# Contents

# Chapter 1. Summary

## 1.1 General Description

Based on Primary Side Regulation (PSR) Flyback topology, the 10W Charger EV1 Evaluation board is designed as an MP-form-factor, cost-effective, optimal efficiency, charger reference design to facilitate further customization by users. AP3983R PSR Switcher, co-packaged a 700V N-MOSFE and a PSR control die, along with APR3415B Synchronous Rectification (SR) Switcher, co-packaged a MOS die with an SR controller, enable high-efficiency and small size form-factor 10W charger designs. The overall efficiency of the evaluation board can meet DOE VI and CoC Tier 2 energy efficiency requirements.

| Parameter | Value |
|---|---|
| Input Voltage | 90 to 264VAC |
| Input standby power | 75mW |
| Main output Vo / Io | 5V – 2.0A |
| Efficiency | ~ 85% |
| Total Output Power | 10W |
| Protections | OCP, OVP, OLP,OTP |
| XYZ Dimension | 29 x 32 x 15 mm |
| ROHS Compliance | Yes |

## 1.2 Key Features

### 1.2.1 AP3983R

- 90 ~264$V_{AC}$ input range
- Primary side regulation without an Opto-coupler.
- Co-package PSR controller with 700V MOS die in SO-7 Package
- Multi-Mode PFM method operations, the switching frequency between 24Khz and 80Khz.
- With Valley-on detection for switching at Valley-on region to improve power converting efficiency & EMI performance.
- Burst mode operation and low start-up operating quiescent current to achieve 75mW low standby power.
- Three-mode operation to provide accurate constant voltage (CV) regulation & constant current (CC) performance.
- Soft start during startup process and built-in Jittering Frequency function to improve EMI emission.
- Internal Auto Recovery OCP, OVP, OLP, OTP Power Protection, cycle by cycle current limit, also with DC polarity protection
- Built–in Cable Compensation mode.
- Brown out Protection.

### 1.2.2 APR3415B

- Synchronous rectification of DCM Operation
- Co-package 50V 17mΩ Rdson MOS die with SR Controller in SO-8 package
- Eliminate resonant ring interference
- Fast detection of supply voltage
- Minimum supporting components

## 1.3 Applications

- Switching AC-DC Adaptors & Chargers
- Home Appliances system powers
- Auxiliary Vcc power supply for large power systems

## 1.4 Main Power Specifications (CV & CC Mode)

## 1.5 Evaluation Board Picture:

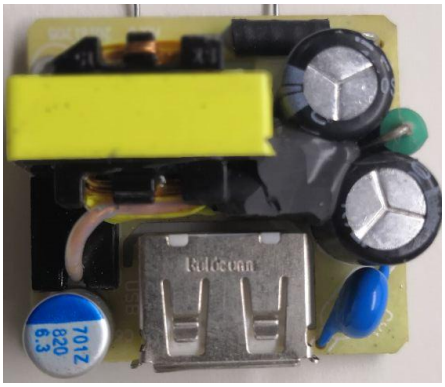


**Figure 1: Top View**

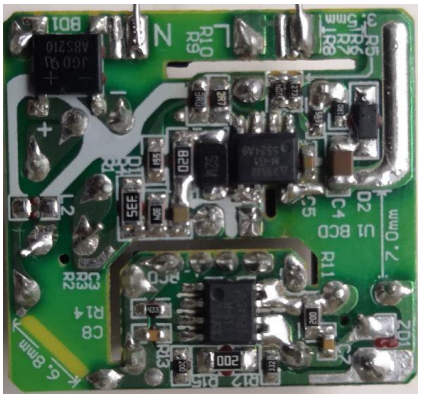


**Figure 2: Bottom View**

# Chapter 2. Power Supply Specification

## 2.1 Specification and Test Results

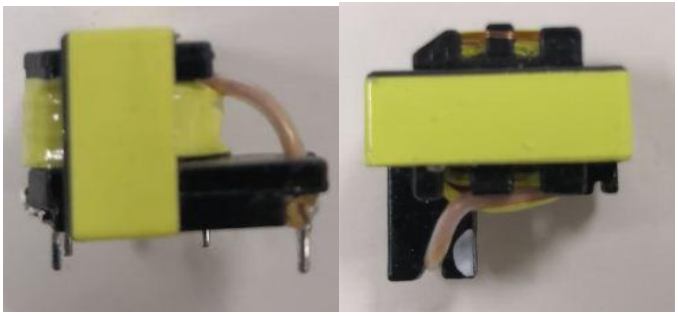
| Parameter | Test conditions | Min | Nom | Max | Eff /DOE Level VI | Eff /CoC V5 Tier2 | Test Summary |
|---|---|---|---|---|---|---|---|
| $V_{ACIN}$ Input Voltage | - | 90 $V_{RMS}$ | 115/230 | 264 $V_{RMS}$ | - | - | - |
| $F_{LINE}$ Frequency | - | 47Hz | 50/60 | 64Hz | - | - | - |
| $I_{IN}$ Input Current | - | - | - | 0.23 $A_{RMS}$ | - | - | Pass |
| No load Pin | At 230Vac/50Hz, @ 5V, Pin < 75mW | - | - | 75mW | - | - | Pass, 230Vac: **46mW** |
| 5VDC / 2A @115Vac/230Vac Average efficiency | Board end | - | 5V/2A | - | 78.7% | | Pass, 115Vac: 84.65% 230Vac: 84.39% |
| Thermal Performance | 5V-2A @ 90Vac | AP3983R IC =86.4C @85Vac | | AP3983R IC=88.0C @264Vac | | | Pass |
| EMI Scan Data | 5V-2A @115Vac L & N | | Under Limit line < -6db | | | | Pass |
| | 5V-2A @230Vac L & N | | Under Limit line < -6db | | | | Pass |
| | | | | | | | |

