| | Output Specification |
|---|---|
| Output Voltage | 5 V, 9 V, 12 V, 15 V, 20 V, 28 V, 36 V, 48 V |
| Max Current | 5 A |
| Min Current | zero |

| | |
|---|---|
| Efficiency | 95.2% & 96.2% @ 115 Vac & 230 Vac and 48V 5A |
| Protection | OVP, OCP, SCP, OTP |
| PCBA Size | 98 mm × 62 mm × 21.5 mm |

### Circuit Description

This reference design describes a 240 W PD3.1 solution using NCP1680, NCP13994, NCP4306 and FAN65004, three stages structure power supply for PD3.1 smart phone super charger, NB adaptor and general power supply supporting 240 W with high efficiency and compact profile if removing DC−DC daughter card.

The featured PFC solution uses NCP1680 totem pole PFC controller with CRM and VSFF control, HF current mode LLC controller and syn. controller NCP4306 are used for DC−DC converter for fixed 52 V output, FAN65004 is used for variable output from 5 V to 48 V to meet PD3.1 specification. 2 SJ FET are used for PFC slow leg SW and 4 iGaN NCP58921 are used for PFC fast leg SW and LLC SW.

This reference design provides the complete circuit schematic details, PCB layout, EVM photo, inductor, transformer specification and BOM for 240 W PD3.1 solution, also some key waveforms for reference.

A dual layer PCB is designed for a demonstration although totem pole PFC has more component and complex replacement, also consider easy to test, less daughter card is used, DC−DC daughter is also easy to be replaced by new design with PD3.1 protocal controller.

LLC controller has a high startup current source and PFC controller has a low operation current, so LLC startup current source should supply PFC and LLC Vcc during startup, PFC controller has a low Vcc_on threshold so PFC will start first then LLC Vcc continues to rise to Vcc_on threshold, PFC has completed startup and PFCOK signal has a high level output while Vcc reaches Vcc_on, a capacitor with large capacitance is used for LLC Vcc to maintain enough voltage to ensure PFC operation until LLC operation then LLC's auxiliary winding supplies all Vcc voltage.

Another special design is between PFCOK pin of PFC and VBULK pin of LLC, this is a bidirectional signal that PFCOK is as LLC's brown out control and VBULK pin provides negative pulse to PFC for forced standby while LLC is in skip mode.

No 48 V PD3.1 controller in current market so 3 DIP switch combination are decoded to control DC−DC converter's feedback divider to simulate PD3.1 output voltage up to 48 V.

**Key Features**

- AC Input from 90 V to 264 V
- TPPFC + LLC + DC−DC Topology
- High Frequency Operation with iGaN
- Skip Operation for PFC and LLC at Light Load and PFM Mode for DC−DC Converter
- External Discrete Circuit to Simulate PD3.1 Multi−output
- Output Voltage and Current 5 V, 9 V, 12 V, 15 V, 20 V, 28 V, 36 V, 48 V and 5 A
- Max Output Power: 240 W
- Simulate PD3.1 to Support up to 48 V
- Ripple & Noise: <100 mV
- AVG Efficiency: 94.5% & 95.2% at 115 Vac & 230 Vac and 48 V
- Full Load Efficiency: 95.2% & 96.2% at 115 Vac & 230 Vac and 48 V 5 A
- Output Precise OVP
- Output OCP, SCP
- Open Loop Protection
- 2 layers PCB Used and Small Size with Compact Design
- PCBA size: 98 mm × 62 mm × 21.5 mm
- Power Density: 30 W/in^3

