# EVBUM2652/D

# 8 W Auxiliary Power for White Goods and Industrial Equipment with FSL518APG

ON Semiconductor®

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## EVAL BOARD USER'S MANUAL

**Table 1. GENERAL SPECIFICATIONS**

| Devices | Applications | Input Voltage | Output Power | Topology | Board Size |
|---|---|---|---|---|---|
| FSL518APG | White Goods and Industrial Power Supplies | 90–265 Vac | 8 W | Isolated Flyback | 80 × 38 × 20 mm<br>2.15 W/inch$^3$ |
| **Output Spec.** | **Turn on Time** | **Efficiency** | **Operating Temperature** | **Cooling** | **Standby Power** |
| 12 V/0.66 A | < 200 ms | Above 85% @ Full Load | 0–50°C | Open Frame in Still Air | < 50 mW @ 230 Vac |

### Description

This user manual provides elementary information about an isolated flyback with FSL518APG, it performs high efficiency and smaller than 50 mW no−load power consumption. FSL518APG is an integrated pulse width modulation (PWM) and 800 V power switch with SENSEFET®, it can help to save external MOSFET and sense resistor, increase power density and reliability. This application is targeting auxiliary power supply for white goods and industrial equipment, such as refrigerator, E−metering or similar types of equipment.

The PWM controller includes an integrated variable frequency oscillator, Under−Voltage Lockout (UVLO), Leading Edge Blanking (LEB), optimized gate driver, internal soft−start, and temperature−compensated precise current source for loop compensation and self−protection circuitry. This design focuses mainly on the FSL518APG current−mode PWM controller. Please refer to FSL518APG's materials to get more information about this device.

The FSL518APG is a current−mode PWM controller, it can have better response to handle dynamic operation. Controller combines line detection and burst−mode adjustment in one pin. It's easy to achieve these functionalities just need voltage divider and one Zener diode. Line detection includes brown−in, brown−out and line OVP, burst−mode adjustment is for fine tune audible noise and light load efficiency. Of course, it also provides frequency reduction with loading decreasing for gaining more design margin to improve light load efficiency.

### Key Features

- Integrated Rugged 800 V Super Junction MOSFET with SENSEFET Technology
- Built−in HV Current Source for Start−up
- Peak−Current−Mode Control with Slope Compensation
- Line Compensation for Maximum Over−Power Limiting
- Advanced Soft−start for Low Electrical Stress
- Peak−Current−Mode Control with Built−in Slope Compensation
- Pulse−by−pulse Current Limit
- Line Brown−in, Brown−out, and Over−Voltage Protection (LOVP)
- Adjustable Burst−mode Operation
- Frequency Hopping for Better EMI
- Various Protections:
  - Auto Restart Mode: Brown−out, OLP, OVP, AOCP and TSD
  - Recovery Immediately by Triggering Level: LOVP

## DETAIL DEMO−BOARD SCHEMATIC DESCRIPTION

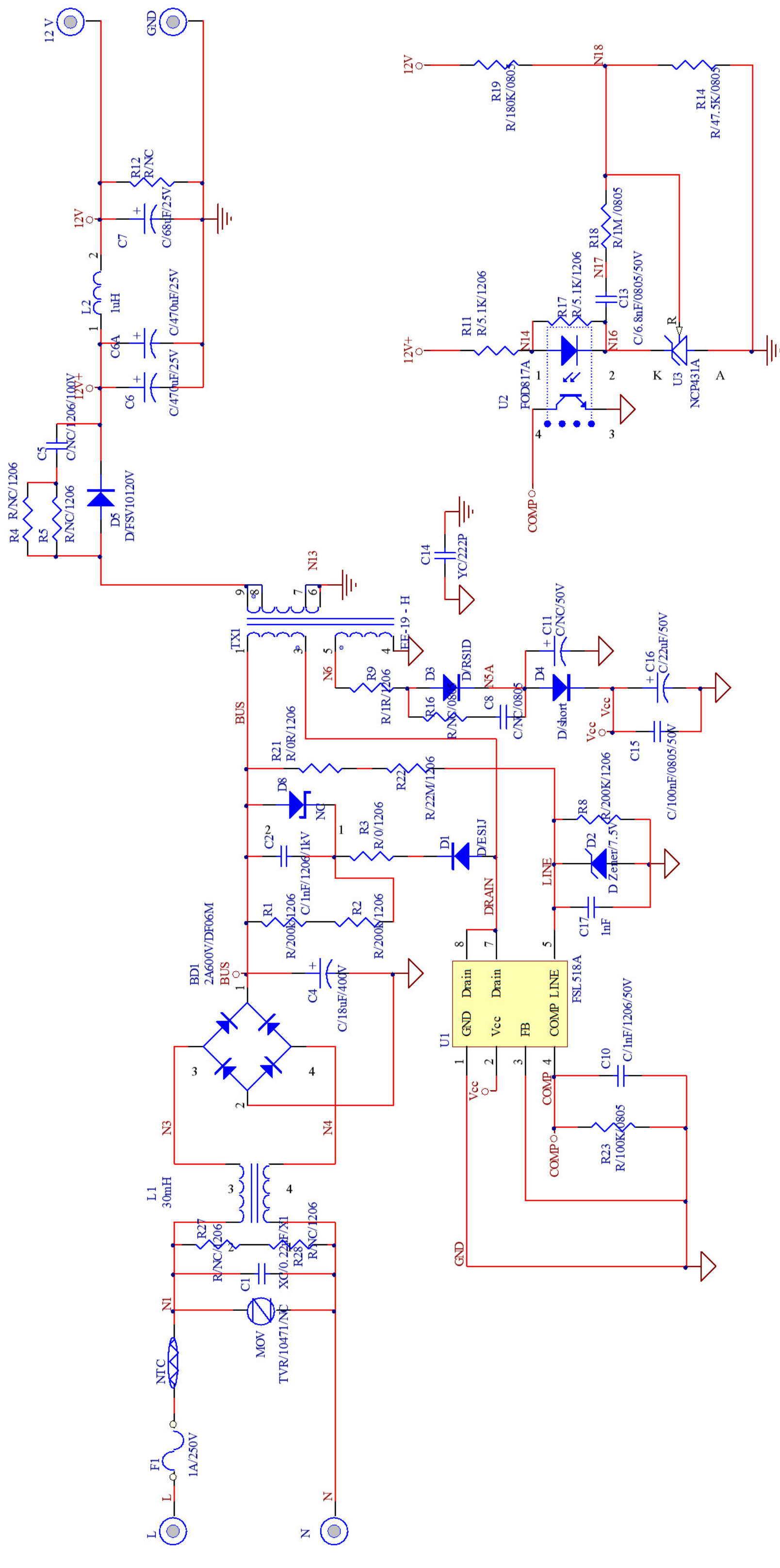

**Figure 1. FSL518AFLYGEVB Demo−Board – Main Board Schematic**

**The input EMI filter** is formed by components L1 and C1. Bleeder for X−cap, R27 and R28, are left not connected.

**The primary side of flyback converter** is composed of these devices; power transformer TX1, dc−link capacitor, TVS snubber, the integrated switcher U1 (FSL518APG) and related components. Meanwhile, the integrated switcher has a peak current mode PWM controller and 800 V super junction MOSFET. D1, R3 and D8 form TVS snubber to protect instant voltage spike produced by leakage inductance. The FB pin of U1 needs to connect to reference ground due to isolated flyabck already exists regulator as NCP431A so that don't need to employ internal error amplifier. U2 couples the reactive current of U3 to primary side and connect to COMP pin, the coupled current and internal sourcing current is converted to control voltage of PWM for output voltage regulation, R23 and C10 can be used for adjusting response of feedback signal. LINE pin of U1 connects voltage divider from bulk capacitor to detect input voltage for some protections of brown−in, brown−out and LOVP. Besides, there is parallel−connected D2 on LINE pin to adjust burst threshold to fine tune audible noise and light load efficiency. C17 is used to avoid larger switching noise interference, which is usually recommended around 1 nF~3.3 nF. Auxiliary winding shares same ground reference with U1. That is, reference ground is negative terminal of output of bridge rectifier BD1. Transformer winding is also used for providing VCC voltage in normal operation. R9 and D3 provide path to delivery energy when PWM is turned off. C16 can keep enough voltage if PWM is turned off for a while, and C15 is for better stability.

