# EVBUM2640

# FSL117MRIN Evaluation Board User's Manual

**ON Semiconductor®**

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**EVAL BOARD USER'S MANUAL**

## GENERAL BOARD DESCRIPTION

FSL117MRIN Power Switch which is utilized in the evaluation board can be applied for home appliance applications. FSL117MRIN is an integrated Pulse−Width Modulation (PWM) controller and SENSEFET® specifically designed for high performance off−line SMPS. In order to minimize the power consumption in stand−by mode, the start up current source supplied by JFET is turned off during normal operation and the burst operation. Furthermore, A soft burst operation reduces audible noise during stand−by mode.

The board is designed to minimize the power consumption in stand−by mode and to have high efficiency in normal mode. The power stage has single output. It is a 12 $V_{OUT}$.

### Features of FSL117MRIN

- Advanced Burst Mode Operation for Low Stand−by Power
- Random Frequency Fluctuation for Low EMI
- Pulse−by−Pulse Current Limit
- Various Protection Functions: Overload Protection (OLP), Over−Voltage Protection (OVP), Abnormal Over−Current Protection (AOCP), Internal Thermal Shutdown (TSD) with Hysteresis, Output−Short Protection (OSP), Line Over−Voltage Protection (LOVP), and Under−Voltage Lock Out (UVLO) with Hysteresis
- Auto−Restart Mode
- Internal Start−up Circuit
- Internal High−Voltage SENSEFET (700 V)
- Built−in Soft Start: 15 ms

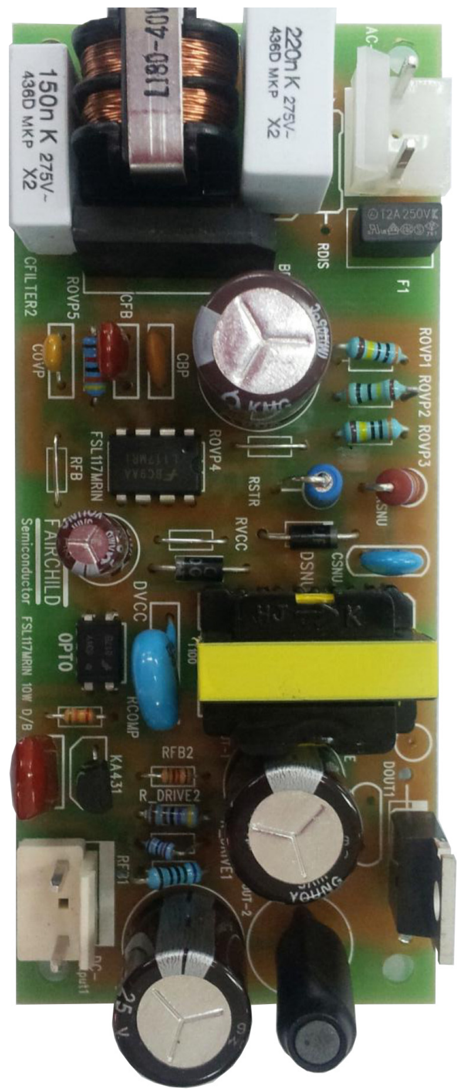



**Figure 1. FSL117MRIN Evaluation Board**

### Block Diagram of FSL117MRIN

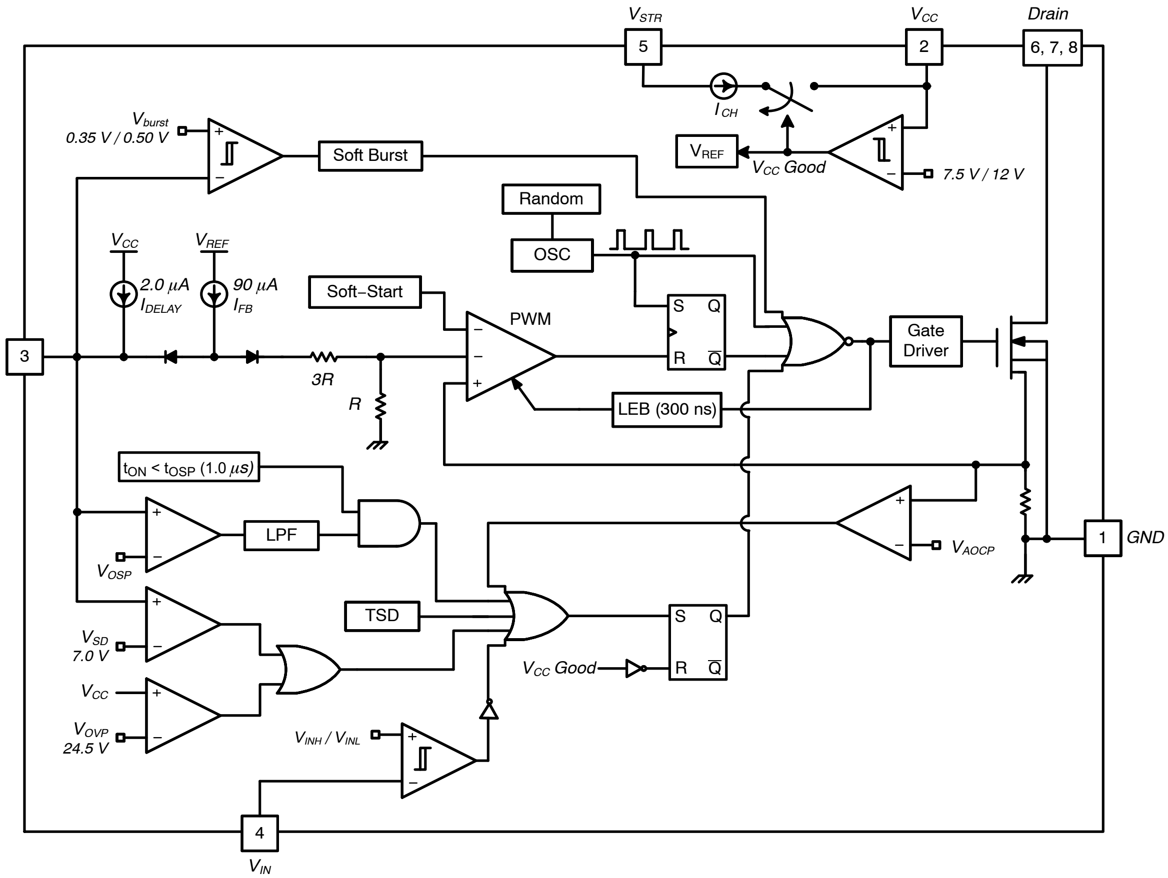



**Figure 2. Block Diagram of FSL117MRIN**

### Input−Output Specifications of the Evaluation Board

**Table 1. INPUT−OUTPUT SPECIFICATIONS**

| Description | Voltage | Current | Max Power |
|---|---|---|---|
| Input Voltage ($V_{IN}$) | 85~265 Vac<br>50~60 Hz | – | – |
| Output Voltage 1 ($V_{OUT1}$) | 12 Vdc | 0.83 A | 9.96 W (100%) |
| Total Output Power | – | – | 9.96 W (100%) |

### Summary of Performance

**Table 2. SUMMARY OF PERFORMANCE**

| Symbol | Description | Value | Comments |
|---|---|---|---|
| $P_{IN,@0.000W}$<br>$P_{IN,@0.120W}$<br>$P_{IN,@0.240W}$<br>$P_{IN,@0.360W}$<br>$P_{IN,@0.480W}$ | Stand−by Power (without discharge resistor / FSL117MRIN) | 0.053 W<br>0.231 W<br>0.397 W<br>0.540 W<br>0.701 W | 230 Vac input, $P_{IN}$ was averaged for 10 minutes |
| $\eta_{85Vac}$<br>$\eta_{115Vac}$<br>$\eta_{230Vac}$<br>$\eta_{264Vac}$ | Efficiency (η) $P_{OUT}$ = 23.0 W | Avg. 82.87%<br>Avg. 84.38%<br>Avg. 84.25%<br>Avg. 83.53% | Average of 25, 50, 75 and 100% load (open frame, room temperature / still air) |
| $T_{PKG,85Vac}$<br>$T_{PKG,115Vac}$<br>$T_{PKG,230Vac}$<br>$T_{PKG,264Vac}$ | Temperature (FSD156MRBN) | 69.0°C<br>57.9°C<br>52.3°C<br>54.7°C | Around Drain PIN of package surface of the IC @ full load (enclosed rectangular box) |

### Schematic of the Evaluation Board

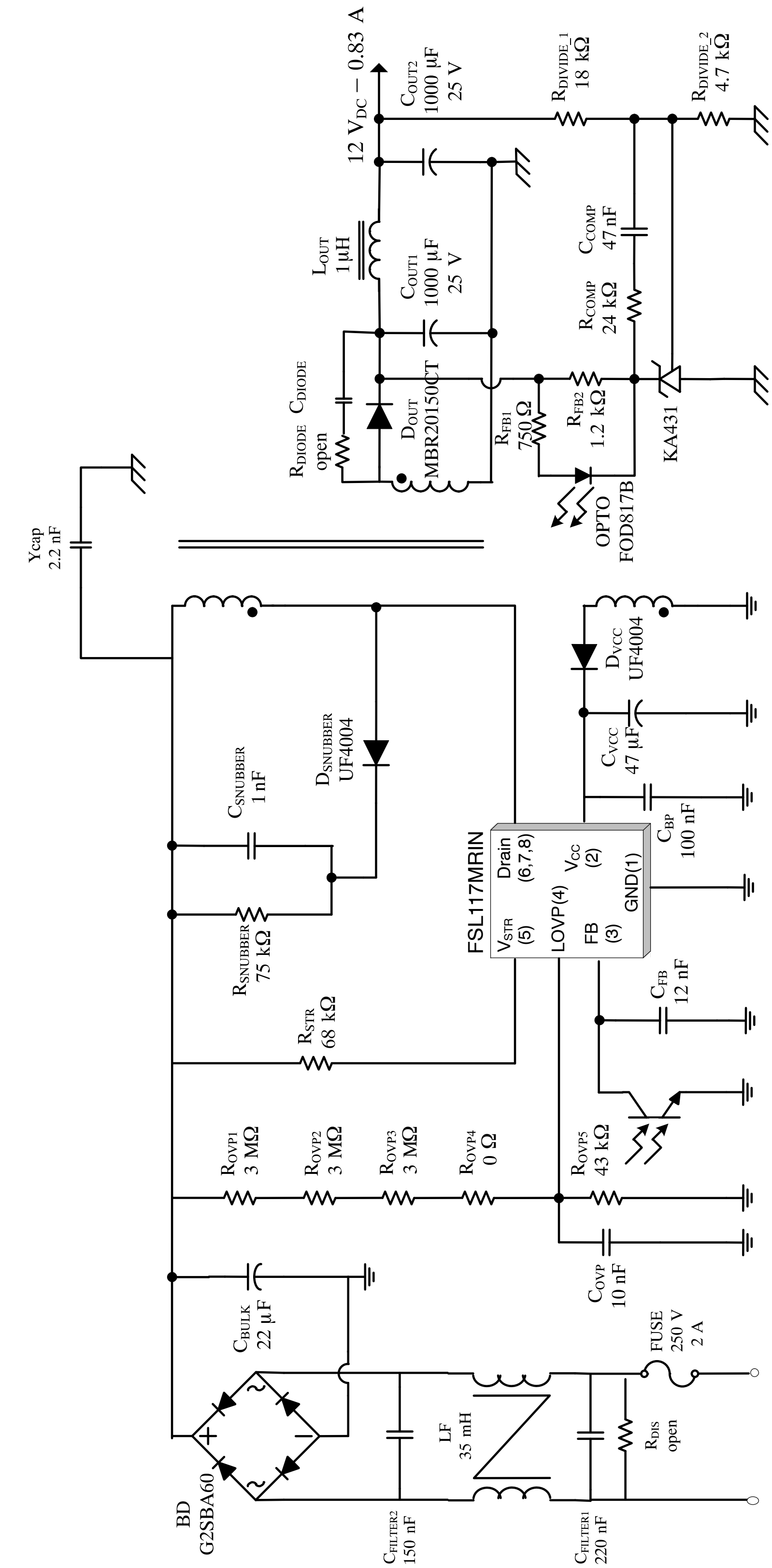



**Figure 3. Schematic of the Evaluation Board**

## Photographs of Evaluation Board

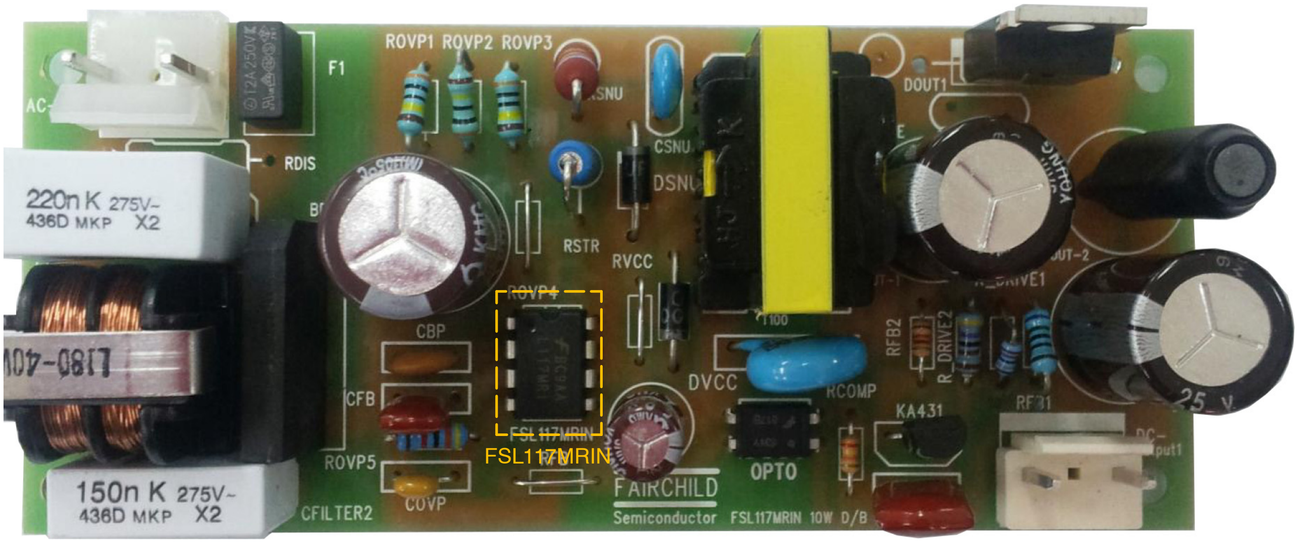



Figure 4. Top Side Photograph of the Evaluation Board

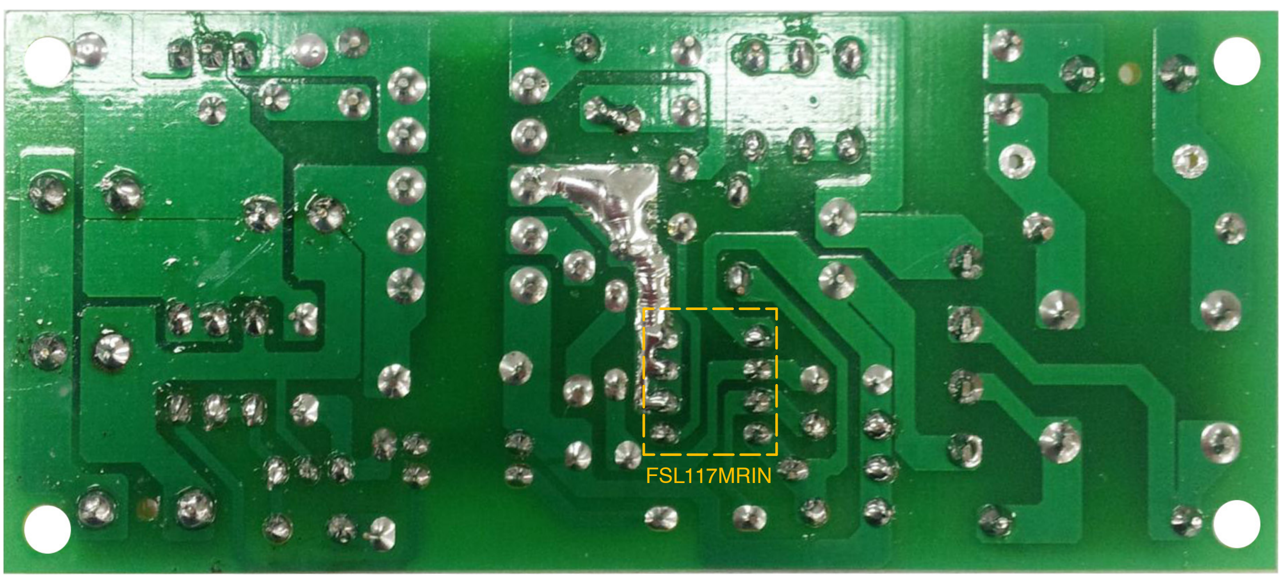



Figure 5. Bottom Side Photograph of the Evaluation Board

### Bill of Materials

The selected components for the evaluation board are shown in Table 3.