## BOARD PHOTOS

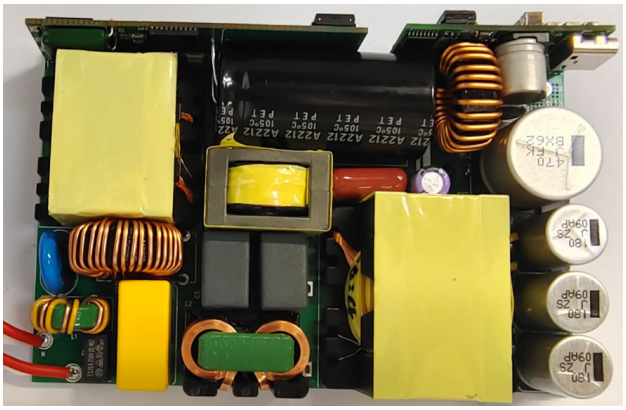

**Figure 1. The Front View of 240 W EVM**

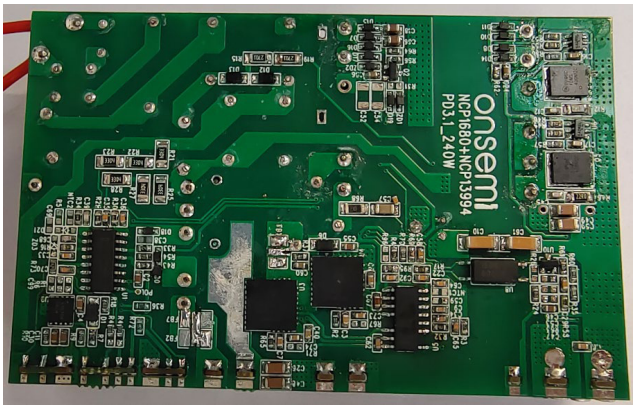


**Figure 2. Reverse Side of 240 W EVM**

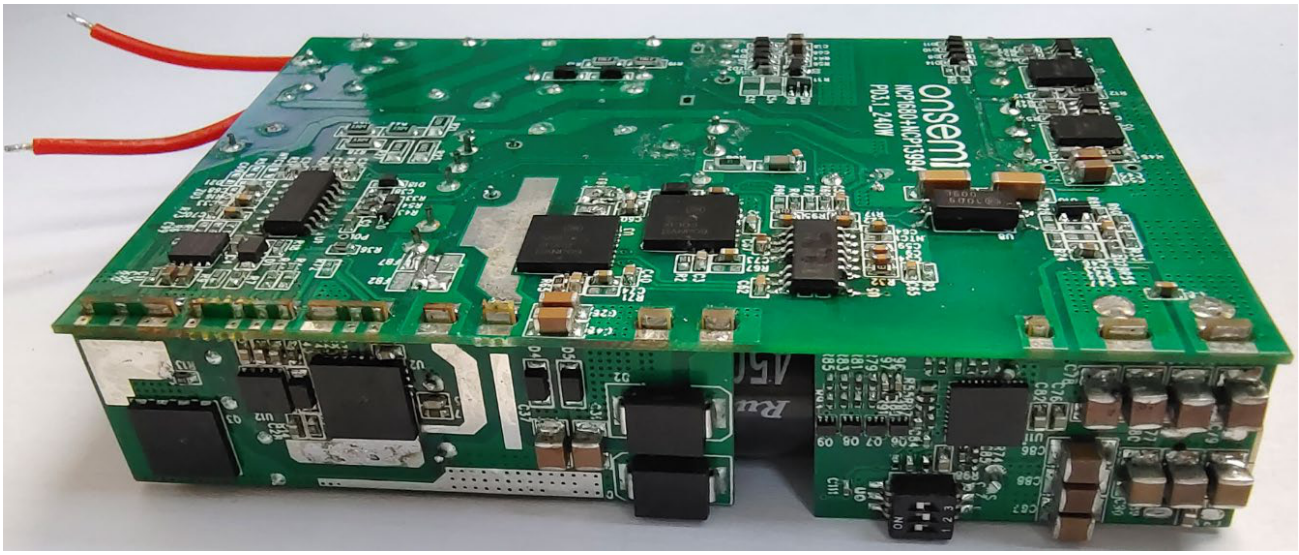


**Figure 3. Profile of 240 W EVM**

## CIRCUIT SCHEMATIC

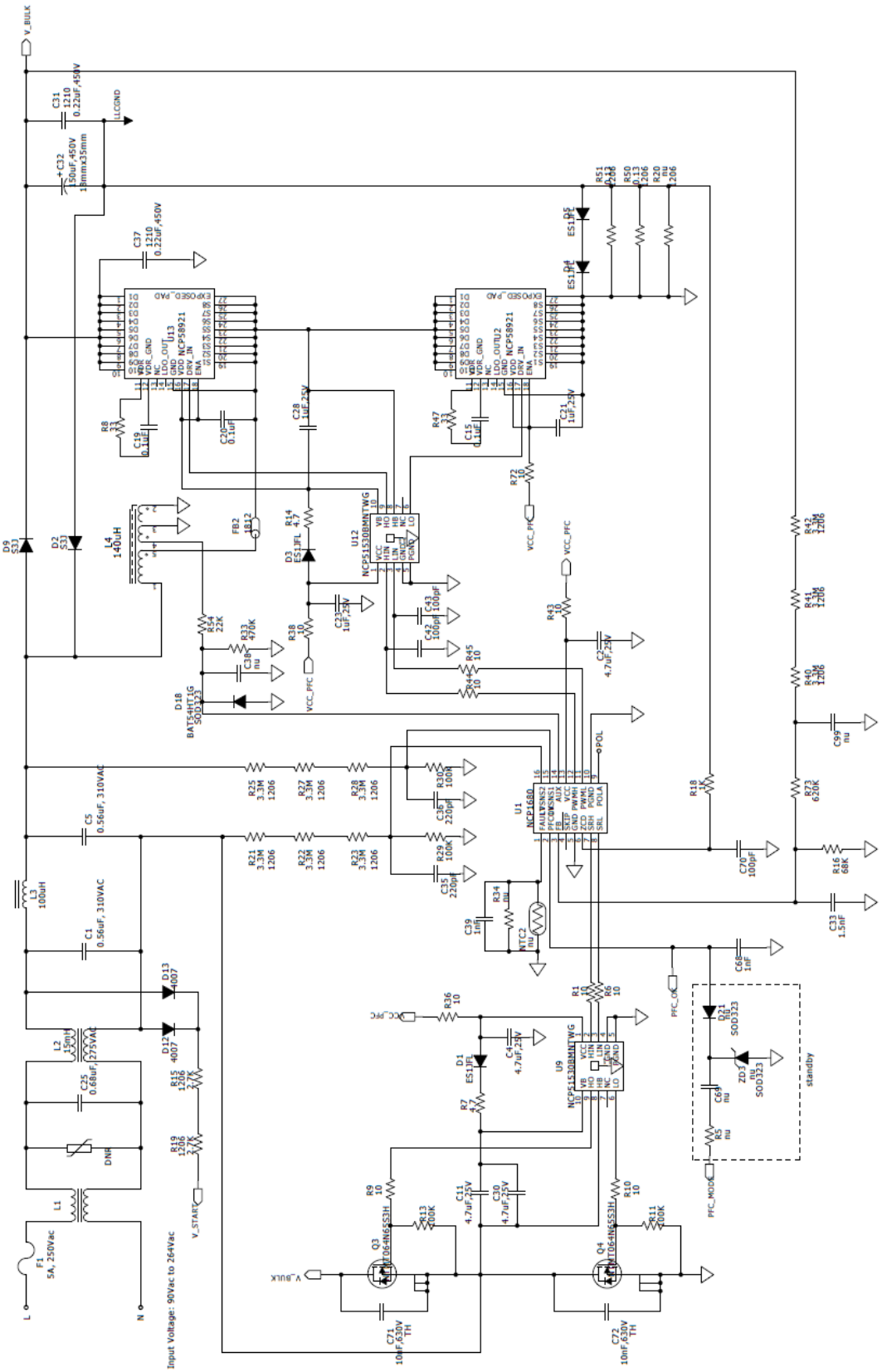


**Figure 4. Schematic for TPPFC Portion**

## CIRCUIT SCHEMATIC (LLC PORTION)

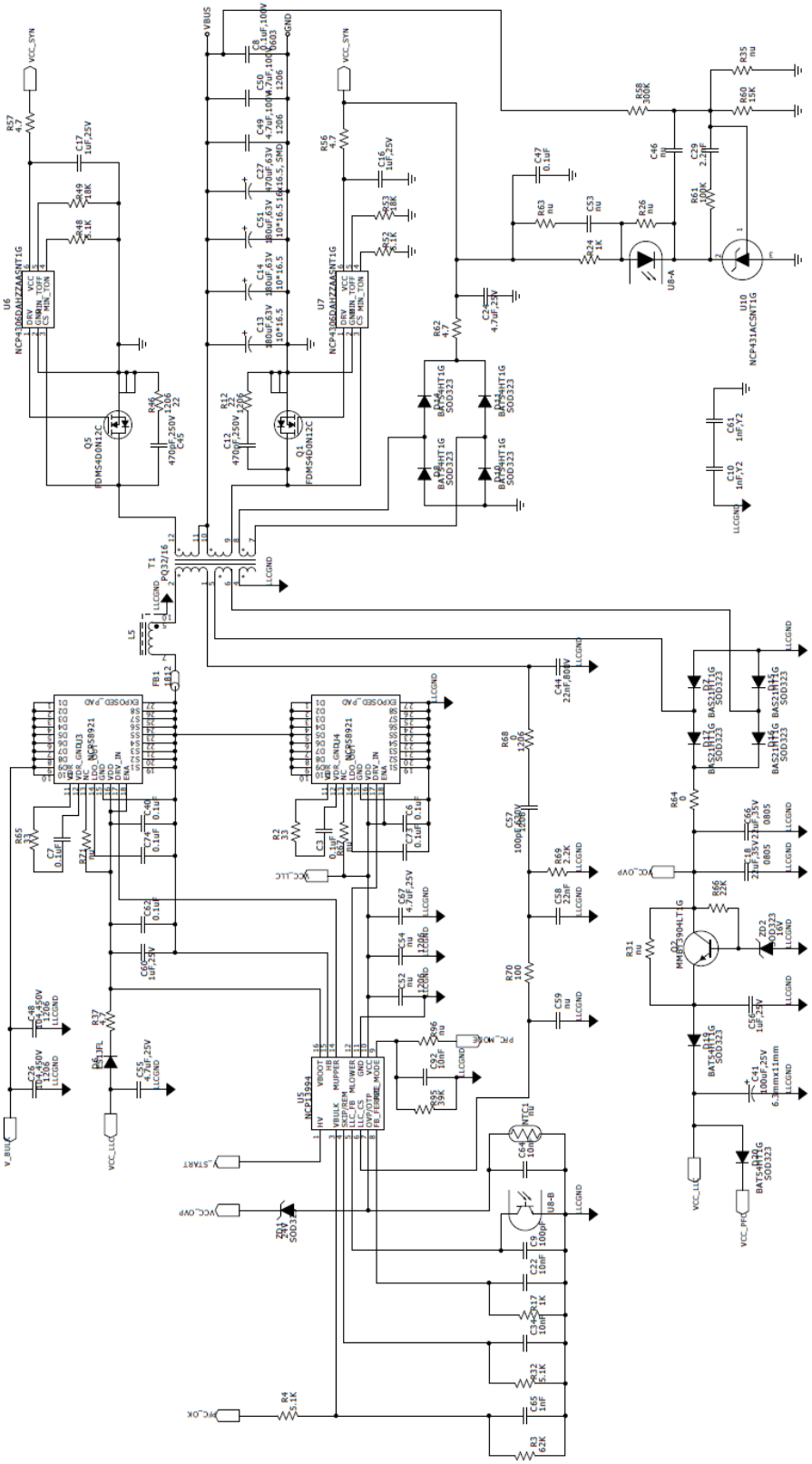

**Figure 5. Schematic for LLC Portion**

## CIRCUIT SCHEMATIC (DC−DC PORTION)

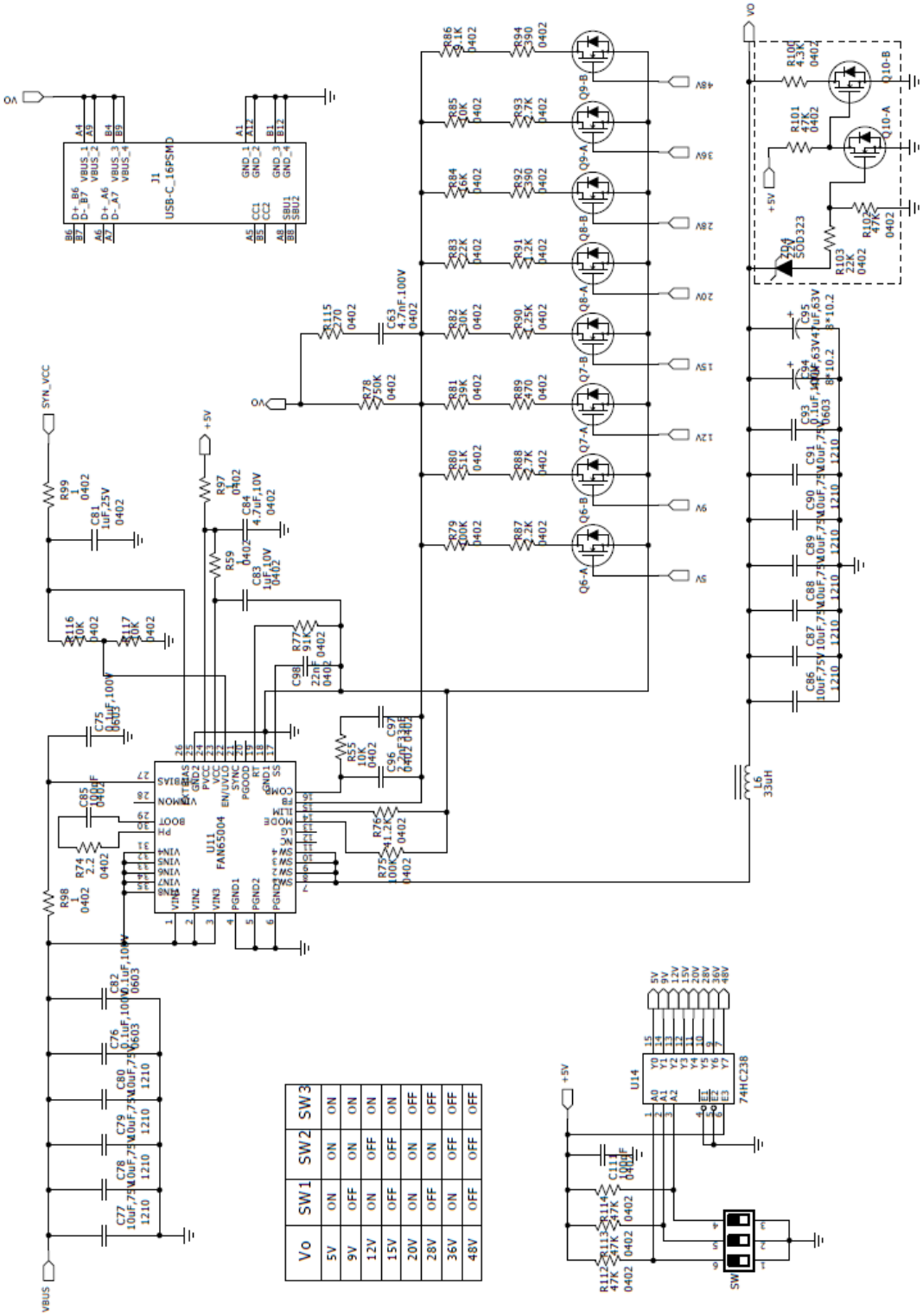


**Figure 6. Schematic for DC−DC Converter**

## PCB LAYOUT

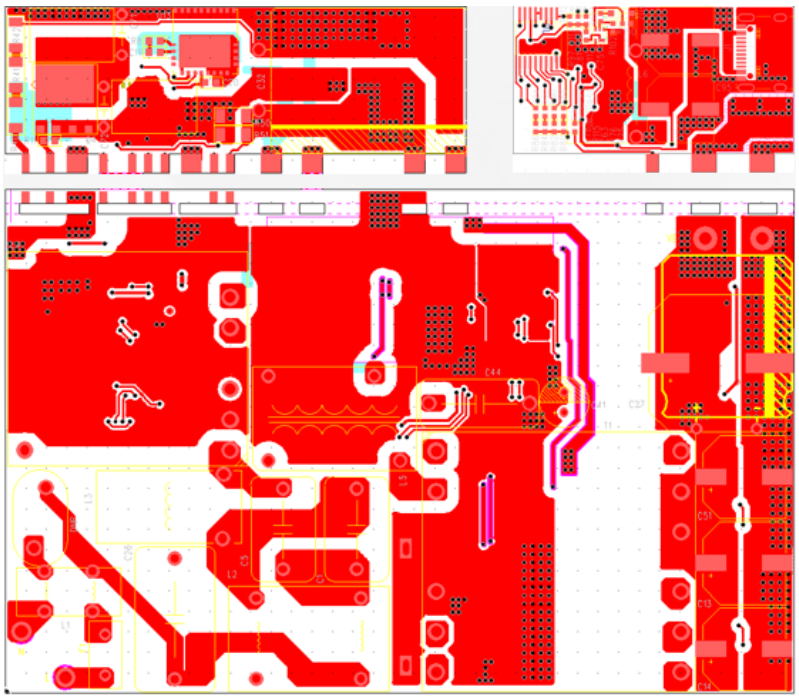

Figure 7. Top View

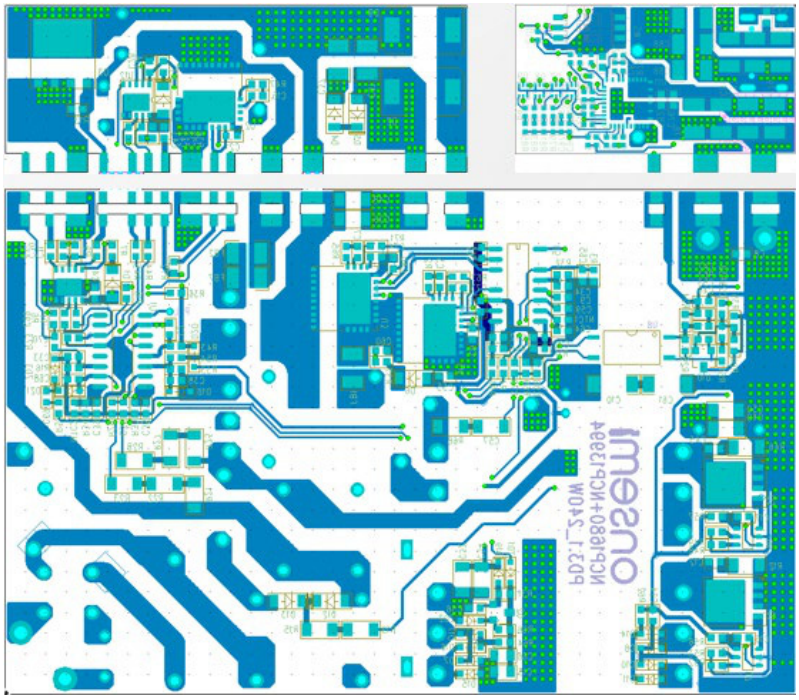

Figure 8. Bottom View

## PFC INDUCTOR DESIGNS

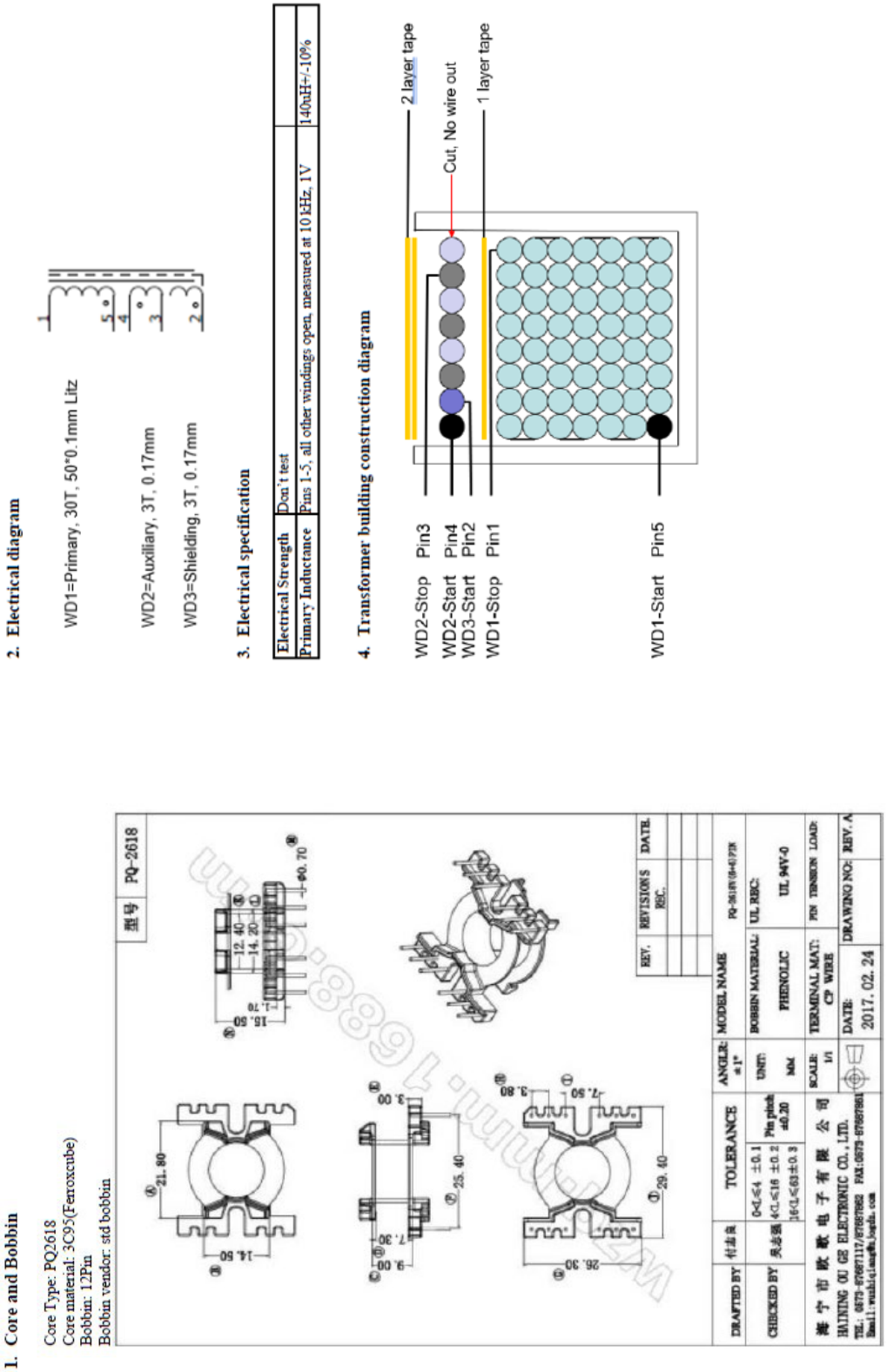


Figure 9. PFC Inductor Designs

## LLC RESONANT INDUCTOR DESIGNS

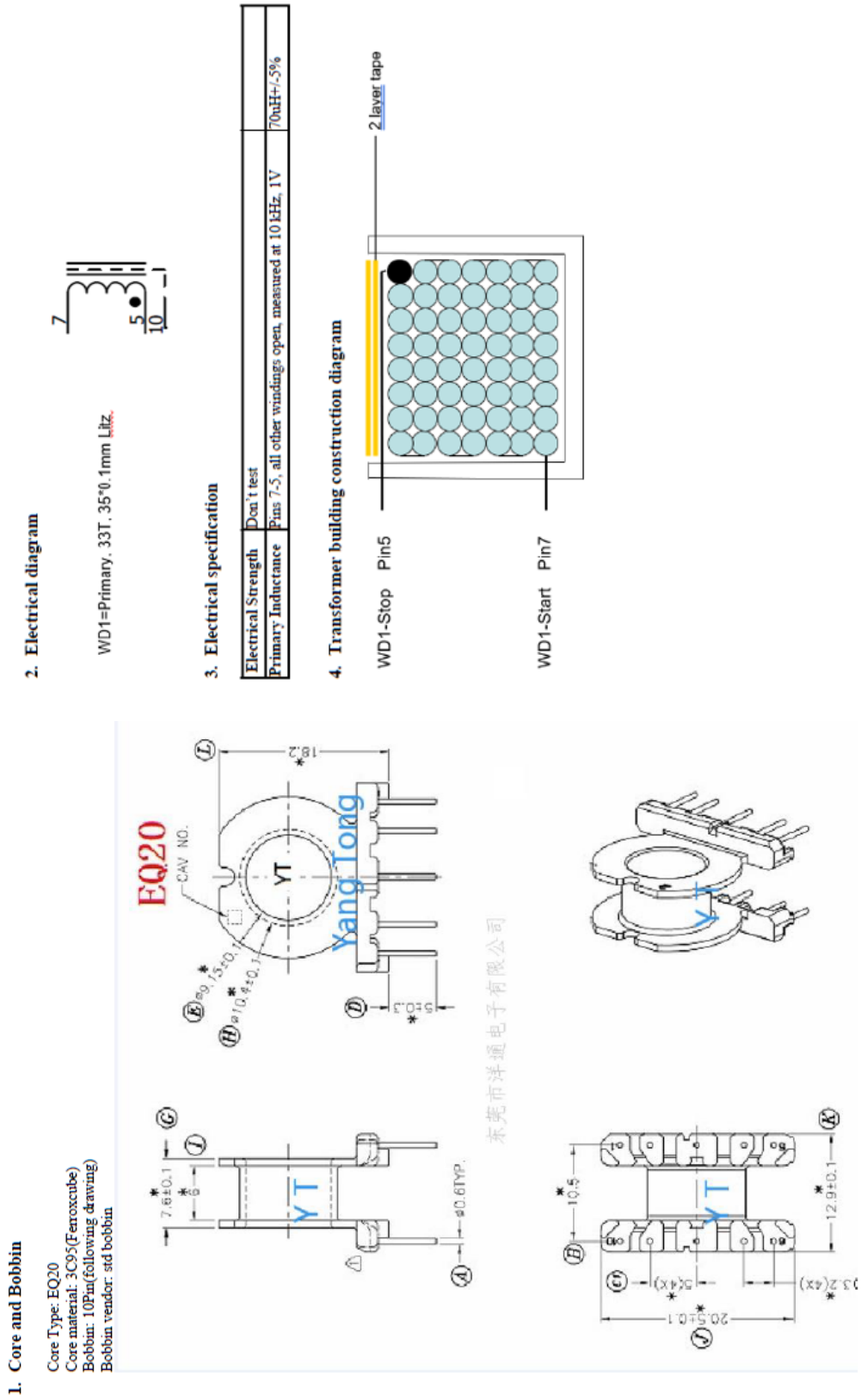


Figure 10. LLC Resonant Inductor Designs

## LLC TRANSFORMER DESIGNS

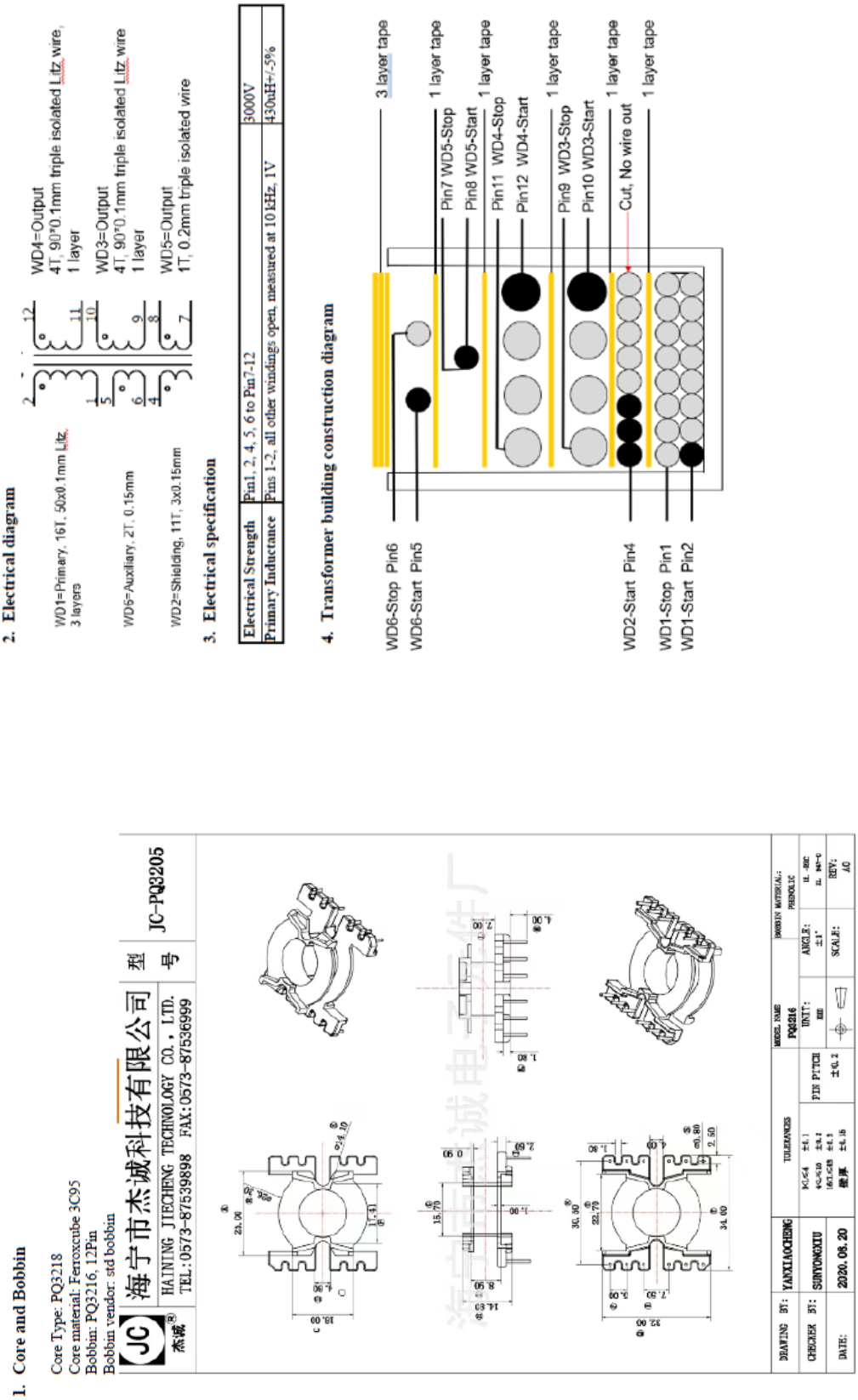


Figure 11. LLC Transformer Designs

### AVG. Efficiency and 10% Load Efficiency

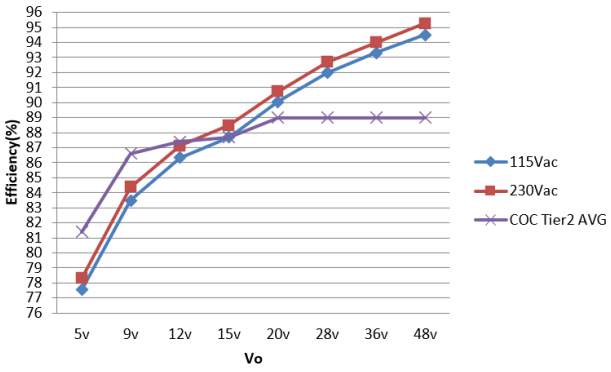


Figure 12. Avg. Efficiency

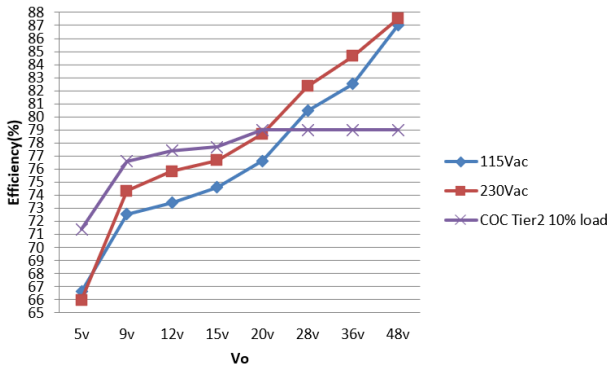


Figure 13. 10% Load Efficiency

### Standby Power and PF

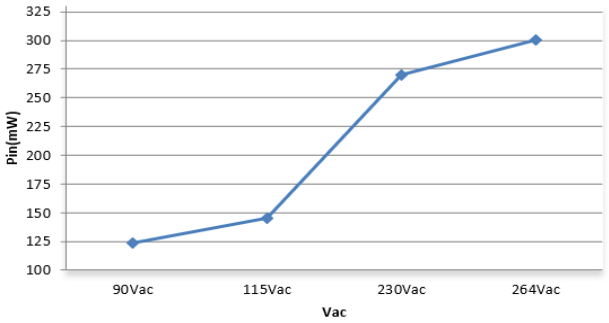


Figure 14. Standby Power

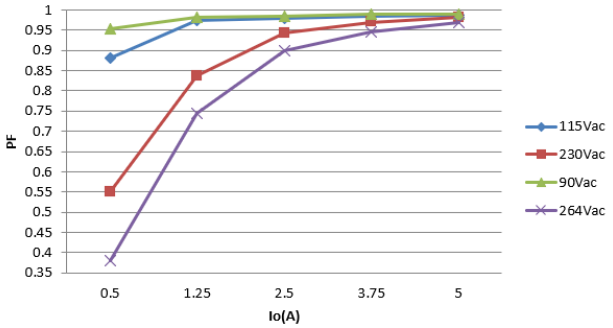


Figure 15. PF

### Efficiency vs. Load

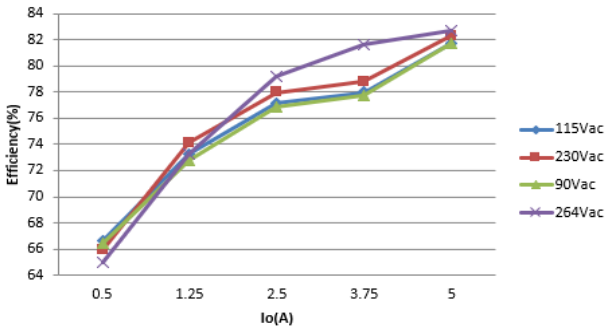


Figure 16. 5 V

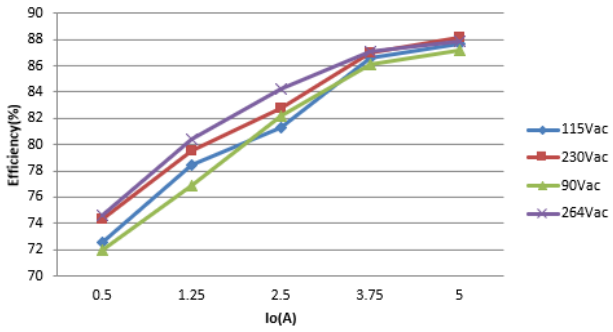


Figure 17. 9 V

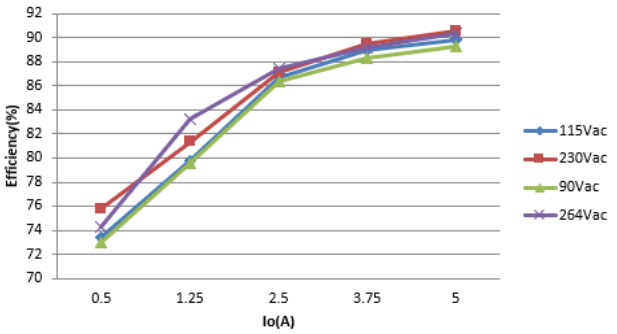


Figure 18. 12 V

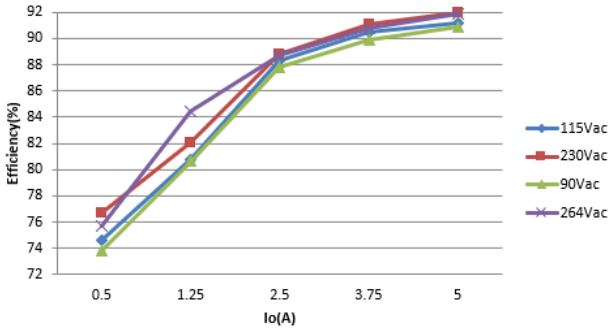


Figure 19. 15 V

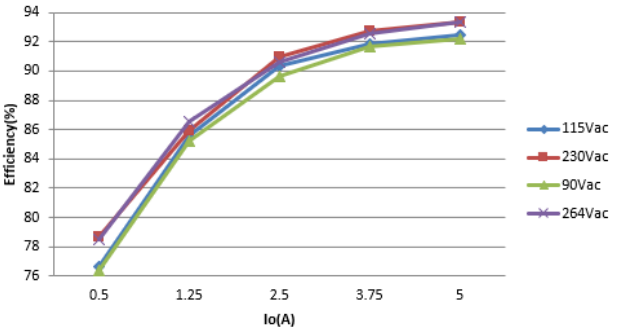


Figure 20. 20 V

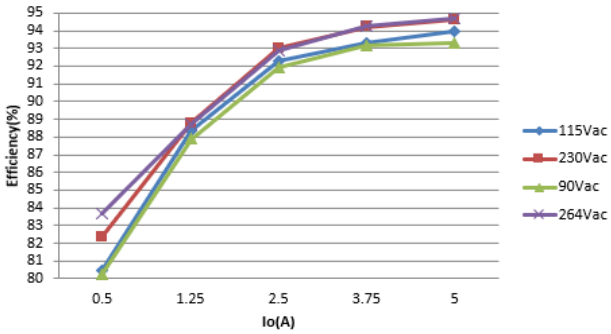


Figure 21. 28 V

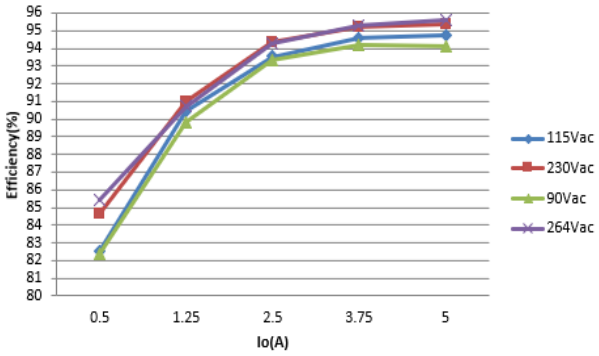


Figure 22. 36 V

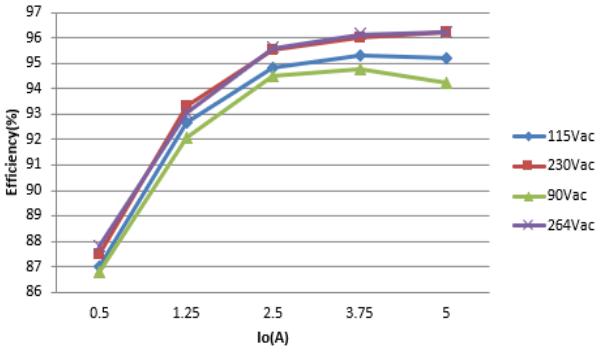


Figure 23. 48 V

### PFC Waveform at 90 Vac and Full Load

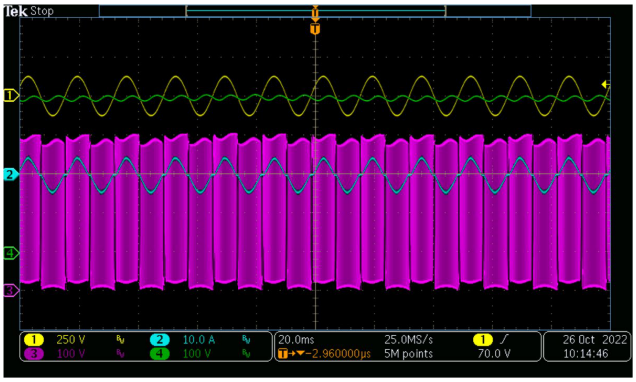


