# EVHR1204-S-00A

## 400W Battery Charger for Power Tools Evaluation Board

## DESCRIPTION

The EVHR1204-S-00A is a 21V/18A 400W Battery charger for power tools.

This reference design is a complete battery charger design for cordless power tool, which is widely used in drilling, grinding, cutting, polishing, and various garden tools. The design can be used in Li-ion and Li-poly chemistry battery with a voltage range from 10V to 21V. The maximum current can support up to 18A. The charger provides constant voltage and constant current control with programmable voltage and current.

The HR1204 integrates a digital PFC controller and a half-bridge resonant controller into a single chip. It uses very low power at no load or ultra-light load.

The PFC of the HR1204 employs a patented average current control scheme, which can operate in continuous conduction mode (CCM) and discontinuous conduction mode (DCM) according to the instantaneous condition of the input voltage and output load.

The half-bridge LLC converter achieves high efficiency with zero-voltage switching (ZVS). The HR1204 implements an adaptive dead-time adjustment (ADTA) function so the LLC converter can easily achieve ZVS from heavy load to light load. Additionally, the HR1204 can prevent the LLC converter from operating in capacitive mode, making it more robust and easier to design.

The EVHR1204-S-00A has excellent efficiency and a high power factor for the entire load range. Full protection features include overload protection; short-circuit protection (SCP), over-voltage protection (OVP), and anti-capacitive mode protection. The EVHR1204-S-00A also meets the Class C standard of IEC61000-3-2 and EN55022 standard.

## ELECTRICAL SPECIFICATIONS

| Parameter | Symbol | Value | Units |
|---|---|---|---|
| Input AC voltage | $V_{IN\_AC}$ | 90 to 265 | V |
| Output current | $I_{OUT}$ | 18 | A |
| Output voltage | $V_{OUT}$ | 10-21 | V |
| Output power | $P_{OUT}$ | 400 | W |
| Efficiency@120V | η | ＞90 | % |
| Output Current Ripple | Δ Iout | ± 10 | % |

## FEATURES

- Wide Operating Input Range (from 90V to 265V)
- Designed to Charge Wide Range of Battery in the Voltage Range of 10 to 21 V
- Delivers up to 18 A of Continuous Charging Current for Fast Charging of Batteries
- High Efficiency up to 90%
- Low Standby Power of < 250 mW When Battery is Not Connected
- Meets Class A Standard of IEC61000-3-2
- Meets EN55022 Standard
- Meets EN61000-4-5 Level 4 for Surge Immunity (4kV)
- High Power Factor (PF)
- Overload Protection (Auto-Restart Mode)
- Short-Circuit Protection (SCP) (Auto-Restart Mode)
- Over-Voltage Protection (OVP)
- Anti-Capacitive Mode Protection

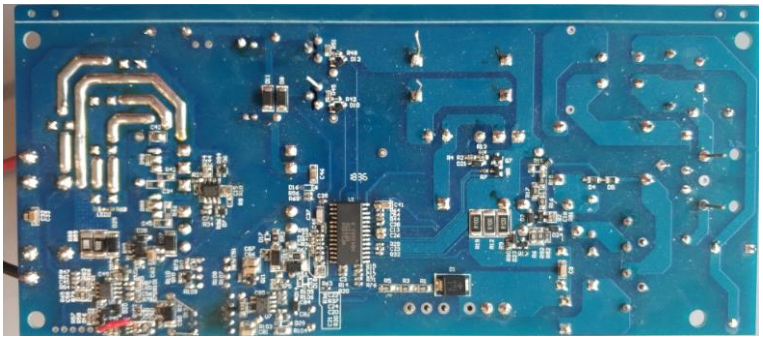
## APPLICATIONS

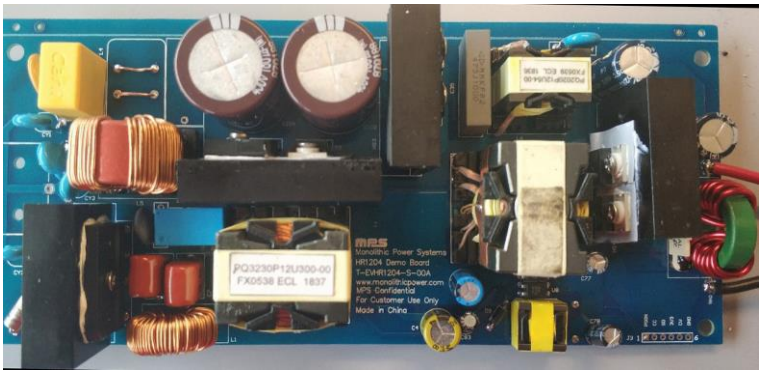
- Cordless Power Tools
- Cordless Garden Tools
- Battery Chargers for
  – Vacuum Cleaner
  – Robotic Mower
  – E-Bike, E-Cycle