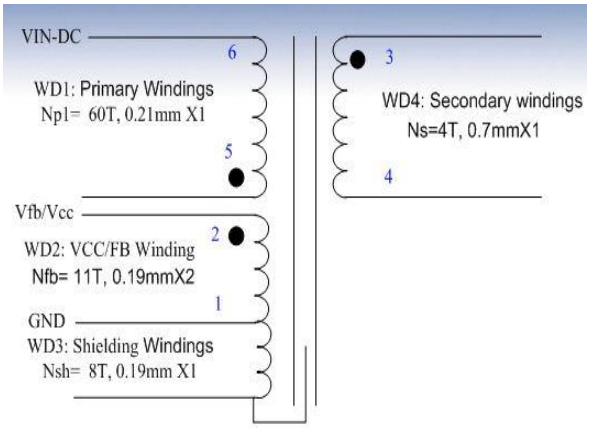
DoE VI Eff ≥ 0.0834xLn(Po)-0.0014xPo+0.609 <Vo<6V
DoE VI Eff ≥ 0.071xLn(Po)-0.0014xPo+0.67 Vo>6V

## 2.1 Transformer Specification

### AP3983R (90$V_{AC}$ ~ 265$V_{AC}$ one outputs 10W Transformer Spec.)

**1) Core and Bobbin: EE16C, 2+2+2 pin**






**2) Transformer Parameters**

1. Primary Inductance (Pin5-Pin6), all other windings are open Lp =1.05mH ±7% @1KHz

| EE16C （Ae = 19mm^2） | | | | | | |
|---|---|---|---|---|---|---|
| NO Winding | NAME | TERMINAL NO. | | WINDING | | |
| | | START | FINISH | WIRE | TURNS | Layers |
| 1 | Np1 | 5 | 6 | Φ 0.21mm | 60Ts | 3 |
| 2 | Na | 2 | 1 | Φ 0.19mm x 2 | 11 Ts | 1 |
| 3 | Shield | 1（GND） | NC | Φ 0.19mm x 1 | 8T | 1 |
| 4 | Ns | 3(+) | 4 | Φ 0.7W x 1 | 4 Ts | 1 |
| Primary Inductance | | Pin 5-6,all other windings open, measured at 1kHz, 0.4VRMS | | 1.05mH ± 7 % | | |
| Primary Leakage Inductance | | Pin 5-6, all other windings shorted, measured at 10kHz, 0.4VRMS | | 80 uH (Max.) | | |