**Figure 24. 90 Vac and Full Load (ch1−Vin, ch2−Iin, ch3−fast leg SW, ch4−Vbulk)**

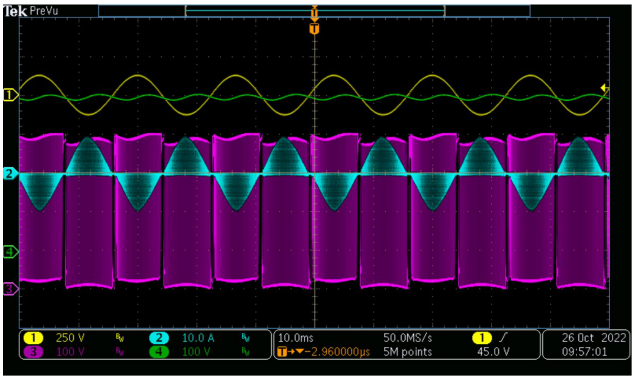


**Figure 25. 90 Vac and Full Load (ch1−Vin, ch2−IL, ch3−fast leg SW, ch4−Vbulk)**

### Load Transition

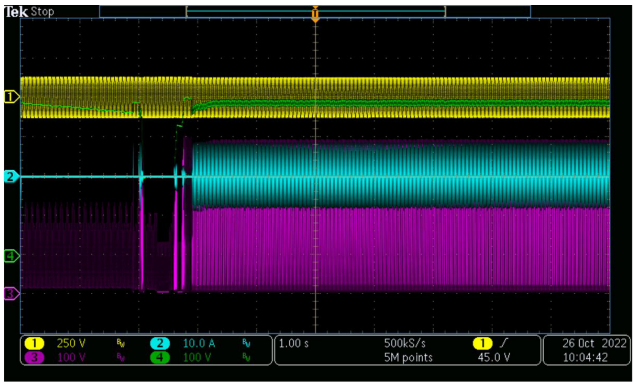


**Figure 26. 0 to Full Load Transition at 90 Vac (ch1−Vin, ch2−IL, ch3−fast leg SW, ch4−Vbulk)**

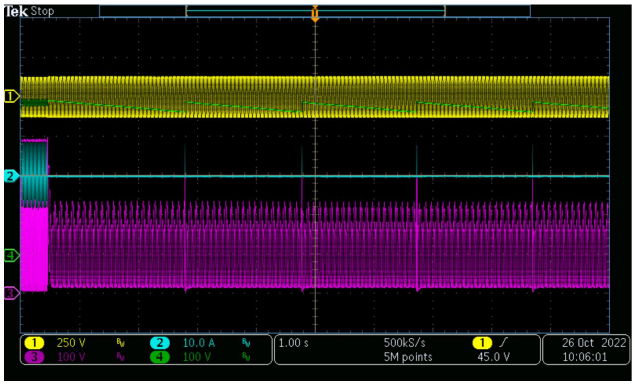


**Figure 27. Full Load to 0 Transition at 90 Vac (ch1−Vin, ch2−IL, ch3−fast leg SW, ch4−Vbulk)**

### Line Transition

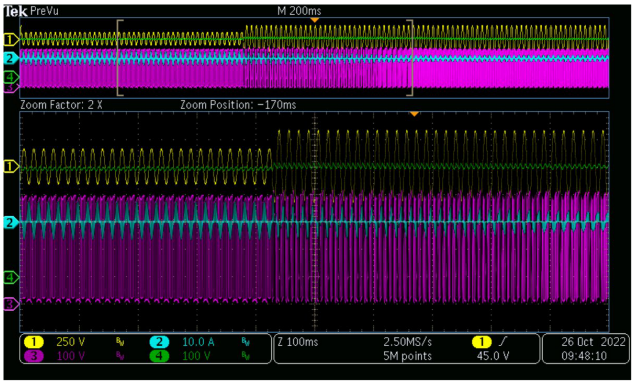


**Figure 28. 115 Vac to 230 Vac Transition at Full Load (ch1−Vin, ch2−IL, ch3−fast leg SW, ch4−Vbulk)**

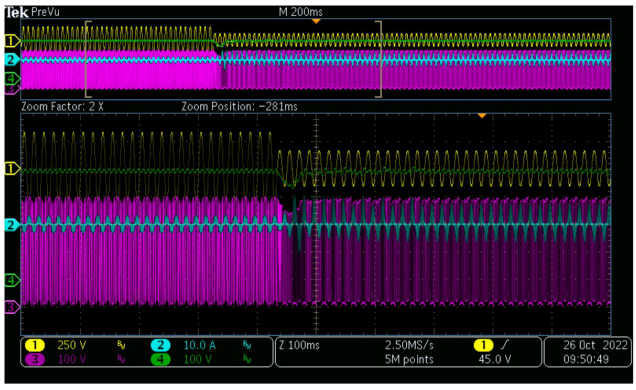


**Figure 29. 230 Vac to 115 Vac Transition at Full Load (ch1−Vin, ch2−IL, ch3−fast leg SW, ch4−Vbulk)**

### LLC Start and Operation Waveform

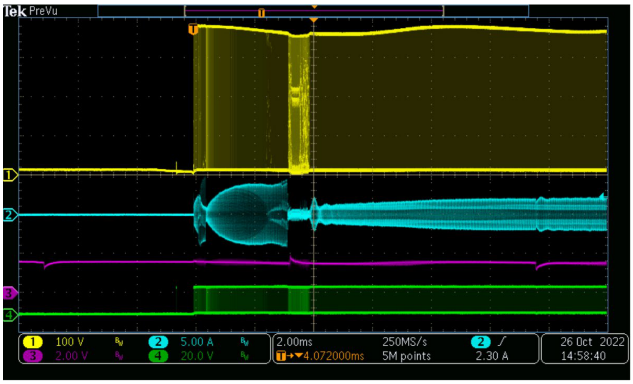


**Figure 30. Power on at 115 Vac and 48 V & 5 A (ch1−Vsw, ch2−Ip, ch3−Vbulk pin, ch4−Vmlower)**

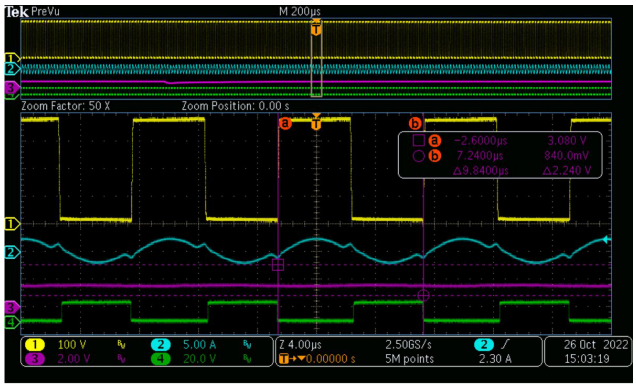


**Figure 31. Stable Operation at 115 Vac and 48 V & 5 A (ch1−Vsw, ch2−Ip, ch3−Vbulk pin, ch4−Vmlower)**

### Hold Time and Secondary Stress

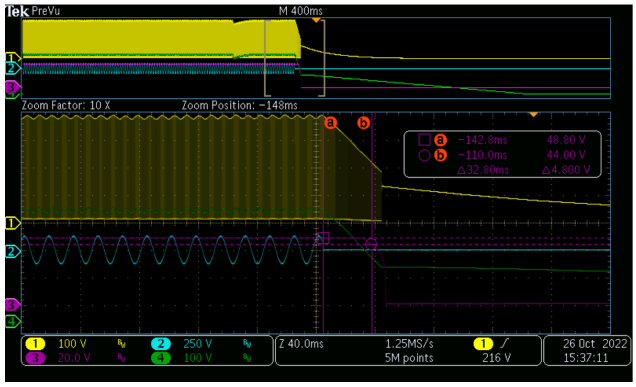


**Figure 32. Hold Time During Power Off at 90 Vac and 48 V & 5 A (ch1−Vsw, ch2−Vin, ch3−Vo, ch4−Vbulk)**

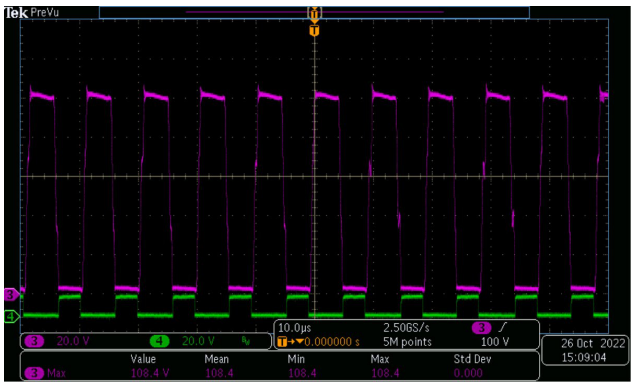


**Figure 33. Secondary Stress at 48 V & 5 A (ch3−Vds−sec, ch4−Vsyn−drv)**

### LLC Operation Waveform at Skip Mode

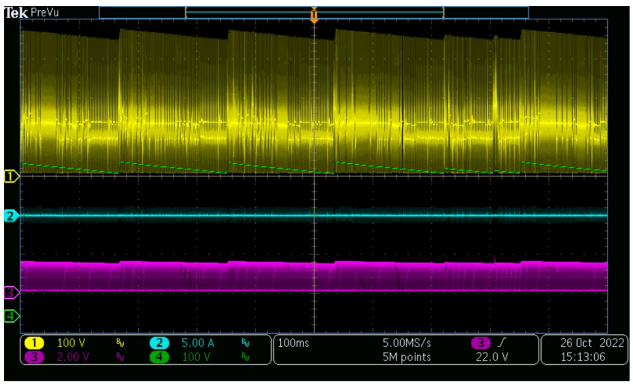


**Figure 34. Wavefore at 48 V & 0 A (ch1−Vsw, ch2−Ip, ch3−Vbulk pin, ch4−Vbulk)**

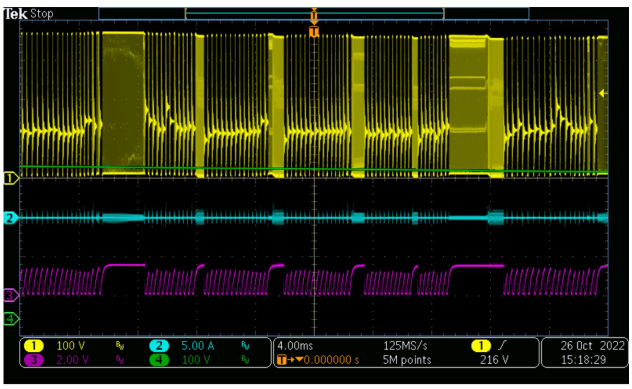


**Figure 35. Wavefore at 48 V & 0.2 A (ch1−Vsw, ch2−Ip, ch3−Vbulk pin, ch4−Vbulk)**

### Startup Timing at No Load and Full Load

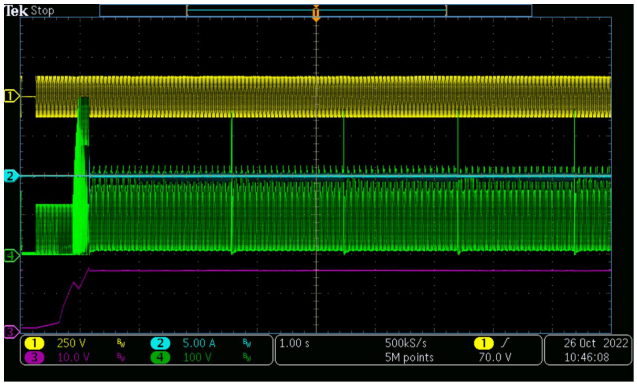


**Figure 36. Wavefore at 48 V & 0 A (ch1−Vin,ch2−Ip−Ilc,ch3−Vcc−Ilc, ch4−Vfast leg sw)**

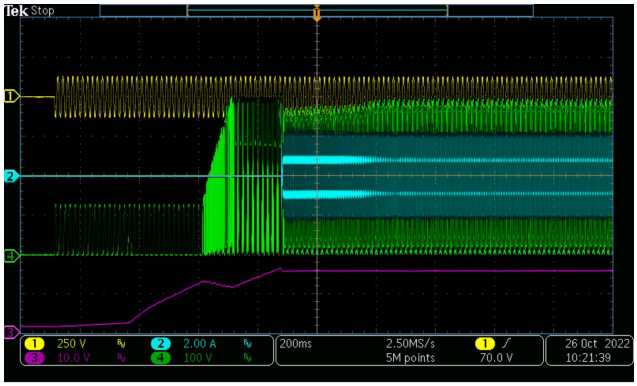