**The secondary−side output** is mainly composed of D5, C6 and C6A. When the MOSFET integrated in the switcher turns off, energy stored in the coupled inductor is transferred to the secondary side. At the time, there is switching noise on the output voltage, which can be, however, reduced by a LC filter on each output terminal formed by L2 and C7. U3 is a shunt regulator, and output is taken into account for generating feedback signal with network formed by R19 and R14. R18, C13, and R11 are used to adjust feedback response and bias U3. R17 provides additional biasing current for U3 to keep its required operating current. Cathode current of U3 is coupled to primary side by an opto−coupler, U2.

## CIRCUIT LAYOUT

The PCB consists of a double layer FR4 board with 2 oz. copper cladding.

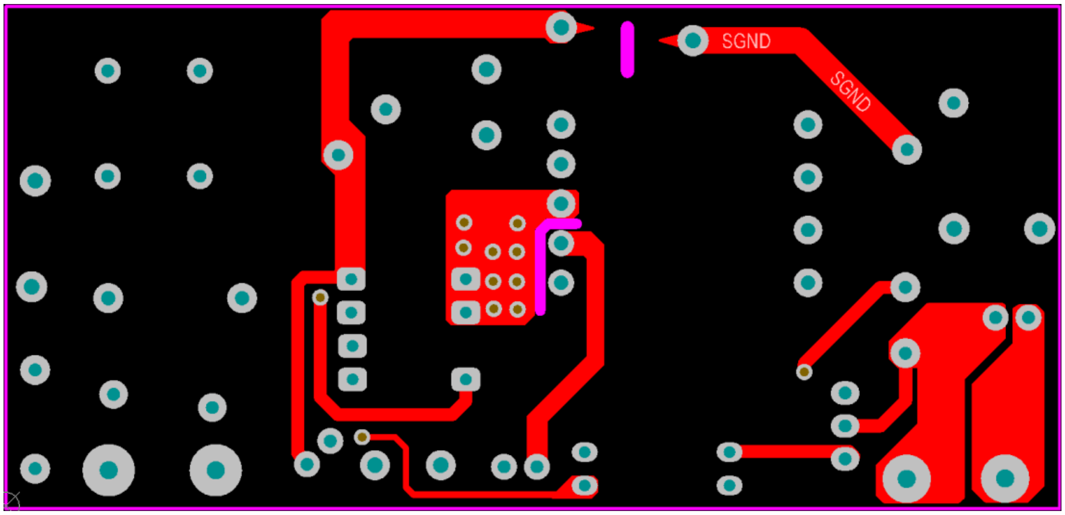


**Figure 2. Main Board Top Layer**

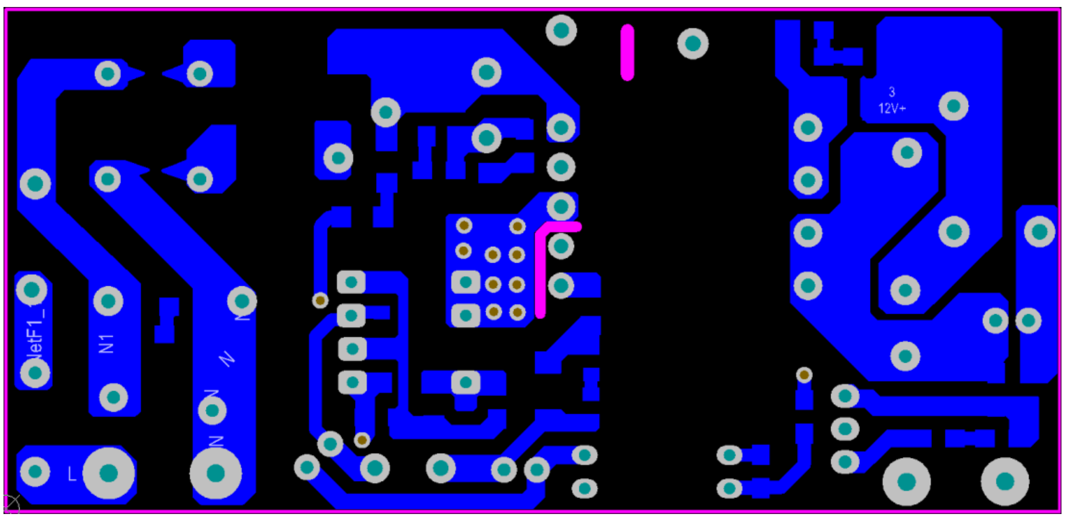


**Figure 3. Main Board Bottom Layer**

## CIRCUIT LAYOUT (Continued)

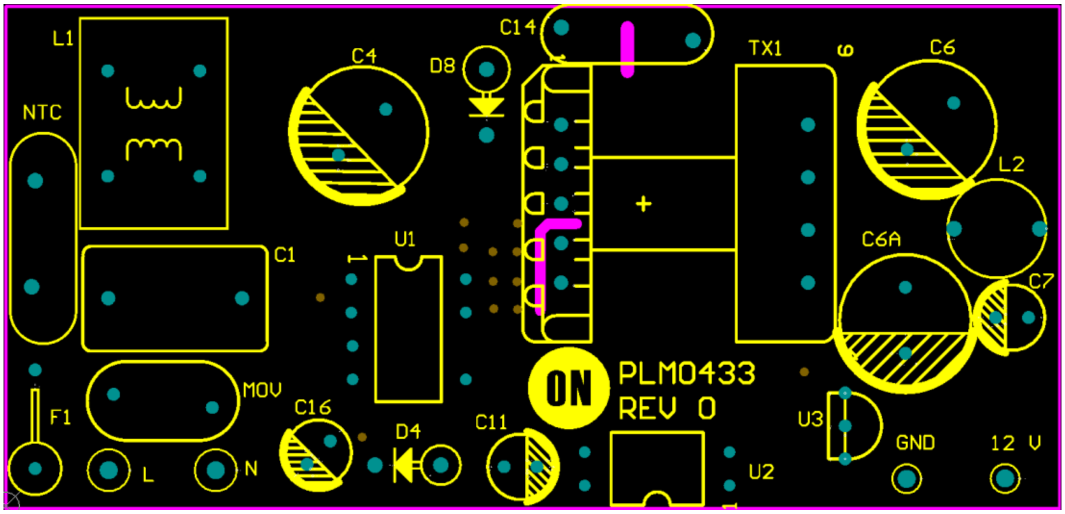