# Chapter 3. Schematic

## 3.1 Evaluation Board Schematic

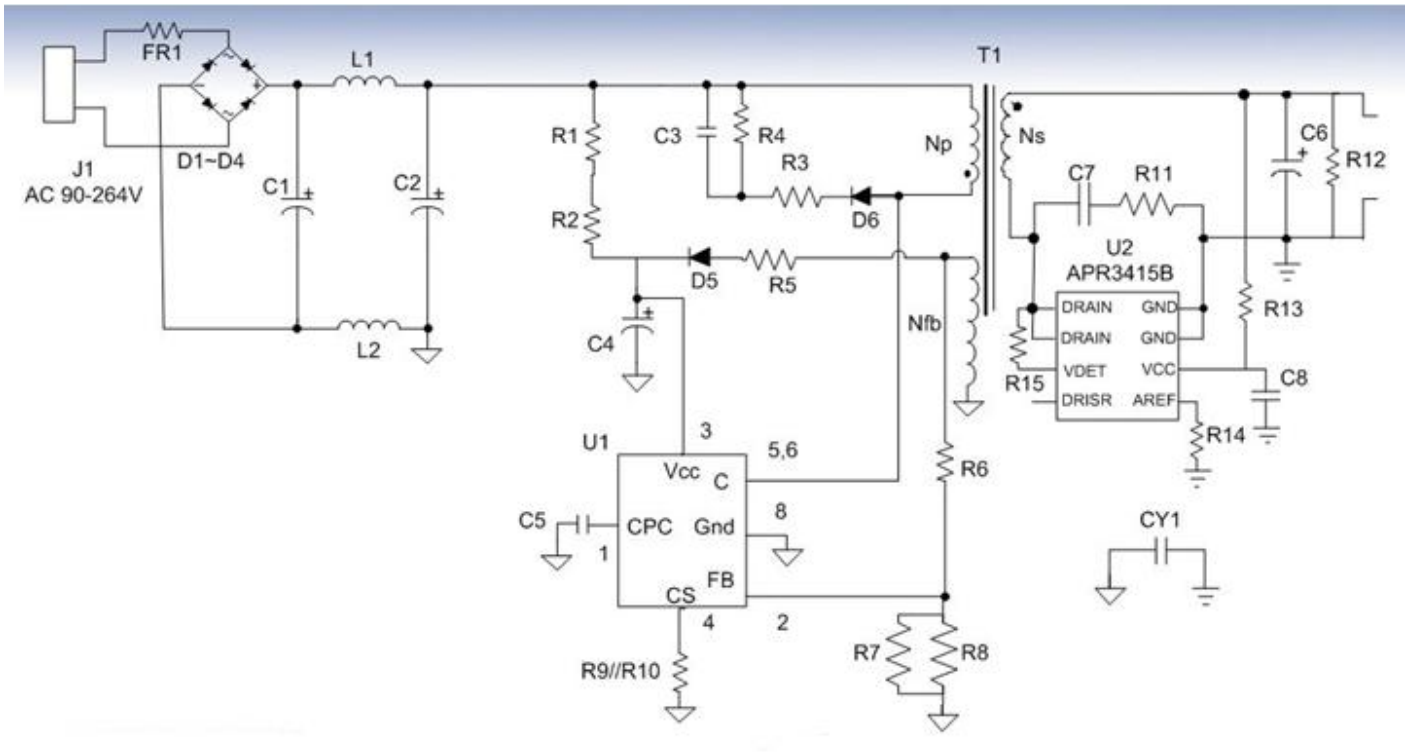



**Figure 3: Evaluation Board Schematic**

### 3.2 Bill of Material (BOM)

| Item | QTY per board | REF. DES. | Description | MFG or Supplier | MFG P/N or Supplier P/N Digi key # |
|---|---|---|---|---|---|
| 1 | 1 | C1 | 10uf /400V 8 x 12mm | Wurth Electro | |
| 2 | 1 | C2 | 10uf /400V 8 x 12mm | Wurth Electro | |
| 3 | 1 | C3 | 1nf /250V 0805 X7R | Holy Stone | |
| 4 | 1 | C4 | 4.7uF/50V 1206 X7R | Holy Stone | |
| 5 | 1 | C5 | 10nf / 50V, 0603 X7R | Holy Stone | |
| 6 | 1 | C6 | 820uf /6.3V E-cap | Wurth Electro | |
| 7 | 1 | C7 | 1nf / 50V, 0603 X7R | Holy Stone | |
| 8 | 1 | C8 | 0.1uf / 50V, 0603 X7R | Holy Stone | |
| 9 | 1 | R1 | 1.5M ohm 0805 | Yageo | |
| 10 | 1 | R2 | 3.3M ohm 1206 | Yageo | |
| 11 | 1 | R3 | 82R hom 1206 | Yageo | |
| 12 | 1 | R4 | 300kohm 0805 | Yageo | |
| 13 | 1 | R5 | 1R ohm 0603 | Yageo | |
| 14 | 1 | R6 | 56K ohm 0603 | Yageo | |
| 15 | 1 | R7 | 27K ohm, 0603 | Yageo | |
| 16 | 1 | R8 | 200K ohm, 0603 | Yageo | |
| 17 | 1 | R9 | 3R ohm 0805 | Yageo | |
| 18 | 1 | R10 | 2.7R ohm 0805 | Yageo | |
| 19 | 1 | R11 | 20R ohm 0805 | Yageo | |
| 20 | 1 | R12 | 3.2K ohm, 0603 | Yageo | |
| 21 | 1 | R13 | 20R ohm 0603 | Yageo | |
| 22 | 1 | R14 | 43K ohm 0603 | Yageo | |
| 23 | 1 | R15 | 20R ohm 1206 | Yageo | |
| 24 | 1 | BD1 | ABS210 | Diodes 2A-600V | |
| 25 | 2 | D5, D6 | 1N4007 | Diodes 1A-600V | |
| 26 | 1 | FR1 | 3.3R hom | Fuse resistor | |
| 27 | 1 | L1 | 220uh | Inductor | |
| 28 | 1 | CY1 | 100pf/250Vac Y1 | Holy Stone | |
| 29 | 1 | U1 | AP3983RMTR-G1 sop-7 | Diodes | |
| 30 | 1 | U2 | AP3415BTM-G1 sop-8 | Diodes | |
| 31 | 1 | T1 | EE16 core PC40 | | |

# Chapter 4. The Evaluation Board (EVB) Connections

## 4.1 Evaluation Board PCB Layout

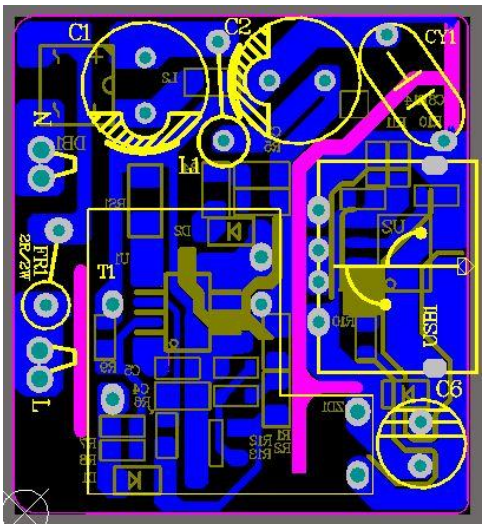



Figure 4: PCB Board Layout Top View

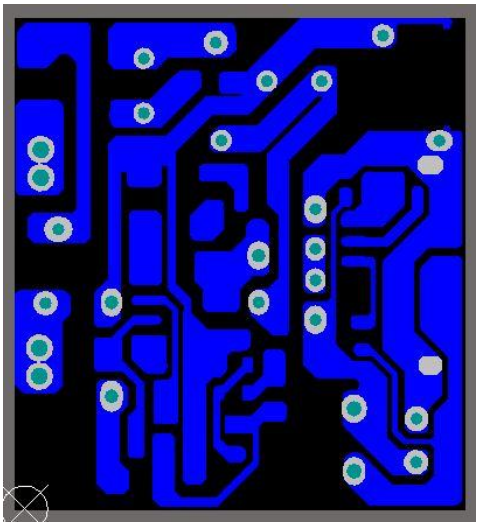


Figure 5: PCB Board Layout Bottom View

## 4.2 Quick Start Guide Before Connection

1. The evaluation board is preset at 5V/2A from output + & -
2. Ensure that the AC source is switched OFF or disconnected before doing connection.
3. Connect the AC line wires of power supply to “L and N” on the left side of the board.
4. Turn on the AC main switch.
5. Measure Red & Black wires to ensure correct output voltages at 5V respectively.

# Chapter 5. Testing the Evaluation Board

## 5.1 Input & Output Characteristics

### 5.1.1 Input Standby Power

| Input Voltage | 115Vac/60Hz | 230Vac/50Hz | Note |
|---|---|---|---|
| Pin (w) | 27mW | 46mW | At no loading |

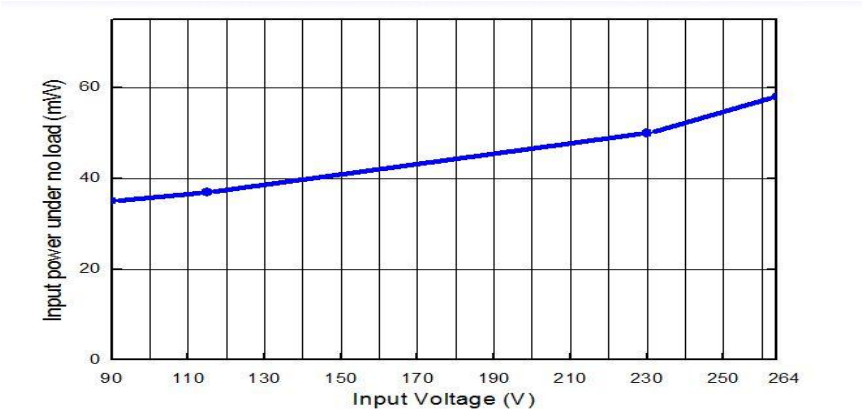



**Figure 6: The Efficiency curve with at different AC input**

### 5.1.2 Input Power Efficiency at Different Loading

| AC input | Efficiency (%) | | | | | Avg. Efficiency |
|---|---|---|---|---|---|---|
| | 10% | 25% | 50% | 75% | 100% | |
| 90VAC/60Hz | | | | | | |
| 115VAC/60Hz | 82.65% | 84.97% | 84.37% | 84.61% | 84.65% | 84.65% |
| 230VAC/50Hz | 78.65% | 82.21% | 84.44% | 85.22% | 85.69% | 84.39% |
| 264VAC/50Hz | | | | | | |
| Avg. Efficiency | | | | | | |