**Table 3. BILL OF MATERIALS FOR EVALUATION BOARD**

| Part # | Value | Note | Part # | Value | Note |
|---|---|---|---|---|---|
| Fuse | | | Capacitor | | |
| FUSE | 250 V 2 A | | CFILTER1 | 220 nF / 275 V | Box (Pilkor) |
| Resistor | | | CFILTER2 | 150 nF / 275 V | Box (Pilkor) |
| RDIS | open | | CBULK | 22 μF / 400 V | Electrolytic (SamYoung) |
| ROVP1 | 3 MΩ | 1%, 1/4 W | CSNUBBER | 1 nF / 1 kV | film (sewha) |
| ROVP2 | 3 MΩ | 1%, 1/4 W | CVCC | 47 μF / 50 V | Electrolytic (KMG) |
| ROVP3 | 3 MΩ | 1%, 1/4 W | CFB | 12 nF / 100 V | film (sewha) |
| ROVP4 | 0 Ω | Jumper | CBP | 100 nF | film (sewha) |
| ROVP5 | 43 kΩ | 1%, 1/4 W | COVP | 10 nF | film (sewha) |
| RSTR | 68 kΩ | 1 W | COUT1 | 1000 μF / 25 V | Electrolytic (SamYoung) |
| RSNUBBER | 75 kΩ | 1 W | COUT2 | 1000 μF / 25 V | Electrolytic (SamYoung) |
| RVCC | 0 Ω | Jumper | CDIODE | open | |
| RFB | 0 Ω | Jumper | CCOMP | 47 nF | film (sewha) |
| RDIODE | open | | YCAP | 2.2 nF | film (sewha) |
| RFB1 | 750 Ω | 1/4 W | | | |
| RFB2 | 1.2 kΩ | 1/4 W | Inductor | | |
| RCOMP | 24 kΩ | 1/4 W | LOUT | 1 μH | |
| RDIVIDE1 | 18 kΩ | 1%, 1/4 W | LF | 35 mH | |
| RDIVIDE2 | 4 kΩ | 1%, 1/4 W | Transformer | | |
| IC | | | T101 | 1 mH | EE2219 |
| SMPS | FSL117MRIN | ON Semiconductor | | | |
| SHUNT | KA431LZ | ON Semiconductor | | | |
| OPTO | FOD817B | ON Semiconductor | | | |
| Diode | | | | | |
| DSNUBBER | UF4004 | Vishay | | | |
| DVCC | UF4004 | Vishay | | | |
| DOUT | MBR20150CT | ON Semiconductor | | | |
| BD | G2SBA60 | Vishay | | | |

### Transformer Specification

- Core: EE2219 (Ae = 40.1 $mm^2$)
- Bobbin: EE2219

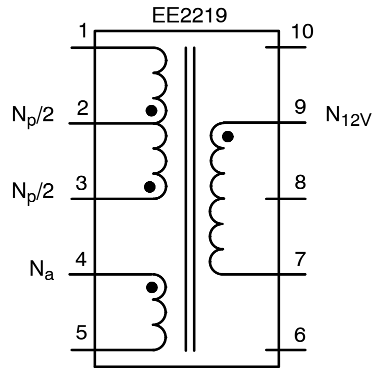



**Figure 6. Transformer Specification**

**Table 4. WINDING SPECIFICATION**

| | | | | | Barrier Tape | | |
|---|---|---|---|---|---|---|---|
| | Pin(S → F) | Wire | Turns | Winding Method | TOP | BOT | Ts |
| $N_p/2$ (BOT) | 3 → 2 | 0.25φ x 1 | 34 | Solenoid winding | – | – | |
| Insulation: Polyester Tape t = 0.025 mm, 2 Layers | | | | | | | |
| $N_{12V}$ | 9 → 7 | 0.4φ x 2 (TIW) | 12 | Solenoid winding | – | – | |
| Insulation: Polyester Tape t = 0.025 mm, 2 Layers | | | | | | | |
| $N_a$ | 4 → 5 | 0.2φ x 1 | 14 | Solenoid winding | | – | |
| Insulation: Polyester Tape t = 0.025 mm, 2 Layers | | | | | | | |
| $N_p/2$ (TOP) | 2 → 1 | 0.25φ x 1 | 33 | Solenoid winding | – | – | |
| Insulation: Polyester Tape t = 0.025 mm, 2 Layers | | | | | | | |

*Electrical Characteristics*

**Table 5. ELECTRICAL CHARACTERISTICS**

| | Pin | Spec | Remark |
|---|---|---|---|
| Inductance | 3 → 1 | 1.0 mH ±6% | 67 kHz, 1 V |

## PERFORMANCE DATA

**Stand−by Power without AC Discharge Resistor**

**Table 6.**

| Test Condition | 12 $V_{OUT}$ |
|---|---|
| Load | 0.000 A~0.040 A |
| Output Power | 0.000 W~0.480 W |

**Table 7. STAND−BY POWER**

| FSL117MRIN | | | Pin (W) | | | |
|---|---|---|---|---|---|---|
| Vo (V) | Io (A) | Po (W) | 85 Vac | 115 Vac | 230 Vac | 265 Vac |
| 12 | 0.000 | 0.000 | 0.037 | 0.039 | 0.053 | 0.059 |
| 12 | 0.005 | 0.060 | 0.141 | 0.143 | 0.164 | 0.172 |
| 12 | 0.010 | 0.120 | 0.205 | 0.207 | 0.231 | 0.239 |
| 12 | 0.015 | 0.180 | 0.284 | 0.287 | 0.316 | 0.326 |
| 12 | 0.020 | 0.240 | 0.362 | 0.365 | 0.397 | 0.410 |
| 12 | 0.025 | 0.300 | 0.438 | 0.443 | 0.477 | 0.491 |
| 12 | 0.030 | 0.360 | 0.497 | 0.503 | 0.540 | 0.555 |
| 12 | 0.035 | 0.420 | 0.575 | 0.581 | 0.622 | 0.638 |
| 12 | 0.040 | 0.480 | 0.650 | 0.657 | 0.701 | 0.719 |

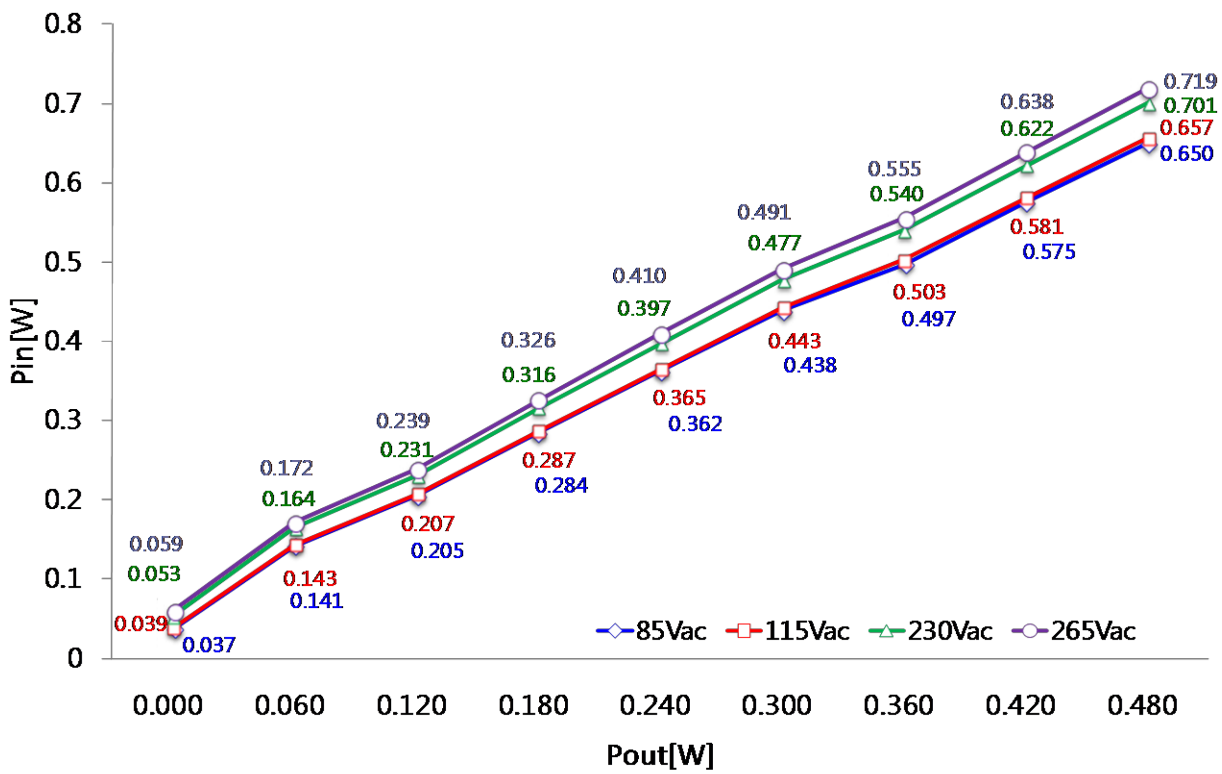



**Figure 7. Graph of Standby Power**

NOTE: Test results ($P_{IN}$) were averaged for 10 minutes at each load

**Efficiency**

**Table 8.**

| Test Condition | 12 $V_{OUT}$ |
|---|---|
| Load | 0.083 A~0.83 A |
| Output Power | 0.99 W~9.96 W |

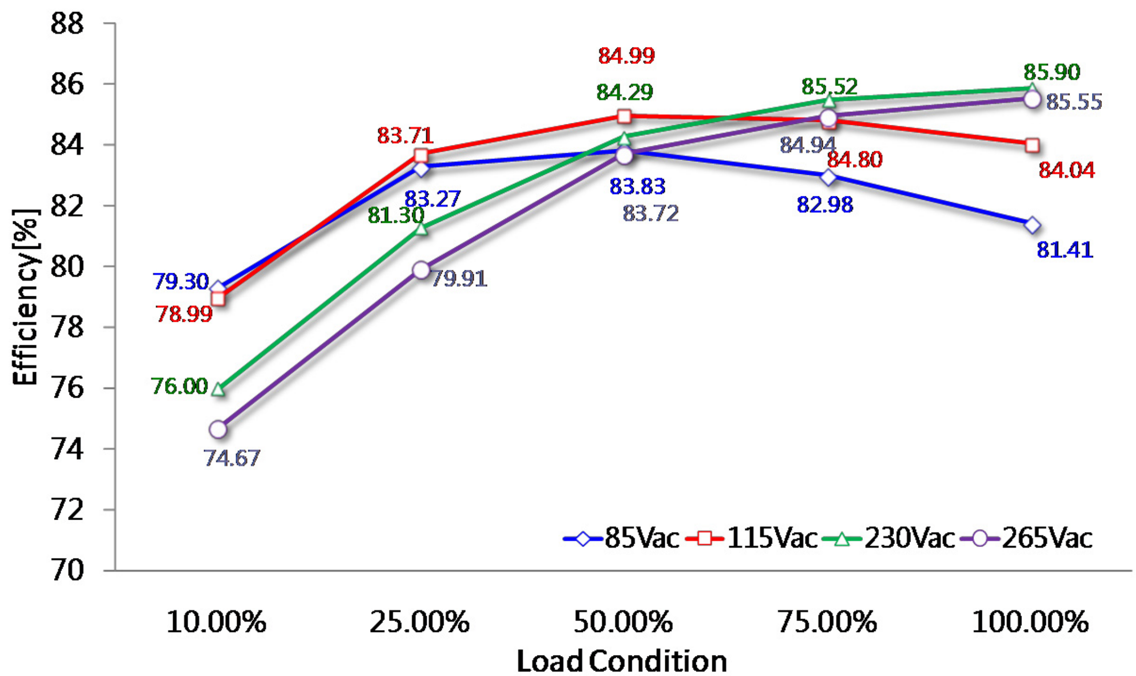



**Figure 8. Graph of Efficiency**

**Table 9. EFFICIENCY OF THE EVALUATION BOARD**

| Vin | 12.0 V | | Pout [W] | Pin [W] | Efficiency [%] | Load |
|---|---|---|---|---|---|---|
| | Iout [A] | Vout [V] | | | | |
| 85 Vac | 0.083 | 12.010 | 1.00 | 1.26 | 79.30 | 10.00% |
| | 0.209 | 12.010 | 2.51 | 3.01 | 83.27 | 25.00% |
| | 0.414 | 12.000 | 4.97 | 5.93 | 83.83 | 50.00% |
| | 0.620 | 12.000 | 7.44 | 8.97 | 82.98 | 75.00% |
| | 0.827 | 11.990 | 9.92 | 12.18 | 81.41 | 100.00% |
| Average (25, 50, 75, 100%) | | | | | 82.87 | |
| 115 Vac | 0.083 | 12.010 | 1.00 | 1.26 | 78.99 | 10.00% |
| | 0.209 | 12.010 | 2.51 | 3.00 | 83.71 | 25.00% |
| | 0.414 | 12.000 | 4.97 | 5.85 | 84.99 | 50.00% |
| | 0.620 | 12.000 | 7.44 | 8.77 | 84.80 | 75.00% |
| | 0.827 | 11.990 | 9.92 | 11.80 | 84.04 | 100.00% |
| Average (25, 50, 75, 100%) | | | | | 84.38 | |
| 230 Vac | 0.083 | 12.010 | 1.00 | 1.31 | 76.00 | 10.00% |
| | 0.209 | 12.010 | 2.51 | 3.09 | 81.30 | 25.00% |
| | 0.414 | 12.000 | 4.97 | 5.89 | 84.29 | 50.00% |
| | 0.620 | 12.000 | 7.44 | 8.70 | 85.52 | 75.00% |
| | 0.827 | 11.990 | 9.92 | 11.54 | 85.90 | 100.00% |
| Average (25, 50, 75, 100%) | | | | | 84.25 | |
| 265 Vac | 0.083 | 12.010 | 1.00 | 1.34 | 74.67 | 10.00% |
| | 0.209 | 12.010 | 2.51 | 3.14 | 79.91 | 25.00% |
| | 0.414 | 12.000 | 4.97 | 5.93 | 83.72 | 50.00% |
| | 0.620 | 11.990 | 7.43 | 8.75 | 84.94 | 75.00% |
| | 0.827 | 11.990 | 9.92 | 11.59 | 85.55 | 100.00% |
| Average (25, 50, 75, 100%) | | | | | 83.53 | |

## EMI Test Result

*EMI Test Result at $V_{IN}$ = 220 Vac*

**Table 10.**

| Test Condition | 12 $V_{OUT}$ |
|---|---|
| Load | 0.8 A |
| Output Power | 9.6 W |