**Figure 37. Wavefore at 48 V & 5 A (ch1−Vin,ch2−Ip−Ilc,ch3−Vcc−Ilc, ch4−Vfast leg sw)**

### Load Dynamic Response at 5 V

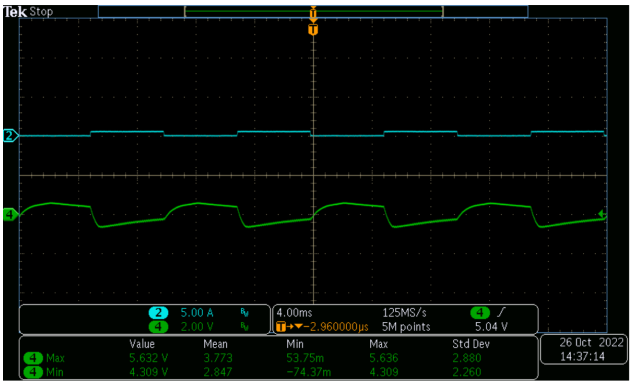


**Figure 38. 5 V & 0 A to 0.5 A, 10 ms Cycle, 0.25 A/μs (ch2−Io, ch4−Vo)**

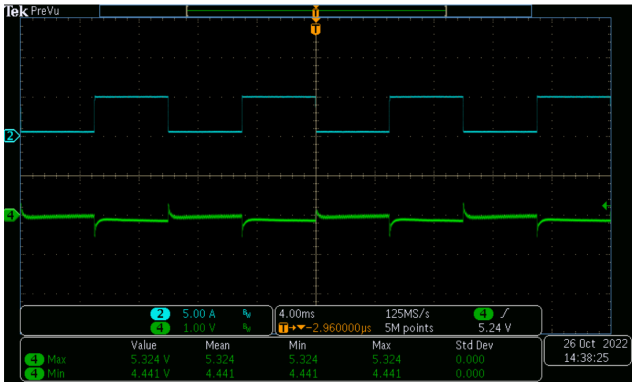


**Figure 39. 5 V & 0.5 A to 5 A, 10 ms Cycle, 0.25 A/μs (ch2−Io, ch4−Vo)**

### Load Dynamic Response at 48 V


**Figure 40. 48 V & 0 A to 0.5 A, 10 ms Cycle, 0.25 A/μs (ch2−Io, ch4−Vo)**

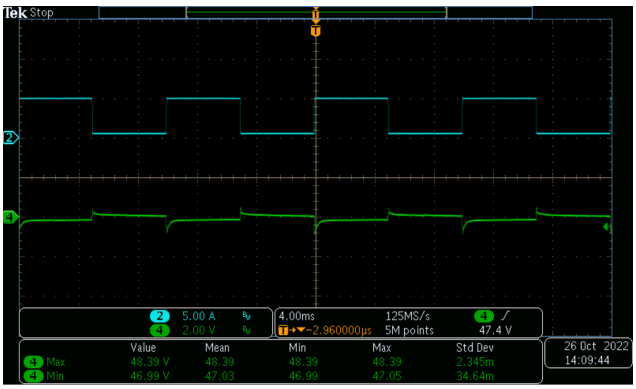


**Figure 41. 48 V & 0.5 A to 5 A, 10 ms Cycle, 0.25 A/μs (ch2−Io, ch4−Vo)**

### DC−DC OCP Waveform

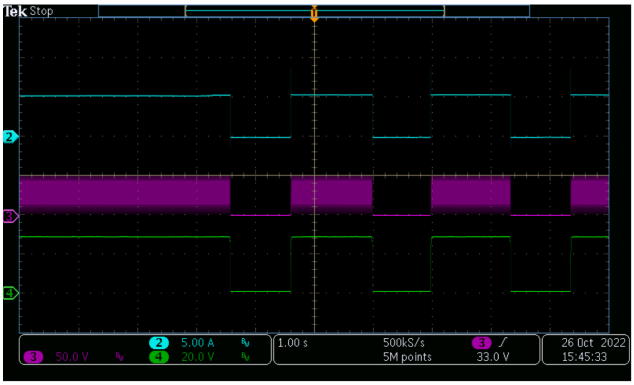


**Figure 42. OCP at 52 V Input and 48 V 5.5 A Output (ch2−Io, ch3−Vsw, ch4−Vo)**

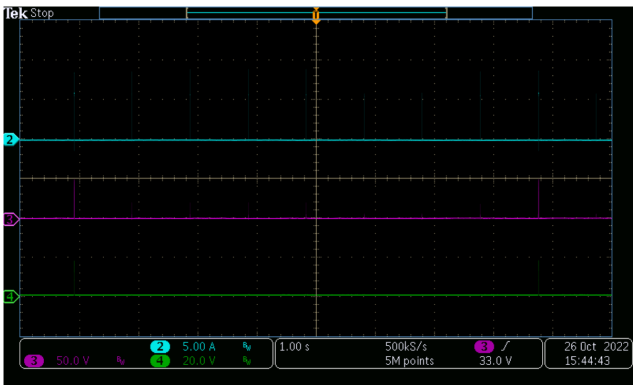


**Figure 43. OCP at 52 V Input and 48 V 6 A Output (ch2−Io, ch3−Vsw, ch4−Vo)**

**Thermal Camera Image (Tested after 15 min Operation)**

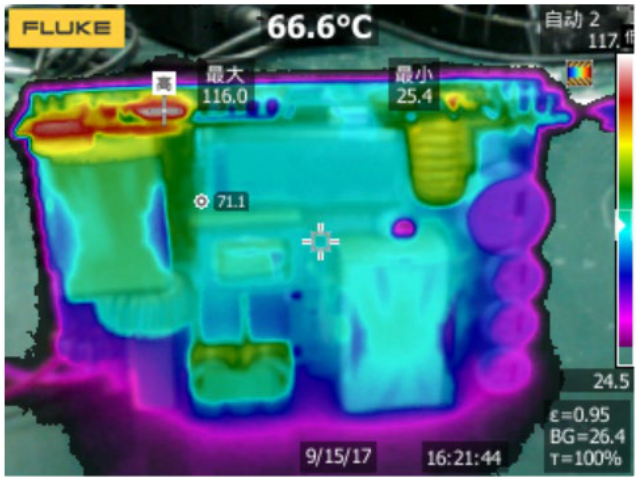


**Figure 44. 90 Vac & 48 V 5 A, Front Side**

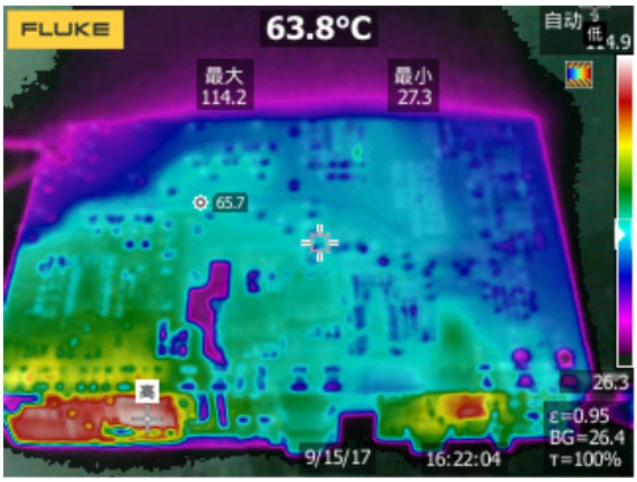


**Figure 45. 90 Vac & 48 V 5 A, Reverse Side**

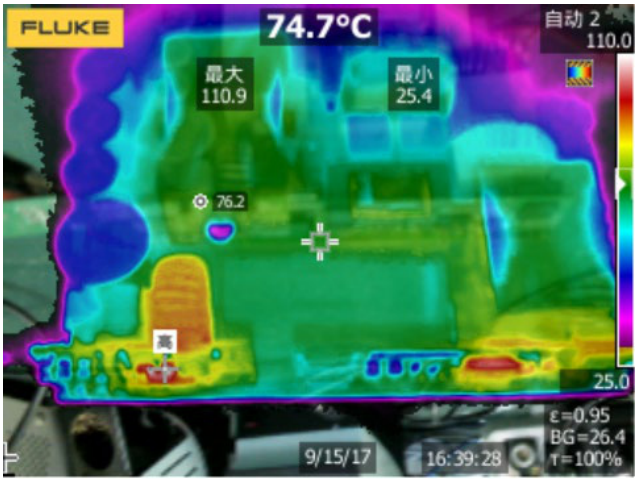


**Figure 46. 115 Vac & 48 V 5 A, Front Side**

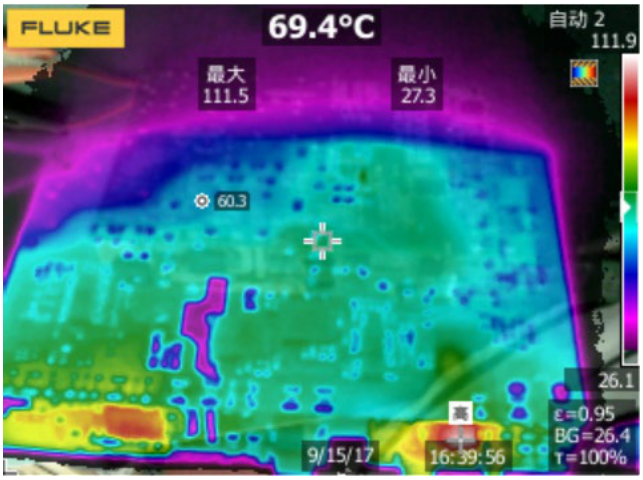


**Figure 47. 115 Vac & 48 V 5 A, Reverse Side**

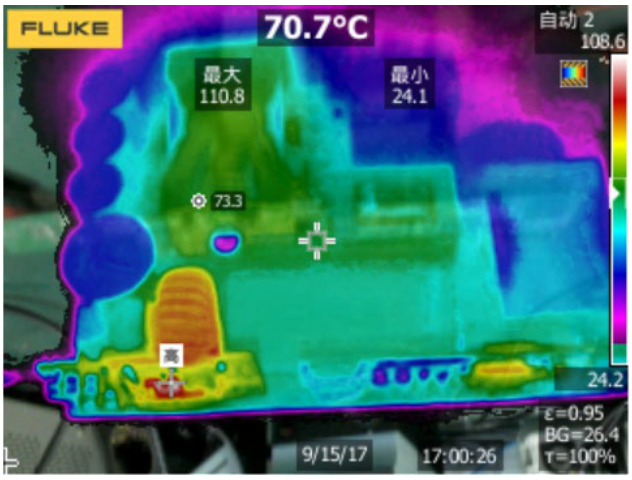


**Figure 48. 230 Vac & 48 V 5 A, Front Side**

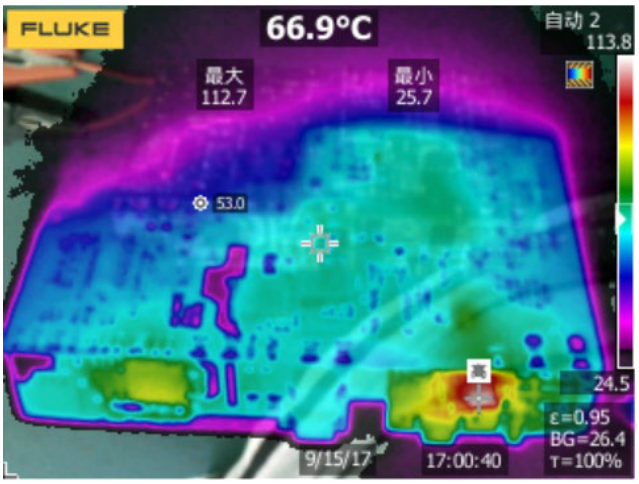


**Figure 49. 230 Vac & 48 V 5 A, Reverse Side**

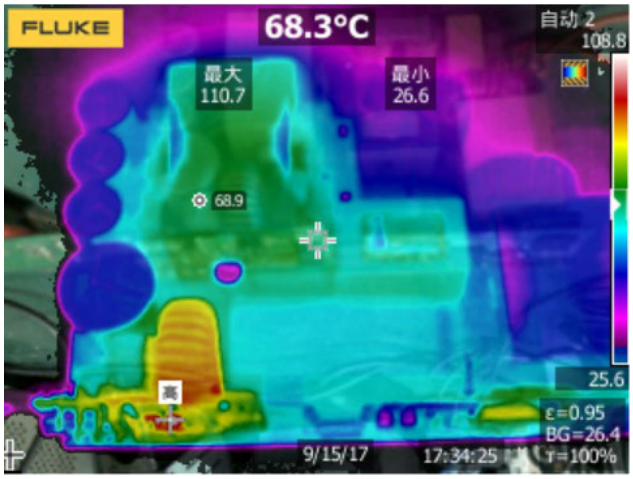


Figure 50. 264 Vac & 48 V 5 A, Front Side

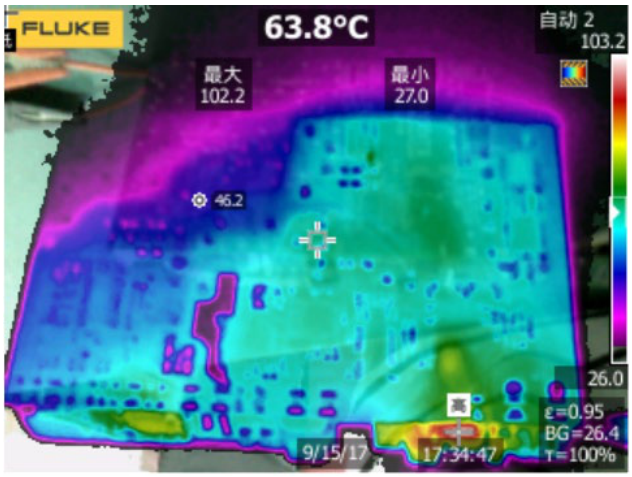


Figure 51. 264 Vac & 48 V 5 A, Reverse Side

**Table 1. BOM**

| Item | Qty | Reference | Type | Part Name | Package | MFR | Value | Description |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | U14 | 3−8 line decode | MC74HC238ADTR2G | TSSOP16 | **onsemi** | | 3−LINE TO 8−LINE DE-CODER\DEMULTIPLEX-ER |
| 2 | 11 | C3 C6−7 C15 C19−20 C40 C47 C62 C73−74 | Ceramic Capacitor | /885012206095 | 603 | Wurth | 0.1 μF | Capacitor, Ceramic, 50 V, 10% |
| 3 | 5 | C8 C75−76 C82 C93 | Ceramic Capacitor | /885012206120 | 603 | Wurth | 0.1 μF, 100 V | Capacitor, Ceramic, 100 V, 10% |