**Figure 4. Main Board Top Side Components**

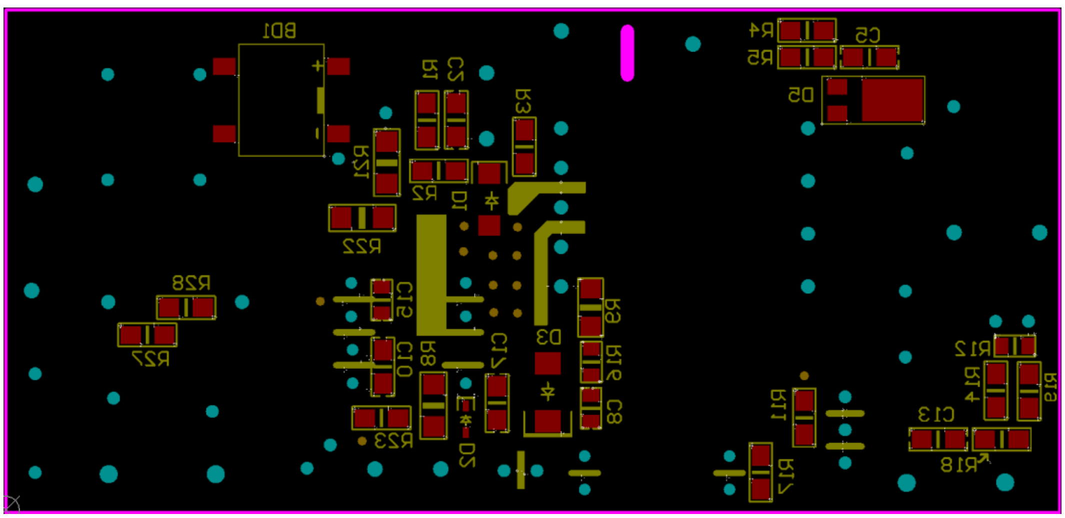

**Figure 5. Main Board Bottom Side Components**

## BOARD PICTURES

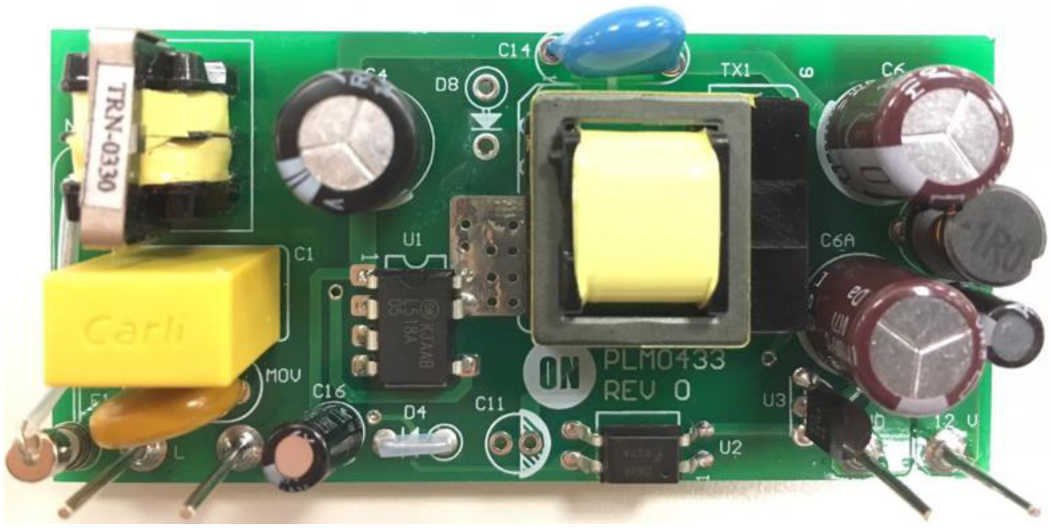


Figure 6. Main Board Photo − Top Side

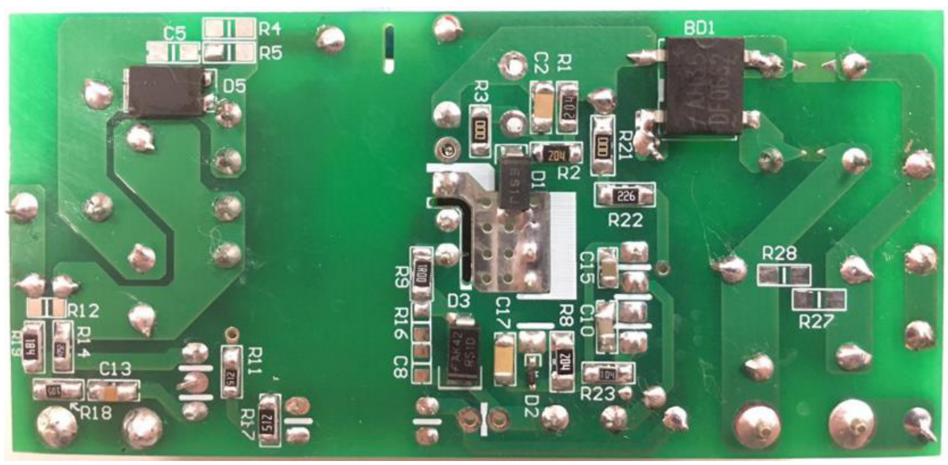


Figure 7. Main Board Photo − Bottom Side

## TRANSFORMER DATA

**Bobbin & Core : EE-19-H-9P**

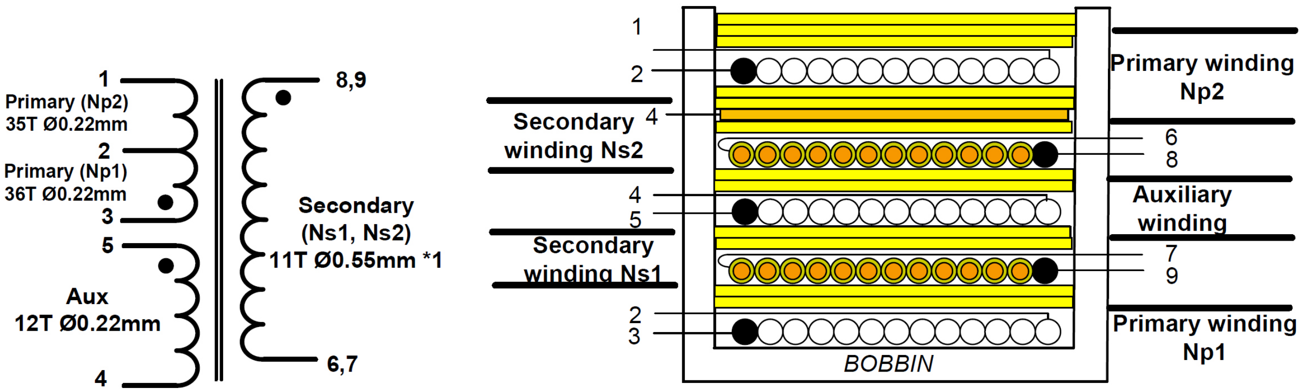


**Table 2.**

| | Pin | Specification | Remark |
|---|---|---|---|
| Primary–Side Inductance | Drain – B+ | 745 μH (Typ.) | 100 kHz, 1 V |

**Table 3.**

| Layer | TERMINAL | | WIRE | Turns | Isolation Layer |
|---|---|---|---|---|---|
| | Start Pin | End Pin | | | Turns |
| Primary Winding (Np1) | 3 | 2 | 2UEW 0.22 * 1 | 36 | 2 |
| Secondary (Ns1) | 9 | 7 | 0.55 * 1 | 11 | 1 |
| AUX Winding | 5 | 4 | 2UEW 0.18 * 1 | 12 | 1 |
| Secondary (Ns2) | 8 | 6 | 0.55 * 1 | 11 | 1 |
| Copper Shield | 4 | – | | 1.2 | 2 |
| Primary Winding (Np2) | 2 | 1 | 2UEW 0.22 * 1 | 35 | 3 |

*Copper shield is open loop and connect to ground.