**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 AC input to the prototype board.

# EVHR1204-S-00A EVALUATION BOARD

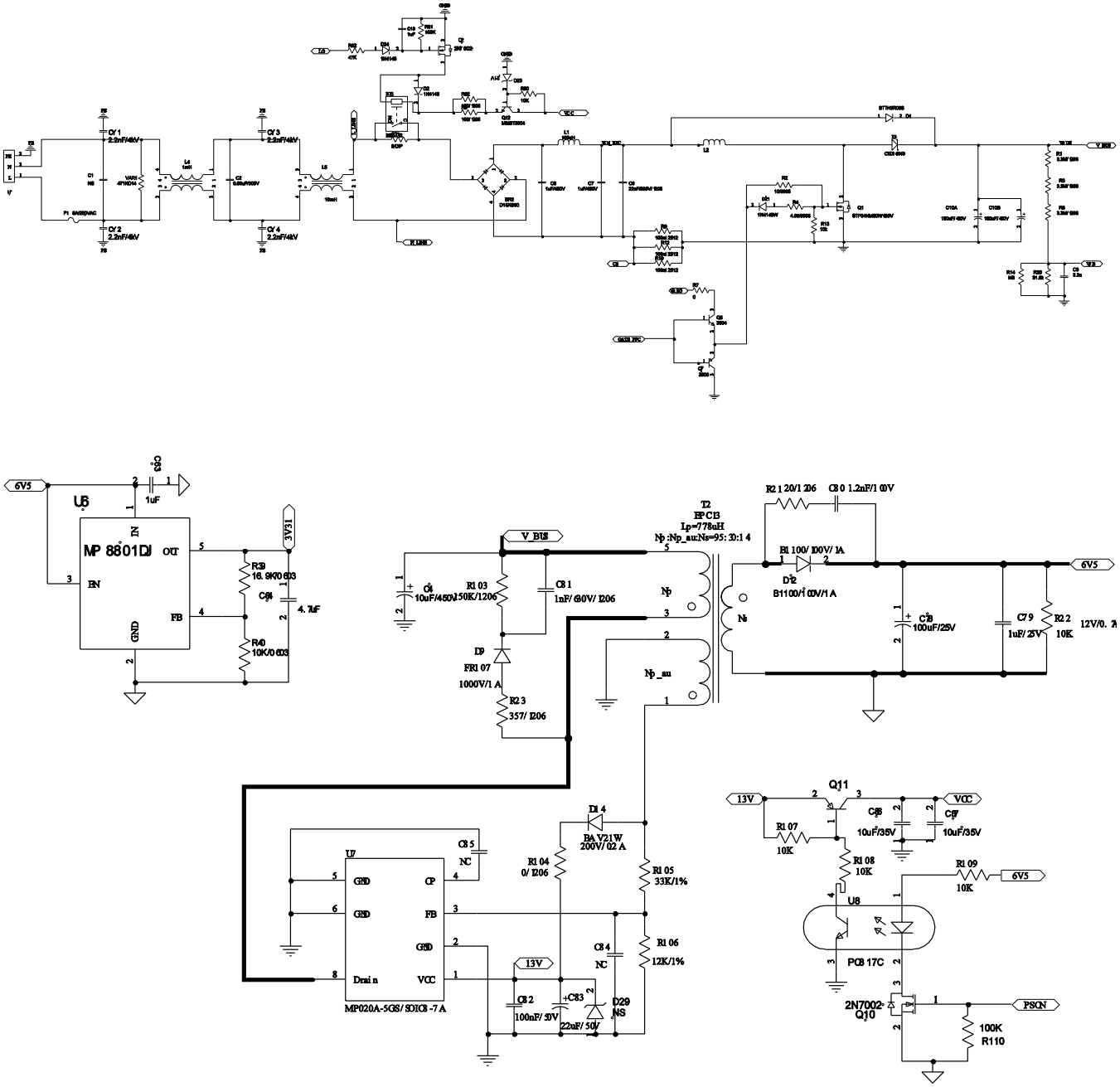


