



The Future of Analog IC Technology®

# EVHR2000-S-00A Fluorescent Lamp HB Driver with PFC

## DESCRIPTION

The EVHR2000-S-00A is an evaluation board for the HR2000. The HR2000 is a fluorescent lamp ballast controller with PFC function and high voltage half-bridge driver. Only 16pin is used to offer cost effective solutions with minimized external components.

The EVHR2000DS-00A is designed to drive 16W fluorescent lamp. With the simple and sufficient on-time control APFC, the demo board provides 400V DC bus voltage for ballast and clean load for Grid. The power factor is greater than 0.9 in all input voltage range. The over-voltage and over-current protection of PFC stage are integrated to ensure the safety.

The half-bridge ballast controller directly drives two MOSFETs to control the fluorescent lamp. The preheat and ignition time are programmed to proper level to meets the characteristics of fluorescent lamp. The over-voltage, over-current, capacitive-mode, and end-of-life (EOL) protection are all integrated.

The EVHR2000DS-00A meets EN55015 EMI standard. And THD meets IEC61000-3-2 Class C standard.

## ELECTRICAL SPECIFICATION

| Parameter            | Symbol            | Value    | Units |
|----------------------|-------------------|----------|-------|
| Input Voltage        | V <sub>in</sub>   | 198-264  | VAC   |
| AC Line Frequency    | f <sub>LINE</sub> | 50       | Hz    |
| Lamp Voltage         | V <sub>lamp</sub> | 55       | Vrms  |
| Lamp Current         | I <sub>lamp</sub> | 0.29     | A     |
| Lamp Power           | P <sub>lamp</sub> | 16       | W     |
| Preheat Current      | I <sub>pre</sub>  | 0.18-0.3 | A     |
| Preheat time         | t <sub>Pre</sub>  | 674      | ms    |
| Open circuit voltage | V <sub>oc</sub>   | 300      | Vrms  |
| Burning frequency    | f <sub>run</sub>  | 40-50    | kHz   |
| Efficiency           | η                 | >80      | %     |
| Power Factor         | PF                | >90      | %     |

## Features

### PFC PART

- Only four pins realize PFC function.
- Ton control.
- Boundary Conduction Mode operation.
- Less peripheral components.
- Over voltage and over current protection.

### HALF-BRIDGE PART

- 600V bootstrap half-bridge driver.
- Programmable preheat current.
- Programmable preheat time.
- Programmable ignition time.
- Single ignition attempt.
- Over voltage protection.
- Over current protection.
- End-Of-Life protection
- Capacitive mode protection.
- Minimized external components.
- Over temperature protection

## APPLICATIONS

- Tube fluorescent lamp ballast
- Compact fluorescent lamp ballast

All MPS parts are lead-free and adhere to the RoHS directive. For MPS green status, please visit MPS website under Quality Assurance.

"MPS" and "The Future of Analog IC Technology", are Registered Trademarks of Monolithic Power Systems, Inc.



**Warning:** Although this board is designed to satisfy safety requirements, the engineering prototype has not been agency approved. Therefore, all testing should be performed using an isolation transformer to provide the AC input to the prototype board.

### EVHR2000-S-00A EVALUATION BOARD



**FRONT**

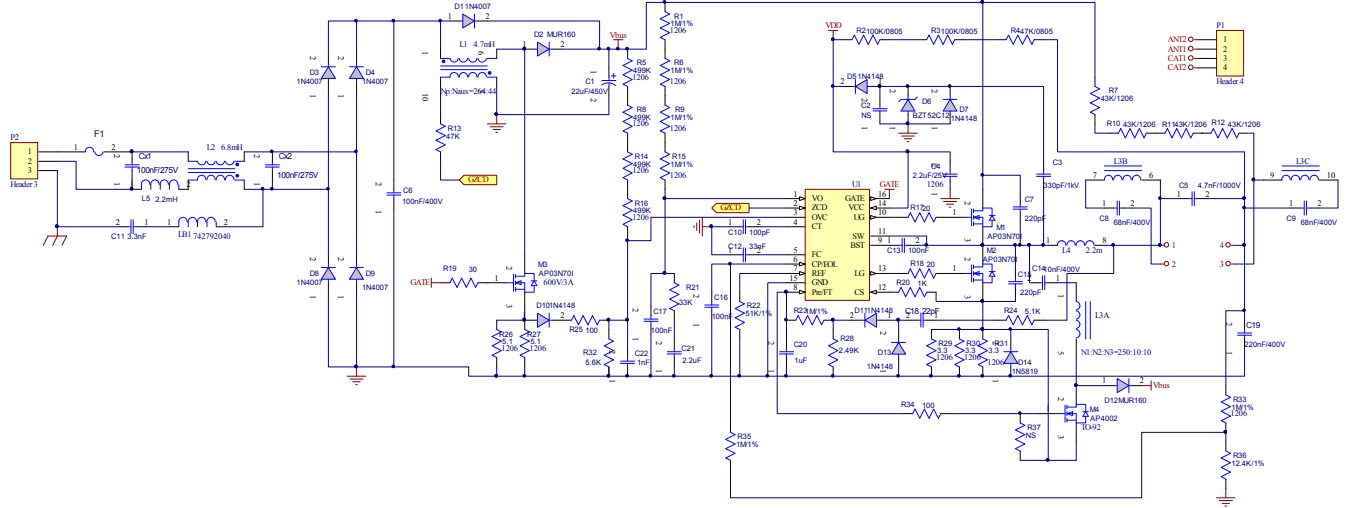


**BACK**

(L x W x H) 26cm x 2.7cm x 2.4cm

| Board Number   | MPS IC Number |
|----------------|---------------|
| EVHR2000-S-00A | HR2000DS      |