## TEST DATA

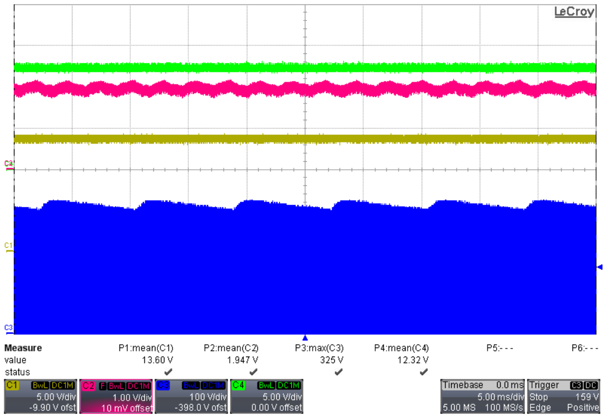


**Figure 8. Operation, Full Load, 115 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

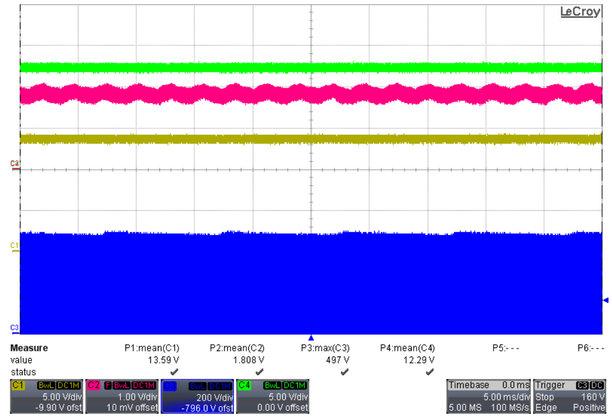


**Figure 9. Operation, Full Load, 230 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

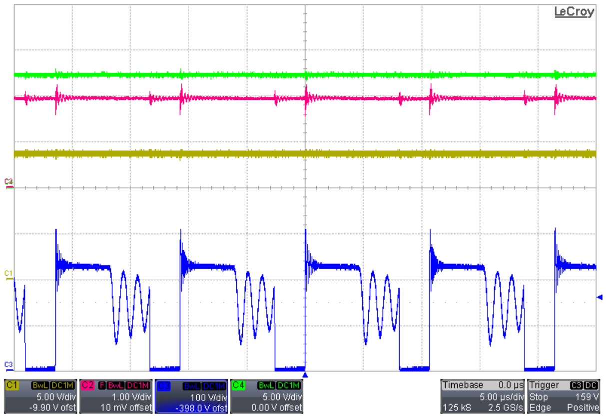


**Figure 10. Zoom in Operation, Full Load, 115 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

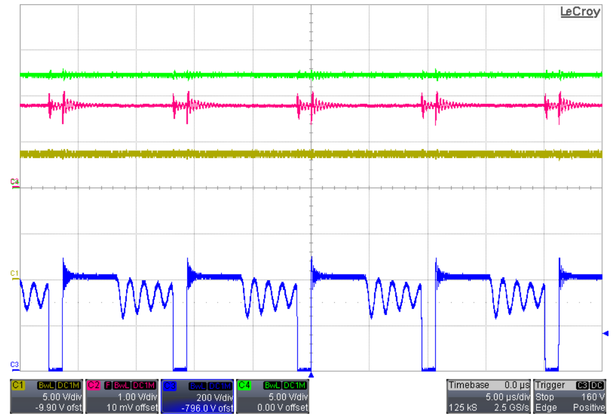


**Figure 11. Zoom in Operation, Full Load, 230 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

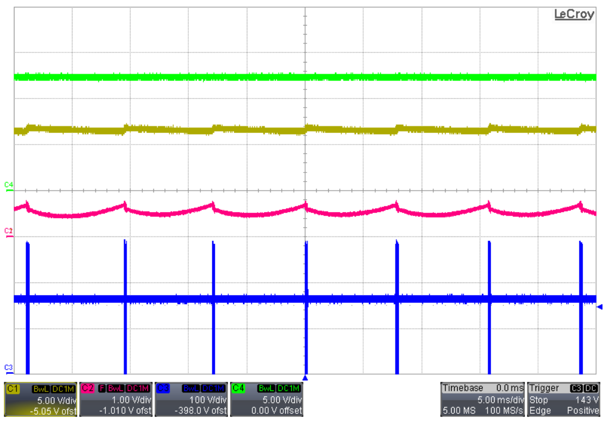


**Figure 12. Operation, No Load, 115 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

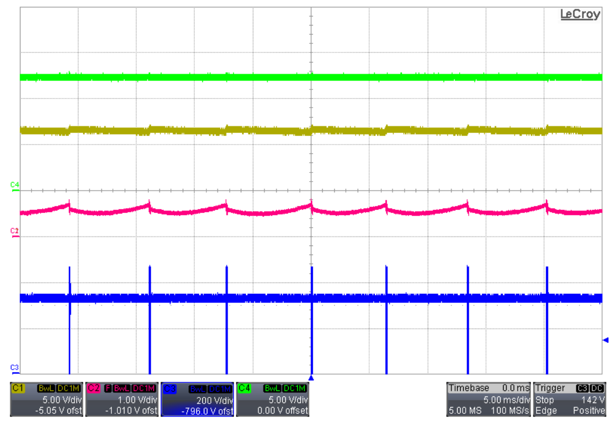


**Figure 13. Operation, No Load, 230 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

## TEST DATA (Continued)

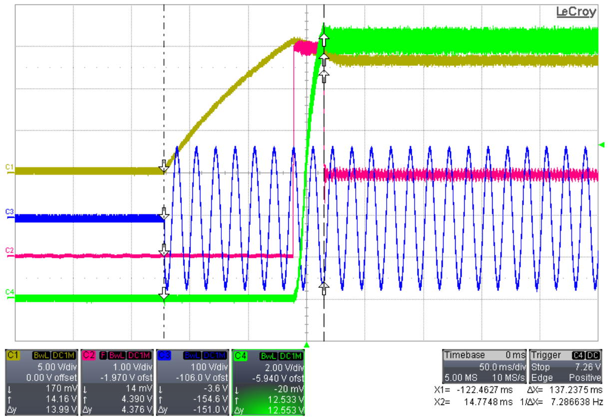

**Figure 14. Ton On time, 115 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Vac, Ch4: Vo)**

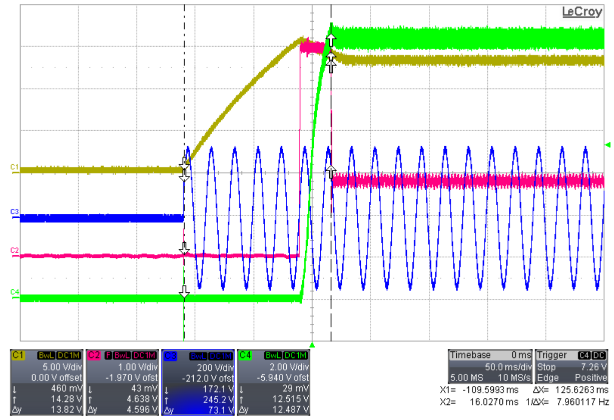

**Figure 15. Ton on time, 230 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Vac, Ch4: Vo)**

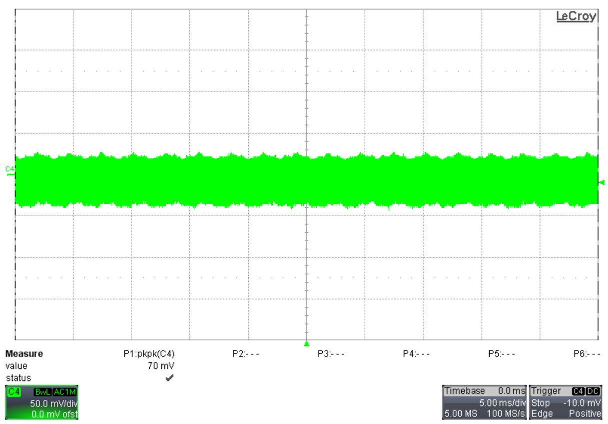

**Figure 16. Output Ripple, Full Load, 115 Vac (Ch4: $V_O$ (AC))**

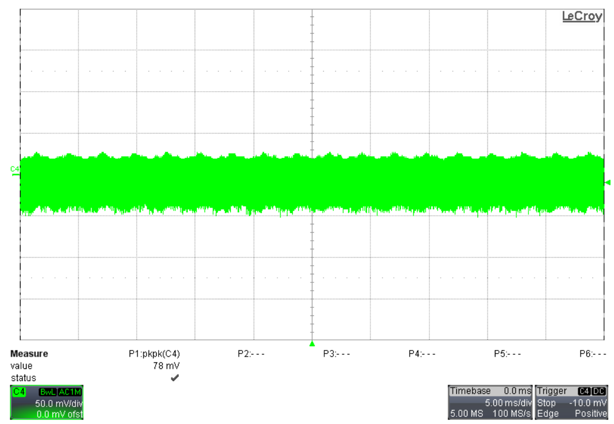