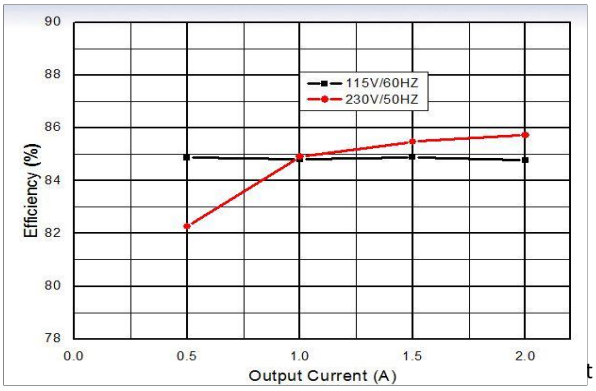



**Figure 7: The efficiency curve with different loading**

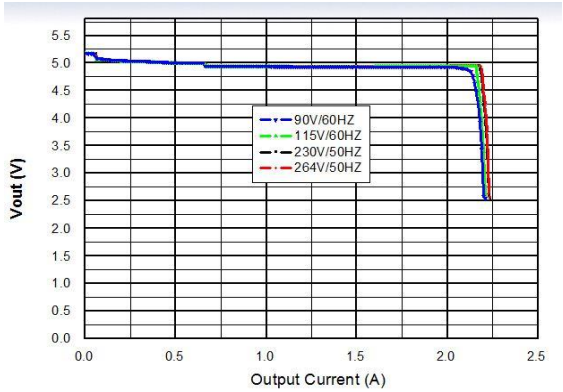



**Figure 8: CV & CC Curve at OCP set points**

### 5.1.3 OCP Current set point with at different AC line

| AC input | 90VAC | 115VAC | 230VAC | 264VAC | Note |
|---|---|---|---|---|---|
| I _max | 2.25A | 2.26A | 2.22A | 2.22A | |

### 5.1.4 PSU Output Characteristics:

**Line Regulation (at full loading condition):**

| AC input Voltage | 90VAC/60Hz | 115VAC/60Hz | 230VAC/50Hz | 265VAC/50Hz | Note |
|---|---|---|---|---|---|
| 5.00Vo | 5.342V/2A | 5.353V/2A | 5.378V/2A | 5.385V/2A | 0.8%<1% |

**Cross Load Regulation (at nominal line AC input voltage):**

| AC input Voltage | 115VAC/60Hz | 230VAC/50Hz |
|---|---|---|
| 5V Full Load | 5.353V / 2A | 5.378V/2A |
| 5V 10% of FL | 4.99V /0.2A | 4.991V/0.2A |
| Note: cable compensation | 7.2% | 7.7% |

Note: All output voltages are measured at output PCB END.