| 4 | 2 | C31 C37 | Ceramic Capacitor | C3225X7T2W224K | 1210 | TDK | 0.22 μF, 450 V | Capacitor, Ceramic, Chip, 10% |
| 5 | 2 | C1 C5 | X2 Capcitor | PX564K2C1001 | THT, 10 mm, 13 mm × 8 mm × 14 mm | KYET | 0.56 μF, 310 VAC | X2 capacitor, Safety standard approved, 10% |
| 6 | 1 | C25 | X2 Capcitor | MPX684K31D4KN15800 | THT, 15 mm, 18 mm × 10 mm × 15 mm | KNSCHA | 0.68 μF, 275 VAC | X2 capacitor, Safety standard approved, 10% |
| 7 | 1 | C33 | Ceramic Capacitor | /885012206084 | 603 | Wurth | 1.5 nF | Capacitor, Ceramic, 50 V, 10% |
| 8 | 2 | C85 C111 | Ceramic Capacitor | /885012206083 | 402 | Wurth | 100 nF | Capacitor, Ceramic, 50 V, 10% |
| 9 | 4 | C9 C42−43 C70 | Ceramic Capacitor | /885012206077 | 603 | Wurth | 100 pF | Capacitor, Ceramic, 50 V, 10% |
| 10 | 1 | C57 | Ceramic Capacitor | /885342008004 | 1206 | Wurth | 100 pF, 630 V | Capacitor, Ceramic, SMD, 5% |
| 11 | 2 | C26 C48 | Ceramic Capacitor | C3216X7T2W104K | 1206 | TDK | 104, 450 V | Capacitor, Ceramic, SMD, 5% |
| 12 | 4 | C22 C34 C64 C92 | Ceramic Capacitor | /885012206089 | 603 | Wurth | 10 nF | Capacitor, Ceramic, 50 V, 10% |
| 13 | 2 | C71−72 | Ceramic Capacitor | CL112J103J050 | TH type | KYET | 10 nF, 630 V | Capacitor, film, TH, 5% |
| 14 | 10 | C77−80 C86−91 | Ceramic Capacitor | C3225X7R1N106K250AC | 1210 | TDK | 10 μF, 75 V | Capacitor, Ceramic, 75 V, 10% |
| 15 | 3 | C39 C65 C68 | Ceramic Capacitor | /885012206083 | 603 | Wurth | 1 nF | Capacitor, Ceramic, 50 V, 10% |
| 16 | 2 | C10 C61 | Ceramic Capacitor | /8853522100131 | 1808 | Wurth | 1 nF, Y2 | HV Ceramic Capacitor, safety standard approved, 10% |
| 17 | 1 | C83 | Ceramic Capacitor | /885012105012 | 402 | Wurth | 1 μF, 10 V | Capacitor, Ceramic, 10 V, 20% |
| 18 | 7 | C16−17 C21 C23 C28 C56 C60 | Ceramic Capacitor | /885012206076 | 603 | Wurth | 1 μF, 25 V | Capacitor, Ceramic, 25 V, 10% |
| 19 | 1 | C81 | Ceramic Capacitor | C1005X5R1E105K050BC | 402 | TDK | 1 μF, 25 V | Capacitor, Ceramic, 25 V, 10% |