EVALUATION BOARD SCHEMATIC



**EVHR2000-S-00A BILL OF MATERIALS**

| Qty | Ref                        | Value           | Description                                       | Package | Manufacturer       | Part Number               |
|-----|----------------------------|-----------------|---|---------|--------------------|---------------------------|
| 1   | C1                         | 22 $\mu$ F/450V | Electrolytic Capacitor;450V;<br>Electrolytic;DIP  | DIP     | 江海                 | CD110-450V22              |
| 1   | C2                         | NS              |   |         |                    |                           |
| 1   | C3                         | 330pF/1kV       | Capacitor;1000V                                   | DIP     | ANY                |                           |
| 1   | C4                         | 2.2 $\mu$ F/25V | Ceramic Capacitor;<br>25V;X7R;1206                | 1206    | muRata             | GRM31MR71E225KA93L        |
| 1   | C5                         | 4.7nF/1000V     | Capacitor;1000V                                   | DIP     | 法拉                 | MMKP82-1000V-<br>472P10JA |
| 1   | C6                         | 100nF/400V      | Capacitor;400V;CBB                                | DIP     | Panasonic          | ECQE4104KF                |
| 2   | C7, C15                    | 220pF           | Ceramic Capacitor;<br>1000V;U2J;1206              | 1206    | muRata             | GRM31A7U3A221JW31D        |
| 2   | C8, C9                     | 68nF/400V       | Capacitor;400V;CBB                                | DIP     | Panasonic          | ECQE400VDC683K            |
| 1   | C10                        | 100pF           | Ceramic Capacitor;<br>50V;C0G;0603                | 0603    | TDK                | C1608COG1H101J            |
| 1   | C11                        | 3.3nF           | Y Capacitor;2600V;20%                             | DIP     | 鸿科                 | JY10F332MY72N             |
| 1   | C12                        | 33nF            | Ceramic Capacitor;<br>50V;X7R;0603;               | 0603    | muRata             | GRM188R71H333KA61D        |
| 3   | C13,<br>C16, C17           | 100nF           | Ceramic<br>Capacitor;50V;X7R;0603;                | 0603    | TDK                | C1608X7R1H104K            |
| 1   | C14                        | 10nF/400V       | Capacitor;400V;CBB                                | DIP     | Panasonic          | ECQE4103KF                |
| 1   | C18                        | 22pF            | Capacitor;6000V;5%                                | DIP     | 鸿科                 | 3J07SL220JY72N            |
| 1   | C19                        | 220nF/400V      | Capacitor;400V;CBB                                | DIP     | Panasonic          | ECQE4224KF                |
| 1   | C20                        | 1 $\mu$ F       | Ceramic Capacitor;<br>25V;X7R;0805                | 0805    | muRata             | GRM21BR71E105KA99L        |
| 1   | C21                        | 2.2 $\mu$ F     | Ceramic Capacitor;<br>16V;X7R;0805                | 0805    | muRata             | GRM21BR71C225KA12L        |
| 1   | C22                        | 1nF             | Ceramic Capacitor;<br>50V;X7R;0603;               | 0603    | muRata             | GRM188R71H102KA01D        |
| 2   | Cx1, Cx2                   | 100nF/275V      | Capacitor;275V                                    | DIP     | Carli              | PX104K3ID19L270D9R        |
| 5   | D1, D3,<br>D4, D8,<br>D9   | 1N4007          | Diode;1000V;1A                                    | DO-41   | Diodes             | 1N4007                    |
| 2   | D2, D12                    | MUR160-T        | Diode;600V;1A                                     | DO-41   | HQ                 | MUR160-T                  |
| 5   | D5, D7,<br>D10,D11,<br>D13 | 1N4148W         | Diode;75V;0.15A;                                  | SOD-123 | Diodes             | 1N4148W                   |
| 1   | D14                        | 1N5819HW        | Schottky Diode,40V,1A                             | SOD-123 | Diodes             | 1N5819                    |
| 1   | D6                         | BZT52C12        | Zener Diode;<br>12V;5mA/500mW;                    | SOD-123 | Diodes             | BZT52C12                  |
| 1   | F1                         | SS-5-1A         | Fuse;250V;1A                                      | DIP     | COOPER<br>BUSSMANN | SS-5-1A                   |
| 1   | L1                         | 4.7mH           | PFC Inductor, EE16,<br>Np:Ns=264:44               | DIP     | E-MEI              | FX308                     |
| 1   | L2                         | 7446121007      | Common Chock, 6.8mH/1A                            | DIP     | Wurth              | 7446121007                |
| 1   | L3                         | FX307           | Preheat Transformer,EE16,<br>Np:Ns1:NS2=250:10:10 | DIP     | E-MEI              | FX307                     |
| 1   | L4                         | 2.2mH           | Resonant Inductor,<br>EF20, Np=220                | DIP     | E-MEI              | FX306                     |