**Figure 17. Output Ripple, Full Load, 230 Vac (Ch4: $V_O$ (AC))**

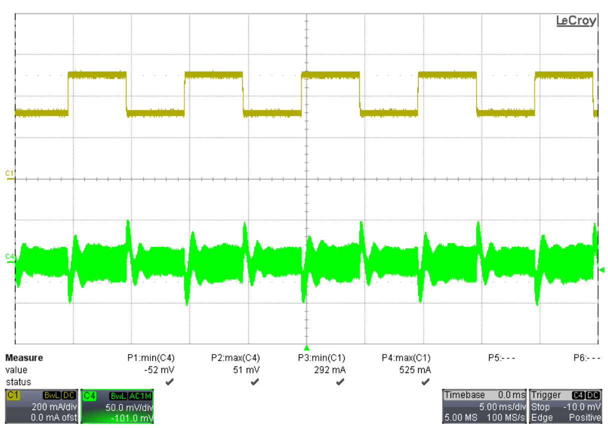

**Figure 18. Dynamic Operation (20%~80% of the Full Load, 5 ms Duty Cycle, 2.5 A/μs Rise/Fall Time), 115 Vac (Ch1: Io, Ch4: Vo(AC))**

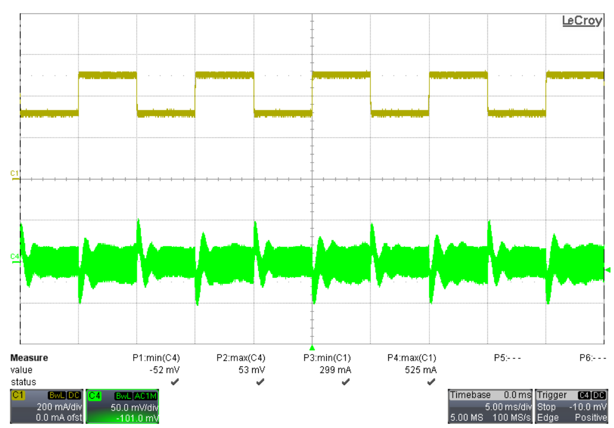

**Figure 19. Dynamic Operation (20%~80% of the Full Load, 5 ms Duty Cycle, 2.5 A/μs Rise/Fall Time), 230 Vac (Ch1: Io, Ch4: Vo(AC))**

## TEST DATA (Continued)

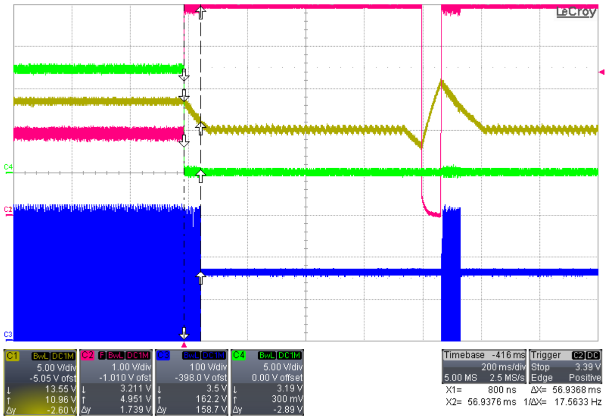

**Figure 20. Output Short Triggers OLP, Full Load, 115 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

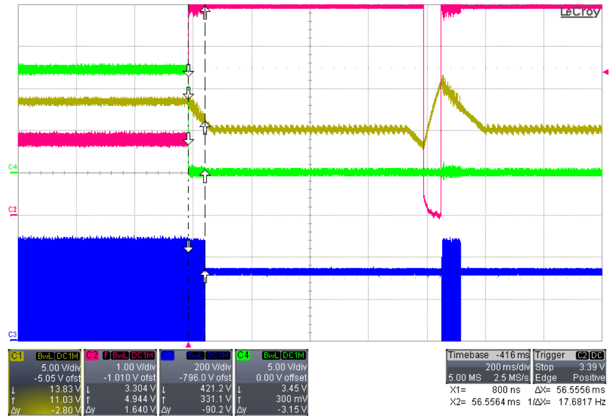

**Figure 21. Output Short Triggers OLP, Full Load, 230 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

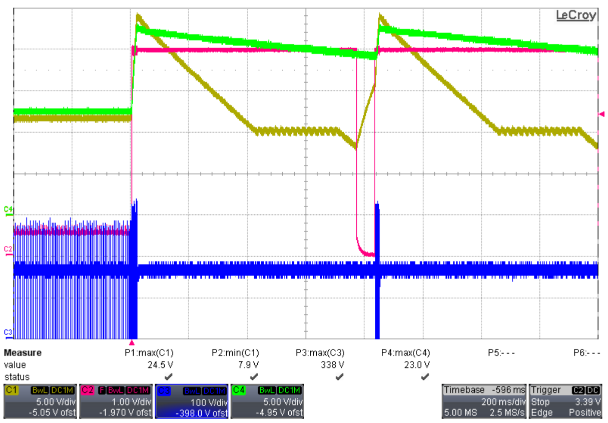

**Figure 22. Short Photo Couple of Secondary Side to Trigger $V_{CC}$ OVP, No Load, 115 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

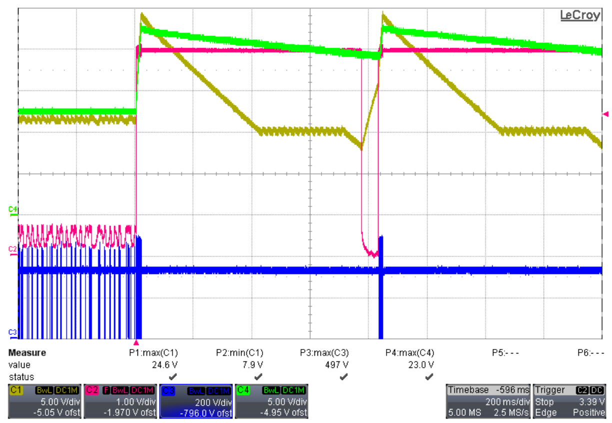

**Figure 23. Short Photo Couple of Secondary Side to Trigger $V_{CC}$ OVP, No Load, 230 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo**

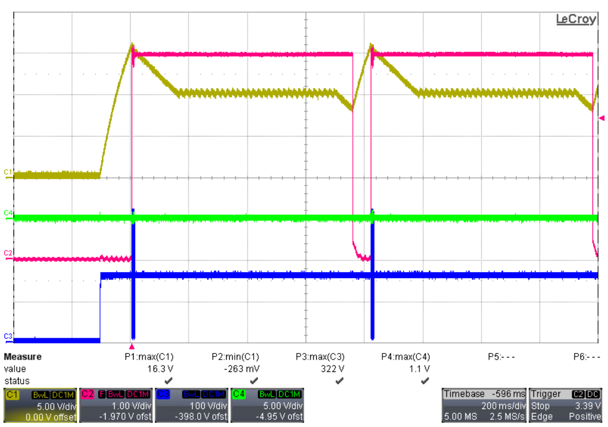

**Figure 24. Short Output Schottky Diode to Trigger AOCP, Full Load, 115 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