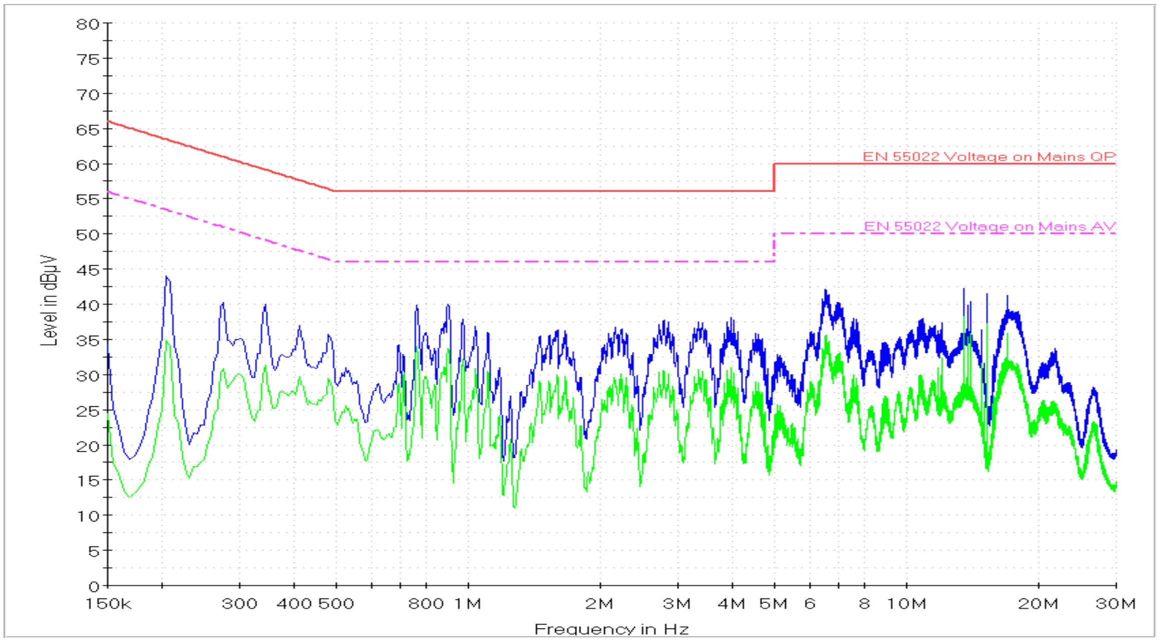



**Figure 9. EMI Test Result @ $V_{IN}$ = 220 Vac & Full Load**

*EMI Test Result at $V_{IN}$ = 110 Vac*

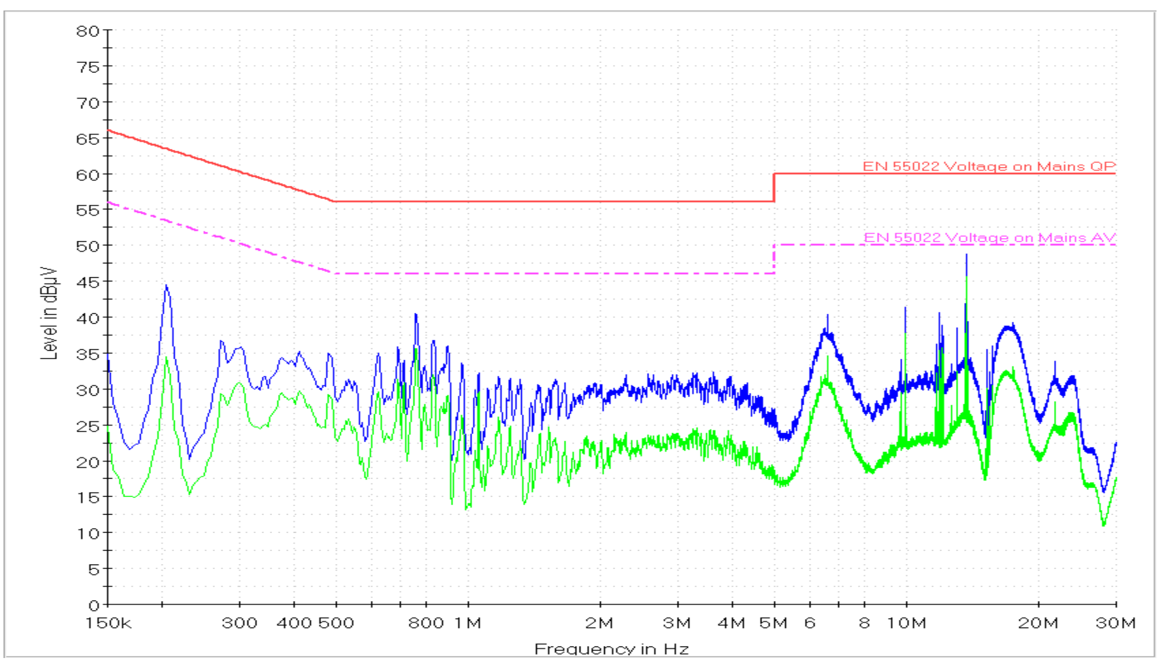



**Figure 10. EMI Test Result @ $V_{IN}$ = 110 Vac & Full Load**

## Thermal Characteristics

**Table 11.**

| Test Condition | 12 $V_{OUT}$ |
|---|---|
| Load | 0.83 A |
| Output Power | 9.96 W |

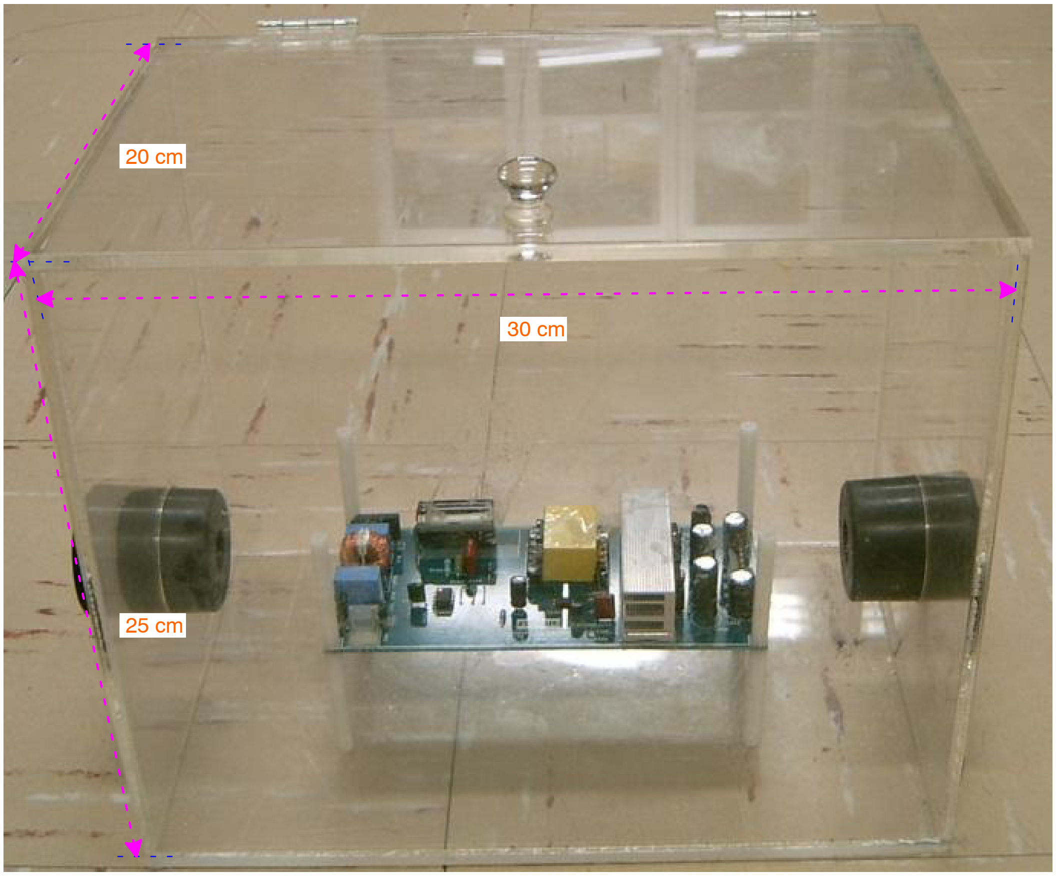



**Figure 11. Rectangular Box**

NOTE: Temperature of each component was measured in the rectangular box (Fig. 11)

*Temperature Measurement*

**Table 12. THERMAL CHARACTERISTICS OF THE EVALUATION BOARD**

| Input Voltage | IC | Transformer | 12 V Diode |
|---|---|---|---|
| 85 Vac | 69.0°C | 44.5°C | 55.1°C |
| 115 Vac | 57.9°C | 44.7°C | 55.4°C |
| 230 Vac | 52.3°C | 46.2°C | 55.7°C |
| 265 Vac | 54.7°C | 47.1°C | 55.5°C |

*Thermal Cam at $V_{IN}$ = 265 Vac, Full Load*

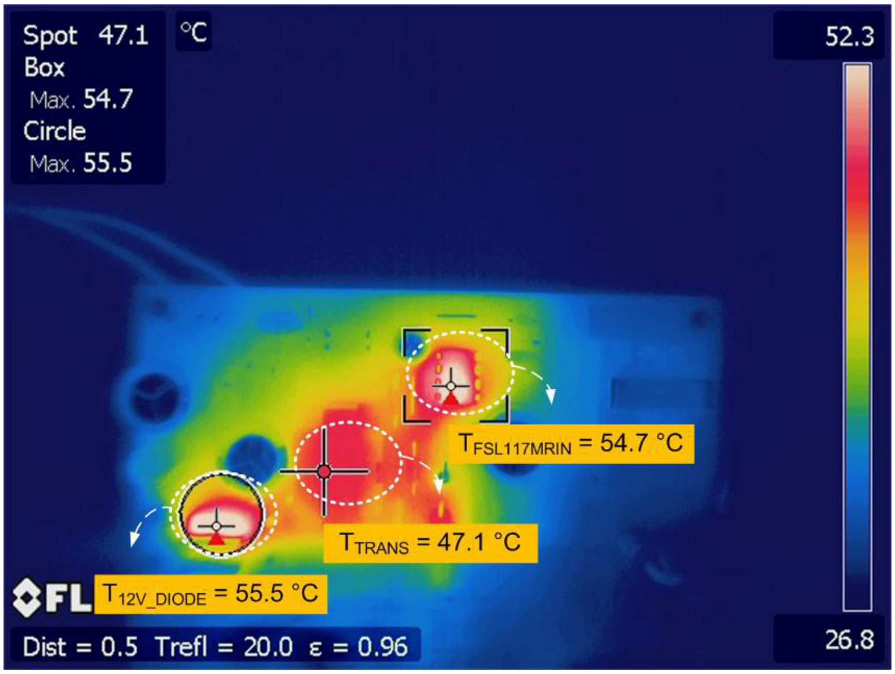



**Figure 12. Thermal Cam @ $V_{IN}$ = 265 Vac & Full Load**

*Thermal Cam at $V_{IN}$ = 230 Vac, Full Load*

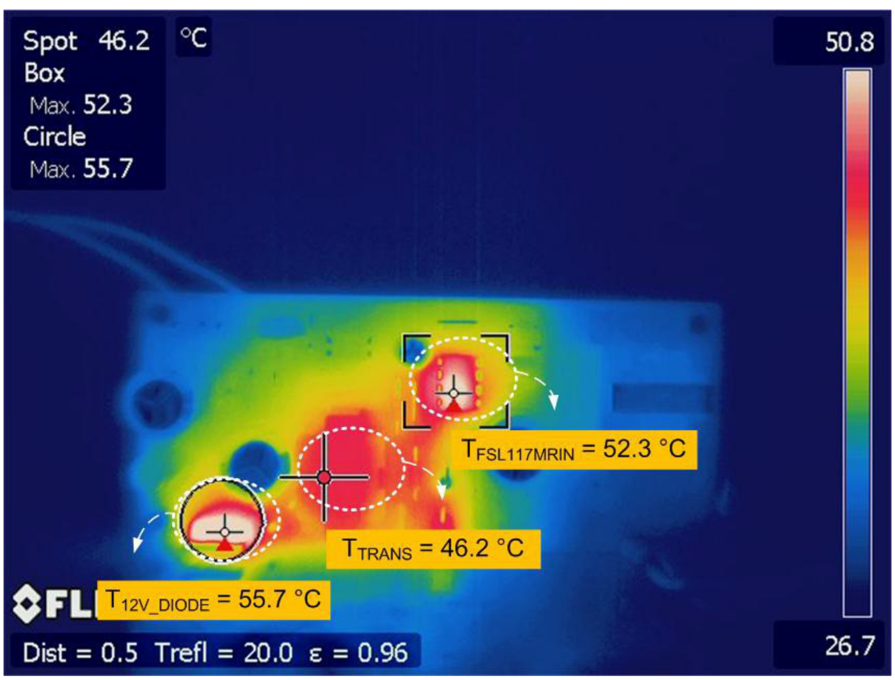



**Figure 13. Thermal Cam @ $V_{IN}$ = 230 Vac & Full Load**

*Thermal Cam at $V_{IN}$ = 115 Vac, Full Load*

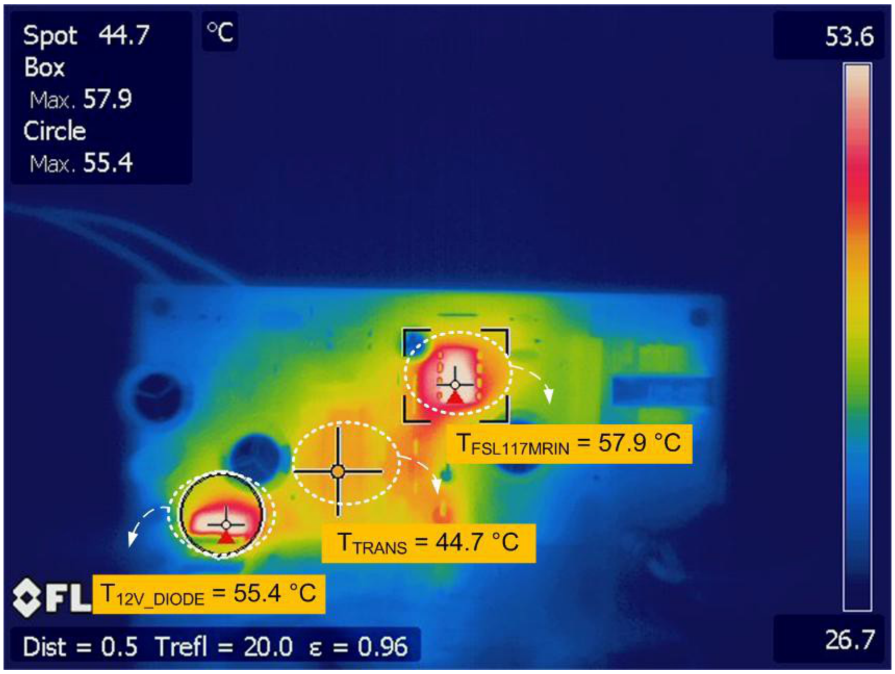



**Figure 14. Thermal Cam @ $V_{IN}$ = 115 Vac & Full Load**

*Thermal Cam at $V_{IN}$ = 85 Vac, Full Load*

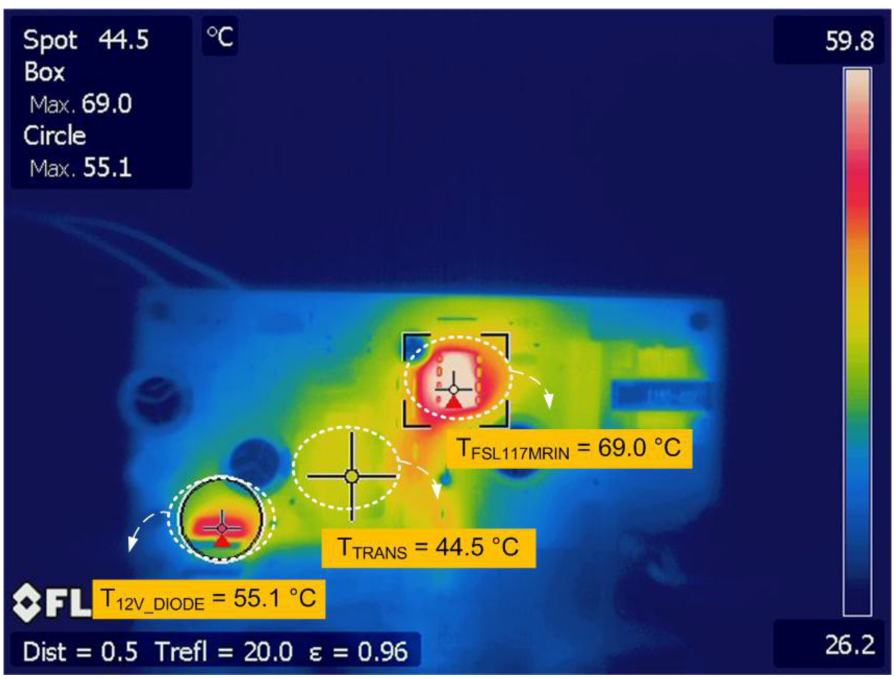



**Figure 15. Thermal Cam @ $V_{IN}$ = 85 Vac & Full Load**

## WAVEFORMS

### Soft−Start

**Table 13.**

| Test Condition | 12 $V_{OUT}$ |
|---|---|
| Load | 0.83 A |
| Output Power | 9.96 W |