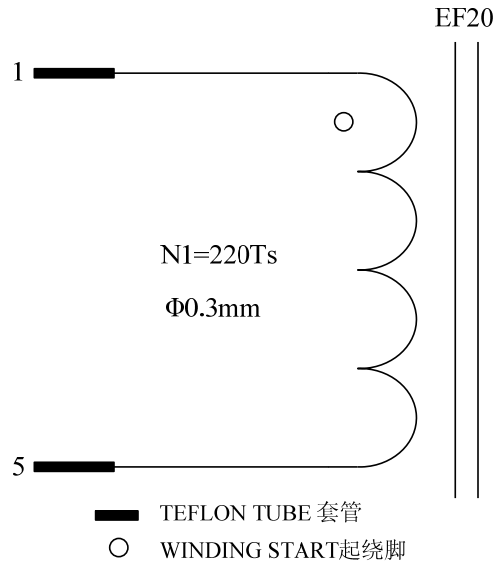
**EVHR2000-S-00A BILL OF MATERIALS (CONTINUED)**

| Qty | Ref                            | Value     | Description                      | Package | Manufacturer         | Part Number      |
|-----|--------------------------------|-----------|----------------------------------|---------|----------------------|------------------|
| 1   | L5                             | 2.2mH     | Inductor;2.2mH;4.73;320mA        | DIP     | Wurth                | 7447720222       |
| 1   | LB1                            | 742792040 | Magnetic Bead                    | 0805    | Wurth                | 742792040        |
| 3   | M1, M2, M3                     | ITA02N60A | N-Channel Mosfet; 600V, 4.5/10V; | TO-220  | IPS                  | ITA02N60A        |
| 1   | M4                             | ITNCS1N60 | N-Channel Mosfet; 600V;15/10V    | TO-92   | IPS                  | ITNCS1N60        |
| 1   | P1                             |           | Header, 6-Pin                    |         |                      |                  |
| 1   | P2                             |           | Header, 3-Pin                    |         |                      |                  |
| 7   | R1, R6, R9, R15, R23, R33, R35 | 1M/1%     | Film Resistor;1%;                | 1206    | Yageo                | RC1206FR-071ML   |
| 2   | R2, R3,                        | 100k/0805 | Film Resistor;5%                 | 0805    | Yageo                | RC0805JR-07100KL |
| 1   | R4                             | 47k       | Film Resistor;5%                 | 0805    | Yageo                | RM10JN473        |
| 4   | R5, R8, R14, R16               | 499k      | Film Resistor;1%;                | 1206    | Yageo                | RC1206FR-07499KL |
| 4   | R7, R10, R11, R12              | 43k/1206  | Resistor;1%;                     | 1206    | Royalohm             | 1206F4302T5E     |
| 1   | R13                            | 47k       | Film Resistor;5%;1/10W           | 0603    | LIZ                  | CR0603JA0473G    |
| 2   | R17, R18                       | 20        | Film Resistor;5%;1/10W           | 0603    | LIZ                  | CR0603JA0200G    |
| 1   | R19                            | 30        | Film Resistor;1%;                | 0603    | Yageo                | RC0603FR-0730RL  |
| 1   | R20                            | 1k        | Film Resistor;1%                 | 0603    | Yageo                | RC0603FR-071KL   |
| 1   | R21                            | 33k       | Film Resistor;1%;                | 0603    | Yageo                | RC0603FR-0733KL  |
| 1   | R22                            | 51k/1%    | Film Resistor;1%                 | 0603    | SYN-<br>TON-<br>TECH | RC0603FR-0751KL  |
| 1   | R24                            | 5.1k      | Film Resistor;5%                 | 0603    | Yageo                | RC0603JR-075K1L  |
| 1   | R25                            | 100       | Film Resistor;1%;                | 1206    | Yageo                | RC1206FR-07100RL |
| 2   | R26, R27                       | 5.1       | Film Resistor;5%;                | 1206    | Yageo                | RC1206JR-075R1L  |
| 1   | R28                            | 2.49k     | Film Resistor;1%                 | 0603    | Yageo                | RC0603FR-072K49L |
| 3   | R29, R30, R31                  | 3.3       | Resistor;1%                      | 1206    | Royalohm             | 1206F330KT5E     |
| 1   | R32                            | 5.6k      | Film Resistor;1%;                | 0603    | Yageo                | RC0603FR-075K6L  |
| 1   | R34                            | 100       | Film Resistor;1%;                | 0603    | Yageo                | RC0603FR-07100RL |
| 1   | R36                            | 12.4k/1%  | Film Resistor;1%;                | 0603    | Yageo                | RC0603FR-0712K4L |
| 1   | R37                            | NS        |                                  |         |                      |                  |
| 1   | U1                             | HR2000    | FL Controller                    | SOIC-16 | MPS                  | HR2000           |