## 5.2 Key Performance Waveforms:

### 5.2.1 System start - up time

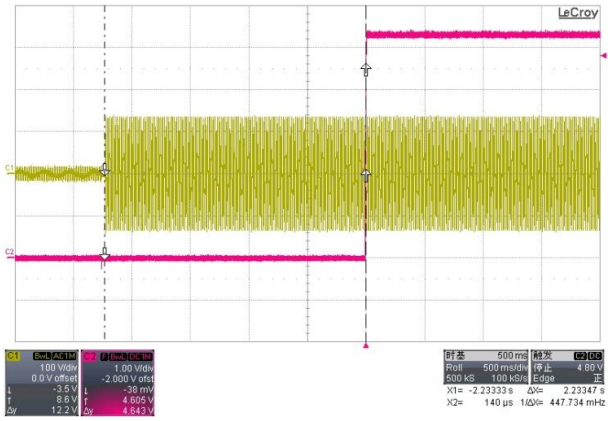



**Figure 9: AP3983R turn on time 2.23sFL at 90Vac**

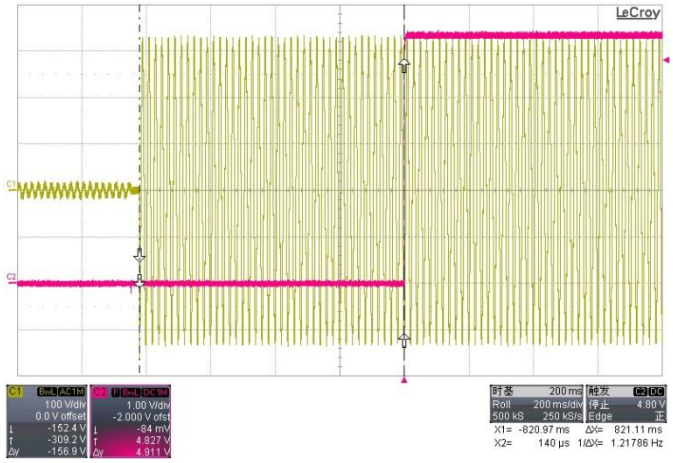



**Figure 10**: **AP3983R turn on time 0.82s at FL, at 230Vac**

### 5.2.2 System main switching Voltage Stress on AP3983R Pin 5 & 6

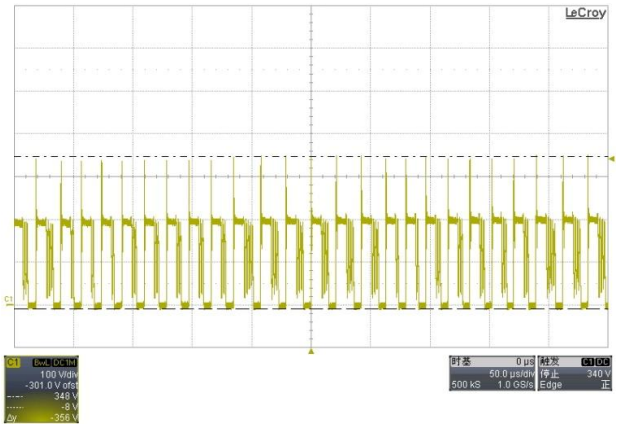



Figure 11: AP3983R Vds at FL at 90 Vac, Vds=356Vp-p

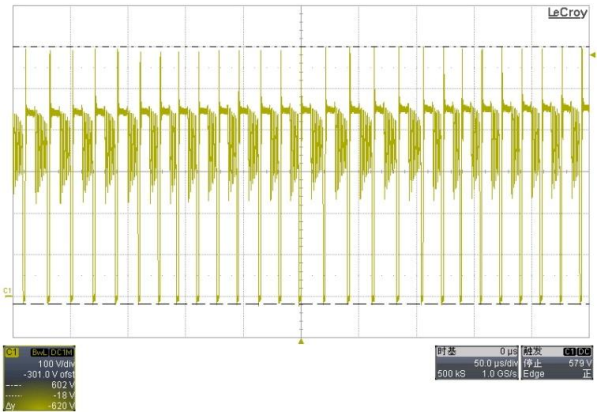



Figure 12: AP3983R Vds at FL at 264 Vac, Vds=620Vp-p

**The system voltage stress on U2 D-S**

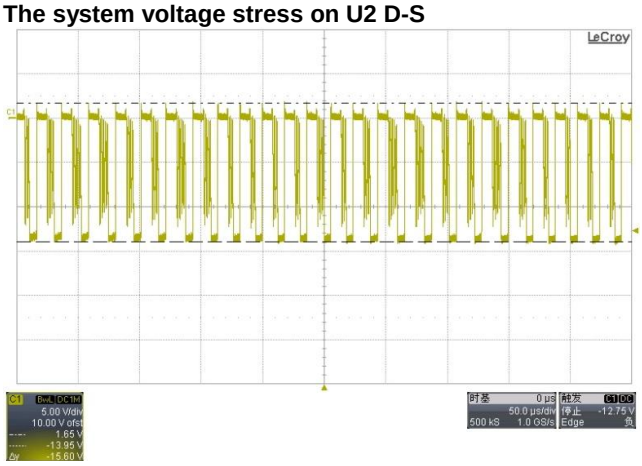



Figure 13: U2 D-S voltage stress at 90Vac FL

Vu2 d_S = 15.5Vp-p 5V/div

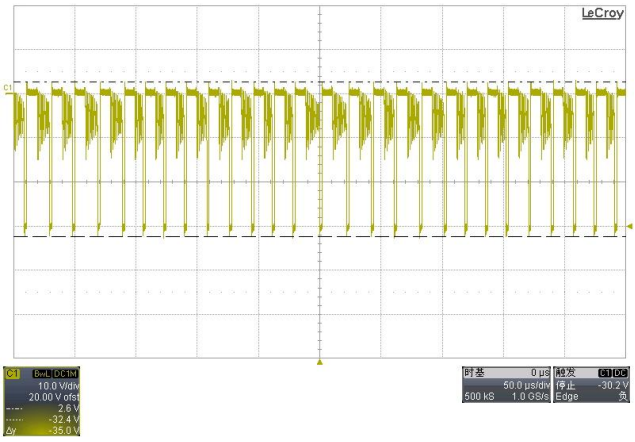



Figure 14: U2 D-S voltage stress at 264Vac at FL

Vu2 d_S = 35Vp-p 10V/div

### 5.2.3 System Output Ripple performance

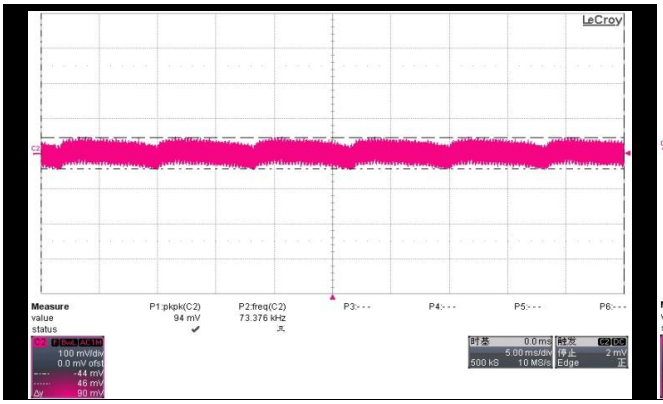



Figure 15: The Ripple at 90Vac_in Vpp=90mv FL

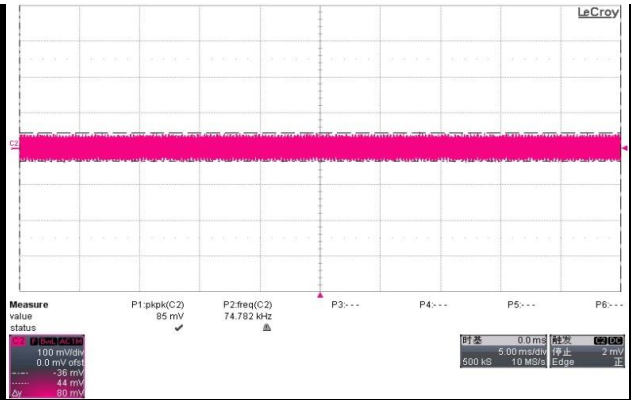