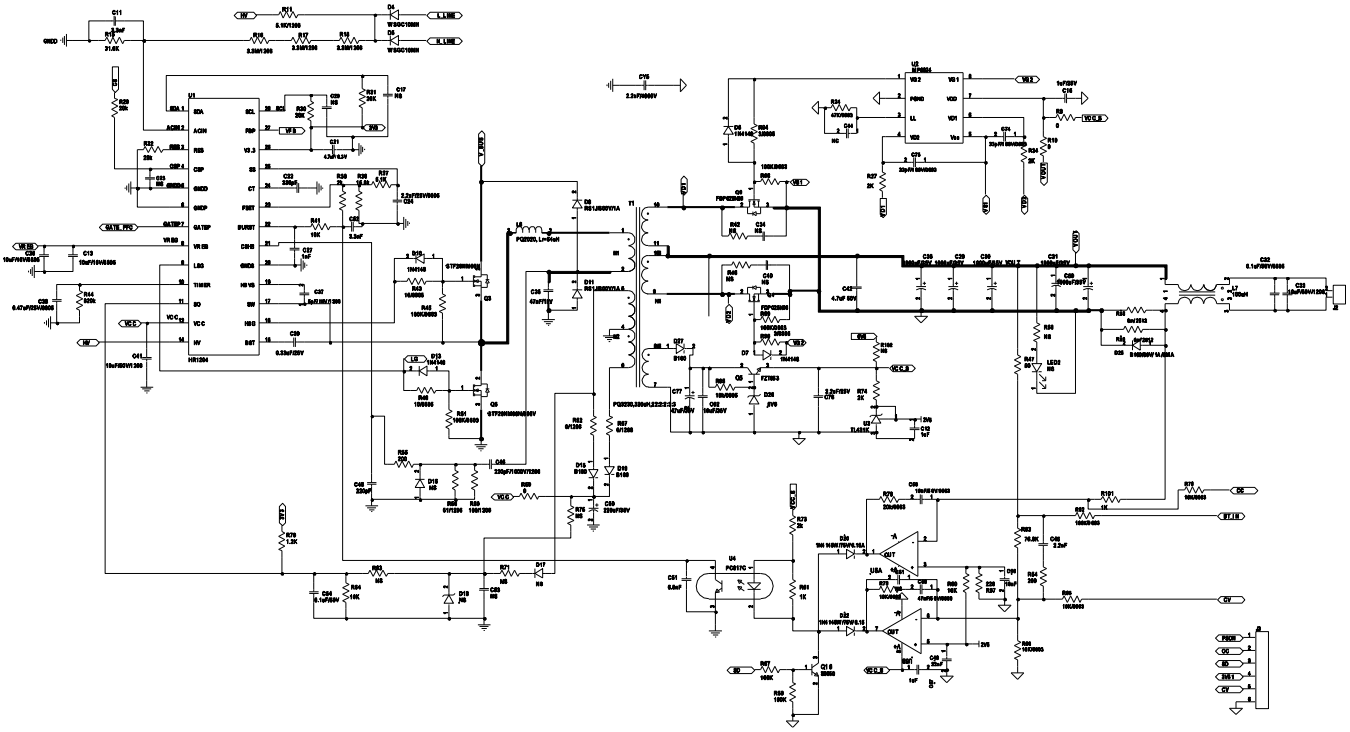


**(L x W x H) (21.4cm x 9cm x 3.5cm)**

| Board Number | MPS IC Number |
|---|---|
| EVHR1204-S-00A | HR1204GM |
| | MP6924DS |
| | MP020A-5GS |
| | MP8801DJ |