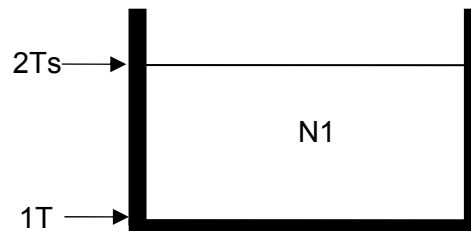
## MAGNETIC COMPONENTS

### A. FX306, Resonant Inductor (L4)

Electrical Diagram:



Winding Diagram



Winding Order

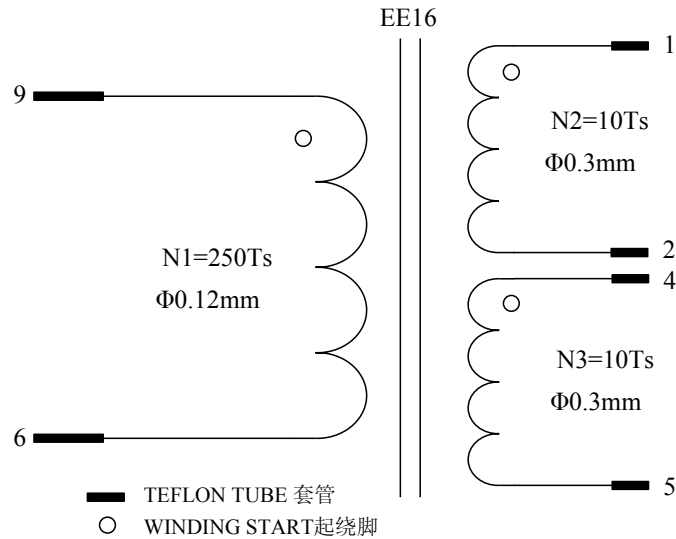
| 胶带圈数<br>(Tape Layer Number) | 绕组顺序<br>(Winding No.) | 始末脚位<br>(Start & End) | 线径 $\phi$<br>(Magnet Wire) | 圈数<br>(Turns) |
|-----------------------------|-----------------------|-----------------------|----------------------------|---------------|
| 1                           |                       |                       |                            |               |
| 2                           | N1                    | 1—5                   | 0.3mm*1                    | 220           |

Electric Characteristics

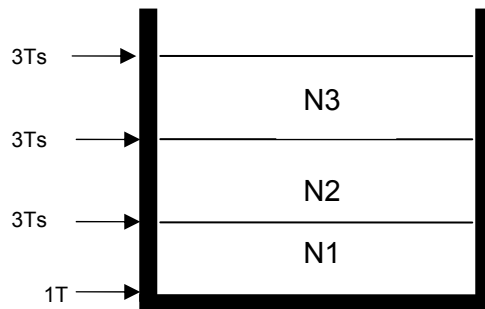
|   |                               |                       |           |         |
|---|-------------------------------|-----------------------|-----------|---------|
| 1 | 电感量<br>(Primary Inductance)   | Lp(1—5)               | 2.2mH±10% | 100kHz  |
| 2 | 匝比<br>(Turn Ratio)            | N1                    | 220       |         |
| 3 | 抗电强度<br>(Electrical Strength) | Pri. Side ~ Sec. Side | AC: 3000V | 1s, 1mA |
|   |                               | Pri. Side ~ Core      | AC: 2000V |         |
|   |                               | Sec. Side ~ Core      | AC: 2000V |         |

## B. FX307, Preheating Transformer (L3)

### Electrical Diagram:



### Winding Diagram



### Winding Order

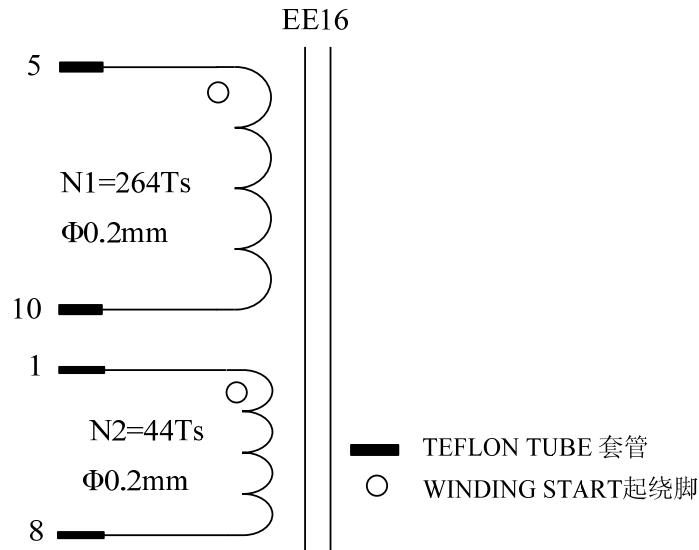
| 胶带圈数<br>(Tape Layer Number) | 绕组顺序<br>(Winding No.) | 始末脚位<br>(Start & End) | 线径 $\phi$<br>(Magnet Wire) | 圈数<br>(Turns) |
|-----------------------------|-----------------------|-----------------------|----------------------------|---------------|
| 1                           |                       |                       |                            |               |
| 3                           | N1                    | 9—6                   | 0.12mm*1                   | 250           |
| 3                           | N2                    | 1—2                   | 0.3mm*1                    | 10            |
| 3                           | N3                    | 4—5                   | 0.3mm*1                    | 10            |