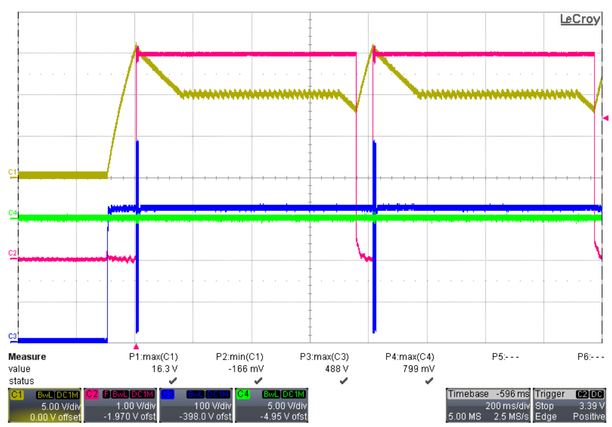

**Figure 25. Short Output Schottky Diode to Trigger AOCP, Full Load, 230 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

## TEST DATA (Continued)

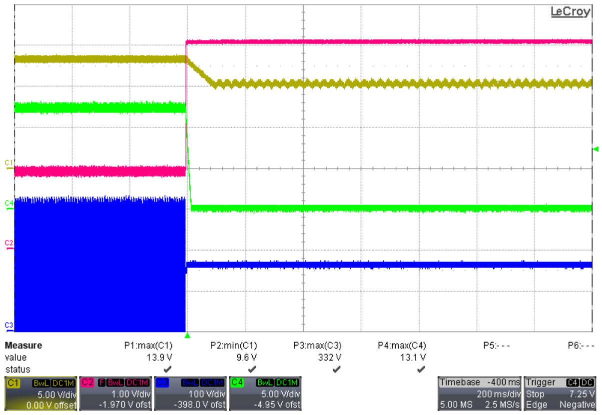


**Figure 26. Heating on IC's Case to Trigger TSD, Full Load, 115 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

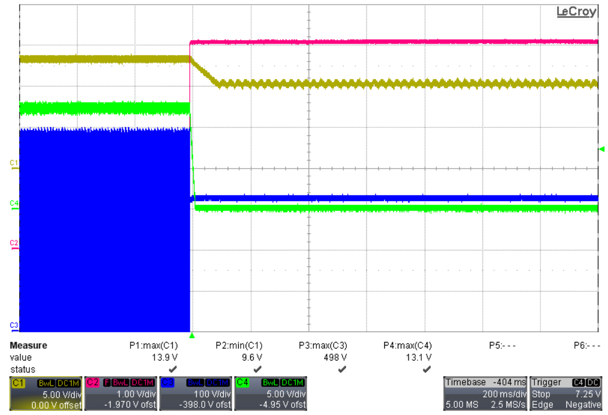


**Figure 27. Heating on IC's Case to Trigger TSD, Full Load, 230 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

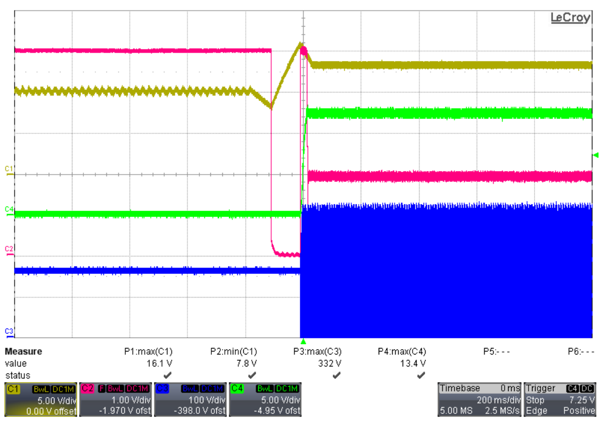


**Figure 28. Remove Heating from IC's Case to Recover TSD Protection, Full Load, 115 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

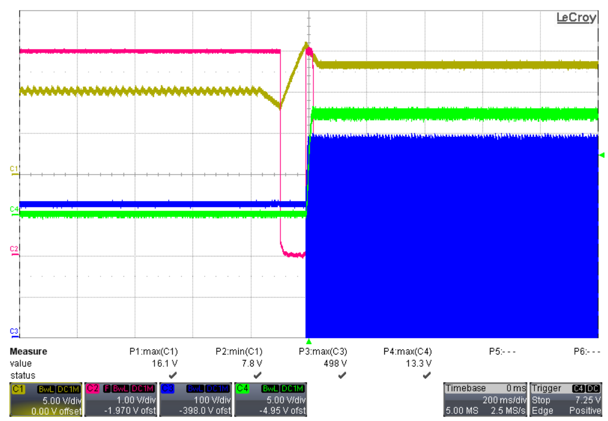


**Figure 29. Remove Heating from IC's Case to Recover TSD Protection, Full Load, 230 Vac (Ch1: $V_{CC}$, Ch2: COMP, Ch3: Drain, Ch4: Vo)**

**Table 4. BROWN IN/OUT**

| Behavior | Vin (Vrms) |
|---|---|
| Brown In | 76 |
| Brown Out | 65 |

NOTE: Test condition is full load.
Gradually increase/decrease input AC by 1 V/step.

**Table 5. NO−LOAD INPUT POWER CONSUMPTION**

| Input Voltage [Vac] | Power Consumption [mW] |
|---|---|
| 115 Vac | 24.18 |
| 230 Vac | 39.50 |

NOTE: Test condition: Outputs are connected to electronic load, but loading is not applied. Input power is integrated over three minutes.

**Table 6. EFFICIENCY**

| Input Voltage [Vac] | 25% Load | 50% Load | 75% Load | 100% Load | Avg. |
|---|---|---|---|---|---|
| 115 Vac | 86.91% | 87.41% | 87.46% | 87.34% | 87.28% |
| 230 Vac | 84.01% | 85.57% | 86.18% | 87.25% | 85.75% |