Figure 16: The Ripple at 264Vac_in Vpp=80mv FL

### 5.2.4 System Dynamic Response performance with Vout @ 0A-2A

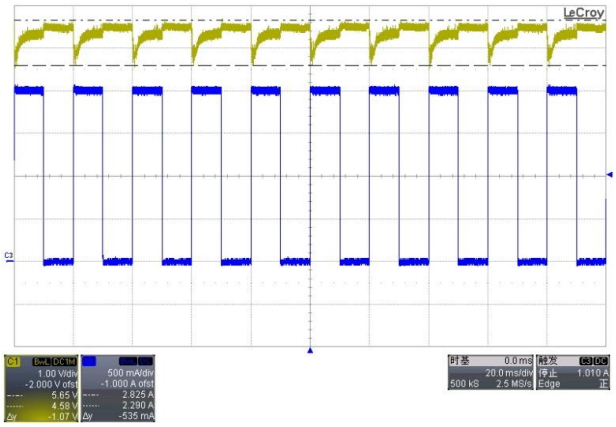



**Figure 17: 90VAC; Load level: 0~2A; Vo: 4.58~5.65V**
**Frequency: 10ms~10mS. Slew rate: 0.25A/us**

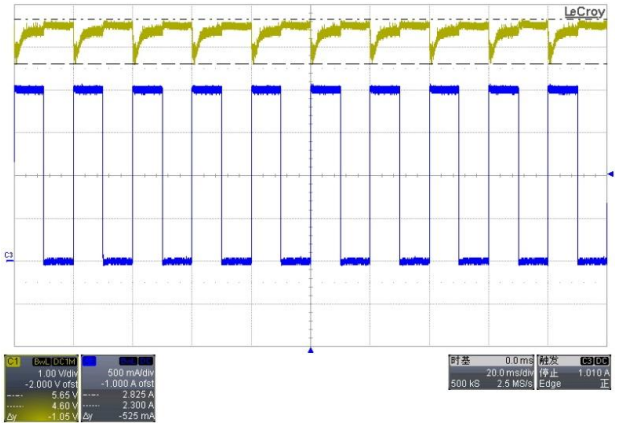



**Figure 18: 264VAC; Load level:0~2A; Vo: 4.60~5.65V**
**Frequency: 10ms~10mS. Slew rate: 0.25A/us**

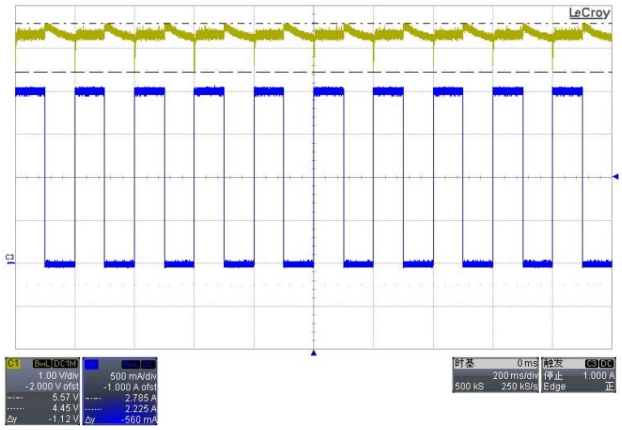



**Figure 19: 90VAC; Load level: 0~2A; Vout: 4.45~5.57V**
**Frequency: 100ms~100mS. Slew rate: 0.25A/us**

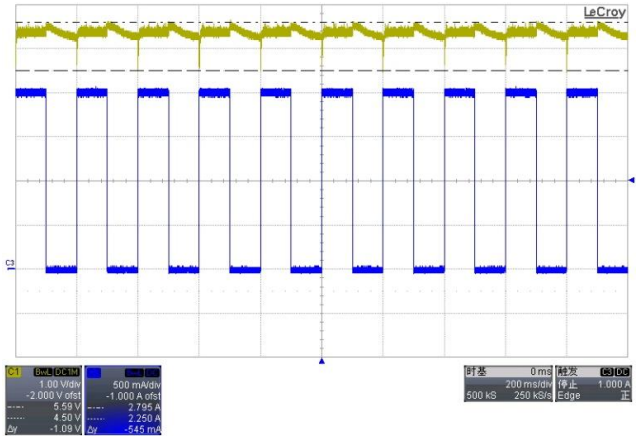



**Figure 20: 264VAC; Load level: 0~2A; Vout: 4.50~5.59V**
**Frequency: 100ms~100mS. Slew rate: 0.25A/us**

### 5.3 Thermal Test data at room Temperature after running 1 hr

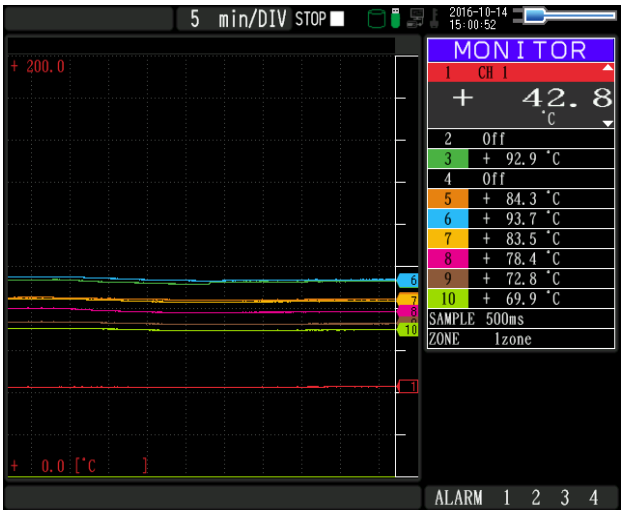



Figure21:

| | |
|---|---|
| 1#Ta | 43.4℃ |
| 6#U1 AP3983R | 95℃ |
| 5#U2 APR3415B | 83.1℃ |

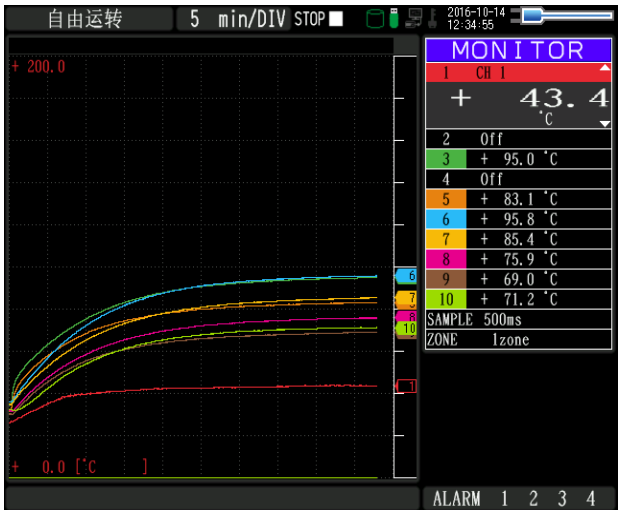
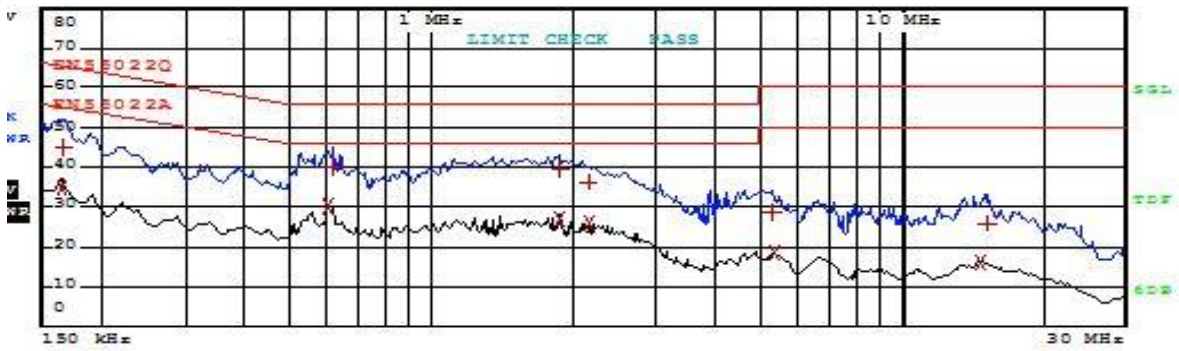