### Electric Characteristics

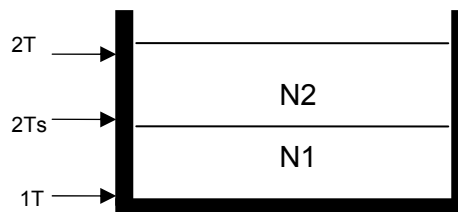
|   |                               |                       |           |         |
|---|-------------------------------|-----------------------|-----------|---------|
| 1 | 电感量<br>(Primary Inductance)   | Lp(9—6)               | >50mH     | 100kHz  |
| 2 | 匝比<br>(Turn Ratio)            | N1:N2:N3              | 250:10:10 |         |
| 3 | 抗电强度<br>(Electrical Strength) | Pri. Side ~ Sec. Side | AC: 3000V | 1s, 1mA |
|   |                               | Pri. Side ~ Core      | AC: 2000V |         |
|   |                               | Sec. Side ~ Core      | AC: 2000V |         |

### C. FX308, PFC Inductor (L1)

#### Electrical Diagram:



#### Winding Diagram



#### Winding Order

| 胶带圈数<br>(Tape Layer Number) | 绕组顺序<br>(Winding No.) | 始末脚位<br>(Start & End) | 线径 φ<br>(Magnet Wire) | 圈数<br>(Turns) |
|-----------------------------|-----------------------|-----------------------|-----------------------|---------------|
| 1                           |                       |                       |                       |               |
| 2                           | N1                    | 5—> 10                | 0.2mm*1               | 264           |
| 2                           | N2                    | 1—> 8                 | 0.2mm*1               | 44            |