*Soft−Start at $V_{IN}$ = 85 Vac, Full Load*

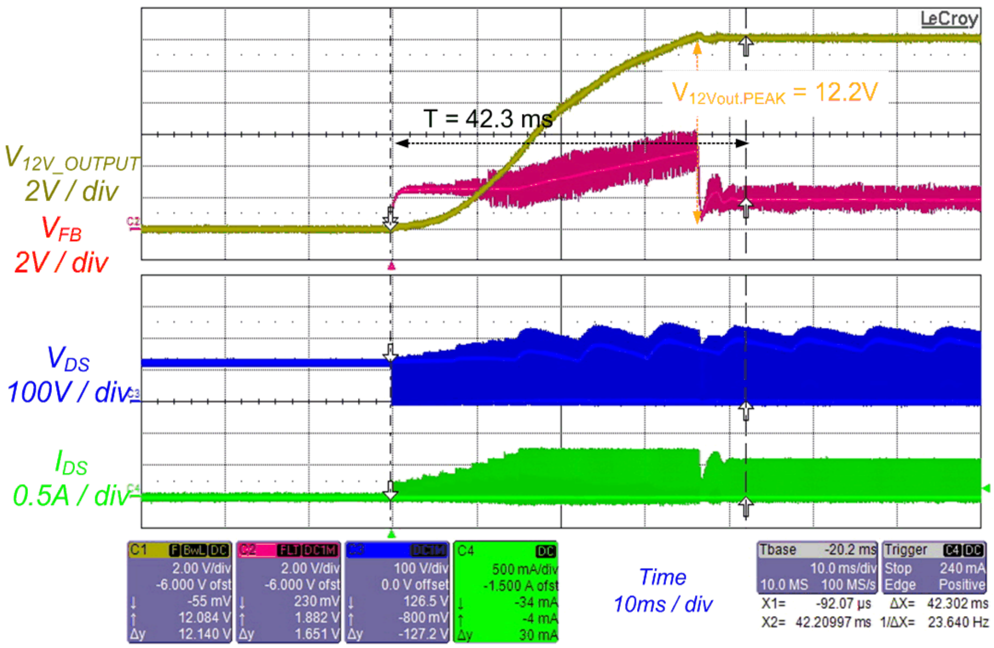



**Figure 16. Soft−Start Waveforms @ $V_{IN}$ = 85 Vac & Full Load**

*Soft−Start at $V_{IN}$ = 90 Vac, No Load*

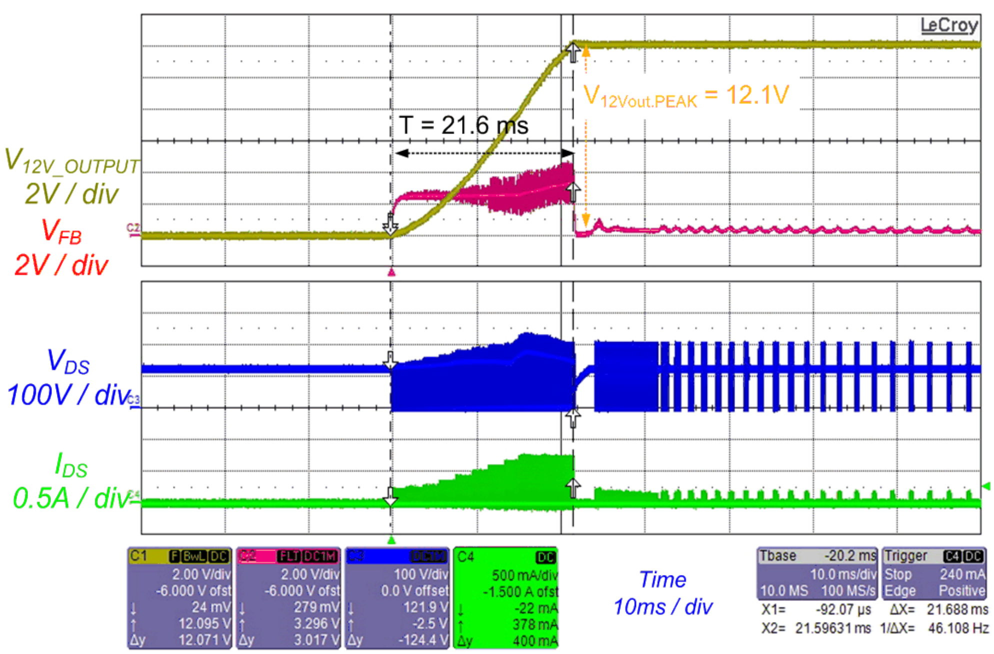



**Figure 17. Soft−Start Waveforms @ $V_{IN}$ = 85 Vac & No Load**

*Soft−Start at $V_{IN}$ = 265 Vac, Full Load*

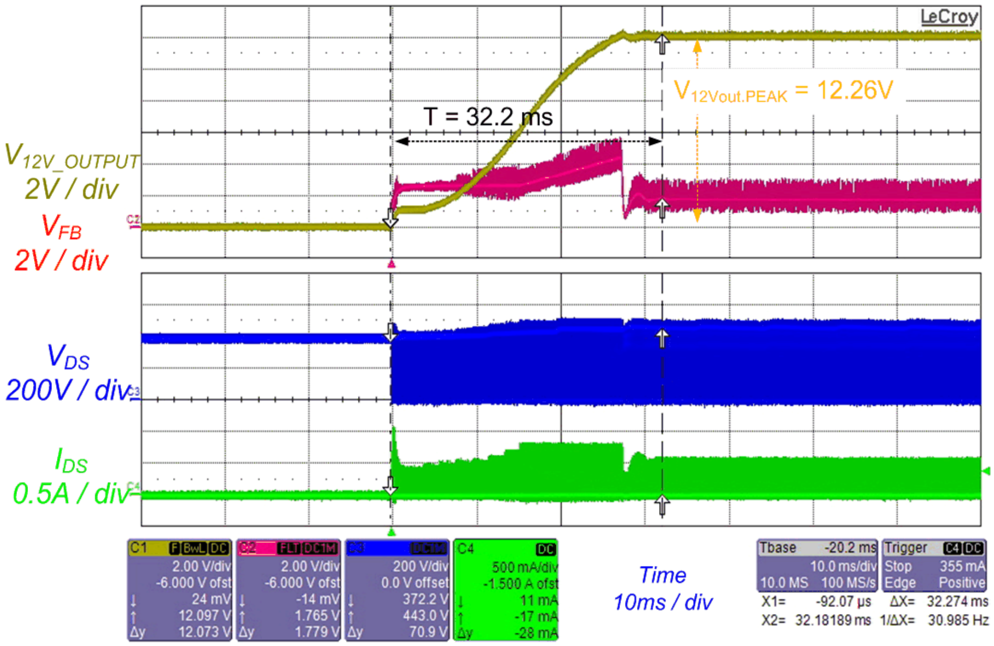



**Figure 18. Soft−Start Waveforms @ $V_{IN}$ = 265 Vac & Full Load**

*Soft−Start at $V_{IN}$ = 265 Vac, No Load*

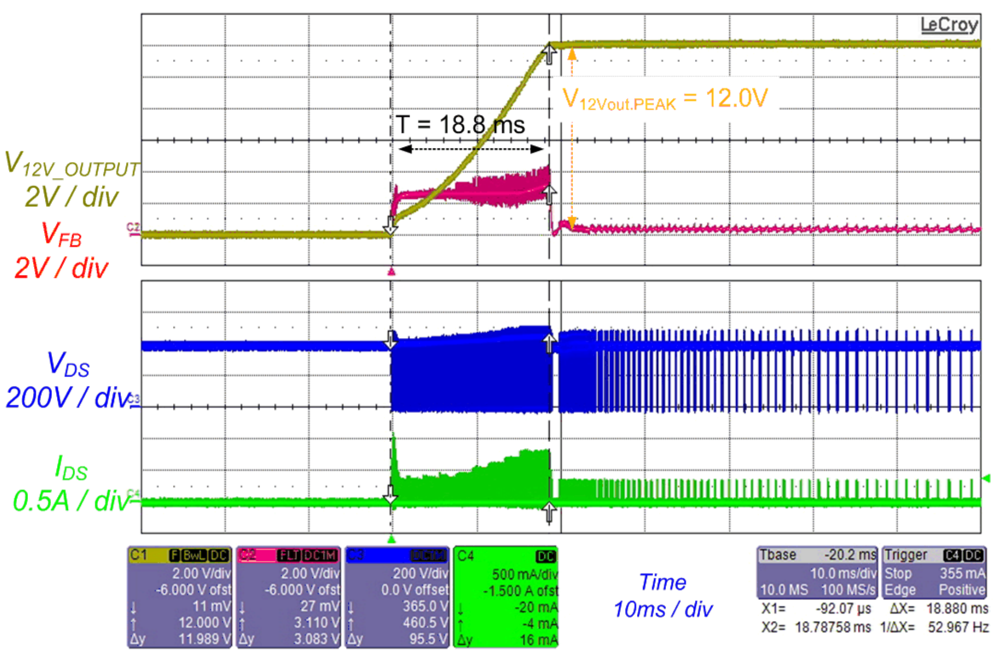



**Figure 19. Soft−Start Waveforms @ $V_{IN}$ = 265 Vac & No Load**

### Start−up

**Table 14.**

| Test Condition | 12 $V_{OUT}$ |
|---|---|
| Load | 0.83 A |
| Output Power | 9.96 W |

*Start−up at $V_{IN}$ = 85 Vac, Full Load*

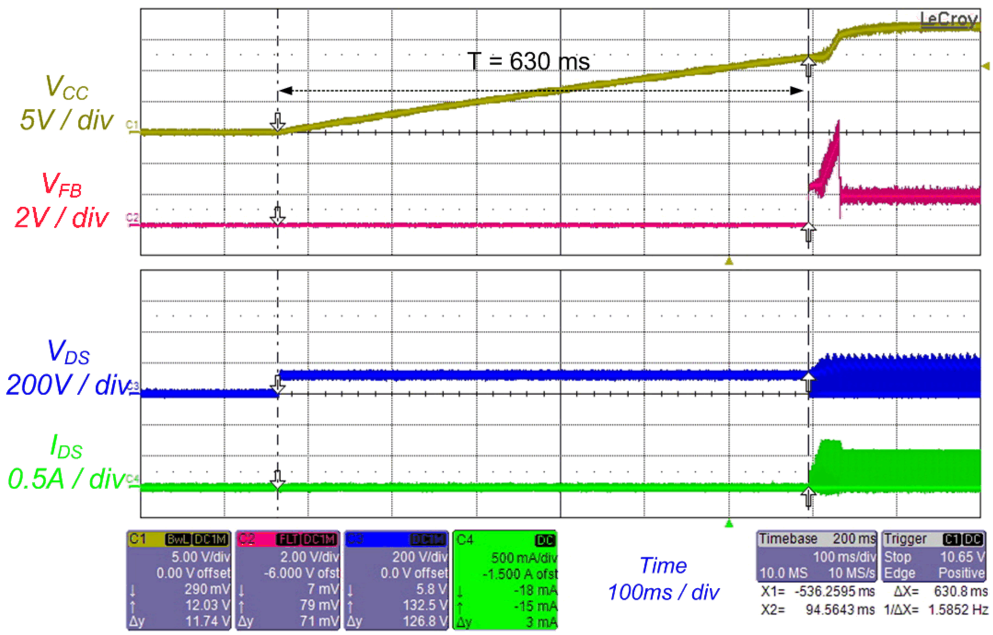



**Figure 20. Start−up Waveforms @ $V_{IN}$ = 85 Vac & Full Load**

*Start−up at $V_{IN}$ = 85 Vac, No Load*

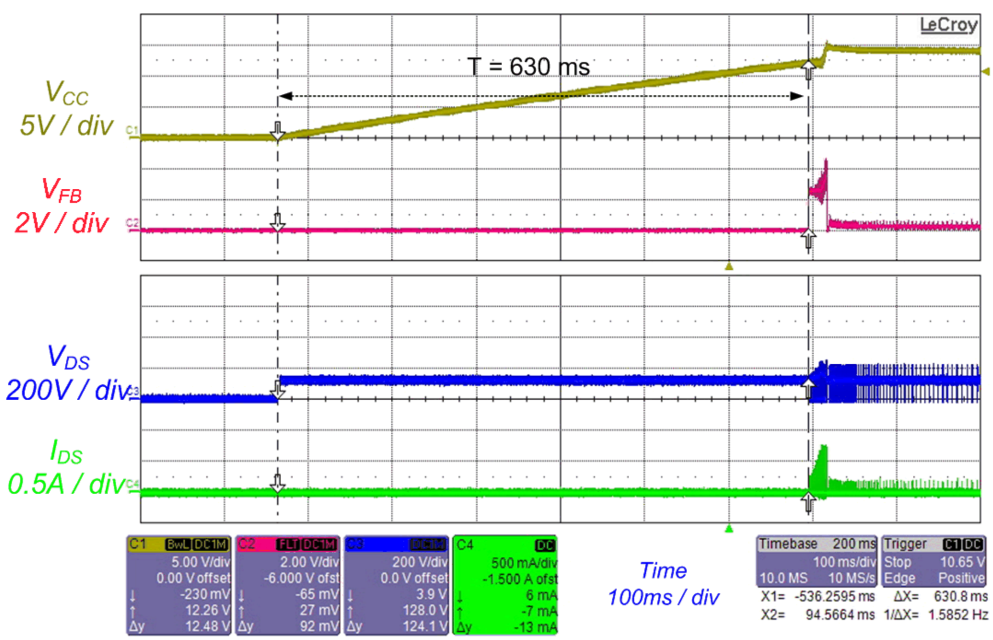



**Figure 21. Start−up Waveforms @ $V_{IN}$ = 85 Vac & No Load**

*Start−up at $V_{IN}$ = 265 Vac, Full Load*

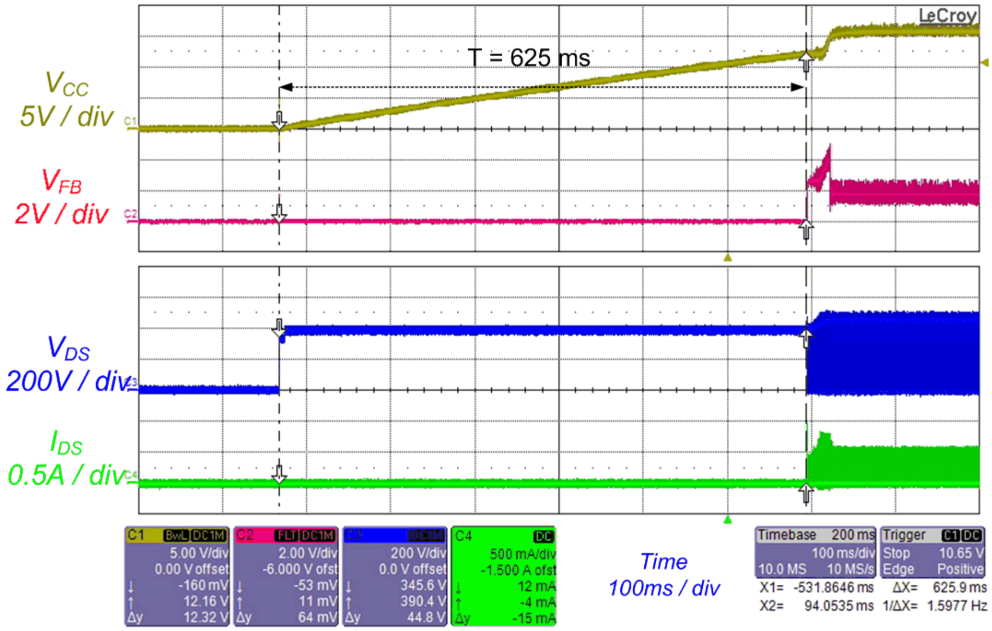



**Figure 22. Start−up Waveforms @ $V_{IN}$ = 265 Vac & Full Load**

*Start−up at $V_{IN}$ = 265 Vac, No Load*

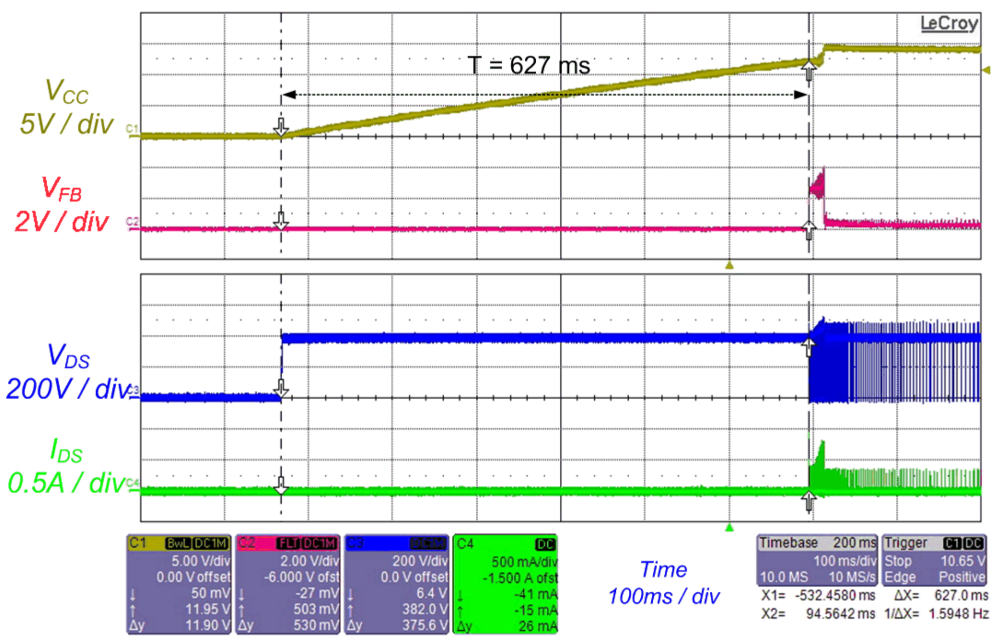



**Figure 23. Start−up Waveforms @ $V_{IN}$ = 265 Vac & No Load**

### Normal Operation

**Table 15.**

| Test Condition | 12 $V_{OUT}$ |
|---|---|
| Load | 0.83 A |
| Output Power | 9.96 W |