Figure22:

| | |
|---|---|
| 1#Ta | 43.4℃ |
| 6#U1 AP3983R | 92.9℃ |
| 5#U1 APR3415B | 84.3℃ |

### 5.4 System EMI Scan

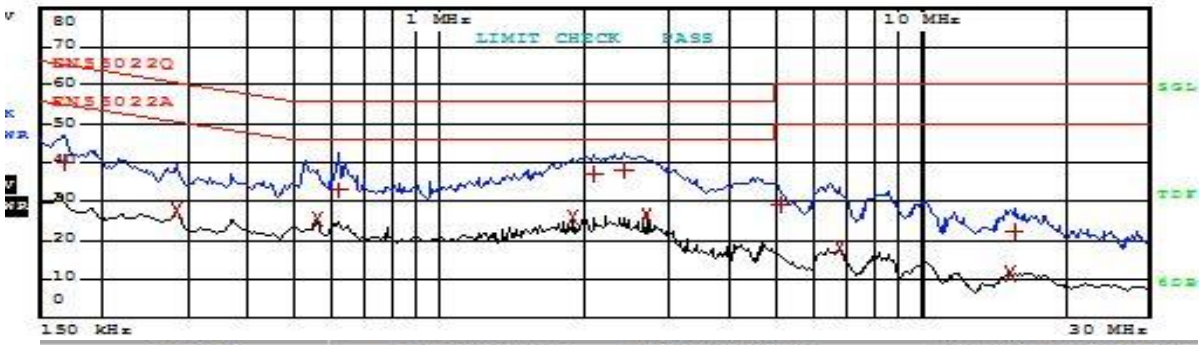
#### 5.4.1 System EMI L - Line Scan Data @115Vac




| TRACE | | FREQUENCY | LEVEL dBµV | DELTA LIMIT dB |
|---|---|---|---|---|
| 2 | Average | 164.052790903 kHz | 34.62 | -20.62 |
| 1 | Quasi Peak | 165.693318812 kHz | 45.05 | -20.11 |
| 2 | Average | 604.06488251 kHz | 30.22 | -15.77 |
| 1 | Quasi Peak | 616.206586648 kHz | 39.84 | -16.15 |
| 1 | Quasi Peak | 1.85951131803 MHz | 39.35 | -16.64 |
| 2 | Average | 1.85951131803 MHz | 26.94 | -19.05 |
| 1 | Quasi Peak | 2.1374603093 MHz | 36.07 | -19.92 |
| 2 | Average | 2.1374603093 MHz | 25.81 | -20.18 |
| 1 | Quasi Peak | 5.28619370567 MHz | 28.70 | -31.29 |
| 2 | Average | 5.33905564273 MHz | 18.63 | -31.37 |
| 2 | Average | 14.5855630539 MHz | 16.12 | -33.87 |
| 1 | Quasi Peak | 15.0275202 MHz | 26.10 | -33.89 |

Figure 23: EMI Scan at 115Vac @ L- line

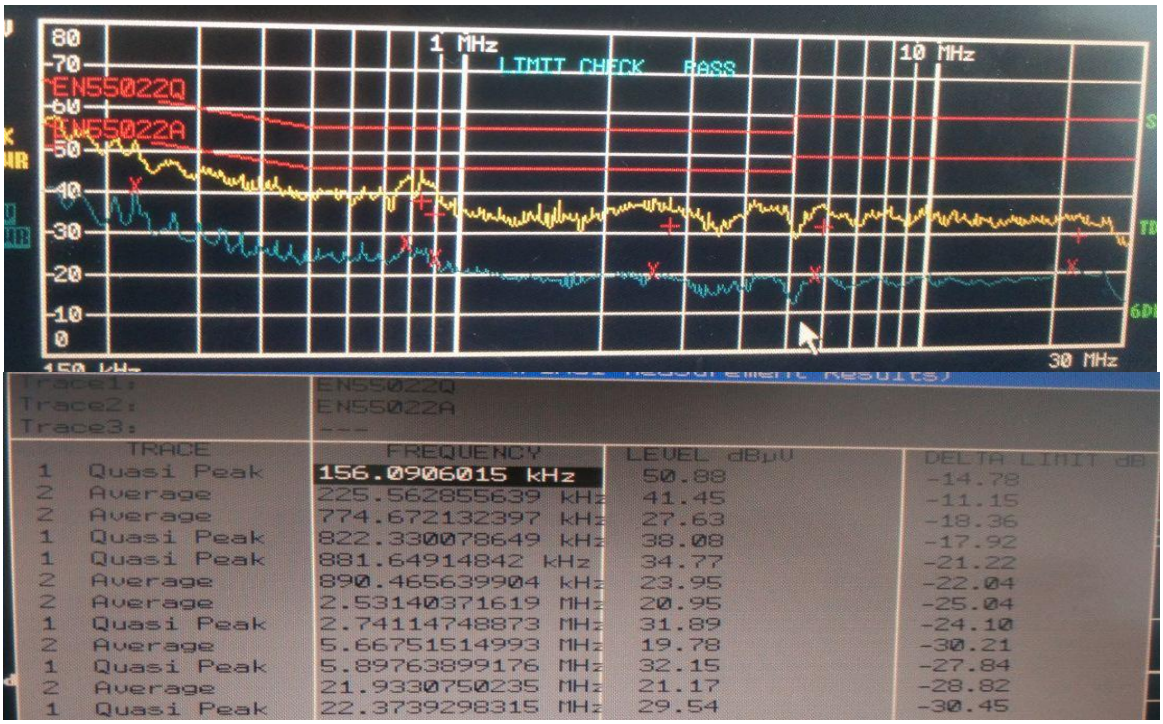
### 5.4.2 System EMI N - Line Scan Data @ 115Vac