| 20 | 1 | C29 | Ceramic Capacitor | /885012206085 | 603 | Wurth | 2.2 nF | Capacitor, Ceramic, 50 V, 10% |
| 21 | 1 | C96 | Ceramic Capacitor | /885012205063 | 402 | Wurth | 2.2 nF | Capacitor, Ceramic, 50 V, 10% |
| 22 | 2 | C35−36 | Ceramic Capacitor | /885012206079 | 603 | Wurth | 220 pF | Capacitor, Ceramic, 50 V, 10% |
| 23 | 1 | C58 | Ceramic Capacitor | /885012206091 | 603 | Wurth | 22 nF | Capacitor, Ceramic, 50 V, 10% |
| 24 | 1 | C98 | Ceramic Capacitor | /885012205052 | 402 | Wurth | 22 nF | Capacitor, Ceramic, 25 V, 10% |
| 25 | 1 | C44 | Film Capacitor | ECWH8223HA | THT, 10 mm, 13 mm × 6 mm × 12 mm | Panasonic | 22 nF, 800 V | Film capacitor |
| 26 | 2 | C18 C66 | Ceramic Capacitor | C2012X5R1V226MT000E | 805 | TDK | 22 μF, 35 V | Capacitor, Ceramic, 35 V, 20% |
| 27 | 1 | C97 | Ceramic Capacitor | /885012205053 | 402 | Wurth | 33 nF | Capacitor, Ceramic, 25 V, 10% |

**Table 1. BOM** (continued)

| Item | Qty | Reference | Type | Part Name | Package | MFR | Value | Description |
|---|---|---|---|---|---|---|---|---|
| 28 | 1 | C63 | Ceramic Capacitor | /885012205084 | 402 | Wurth | 4.7 nF, 100 V | Capacitor, Ceramic, 100 V, 10% |
| 29 | 2 | C49−50 | Ceramic Capacitor | GRM31CC72A475KE11L | 1206 | Murata | 4.7 μF, 100 V | Capacitor, Ceramic, 100 V, 10% |
| 30 | 1 | C84 | Ceramic Capacitor | C1005X5R1A475KTJ00E | 402 | TDK | 4.7 μF, 10 V | Capacitor, Ceramic, 10 V, 10% |
| 31 | 7 | C2 C4 C11 C24 C30 C55 C67 | Ceramic Capacitor | C1608X5R1E475K080AC | 603 | TDK | 4.7 μF, 25 V | Capacitor, Ceramic, 25 V, 10% |
| 32 | 2 | C12 C45 | Ceramic Capacitor | /885342006005 | 603 | Wurth | 470 pF, 250 V | Capacitor, Ceramic, SMD, 5% |
| 33 | 6 | C38 C46 C53 C59 C69 C99 | Ceramic Capacitor | nu | 603 | Wurth | nu | Capacitor, Ceramic, 50 V, 10% |
| 34 | 2 | C54 C52 | Ceramic Capacitor | nu | 1206 | Murata | nu | Capacitor, Ceramic, 25 V, 20% |
| 35 | 2 | D2 D9 | Rectifier | S3J | SMC | **onsemi** | 3 A, 600 V | General Rectifier |
| 36 | 1 | DNR | Varistor | 820513011 | TH type | Wurth | 471 V | Varistor, 10D471K |