*Normal Operation at $V_{IN}$ = 85 Vac*

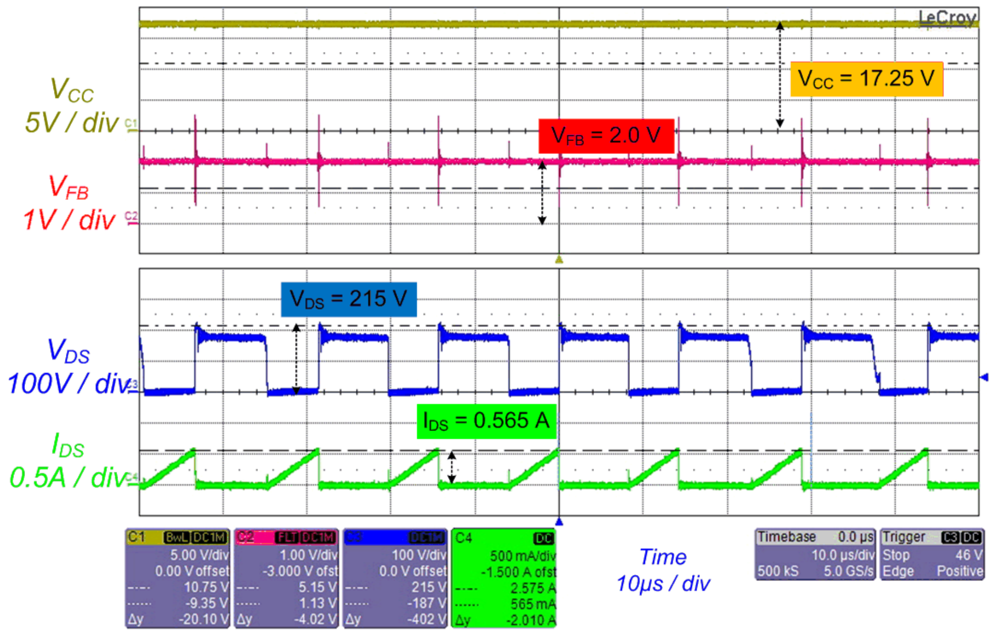



**Figure 24. Normal Operation @ $V_{IN}$ = 85 Vac & Full Load**

*Normal Operation at $V_{IN}$ = 265 Vac*

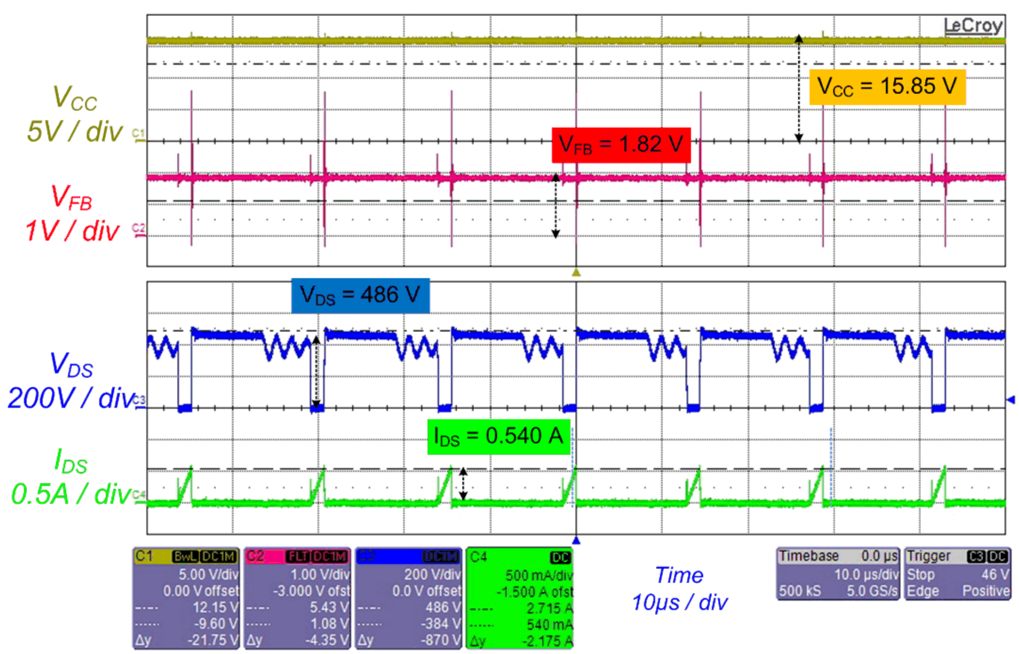



**Figure 25. Normal Operation @ $V_{IN}$ = 85 Vac & No Load**

## Burst Operation

**Table 16.**

| Test Condition | 12 $V_{OUT}$ |
|---|---|
| Load | No Load |
| Output Power | 0 W |

*Burst Operation at $V_{IN}$ = 85 Vac*

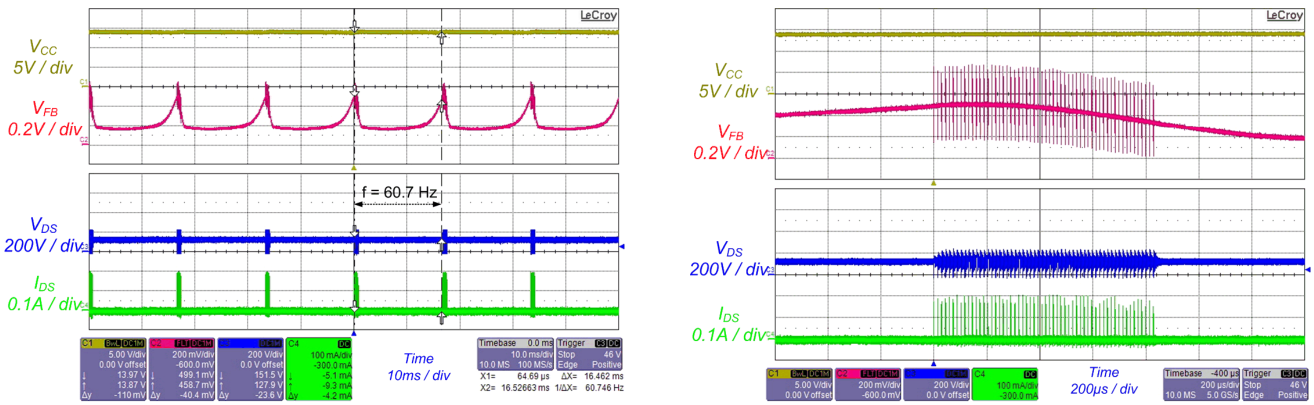



**Figure 26. Burst Operation @ $V_{IN}$ = 85 Vac, No Load**

*Burst Operation at $V_{IN}$ = 85 Vac*

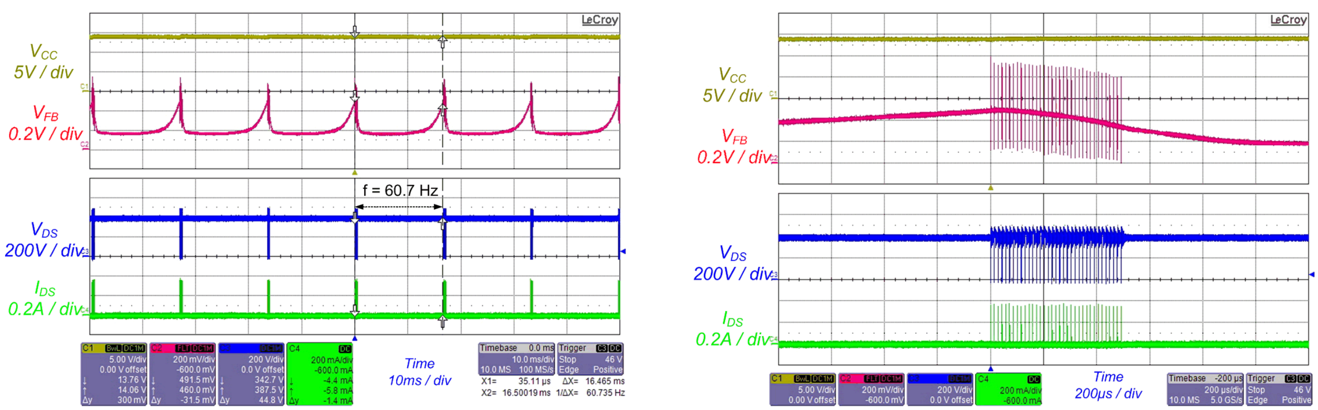



**Figure 27. Burst Operation @ $V_{IN}$ = 265 Vac, No Load**

## Output Voltage Ripple

**Table 17.**

| Test Condition | 12 $V_{OUT}$ |
|---|---|
| 100% load | 0.83 A |
| 75% load | 0.62 A |
| 50% load | 0.41 A |
| 25% load | 0.20 A |
| 0% load | 0 A |