#### Electric Characteristics

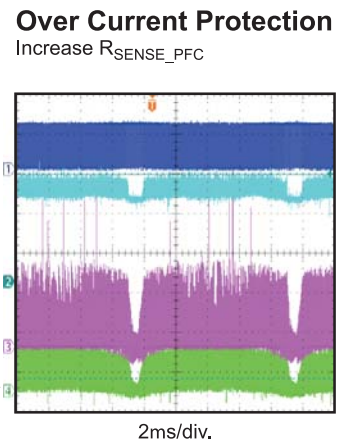
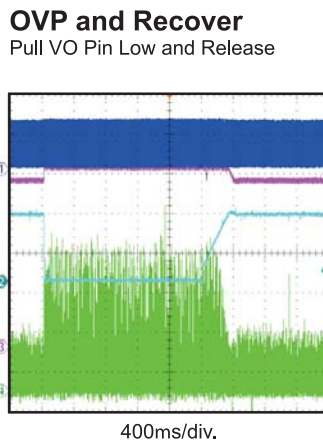
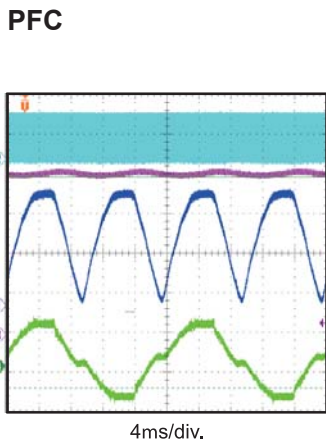
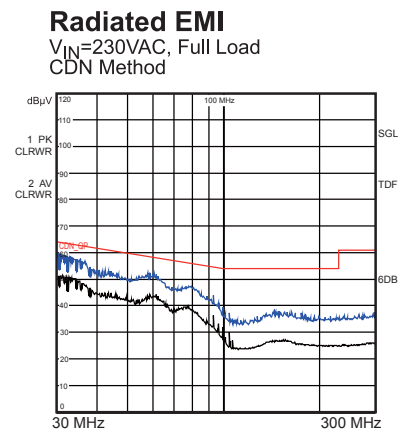
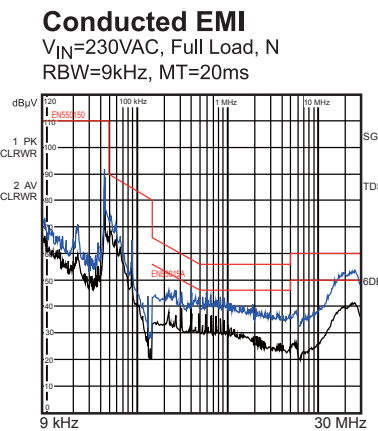
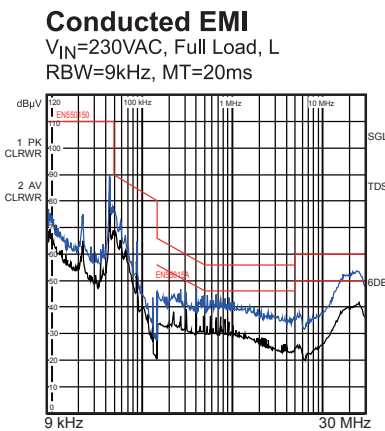
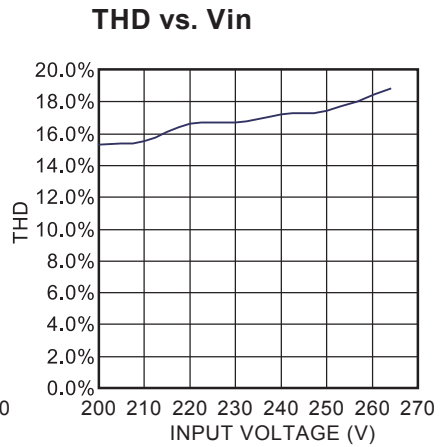
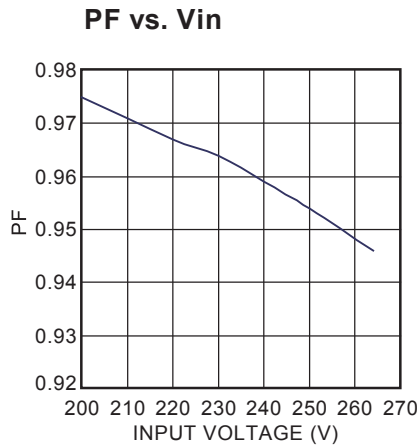
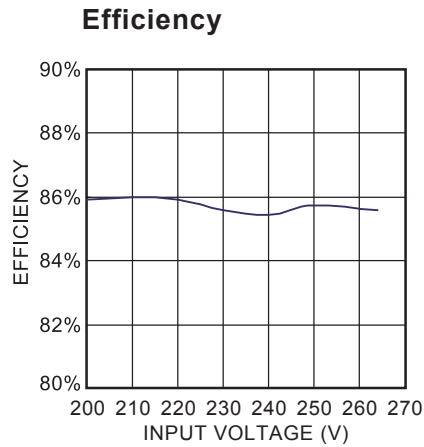
|   |                               |                       |           |         |
|---|-------------------------------|-----------------------|-----------|---------|
| 1 | 电感量<br>(Primary Inductance)   | Lp(1—5)               | 4.7mH±10% | 100kHz  |
| 2 | 匝比<br>(Turn Ratio)            | N1:N2                 | 264:44    |         |
| 3 | 抗电强度<br>(Electrical Strength) | Pri. Side ~ Sec. Side | AC: 3000V | 1s, 1mA |
|   |                               | Pri. Side ~ Core      | AC: 2000V |         |
|   |                               | Sec. Side ~ Core      | AC: 2000V |         |



## EVB TEST RESULTS

Performance waveforms are tested on the evaluation board.

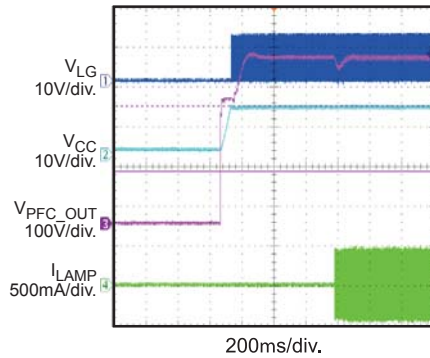
$V_{IN} = 198V_{AC}$  to  $265V_{AC}$ , 16W Lamp,  $T_A = 25^{\circ}C$ , unless otherwise noted.