| 37 | 2 | D12−13 | Standard rectifier | 4007 | SOD123FL | std | 0.8 A, 600 V | General Rectifier, 0.8 A, 600 V |
| 38 | 5 | D1 D3−6 | Ultrafast rectifier | ES1JFL | SOD123FL | **onsemi** | 1 A, 600 V | General Rectifier, 1 A, 600 V |
| 39 | 4 | D7 D15−17 | Switching diode | BAS21HT1G | SOD323 | **onsemi** | 0.25 A, 250 V | Switching diode, SMD |
| 40 | 7 | D8 D10−11 D14 D18−D20 | Switching diode | BAT54HT1G | SOD323 | **onsemi** | 0.25 A, 30 V | Switching diode, SMD |
| 41 | 1 | D21 | Switching diode | nu | SOD323 | **onsemi** | nu | Switching diode, SMD |
| 42 | 1 | L5 | Inductor | 100C21121003 | TH type | Lihang elec. | 70 μH | Ferroxcube EQ20/3C95 core, 10Pin bobbin |
| 43 | 1 | U11 | DC−DC converter | FAN65004C | PQFN36−6*6 | **onsemi** | | DC−DC Converter |
| 44 | 2 | FB1−2 | Ferrite bead | nu | 1812 | | nu | |
| 45 | 1 | L1 | Common filter | T12*6*4 | TH type | Custom | 1 mH | T12 * 6 * 4 MnZn core, 6T in parallel |
| 46 | 1 | L2 | Common filter | SQ1515 | TH type | Custom | 15 mH | CM Filter, SQ1515, 10 * 13 |
| 47 | 1 | F1 | Micro Fuse | 39215000000 | Axial lead | Littlefuse | 5 A, 250 Vac | Micro Fuse, 5 A/250 V |
| 48 | 1 | Q2 | NPN Transistor | MMBT3904LT1G | SOT23 | **onsemi** | | GENERAL PURPOSE NPN SILICON TRANSISTOR |
| 49 | 1 | U10 | Programmable precision reference | NCP431ACSNT1G | SOT23 | **onsemi** | | PROGRAMMABLE PRECISION REFERENCE |
| 50 | 1 | U1 | TPPFC controller | NCP1680 | SO16 | **onsemi** | | TPPFC controller |
| 51 | 1 | U5 | LLC controller | NCP13994 | SO20 | **onsemi** | | LLC Controller |
| 52 | 4 | U2−4 U13 | Driver GaN | NCP58921 | QFN26 | **onsemi** | 650 V, 50 mΩ | iGaN |
| 53 | 2 | U6−7 | Syn. rectified controller | NCP4306DAHZZAASNT1G | TSOP6 | **onsemi** | | Syn. rectified controller |
| 54 | 2 | U9 U12 | HB Driver | NCP51530BMNTWG | DFN10−4*4 | **onsemi** | | HB driver |
| 55 | 5 | Q6−10 | Dual NMOS | 2N7002V | SOT−563F | **onsemi** | 60 V | Dual NMOS |
| 56 | 2 | Q1 Q5 | MOSFET | FDMS4D0N12C | SO8FL | **onsemi** | 120 V | MOSFET, NChan, 120 V |