# EVALUATION BOARD SCHEMATIC





## EVHR1204-S-00A BILL OF MATERIALS

| Qty | Ref | Value | Description | Package | Manufacturer | Manufacturer P/N |
|---|---|---|---|---|---|---|
| 1 | BR2 | D15XB80 | Bridge rectifier, 800V, 15A | DIP | SHINDEN | D15XB80 |
| 10 | C1, C17, C20, C23, C34, C40, C53, C44, C84, C85 | NS | | | | |
| 1 | C49 | 22nF | Ceramic capacitor, 50V, X7R | 0603 | Murata | GRM188R71H223KA01D |
| 2 | C12, C45 | 2.2nF | Ceramic capacitor, 50V, X7R | 0603 | Murata | GRM188R71H222KA01D |
| 1 | C2 | 0.68uF | X-capacitor, 310V | DIP | CARLI | PX684K2WD69H200D9R |
| 1 | C8 | 22nF | Ceramic capacitor, 630V, X7R | 1206 | TDK | C3216X7R2J223K |
| 1 | C81 | 1nF | Ceramic capacitor, 630V, X7R | 1206 | Murata | GRM31A7U2J102JW31D |
| 2 | C6, C7 | 1uF | Capacitor, 450V, CBB | DIP | CARLI | TF684K2Y10BL270D9R |
| 2 | C10A, C10B | 180uF | Electrolytic capacitor, 450V | DIP | JIANGHAI | CD263-450V180 |
| 2 | C3, C11 | 3.3nF | Ceramic capacitor, 50V, X7R | 0603 | Murata | GRM188R71H332KA01D |
| 2 | C13, C26 | 10uF | Ceramic capacitor, 16V, X7R | 0805 | Murata | GRM21BR61C106KE15L |
| 6 | C15, C57, C18, C12, C63, C79 | 1uF | Ceramic capacitor, 50V, X5R | 0603 | Murata | GRM188R61H105KAAL |
| 2 | C21, C64 | 4.7uF | Ceramic capacitor, 6.3V, X7R | 0603 | Murata | GRM188R60J475ME19D |
| 1 | C22 | 330pF | Ceramic capacitor, 50V, COG | 0603 | Murata | C1608COG1H331J |
| 2 | C24,C76 | 2.2uF | Ceramic capacitor, 25V, X7R | 0805 | Murata | GRM21BR71E225KA73L |
| 2 | C27,C48 | 1nF | Ceramic capacitor, 50V, X7R | 0603 | Murata | GRM188R71H102KA01D |
| 5 | C29, C30, C31, C59, C36 | 1000uF | Electrolytic capacitor, 35V | DIP | JIANGHAI | CD287-35V1000 |
| 1 | C32 | 0.1uF | Ceramic capacitor, 50V, X7R | 0805 | Murata | GRM21BR71H104KA01L |
| 4 | C33, C41, C86, C87 | 10uF | Ceramic capacitor, 50V, X5R | 1206 | Murata | GRM31CR61H106KA12L |
| 1 | C60 | 10nF | Ceramic capacitor, 50V, X7R | 0603 | Murata | GRM188R71H103KA01D |
| 1 | C35 | 47nF | Capacitor, 1000V | DIP | FaLa | MMKP82-1000V-473P |
| 1 | C37 | 5pF | Ceramic capacitor, 3000V, NP0 | 1206 | HHEC | C1206N5R0J302T |