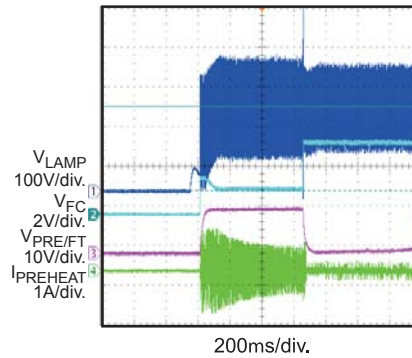
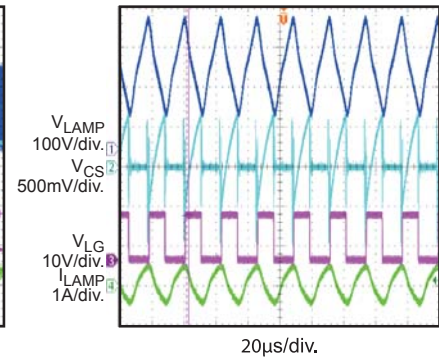
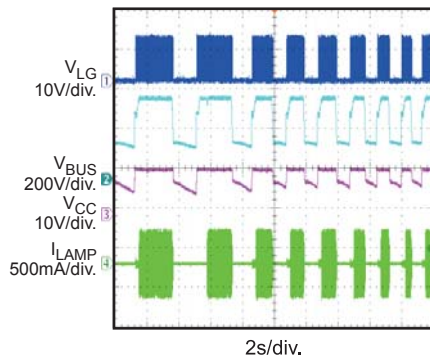
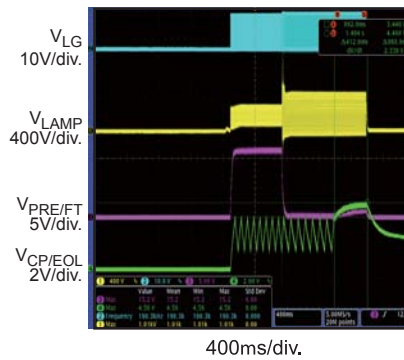
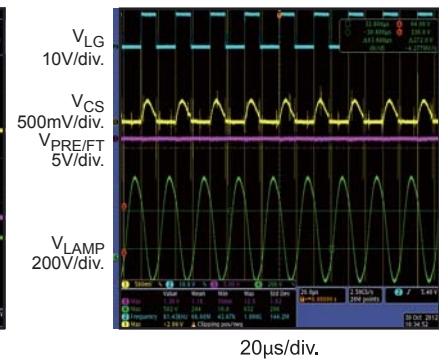
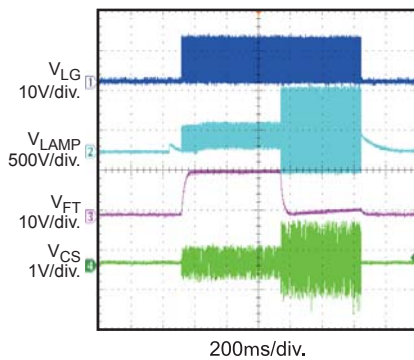
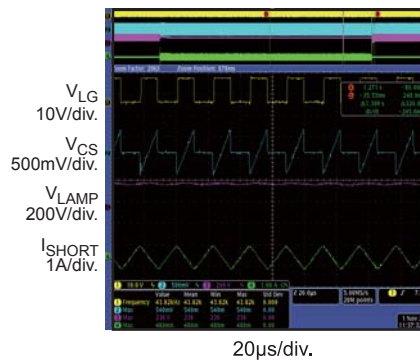
**EVB TEST RESULTS (continued)**

Performance waveforms are tested on the evaluation board.

 $V_{IN} = 198V_{AC}$  to  $265V_{AC}$ , 16W Lamp,  $T_A = 25^{\circ}C$ , unless otherwise noted.

**Start Up**

**Preheat & Ignition**

Controlled Preheat Time, Frequency, Current/Lamp Voltage


**Burn State**

**Quick Power On/Off**

**EOL Protection**

**Capacitive Mode Protection (Always Soft Switching)**

**Open Lamp Protection**

**Short Lamp and Recover**


**HARMONIC DATA**

| Vin (Vac/Hz) | Pin(W) | Power Factor | THD (%) |
|--------------|--------|--------------|---------|
| 200/50       | 22.6   | 0.975        | 15.3    |

| Harmonic Order | EN 61000-3-2/2000<br>active power $\geq 25W$ , class C(%) | Measured Data (%) | Test Result (Pass/Fail) |
|----------------|---|-------------------|-------------------------|
| 3              | 30* $\lambda$   | 13.70             | Pass                    |
| 5              | 10  | 4.80              | Pass                    |
| 7              | 7   | 4.10              | Pass                    |
| 9              | 5   | 1.70              | Pass                    |
| 11~39          | 3   | 1.70              | Pass                    |

| Vin (Vac/Hz) | Pin(W) | Power Factor | THD (%) |
|--------------|--------|--------------|---------|
| 220/50       | 22.33  | 0.967        | 16.6    |

| Harmonic Order | EN 61000-3-2/2000<br>active power $\geq 25W$ , class C (%) | Measured Data (%) | Test Result (Pass/Fail) |
|----------------|--|-------------------|-------------------------|
| 3              | 30* $\lambda$  | 15                | Pass                    |
| 5              | 10   | 5.40              | Pass                    |
| 7              | 7  | 3.80              | Pass                    |
| 9              | 5  | 1.70              | Pass                    |
| 11~39          | 3  | 1.10              | Pass                    |

| Vin (Vac/Hz) | Pin(W) | Power Factor | THD (%) |
|--------------|--------|--------------|---------|
| 264/50       | 22.04  | 0.946        | 18.80   |

| Harmonic Order | EN 61000-3-2/2000<br>active power $\geq 25W$ , class C(%) | Measured Data (%) | Test Result (Pass/Fail) |
|----------------|---|-------------------|-------------------------|
| 3              | 30* $\lambda$   | 17.10             | Pass                    |
| 5              | 10  | 6.40              | Pass                    |
| 7              | 7   | 3.50              | Pass                    |
| 9              | 5   | 1.00              | Pass                    |
| 11~39          | 3   | 0.40              | Pass                    |

## SURGE TEST RESULT

Line to Line 500V and Line to Power Earth 1kV surge test was completed. Input voltage was set at 230Vac/50Hz. Output was loaded at full load and operation was verified following each surge event.