| | TRACE | FREQUENCY | LEVEL dBµV | DELTA LIMIT dB |
|---|---|---|---|---|
| 1 | Quasi Peak | 167.350252 kHz | 40.19 | -24.89 |
| 2 | Average | 283.569280422 kHz | 27.78 | -22.92 |
| 2 | Average | 557.843784289 kHz | 25.51 | -20.48 |
| 1 | Quasi Peak | 616.206586648 kHz | 32.94 | -23.06 |
| 2 | Average | 1.89688749553 MHz | 26.17 | -19.82 |
| 1 | Quasi Peak | 2.0745979178 MHz | 37.02 | -18.98 |
| 1 | Quasi Peak | 2.40854377744 MHz | 37.92 | -18.07 |
| 2 | Average | 2.68713605405 MHz | 26.33 | -19.66 |
| 1 | Quasi Peak | 5.13072753076 MHz | 29.14 | -30.86 |
| 2 | Average | 6.71206330694 MHz | 17.80 | -32.19 |
| 2 | Average | 15.177795402 MHz | 11.67 | -38.33 |
| 1 | Quasi Peak | 15.4828690896 MHz | 22.04 | -37.95 |

**Figure 24: EMI Scan at 115Vac @N_ Line**

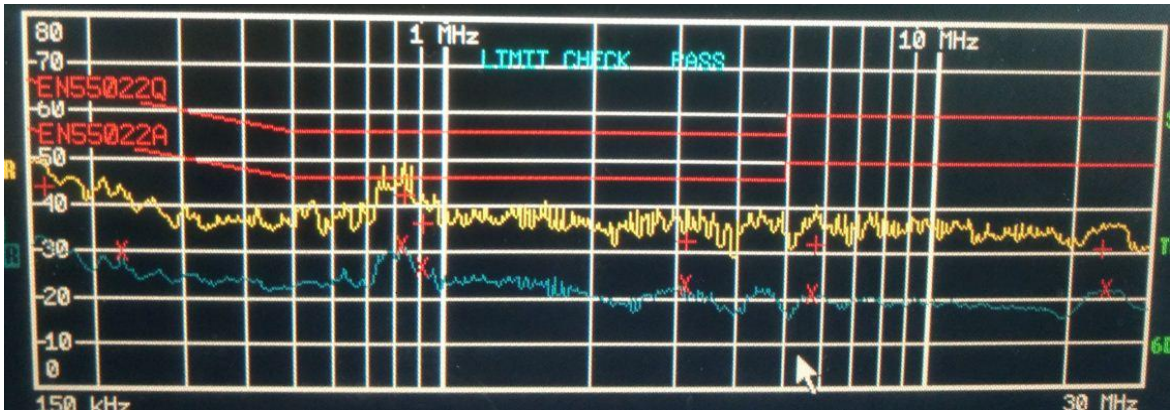
### 5.4.3 System EMI L - Line Scan Data @ 230Vac




| | TRACE | FREQUENCY | LEVEL dBµV | DELTA LIMIT dB |
|---|---|---|---|---|
| 1 | Quasi Peak | 156.0906015 kHz | 50.88 | -14.78 |
| 2 | Average | 225.562855639 kHz | 41.45 | -11.15 |
| 2 | Average | 774.672132397 kHz | 27.63 | -18.36 |
| 1 | Quasi Peak | 822.330078649 kHz | 38.08 | -17.92 |
| 1 | Quasi Peak | 881.64914842 kHz | 34.77 | -21.22 |
| 2 | Average | 890.465639904 kHz | 23.95 | -22.04 |
| 2 | Average | 2.53140371619 MHz | 20.95 | -25.04 |
| 1 | Quasi Peak | 2.74114748873 MHz | 31.89 | -24.10 |
| 2 | Average | 5.66751514993 MHz | 19.78 | -30.21 |
| 1 | Quasi Peak | 5.89763899176 MHz | 32.15 | -27.84 |
| 2 | Average | 21.9330750235 MHz | 21.17 | -28.82 |
| 1 | Quasi Peak | 22.3739298315 MHz | 29.54 | -30.45 |

**Figure 25: EMI Scan at 230Vac @ L_ line**

**5.4.4 System EMI N-Line Scan Data @230Vac**



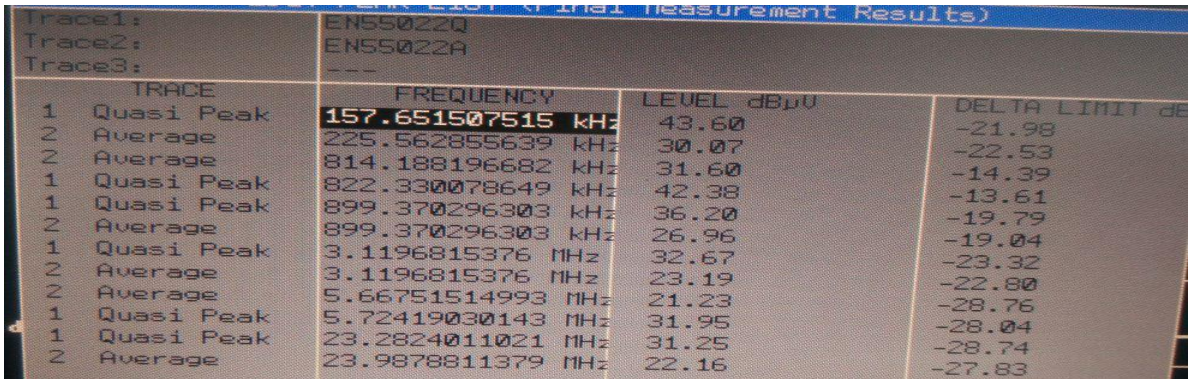




**Figure 26: EMI Scan at 230Vac @ N_ line**

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