**Table 1. BOM** (continued)

| Item | Qty | Reference | Type | Part Name | Package | MFR | Value | Description |
|---|---|---|---|---|---|---|---|---|
| 57 | 2 | Q3–4 | MOSFET | NTMT064N65S3H | Power88 | **onsemi** | 650 V, 64 mΩ | MOSFET, NChan, 650 V |
| 58 | 1 | NTC1 | NTC | nu | 603 | Sunloard | nu | |
| 59 | 1 | NTC2 | NTC | nu | 603 | Sunloard | nu | |
| 60 | 1 | U8 | Optical coupler | FODM1009 | LSOP4 | **onsemi** | | optical coupler, standard SOP package |
| 61 | 1 | L3 | Inductor | T65125–100–080 | TH type | std | 100 μH | KoolMu Toroidal, T65125, 0.8 mm wire, 100 μH |
| 62 | 1 | L6 | Inductor | T65125–33–100 | TH type | std | 33 μH | KoolMu Toroidal,T65125, 1 mm wire, 33 μH |
| 63 | 1 | L4 | Inductor | 100T26181002 | TH type | Lihang elec. | 140 μH | Ferroxcube PQ2618/3C95 core, 12Pin bobbin |
| 64 | 1 | T1 | Transformer | 100T32201001 | TH type | Lihang elec. | | Ferroxcube PQ3218/3C95 core, 12Pin Bobbin |
| 65 | 1 | R64 | Resistor | Std | 603 | Std | 0 Ω | Resistor, Chip, 1/10 W, 1% |
| 66 | 4 | R59 R97–99 | Resistor | Std | 402 | Std | 1 Ω | Resistor, Chip, 1/16 W, 1% |
| 67 | 1 | R90 | Resistor | Std | 402 | Std | 1.3 kΩ | Resistor, Chip, 1/16 W, 1% |
| 68 | 1 | R91 | Resistor | Std | 402 | Std | 1.2 kΩ | Resistor, Chip, 1/16 W, 1% |
| 69 | 10 | R1 R6 R9–10 R36 R38 R43–45 R72 | Resistor | Std | 603 | Std | 10 Ω | Resistor, Chip, 1/10 W, 1% |
| 70 | 1 | R70 | Resistor | Std | 603 | Std | 100 Ω | Resistor, Chip, 1/10 W, 1% |
| 71 | 5 | R11 R13 R29–30 R61 | Resistor | Std | 603 | Std | 100 kΩ | Resistor, Chip, 1/10 W, 1% |
| 72 | 2 | R75 R79 | Resistor | Std | 402 | Std | 100 kΩ | Resistor, Chip, 1/16 W, 1% |
| 73 | 3 | R55 R116–117 | Resistor | Std | 402 | Std | 10 kΩ | Resistor, Chip, 1/16 W, 1% |
| 74 | 1 | R85 | Resistor | Std | 402 | Std | 10 kΩ | Resistor, Chip, 1/16 W, 1% |
| 75 | 1 | R60 | Resistor | Std | 603 | Std | 15 kΩ | Resistor, Chip, 1/10 W, 1% |
| 76 | 1 | R84 | Resistor | Std | 402 | Std | 16 kΩ | Resistor, Chip, 1/16 W, 1% |
| 77 | 2 | R49 R53 | Resistor | Std | 603 | Std | 18 kΩ | Resistor, Chip, 1/10 W, 1% |
| 78 | 3 | R17–18 R24 | Resistor | Std | 603 | Std | 1 kΩ | Resistor, Chip, 1/10 W, 1% |
| 79 | 1 | R74 | Resistor | Std | 402 | Std | 2,2 Ω | Resistor, Chip, 1/16 W, 1% |
| 80 | 1 | R69 | Resistor | Std | 603 | Std | 2.2 kΩ | Resistor, Chip, 1/10 W, 1% |
| 81 | 1 | R87 | Resistor | Std | 402 | Std | 2.2 kΩ | Resistor, Chip, 1/16 W, 1% |
| 82 | 2 | R88 R93 | Resistor | Std | 402 | Std | 2.7 kΩ | Resistor, Chip, 1/16 W, 1% |
| 83 | 2 | R54 R66 | Resistor | Std | 603 | Std | 22 kΩ | Resistor, Chip, 1/10 W, 1% |
| 84 | 2 | R83 R103 | Resistor | Std | 402 | Std | 22 kΩ | Resistor, Chip, 1/16 W, 1% |
| 85 | 1 | R95 | Resistor | Std | 603 | Std | 39 kΩ | Resistor, Chip, 1/10 W, 1% |
| 86 | 1 | R115 | Resistor | Std | 402 | Std | 270 Ω | Resistor, Chip, 1/16 W, 1% |
| 87 | 1 | R58 | Resistor | Std | 603 | Std | 300 kΩ | Resistor, Chip, 1/10 W, 1% |
| 88 | 1 | R82 | Resistor | Std | 402 | Std | 30 kΩ | Resistor, Chip, 1/16 W, 1% |
| 89 | 4 | R2 R8 R47 R65 | Resistor | Std | 603 | Std | 33 Ω | Resistor, Chip, 1/10 W, 1% |
| 90 | 2 | R92 R94 | Resistor | Std | 402 | Std | 390 Ω | Resistor, Chip, 1/16 W, 1% |
| 91 | 1 | R81 | Resistor | Std | 402 | Std | 39 kΩ | Resistor, Chip, 1/16 W, 1% |
| 92 | 1 | R100 | Resistor | Std | 402 | Std | 4.3 kΩ | Resistor, Chip, 1/16 W, 1% |
| 93 | 6 | R7 R14 R37 R56–57 R62 | Resistor | Std | 603 | Std | 4,7 Ω | Resistor, Chip, 1/10 W, 1% |
| 94 | 1 | R76 | Resistor | Std | 402 | Std | 41.2 kΩ | Resistor, Chip, 1/16 W, 1% |

**Table 1. BOM** (continued)

| Item | Qty | Reference | Type | Part Name | Package | MFR | Value | Description |
|---|---|---|---|---|---|---|---|---|
| 95 | 1 | R89 | Resistor | Std | 402 | Std | 470 Ω | Resistor, Chip, 1/16 W, 1% |
| 96 | 1 | R33 | Resistor | Std | 603 | Std | 470 kΩ | Resistor, Chip, 1/10 W, 1% |
| 97 | 5 | R101−102 R112−114 | Resistor | Std | 402 | Std | 47 kΩ | Resistor, Chip, 1/16 W, 1% |
| 98 | 4 | R4 R32 R48 R52 | Resistor | Std | 603 | Std | 5.1 kΩ | Resistor, Chip, 1/10 W, 1% |
| 99 | 1 | R80 | Resistor | Std | 402 | Std | 51 kΩ | Resistor, Chip, 1/16 W, 1% |
| 100 | 1 | R73 | Resistor | Std | 603 | Std | 620 kΩ | Resistor, Chip, 1/10 W, 1% |
| 101 | 1 | R3 | Resistor | Std | 603 | Std | 62 kΩ | Resistor, Chip, 1/10 W, 1% |
| 102 | 1 | R16 | Resistor | Std | 603 | Std | 68 kΩ | Resistor, Chip, 1/10 W, 1% |
| 103 | 1 | R78 | Resistor | Std | 402 | Std | 750 kΩ | Resistor, Chip, 1/16 W, 1% |
| 104 | 1 | R86 | Resistor | Std | 402 | Std | 9.1 kΩ | Resistor, Chip, 1/16 W, 1% |
| 105 | 1 | R77 | Resistor | Std | 402 | Std | 91 kΩ | Resistor, Chip, 1/16 W, 1% |
| 106 | 9 | R5 R26 R31 R34−35 R63 R67 R71 R96 | Resistor | Std | 603 | Std | nu | Resistor, Chip, 1/10 W, 1% |
| 107 | 1 | R68 | Resistor | Std | 1206 | Std | 0 Ω | Resistor, Chip, 1/4 W, 1% |
| 108 | 2 | R50−51 | Resistor | ERJ8BSFR13V | 1206 | Panasonic | 0,13 Ω | Resistor, Chip, 1/2 W, 1% |
| 109 | 2 | R15 R19 | Resistor | Std | 1206 | Std | 2.7 kΩ | Resistor, Chip, 1/4 W, 1% |
| 110 | 2 | R12 R46 | Resistor | Std | 1206 | Std | 22 Ω | Resistor, Chip, 1/4 W, 1% |
| 111 | 9 | R21−23 R25 R27−28 R40−42 | Resistor | Std | 1206 | Std | 3.3 MΩ | Resistor, Chip, 1/4 W, 1% |
| 112 | 1 | R20 | Resistor | nu | 1206 | Panasonic | nu | Resistor, Chip, 1/2 W, 1% |
| 113 | 1 | C41 | Electrolytic solid capacitor | GH101M025E110A | TH, 6.3 mm × 11 mm | CapXon | 100 μF, 25 V | size: 6.3 mm x 11 mm |
| 114 | 1 | C32 | Electrolytic electrolytic capacitor | 450LXW150MEFR18X35 | TH, 18 mm × 35 mm | Rubycon | 150 μF, 450 V | size: 18 mm x 35 mm |
| 115 | 3 | C13−14 C51 | Hybrid Electrolytic capacitor | EEHZS1J181UP | 10 × 16.5, SMD | Panasonic | 180 μF, 63 V | size: SMD10*16.5, ESR 15 mΩ |
| 116 | 1 | C27 | Electrolytic capacitor | EEEFK1J471AM | 16 × 16.5, SMD | Panasonic | 470 μF, 63 V | size: SMD16 * 16.5 |
| 117 | 2 | C94−95 | Hybrid Electrolytic capacitor | EEHZT1J470P | 8 × 10.2, SMD | Panasonic | 47 μF, 63 V | size: SMD8 * 10.2, ESR 25 mΩ |
| 118 | 1 | SW | DIP switch | DSHP03TS−S | SMD | XKB Connectivity | | SMD, 3P, 1.27 mm |
| 119 | 1 | J1 | USB Type C connector | CUS31738616001 | SMD | CSCONN | | 16Pin, SMD |
| 120 | 1 | ZD2 | Zener | MM3Z16VT1G | SOD323 | **onsemi** | 16 V | GENERIC ZENER−DIODE |
| 121 | 1 | ZD4 | Zener | MM3Z22VT1G | SOD323 | **onsemi** | 22 V | GENERIC ZENER−DIODE |
| 122 | 1 | ZD1 | Zener | MM3Z24VT1G | SOD323 | **onsemi** | 24 V | GENERIC ZENER−DIODE |
| 123 | 1 | ZD3 | Zener | nu | SOD323 | **onsemi** | nu | GENERIC ZENER−DIODE |

### Simulated PD3.1 to Support 5 V to 48 V

No PD3.1 controller to support 48 V output in current market so a discrete circuit to simulate PD3.1 and support 5 V to 48 V output as following.

3 DIP switch combination schematic shown as Figure 52 is decoded by 74HC238 to output Y0−7 to NMOS to control feedback divider so 5 V/9 V/12 V/15 V/20 V/28 V/36 V/48 V is set, DIP SW set Vs output is as following table shown as Figure 53, the board photo is shown as Figure 54.

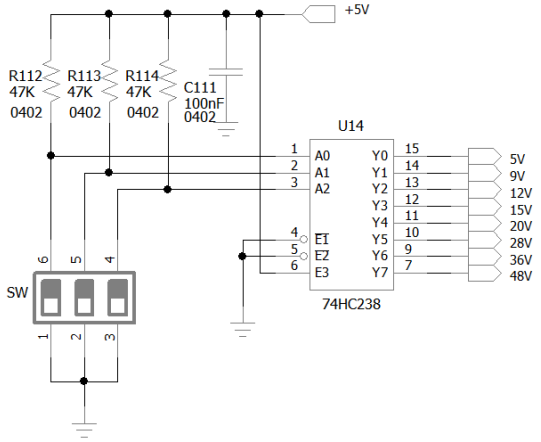


**Figure 52. SW Schematic**

| Vo | SW1 | SW2 | SW3 |
|---|---|---|---|
| 5V | ON | ON | ON |
| 9V | OFF | ON | ON |
| 12V | ON | OFF | ON |
| 15V | OFF | OFF | ON |
| 20V | ON | ON | OFF |
| 28V | OFF | ON | OFF |
| 36V | ON | OFF | OFF |
| 48V | OFF | OFF | OFF |

**Figure 53. SW Table**

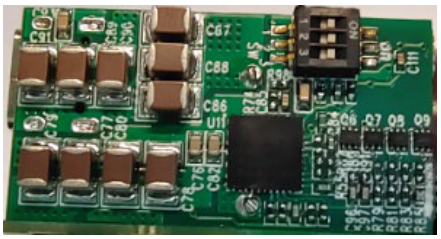

**Figure 54. DC Photo**

### References

[1] **onsemi** datasheet for NCP1680, NCP13994, NCP51530, NCP4306, FAN65004, NCP58921, FDMS4D0N12, NTMT064N65

[2] **onsemi** Design Notes DN05043



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