*12 V Output Voltage Ripple at $V_{IN}$ = 85 Vac*

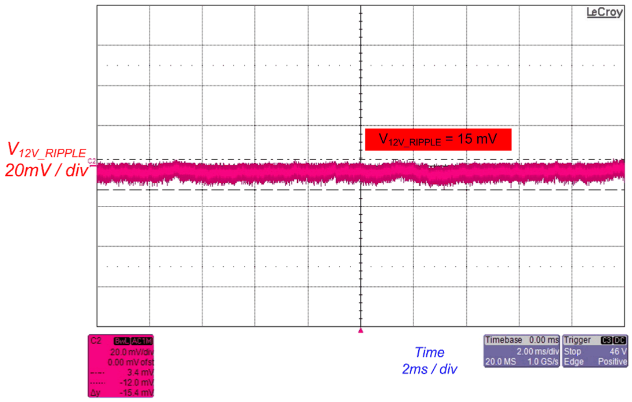



Figure 28. 12 V Ripple @ $V_{IN}$ = 85 Vac, 100% Load

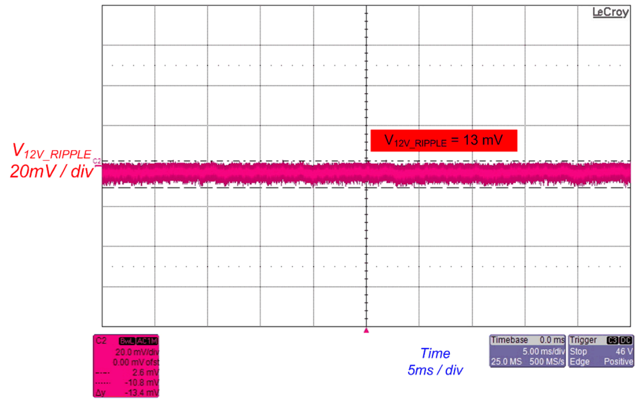



Figure 29. 12 V Ripple @ $V_{IN}$ = 85 Vac, 75% Load

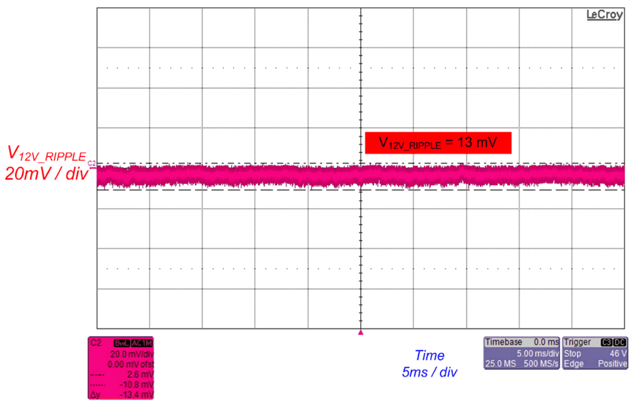



Figure 30. 12 V Ripple @ $V_{IN}$ = 85 Vac, 50% Load

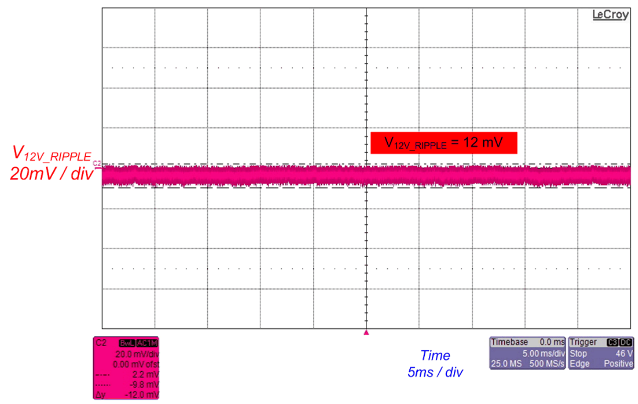



Figure 31. 12 V Ripple @ $V_{IN}$ = 85 Vac, 25% Load

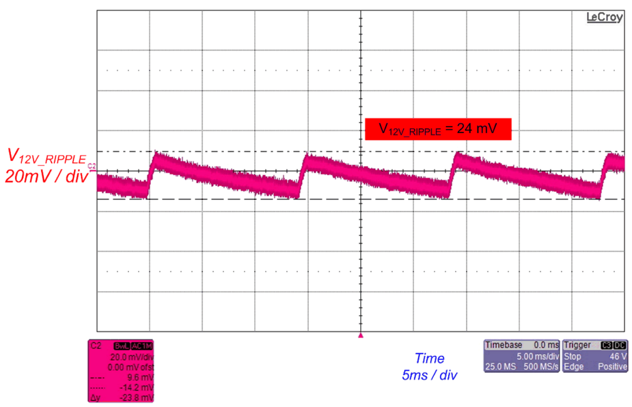



Figure 32. 12 V Ripple @ $V_{IN}$ = 85 Vac, 0% Load

*12 V Output Voltage Ripple at $V_{IN}$ = 115 Vac*

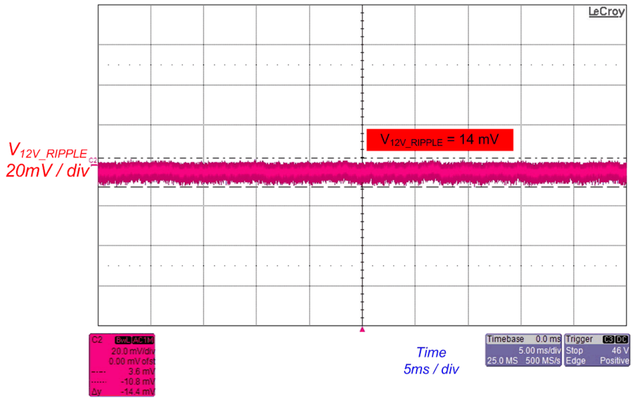



**Figure 33. 12 V Ripple @ $V_{IN}$ = 115 Vac, 100% Load**

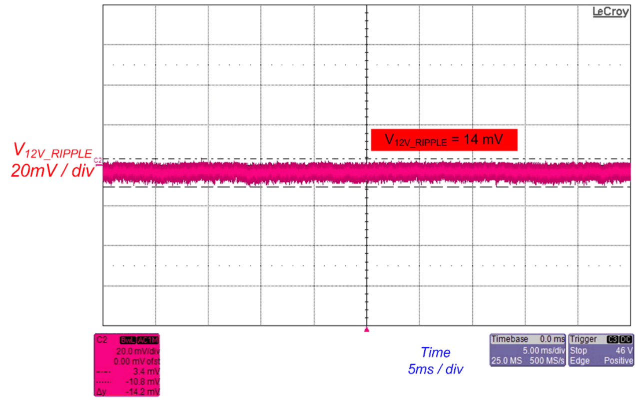



**Figure 34. 12 V Ripple @ $V_{IN}$ = 115 Vac, 75% Load**

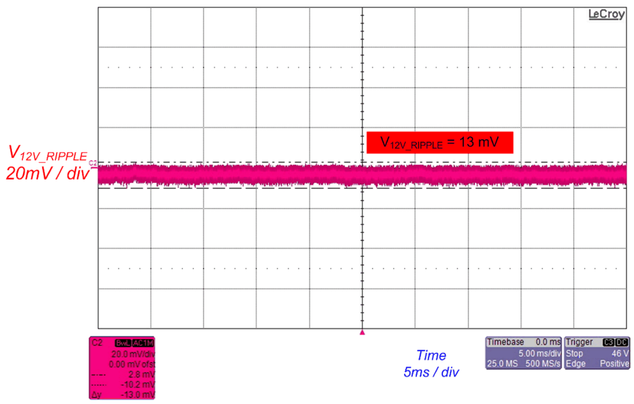



**Figure 35. 12 V Ripple @ $V_{IN}$ = 115 Vac, 50% Load**

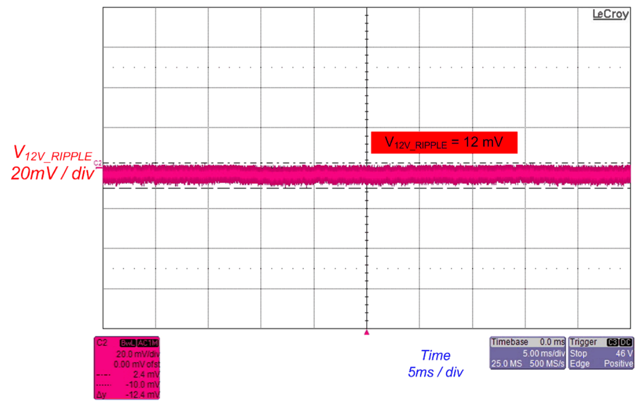



**Figure 36. 12 V Ripple @ $V_{IN}$ = 115 Vac, 25% Load**

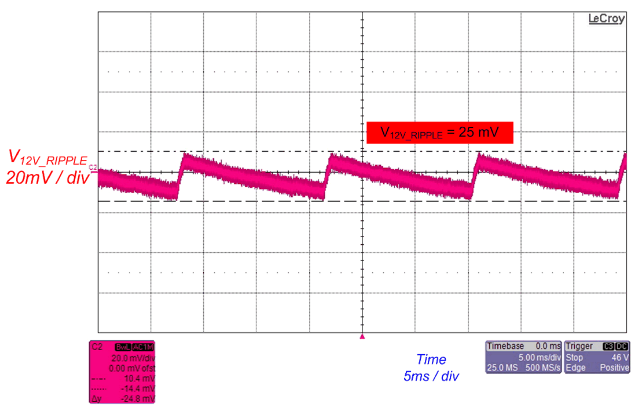



**Figure 37. 12 V Ripple @ $V_{IN}$ = 115 Vac, 0% Load**

*12 V Output Voltage Ripple at $V_{IN}$ = 230 Vac*

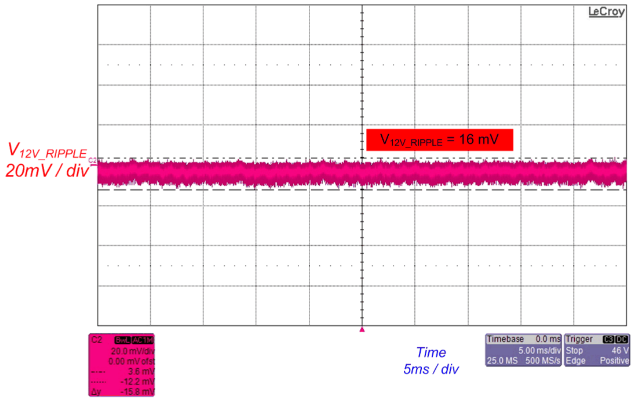



**Figure 38. 12 V Ripple @ $V_{IN}$ = 230 Vac, 100% Load**

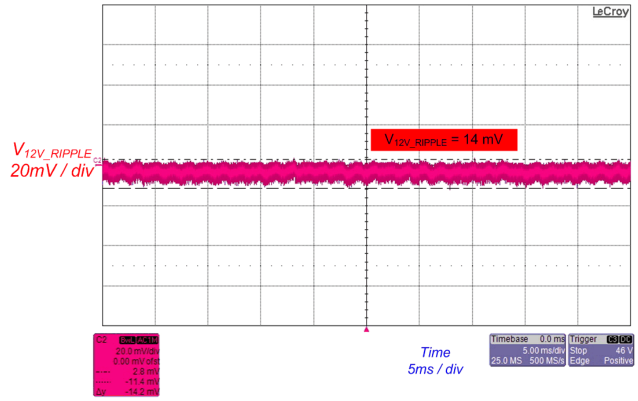



**Figure 39. 12 V Ripple @ $V_{IN}$ = 230 Vac, 75% Load**

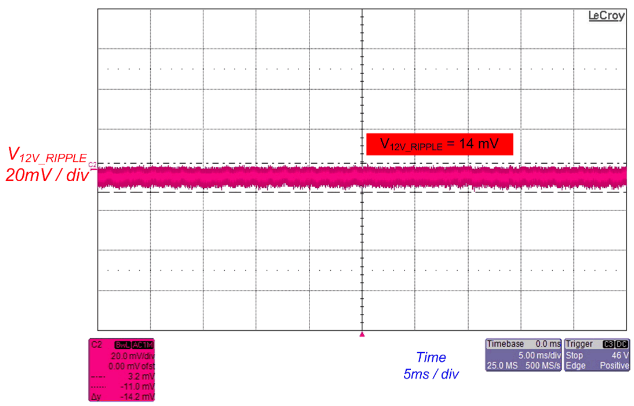



**Figure 40. 12 V Ripple @ $V_{IN}$ = 230 Vac, 50% Load**

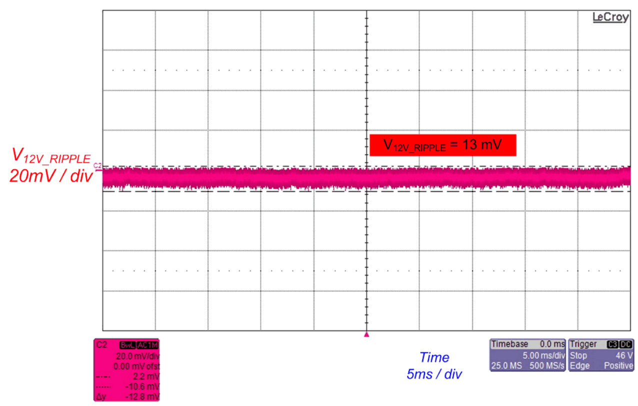



**Figure 41. 12 V Ripple @ $V_{IN}$ = 230 Vac, 25% Load**

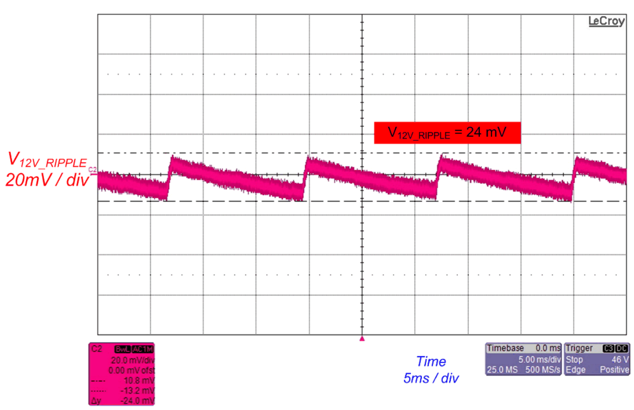



**Figure 42. 12 V Ripple @ $V_{IN}$ = 230 Vac, 0% Load**

*12 V Output Voltage Ripple at $V_{IN}$ = 265 Vac*

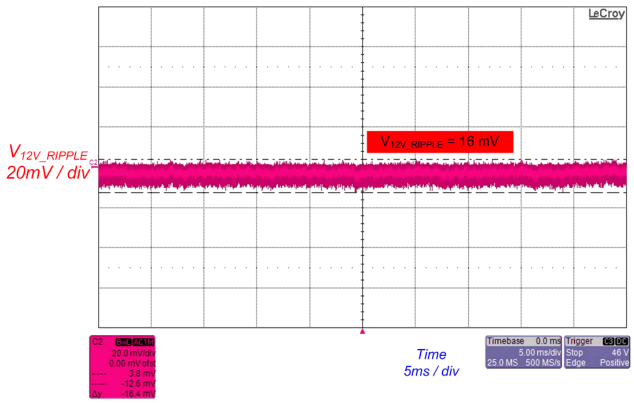



**Figure 43. 12 V Ripple @ $V_{IN}$ = 265 Vac, 100% Load**

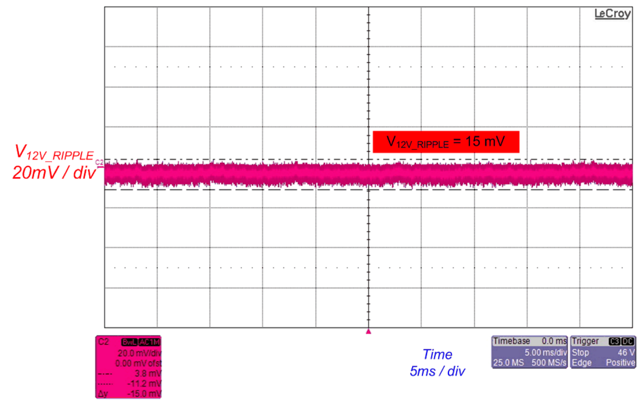



**Figure 44. 12 V Ripple @ $V_{IN}$ = 265 Vac, 75% Load**

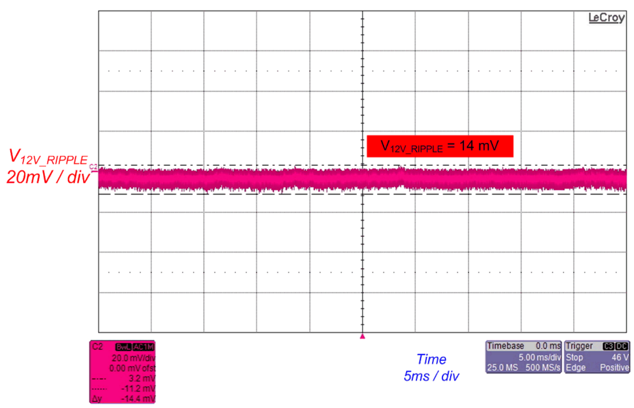



**Figure 45. 12 V Ripple @ $V_{IN}$ = 265 Vac, 50% Load**

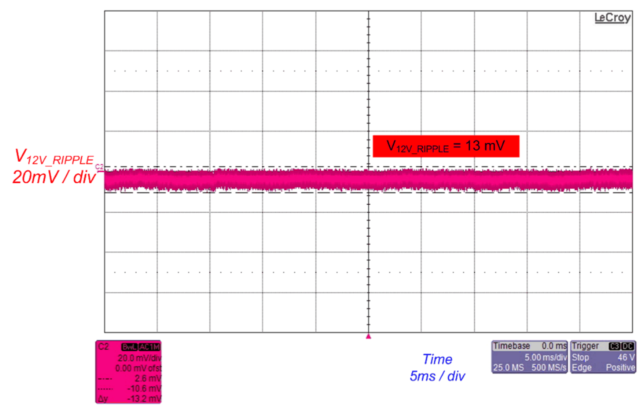



**Figure 46. 12 V Ripple @ $V_{IN}$ = 265 Vac, 25% Load**

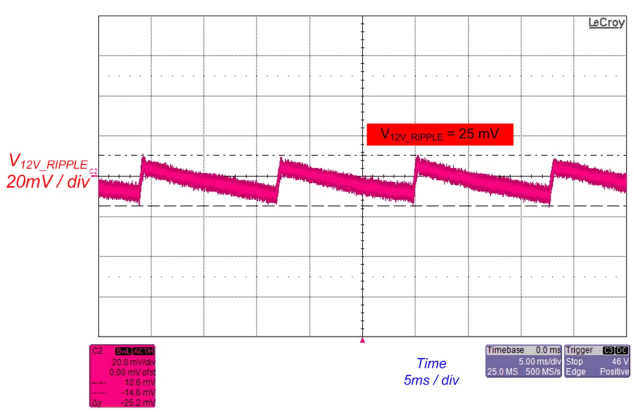
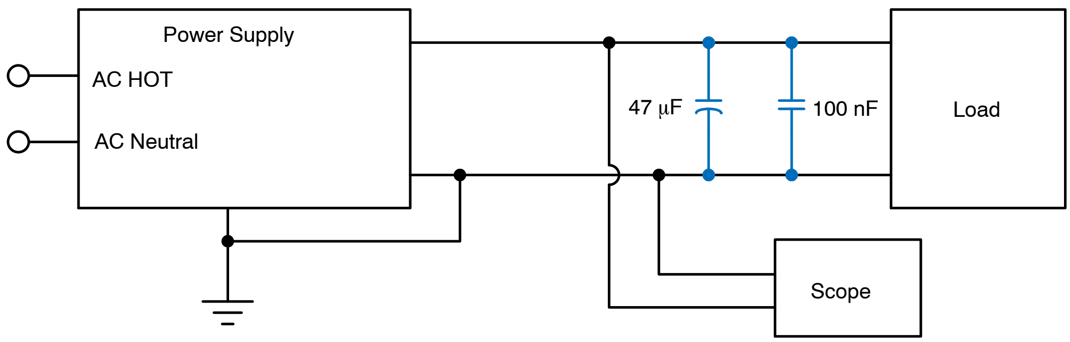



**Figure 47. 12 V Ripple @ $V_{IN}$ = 265 Vac, 0% Load**

- Measure with additional capacitors (47 μF electrolytic and 100 nF mono) on 5 $V_{OUT}$ PCB
- Oscilloscope bandwidth: 20 MHz

**Table 18. OUTPUT RIPPLE VOLTAGE**

| Load | 85 Vac | 110 Vac | 230 Vac | 265 Vac | Unit |
|---|---|---|---|---|---|
| | 12 V Ripple | 12 V Ripple | 12 V Ripple | 12 V Ripple | |
| 100% | 15 | 14 | 16 | 16 | mV |
| 75% | 13 | 14 | 14 | 15 | |
| 50% | 13 | 13 | 14 | 14 | |
| 25% | 12 | 12 | 13 | 13 | |
| 0% | 24 | 25 | 24 | 25 | |




NOTES:
1. Load the output with its maximum load current
2. Connect the probes as shown
3. Repeat the measurement with standby load on the output