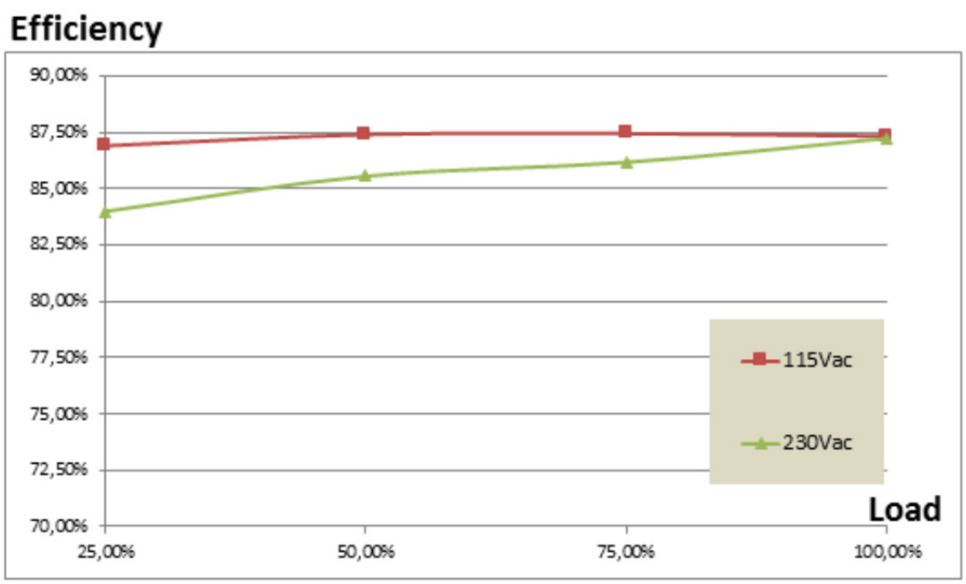


**Figure 30. Board Efficiency**

Table 7. LINE/LOAD REGULATION

| Input Voltage [Vac] | 85 Vac | 115 Vac | 230 Vac | 265 Vac | Line Regulation (±) |
|---|---|---|---|---|---|
| Load | $V_{OUT}$ (V) | $V_{OUT}$ (V) | $V_{OUT}$ (V) | $V_{OUT}$ (V) | $V_{OUT}$ (V) |
| 0 W | 12.389 | 12.387 | 12.386 | 12.385 | 0.016% |
| 0.1 W | 12.389 | 12.386 | 12.385 | 12.384 | 0.020% |
| 0.25 W | 12.388 | 12.385 | 12.384 | 12.383 | 0.020% |
| 0.5 W | 12.387 | 12.384 | 12.382 | 12.381 | 0.024% |
| 25 % | 12.379 | 12.378 | 12.375 | 12.374 | 0.020% |
| 50 % | 12.372 | 12.371 | 12.367 | 12.366 | 0.024% |
| 75 % | 12.365 | 12.364 | 12.360 | 12.358 | 0.028% |
| 100 % | 12.358 | 12.356 | 12.353 | 12.351 | 0.028% |
| Load Regulation (±) | 0.125% | 0.125% | 0.133% | 0.137% | |

NOTE: Equation of line/load regulation is ±(max − min) / (max + min).
Measured within load range shown in specification.