| Surge Level (V) | Input Voltage (Vac) | Injection Location | Injection Phase (°) | Test Result (Pass/Fail) |
|-----------------|---------------------|--------------------|---------------------|-------------------------|
| ±500V           | 230                 | L to N             | 0                   | Pass                    |
| ±500V           | 230                 | L to N             | 90                  | Pass                    |
| ±500V           | 230                 | L to N             | 180                 | Pass                    |
| ±500V           | 230                 | L to N             | 270                 | Pass                    |
| ±1000V          | 230                 | L to PE            | 0                   | Pass                    |
| ±1000V          | 230                 | L to PE            | 90                  | Pass                    |
| ±1000V          | 230                 | L to PE            | 180                 | Pass                    |
| ±1000V          | 230                 | L to PE            | 270                 | Pass                    |
| ±1000V          | 230                 | N to PE            | 0                   | Pass                    |
| ±1000V          | 230                 | N to PE            | 90                  | Pass                    |
| ±1000V          | 230                 | N to PE            | 180                 | Pass                    |
| ±1000V          | 230                 | N to PE            | 270                 | Pass                    |

# PRINTED CIRCUIT BOARD LAYOUT

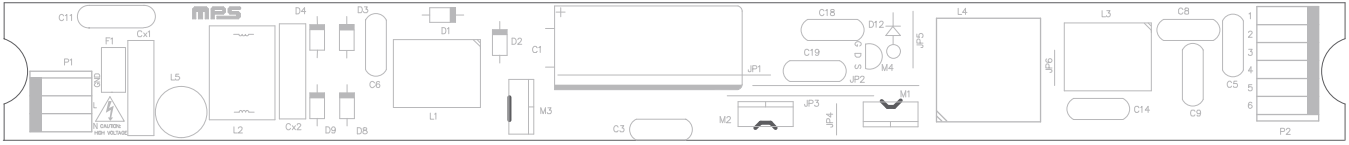


Figure 1—Top Silk Layer

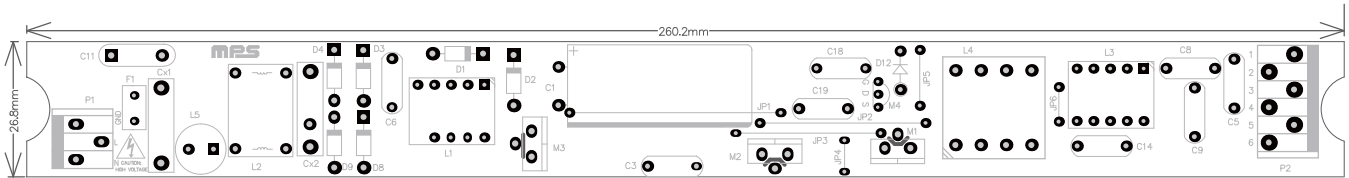


Figure 2—Top Layer

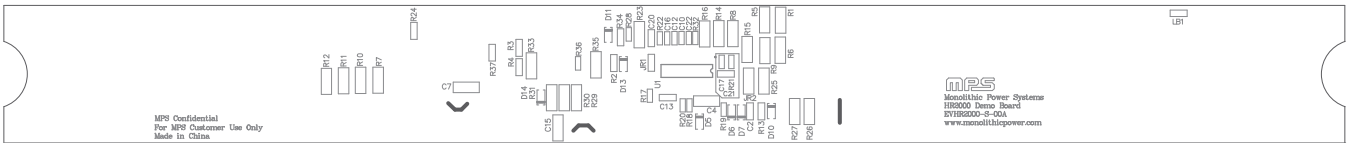


Figure 3—Bottom Silk Layer

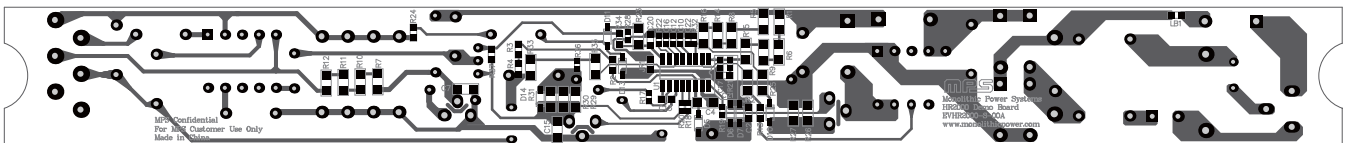


Figure 4—Bottom Layer

## QUICK START GUIDE

1. Connect the fluorescent lamp to EVB's connector 'P2', one side of terminals to '1' and '2' and the other side of terminals to '3' and '4';
2. Preset the AC power supply to  $198V \leq AC \text{ input} \leq 264V$ ; turn off the AC power supply.
3. Connect the AC power supply to 'P1';
4. Turn on the AC power supply, the lamp should be ignited.

**NOTICE:** The information in this document is subject to change without notice. Please contact MPS for current specifications. Users should warrant and guarantee that third party Intellectual Property rights are not infringed upon when integrating MPS products into any application. MPS will not assume any legal responsibility for any said applications.