**Figure 48.**

**Output Voltage Regulation**

**Table 19. OUTPUT VOLTAGE REGULATION**

| VIN | VOUT | Load | | | | |
|---|---|---|---|---|---|---|
| | | 100% | 75% | 50% | 25% | No Load |
| 265 Vac | 12 $V_{OUT}$ | −0.08% | 0.00% | 0.08% | 0.17% | 0.17% |
| 230 Vac | | −0.08% | 0.00% | 0.08% | 0.17% | 0.17% |
| 115 Vac | | 0.00% | 0.00% | 0.08% | 0.17% | 0.17% |
| 85 Vac | | 0.00% | 0.00% | 0.08% | 0.17% | 0.17% |

**Short Test**

*12 V Output Overload at $V_{IN}$ = 85 Vac*

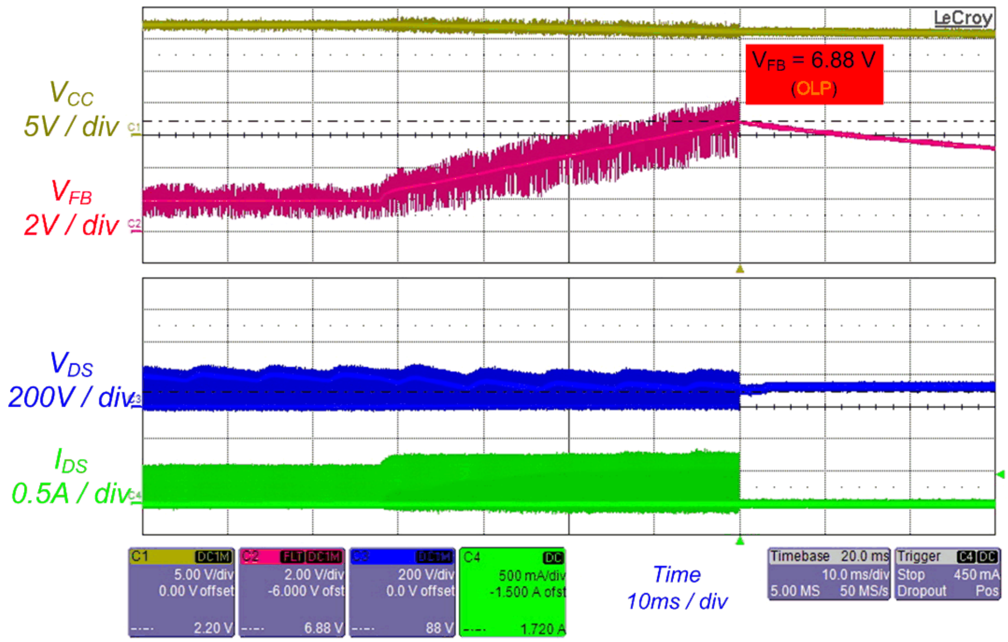



**Figure 49. 12 V Output Overload @ $V_{IN}$ = 85 Vac, Full Load**

*12 V Output Voltage Short at $V_{IN}$ = 85 Vac*

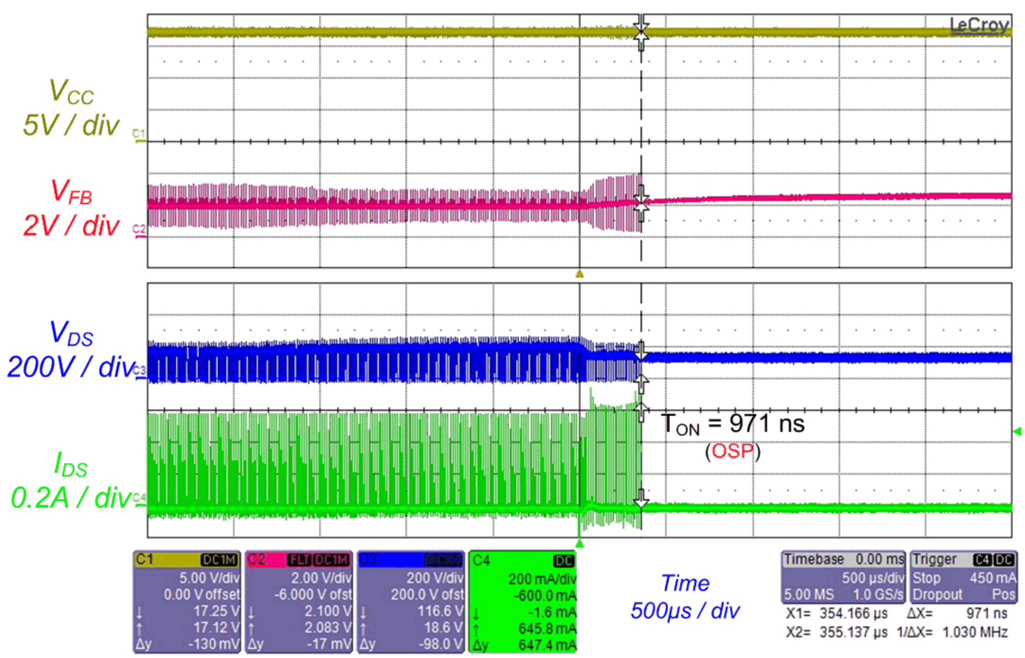



**Figure 50. 12 V Output Voltage Short @ $V_{IN}$ = 85 Vac, Full Load**

*12 V Output Voltage Short at $V_{IN}$ = 265 Vac*

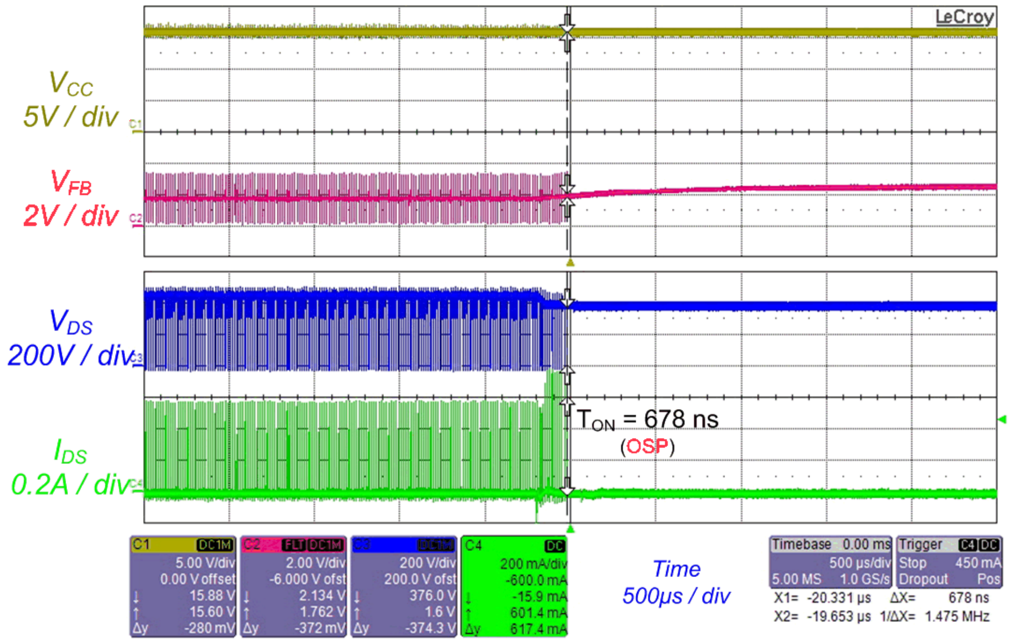



**Figure 51. 12 V Output Voltage Short @ $V_{IN}$ = 265 Vac, Full Load**

*12 V Output Diode Short at $V_{IN}$ = 85 Vac*

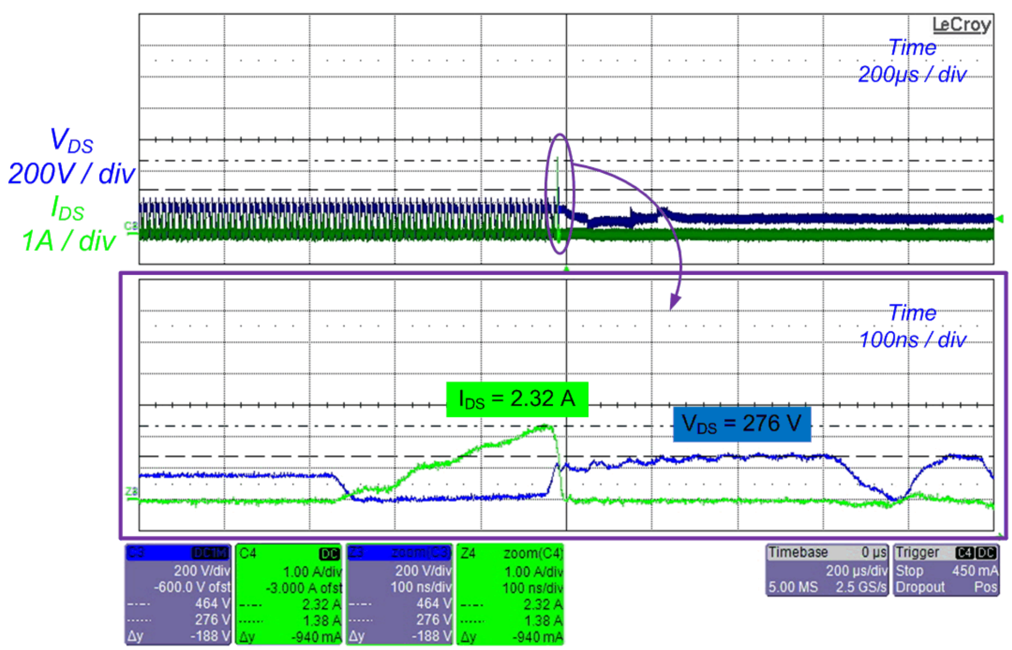



**Figure 52. 12 V Output Diode Short @ $V_{IN}$ = 85 Vac, Full Load**

*12 V Output Diode Short at $V_{IN}$ = 265 Vac*

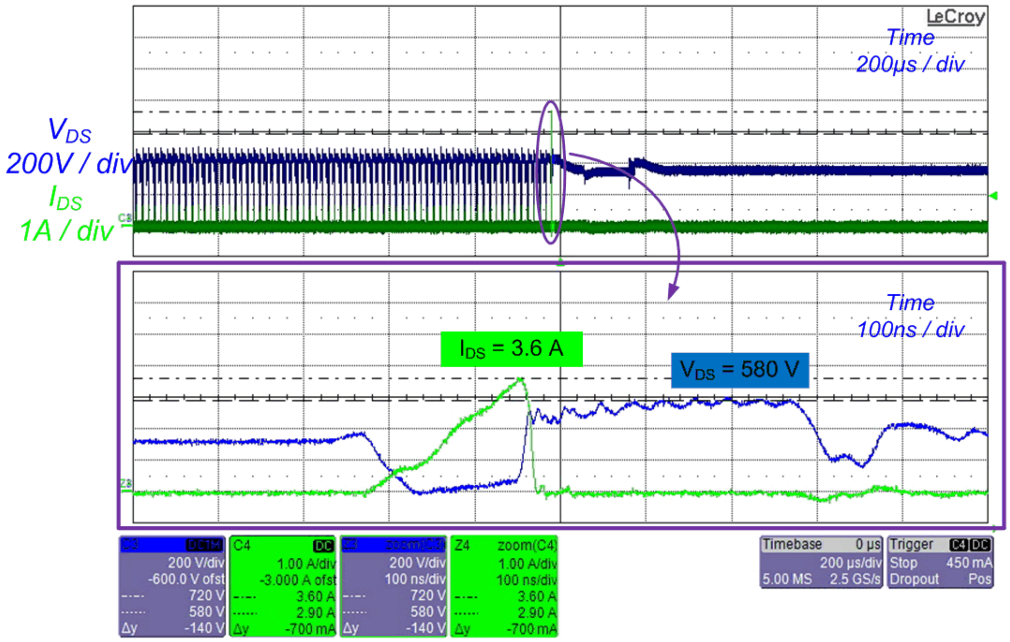



**Figure 53. 12 V Output Diode Short @ $V_{IN}$ = 265 Vac, Full Load**

*2nd Opto−coupler Short at $V_{IN}$ = 85 Vac*

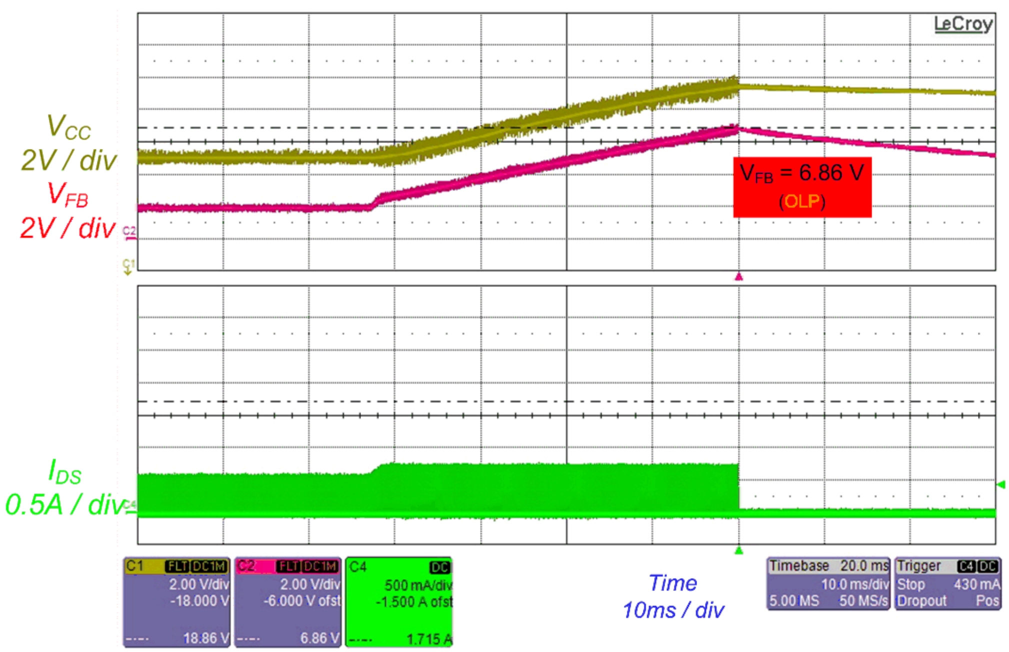



**Figure 54. 2nd Opto Short @ $V_{IN}$ = 85 Vac, Full Load**

*$2^{nd}$ Opto−coupler Short at $V_{IN}$ = 265 Vac*

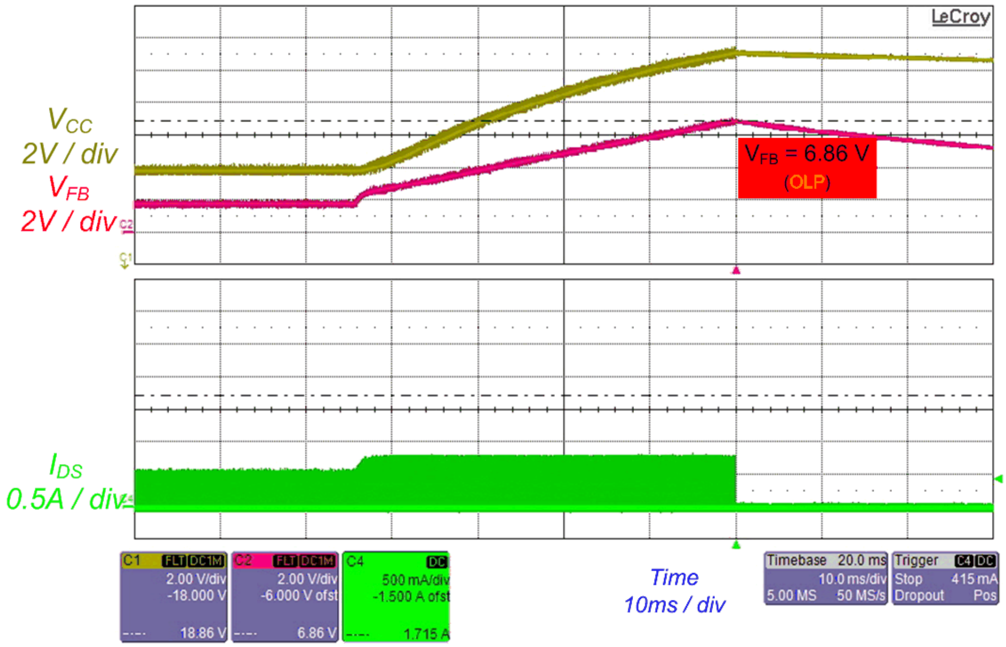



**Figure 55. 2nd Opto Short @ $V_{IN}$ = 265 Vac, Full Load**

**LOVP (Line Over Voltage Protection) Test**

*LOVP at $V_{IN}$ = 265 Vac → $V_{IN}$ = 300 Vac*

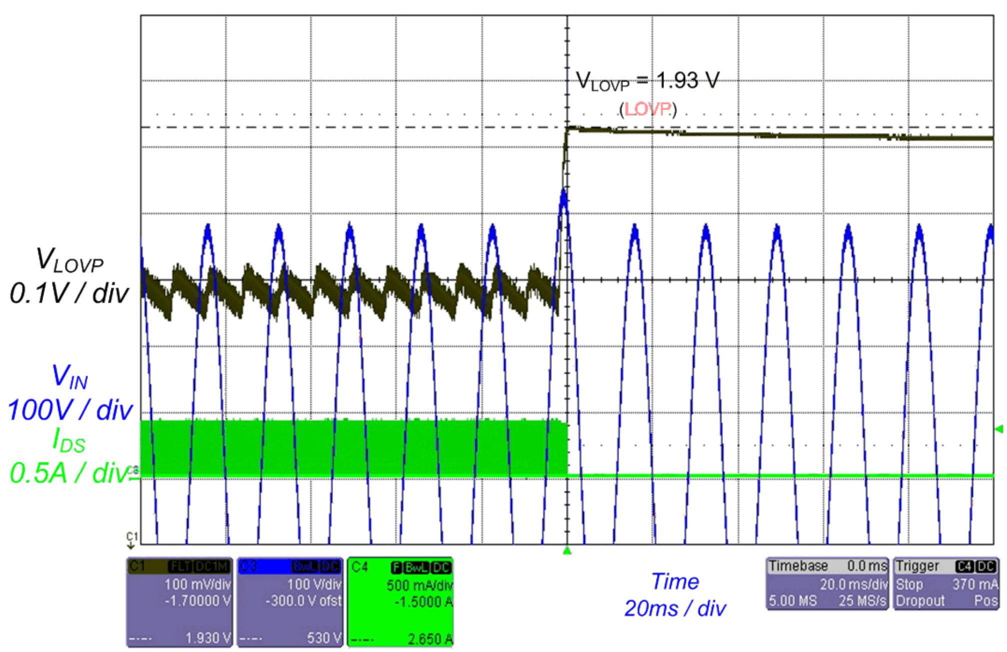



**Figure 56. LOVP @ $V_{IN}$ = 265 Vac → $V_{IN}$ = 300 Vac**

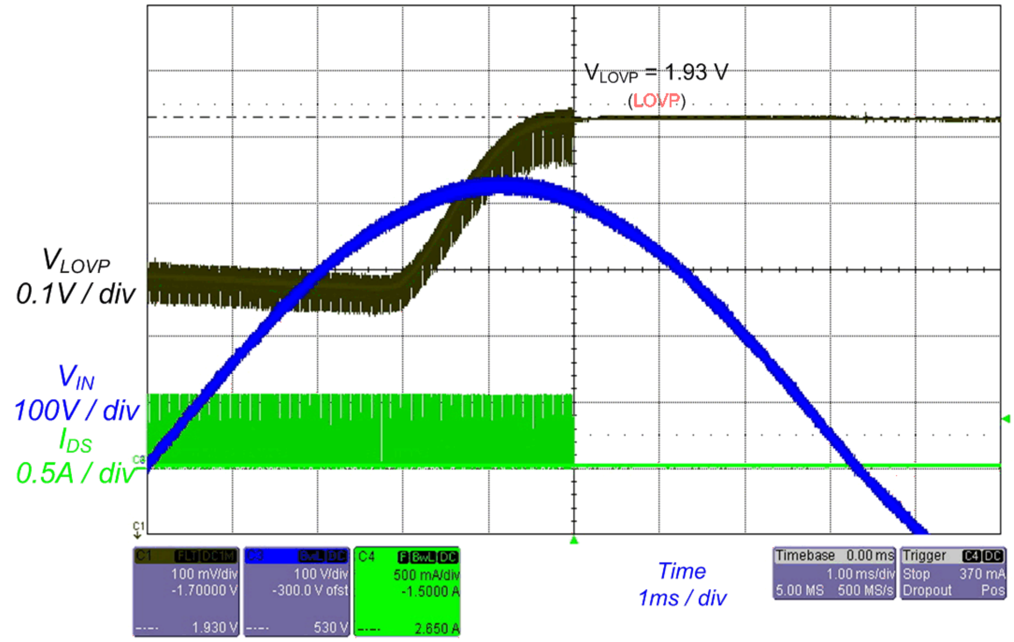



Figure 57. LOVP @ $V_{IN}$ = 265 Vac → $V_{IN}$ = 300 Vac, Enlarge

**Voltage Stress of Secondary Diode and Drain**

*Voltage Stress of Drain at $V_{IN}$ = 265 Vac, Full Load*

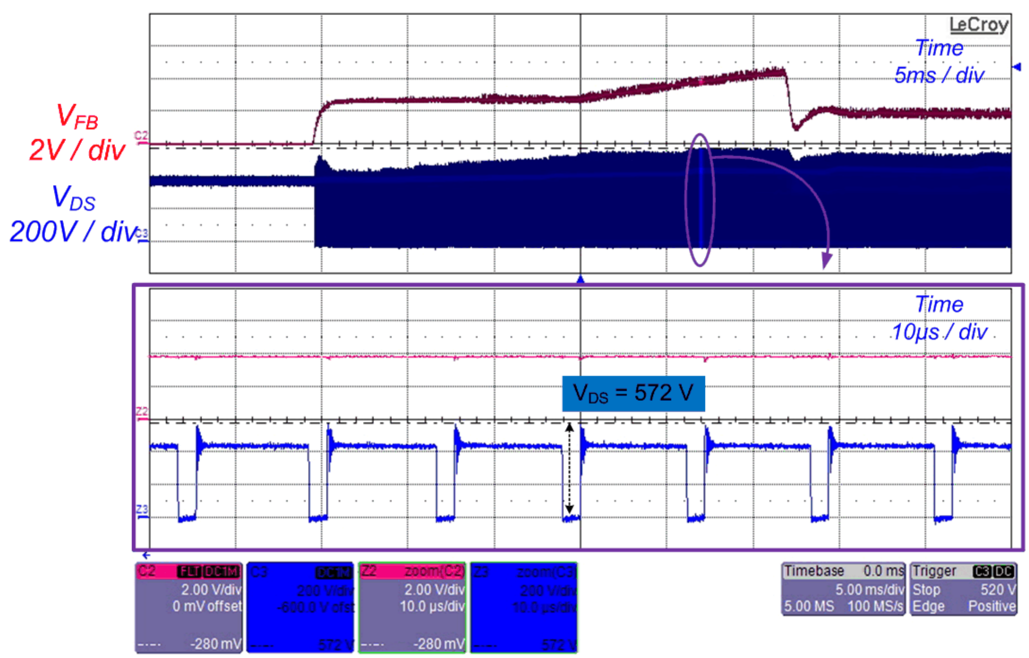



Figure 58. Drain Voltage @ $V_{IN}$ = 265 Vac, Full Load

*Voltage Stress of 2nd Diode at $V_{IN}$ = 265 Vac , Full Load*

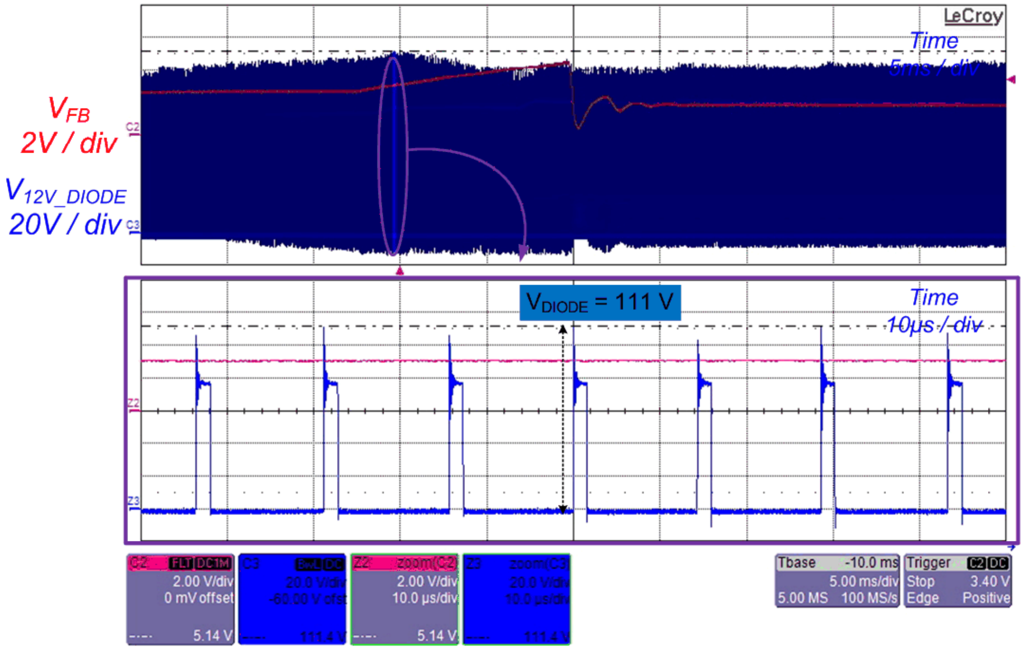



**Figure 59. Diode Voltage @ $V_{IN}$ = 265 Vac, Full Load**

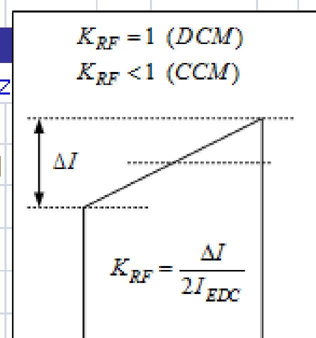
## TRANSFORMER DESIGN USING DESIGN TOOL

| 1. Define the system specifications | | | | | | | |
|---|---|---|---|---|---|---|---|
| Minimum Line voltage ($V_{line}^{min}$) | 85 | V,rms | | | | | |
| Maximum Line voltage ($V_{line}^{max}$) | 280 | V,rms | | | | | |
| Line frequency ($f_L$) | 60 | Hz | | | | | |
| | $V_{o(n)}$ | | $I_{o(n)}$ | | $P_{o(n)}$ | | $K_{L(n)}$ |
| 1st output for feedback | 12 | V | 0.80 | A | 10 | W | 100 |
| 2nd output | 0 | V | 0.00 | A | 0 | W | 0 |
| 3rd output | 0 | V | 0.00 | A | 0 | W | 0 |
| 4th output | 0 | V | 0.00 | A | 0 | W | 0 |
| 5th output | 0 | V | 0.00 | A | 0 | W | 0 |
| 6th output | | V | | A | 0 | W | 0 |
| Maximum output power ($P_o$) = | 9.6 | W | | | | | |
| Estimated efficiency ($E_{ff}$) | 80 | % | | | | | |
| Maximum input power ($P_{in}$) = | 12.0 | W | | | | | |

| 2. Determine DC link capacitor and DC link voltage range | | |
|---|---|---|
| DC link capacitor ($C_{DC}$) | 22 | uF |
| Minimum DC link voltage ($V_{DC}^{min}$) = | 85 | V |
| Maximum DC link voltage ($V_{DC}^{max}$)= | 396 | V |

| 3. Determine Maximum duty ratio (Dmax) | | |
|---|---|---|
| Maximum duty ratio ($D_{max}$) | 0.45 | |