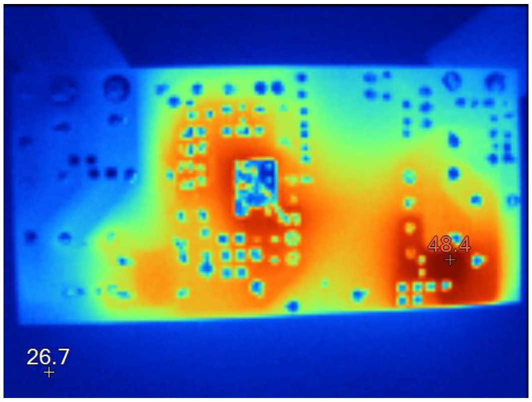


Figure 31. Temperature Checking on Bottom Side, Full Load, 115 Vac

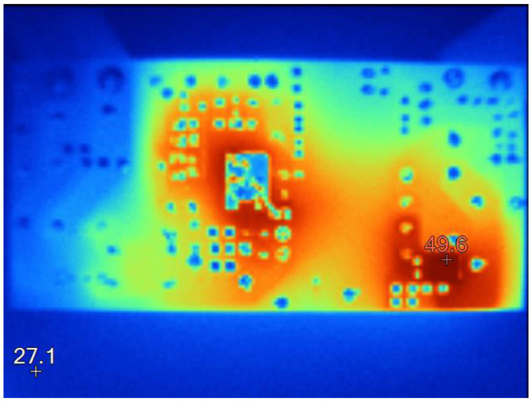


Figure 32. Temperature Checking on Bottom Side, Full Load, 230 Vac

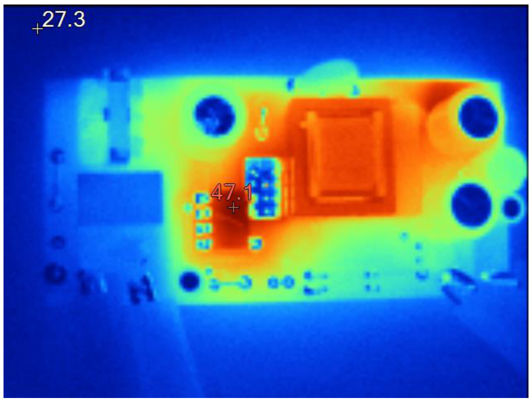


Figure 33. Temperature Checking on Top Side, Full Load, 115 Vac

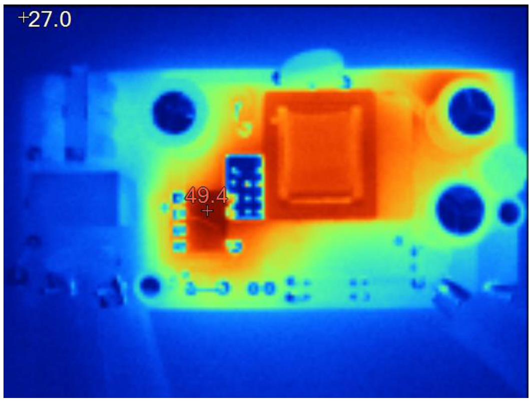


Figure 34. Temperature Checking on Top Side, Full Load, 230 Vac

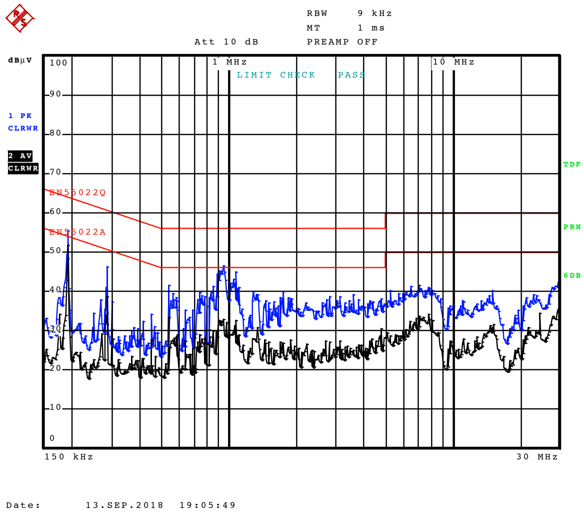


**Figure 35. Conducted EMI, 115 Vac, LINE**

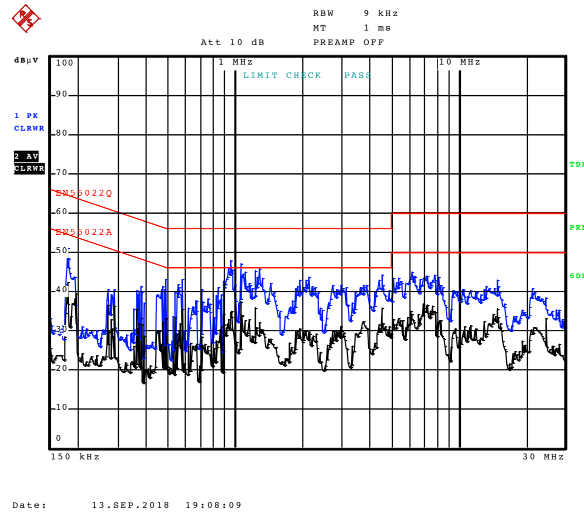


**Figure 36. Conducted EMI, 230 Vac, LINE**

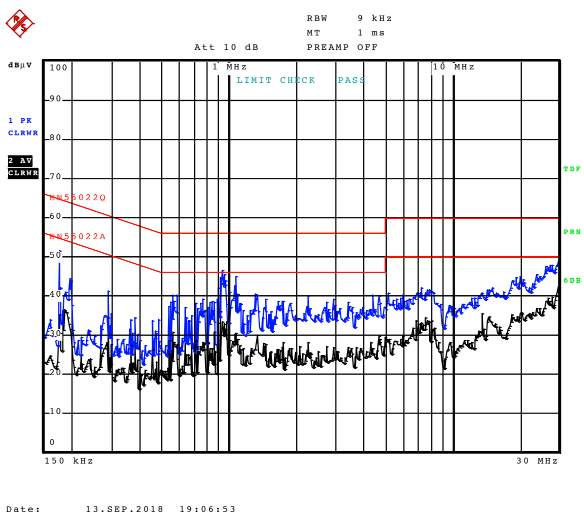


**Figure 37. Conducted EMI, 115 Vac, Neutral**

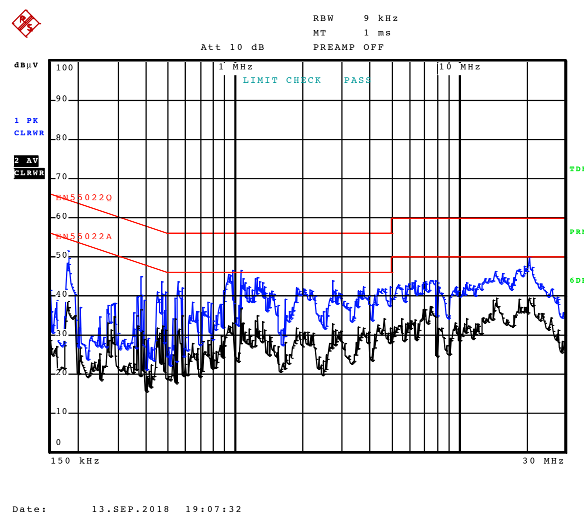


**Figure 38. Conducted EMI, 230 Vac, Neutral**

## BILL OF MATERIALS

**Table 8. BILL OF MATERIALS**

| Parts | Qty | Description | Value | Tolerance | Footprint | Manufacturer | Manufacturer Part Number | Substitution Allowed | Pb−Free |
|---|---|---|---|---|---|---|---|---|---|
| C1 | 1 | X2 Capacitor | 0.33 μF/275 V | ±10% | 17 × 7.5 × 15.5 mm Pitch = 15 m m | CARLI | PX334K3ID1 | Yes | Yes |
| C10, C17 | 2 | MLCC X7R Capacitor | 102 pF/50 V | ±10% | 0805 | Taiwan−Resister | CP102K050XRB | Yes | Yes |
| C13 | 1 | MLCC X7R Capacitor | 682 pF/50 V | ±10% | 0805 | Taiwan−Resister | CP682K050XRB | Yes | Yes |
| C15 | 1 | MLCC X7R Capacitor | 104 pF/50 V | ±10% | 0805 | Taiwan−Resister | CP104K050XRB | Yes | Yes |
| C1 | 1 | X2 Capacitor | 0.22 μF/ 275 V | ±10% | P = 10 mm | CARLI | PX224K3IC5 | Yes | Yes |
| C2 | 1 | MLCC X7R Capacitor | 102 pF/1 kV | ±10% | 1206 | KEMET | C1206C102KDRACTU | Yes | Yes |
| C14 | 1 | Y1 Capacitor | 222 pF/250 V | ±20% | | UNIVERSE | CD12−E2GA222MYASA | Yes | Yes |
| C4 | 1 | Electrolytic Capacitor | 18 μF/400 V | | 10 × 20 mm | AISHI | EHL2GM180G20OT | Yes | Yes |
| C6, C6A | 2 | Electrolytic Capacitor | 470 μF/25 V | | 10 × 12 mm | CHEMI−CON | EKMG250ELL471MJC5S | Yes | Yes |
| C7 | 1 | Electrolytic Capacitor | 68 μF/25 V | ±20% | 5 × 11 mm | Rubycon | 25ZLH68M5X11 | Yes | Yes |
| C16 | 1 | Electrolytic Capacitor | 22 μF/50 V | ±20% | 5 × 11 mm | JACKCON | LHK | Yes | Yes |
| R14 | 1 | Resistor SMD | 47.5 kΩ | ±5% | 0805 | Taiwan−Resister | RP0847K5JR | Yes | Yes |
| R11, R17 | 1 | Resistor SMD | 5.1 kΩ | ±5% | 1206 | Taiwan−Resister | RP1205K1JR | Yes | Yes |
| R18 | 1 | Resistor SMD | 1 MΩ | ±5% | 0805 | Taiwan−Resister | RP0801MJR | Yes | Yes |
| R19 | 1 | Resistor SMD | 180 kΩ | ±1% | 0805 | Taiwan−Resister | RP08180KFR | Yes | Yes |
| R23 | 1 | Resistor SMD | 100 kΩ | ±5% | 0805 | Taiwan−Resister | RP08100KJR | Yes | Yes |
| R1, R2, R8 | 3 | Resistor SMD | 200 kΩ | ±5% | 1206 | Taiwan−Resister | RP12200KJR | Yes | Yes |
| R9 | 1 | Resistor SMD | 1 R | ±5% | 1206 | Taiwan−Resister | RP1201R0JR | Yes | Yes |
| R3, R21 | 1 | Resistor SMD | 0 R | ±5% | 1206 | Taiwan−Resister | RP12000JR | Yes | Yes |
| R22 | 1 | Resistor SMD | 22 MΩ | ±5% | 1206 | Taiwan−Resister | RP1222M0JR | Yes | Yes |
| D1 | 1 | Fast Rectifier | 600 V, 1 A | | DO−214AC | ON Semiconductor | ES1J | Yes | Yes |
| D2 | 1 | Zener Diode | 7.5 V, 0.2 W | | SOD−523F | ON Semiconductor | MM5Z7V5 | Yes | Yes |
| D3 | 1 | Fast Rectifier | 200 V, 1 A | | DO−214AC | ON Semiconductor | RS1D | Yes | Yes |
| D4 | 1 | Jumper Wire | Short | | 5 mm | | | Yes | Yes |
| D5 | 1 | Schottky Rectifier | 120 V, 10 A | | TO−277 | ON Semiconductor | FSV10120V | Yes | Yes |
| L, N, 12V, GND | 4 | TEST PIN | Pin Ψ2.2 × 18.2 mm OEM−10 | | 2.2 × 18.2 mm | KANG YANG | SG004−05 Pin | Yes | Yes |
| F1 | 1 | Fuse | FUSE CERAMIC 1 A/250 V SLOW | | 3.6 × 10 mm | | 37SG | Yes | Yes |
| MOV | 1 | MOV | 470 V | ±10% | | THINKING | MOV−471KD10SBNL | Yes | Yes |
| NTC | 1 | Jumper Wire | short | | 7 mm | | | Yes | Yes |
| L1 | 1 | Common−mode Choke | 30 mH | | UU9.8 | SEN HUEI | TRN0330 | Yes | Yes |
| L2 | 1 | Inductor, Ferrite Core | 1 μH | | DR 6 × 8 | WURTH | 744772010 | Yes | Yes |
| BD1 | 1 | Bridge Rectifier | 600 V, 1.5 A | | SDIP−4 | ON Semiconductor | DF06S | Yes | Yes |
| TX1 | 1 | Transformer | 745 μH | ±5% | EE−19H−9P | SEN HUEI SWARM BOBBIN | TRN0369 SW−19AG | No | Yes |

**Table 8. BILL OF MATERIALS** (continued)

| Parts | Qty | Description | Value | Tolerance | Footprint | Manufacturer | Manufacturer Part Number | Substitution Allowed | Pb−Free |
|---|---|---|---|---|---|---|---|---|---|
| U1 | 1 | PWM with Power SENSEFET | | | PDIP−7 | ON Semiconductor | FSL518APG | No | Yes |
| U2 | 1 | Opto Coupler | CTR = 80−160% | | DIP 4−pin | ON Semiconductor | FOD817A | Yes | Yes |
| U3 | 1 | Shunt Regulator | Adjustable, 2.5 V | 1% | TO−92 | ON Semiconductor | NCP431AVLPRAG | Yes | Yes |
| | 1 | PCB | | | 38 × 80 mm | | PLM0433V0 | No | Yes |
| NTC, D4, F1 | 3 | Teflon Tube | 17L × 305 m | | | | | Yes | Yes |

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