| Max nominal MOSFET voltage ($V_{ds}^{nom}$) = | 465 | V |
| Output voltage reflected to primary ($V_{RO}$)= | 69 | V |

| 4. Determine transformer primary inductance (Lm) | | |
|---|---|---|
| Switching frequency of FPS ($f_s$) | 66 | kHz |
| Ripple factor ($K_{RF}$) | 0.91 | |
| Primary side inductance ($L_m$) = | 1008 | uH |
| Maximum peak drain current ($I_{ds}^{peak}$) = | 0.60 | A |
| RMS drain current ($I_{ds}^{rms}$) = | 0.24 | A |
| Maximum DC link voltage in CCM ($V_{DC}^{CCM}$) | 94 | V |




| 5. Choose the proper FPS considering the input power and current limit | | | | | |
|---|---|---|---|---|---|
| Typical current limit of FPS ($I_{over}$) | 0.80 | A | | | |
| Minimum $I_{over}$ considering tolerance of 12% | 0.70 | A | > | 0.60 | A |
| | ->O.K. | | | | |

Figure 60.

| 6. Determine the proper core and the minimum primary turns | | |
|---|---|---|
| Saturation flux density ($B_{sat}$) | 0.32 | T |
| Cross sectional area of core ($A_e$) | 40.1 | $mm^2$ |
| Minimum primary turns ($N_p^{min}$)= | 62.9 | T |

| 7. Determine the number of turns for each output | $V_{o(n)}$ | | $V_{F(n)}$ | | | | # of turns |
|---|---|---|---|---|---|---|---|
| Vcc (Use Vcc start voltage) | 14 | V | 0.5 | V | 13.9 | => | 14 |
| 1st output for feedback | 12 | V | 0.5 | V | 12 | => | 12 |
| 2nd output | 0 | V | 0 | V | 0.0 | => | 0 |
| 3rd output | 0 | V | 0 | V | 0.0 | => | 0 |
| 4th output | 0 | V | 0 | V | 0.0 | => | 0 |
| 5th output | 0 | V | 0 | V | 0.0 | => | 0 |
| 6th output | 0 | V | 0 | V | 0.0 | => | 0 |
| VF : Forward voltage drop of rectifier diode | | | Primary turns ($N_p$)= | | | | 67 |
| | | | --->enough turns | | | | |
| Ungapped AL value (AL) | 840 | $nH/T^2$ | | | n | = | 5.545 |
| Gap length (G) ; center pole gap = | 0.1612 | mm | | | | | |

| 8. Determine the wire diameter for each winding | Diameter | | Parallel | | $I_{D(n)}^{rms}$ | | ($A/mm^2$) |
|---|---|---|---|---|---|---|---|
| Primary winding | 0.25 | mm | 1 | T | 0.2 | A | 4.9 |
| Vcc winding | 0.2 | mm | 1 | T | 0.7 | A | 22.3 |
| 1st output winding (12V) | 0.4 | mm | 2 | T | 1.5 | A | 5.8 |
| 2nd output winding (0V) | 0 | mm | 0 | T | ##### | A | ##### |
| 3rd output winding (0V) | 0 | mm | 0 | T | ##### | A | ##### |
| 4th output winding (0V) | 0 | mm | 0 | T | ##### | A | ##### |
| 5th output winding (0V) | 0 | mm | 0 | T | ##### | A | ##### |
| 6th output winding (V) | | mm | | T | ##### | A | ##### |
| Copper area ($A_c$) = | 6.72 | $mm^2$ | | | | | |
| Fill factor ($K_F$) | 0.15 | | | | | | |
| Required window area ($A_{wr}$) | 44.79 | $mm^2$ | | | | | |

| 9. Choose the rectifier diode in the secondary side | $V_{D(n)}$ | | $I_{D(n)}^{rms}$ | |
|---|---|---|---|---|
| Vcc diode | 97 | V | 0.10 | A |
| Rectifier diode for 1st output (12V) | 83 | V | 1.46 | A |
| Rectifier diode for 2nd output (0V) | 0 | V | ##### | A |
| Rectifier diode for 3rd output (0V) | 0 | V | ##### | A |
| Rectifier diode for 4th output (0V) | 0 | V | ##### | A |
| Rectifier diode for 5th output (0V) | 0 | V | ##### | A |
| Rectifier diode for 6th output (V) | 0 | V | ##### | A |

Figure 61.

## ADDITIONAL INFORMATION

**TECHNICAL PUBLICATIONS**:
**Technical Library:** www.onsemi.com/design/resources/technical−documentation
**onsemi Website:** www.onsemi.com

**ONLINE SUPPORT:** www.onsemi.com/support
**For additional information, please contact your local Sales Representative at**
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