## EVHR1204-S-00A BILL OF MATERIALS (*continued*)

| Qty | Ref | Value | Description | Package | Manufacturer | Manufacturer P/N |
|---|---|---|---|---|---|---|
| 1 | C38 | 470nF | Ceramic capacitor, 25V, X7R | 0603 | Murata | GRM188R71E474KA12D |
| 1 | C39 | 330nF | Ceramic capacitor, 25V, X7R | 0603 | Murata | GRM188R71E334KA12D |
| 1 | C46 | 220pF | Ceramic capacitor, 1000V, U2J | 1206 | Murata | GMR31A7U3A221JW31D |
| 1 | C50 | 220µF | Electrolytic capacitor, 35V | DIP | JIANGHAI | CD110-35V220 |
| 2 | C51, C52 | 6.8nF | Ceramic capacitor, 50V, X7R | 0603 | Murata | GRM188R71H682KA01D |
| 1 | C42 | 4.7uF | Ceramic capacitor, 50V, X7R | 1210 | Murata | GRM32ER71H475KA88L |
| 1 | C54, C82 | 100nF | Ceramic capacitor, 50V, X7R | 0603 | Murata | GRM188R71H104KA93D |
| 1 | C56 | 12nF | Ceramic capacitor, 50V, X7R | 0603 | Murata | GRM188R71H123KA01D |
| 1 | C58 | 47nF | Ceramic capacitor, 50V, X7R | 0603 | Murata | GRM188R71H473KA01D |
| 2 | C74, C75 | 33pF | Ceramic capacitor, 100V, X7R | 0603 | Murata | GRM1885C1H330JA01D |
| 1 | C77 | 47uF | Electrolytic capacitor, 50V | DIP | JIANGHAI | CD287-50V47 |
| 1 | C78 | 100uF | Electrolytic capacitor, 25V | DIP | Rubycon | 25YXF100M6.3X11 |
| 1 | C4 | 10uF | Electrolytic capacitor, 450V | DIP | 永铭 | LKM_450V_10uF_10*14 |
| 1 | C62 | 10uF | Ceramic capacitor, 35V, X7R | 1206 | TDK | C3216X7R2V106K |
| 1 | C80 | 1.2nF | Ceramic capacitor, 100V, X7R | 0603 | Murata | GRM188R72A122KA01D |
| 1 | C83 | 22uF | Electrolytic capacitor, 50V | DIP | JIANGHAI | CD281L-50V22 |
| 5 | CY1, CY2, CY3, CY4, CY5 | 2.2nF/2600V | Y-capacitor, 2600V, 20% | DIP | 鸿科 | JYK09F222MY72N |
| 2 | D8, D11 | RS1J | Diode, 600V, 1A | SMA | Diodes | RS1J-13-F |
| 1 | D1 | S5J | Diode, 600V, 5A | SMC | 邦达园 | S5J |
| 1 | D3 | C3D06060 | Diode, 600V, 6A | TO-220 | CREE | C3D06060 |
| 2 | D4, D5 | WSRGC10MH | Diode, 1000V, 1A | 1206 | ZOWIE | WSRGC10MH |
| 8 | D2, D10, D13, D20, D21, D22, D24,D26 | 1N4148W | Diode, 75V, 0.15A | SOD-123 | Diodes | 1N4148W |
| 2 | D6,D7 | 1N4148WS | Diode, 75V, 0.15A | SOD-323 | Diodes | 1N4148WS-7 |
| 1 | D12 | B1100 | Schottky diode, 100V, 1A | SMA | Diodes | B1100-13-F |

## EVHR1204-S-00A BILL OF MATERIALS (*continued*)

| Qty | Ref | Value | Description | Package | Manufacturer | Manufacturer P/N |
|---|---|---|---|---|---|---|
| 1 | D14 | BAV21W | Diode, 200V, 0.2A | SOD-123 | Diodes | BAV21W-7-F |
| 4 | D15, D19, D25,D27 | B160 | Schottky diode, 60V, 1A | SMA | Diodes | B160 |
| 4 | D16, D17, D18, D29 | NS | | | | |
| 1 | D23 | BZT52C22 | Zener diode, 22V, 5mA/500mW | SOD-123 | Diodes | BZT52C22 |
| 1 | D28 | BZT52C5V6 | Zener diode, 22V, 5mA/500mW | SOD-123 | Diodes | BZT52C5V6 |
| 1 | D9 | FR107 | Diode, 1000V, 1A | DO-41 | MIC | FR107 |
| 1 | F1 | 0216008.MXEP | Fuse, 250V, 8A | DIP | Little | 0216008.MXEP |
| 1 | L1 | 300µH | Filter inductor, 300µH, 3A | DIP | Wurth | 7447065 |
| 1 | L2 | 300uH | PFC inductor, L = 300µH, PQ3230 | DIP | Emei | FX0538 |
| 1 | L4 | 1mH | Common choke, 1mH, 3A | DIP | Wurth | 744822301 |
| 1 | L5 | 10mH | Common choke, 10mH, 5A | DIP | Wurth | 744825510 |
| 1 | L6 | 54uH | Resonant inductor, PQ2020 | DIP | Emei | FX0539 |
| 1 | L7 | 104uH | Common choke, 104uH, 40A | DIP | CoilCraft | CU8995-AL |
| 1 | LED2 | NS | | | | |
| 1 | Q1 | STW26NM60 | N-channel MOSFET, 600V, 30A | TO-247 | ST | STW26NM60 |
| 2 | Q4, Q9 | FDP025N06 | N-channel MOSFET, 600V, 25A | TO-220-3 | Faichild | FDP025N06 |
| 2 | Q3, Q6 | STF26NM60 | N-channel MOSFET, 600V, 20A | TO-220F | ST | STF26NM60 |
| 4 | Q12, Q8, Q16, Q5 | MMBT3904LT1G | Transistor, 40V, 0.2A | SOT-23 | Onsemi | MMBT3904LT1G |
| 1 | Q5 | BCX5510TA | Transistor, 60V, 1A | SOT-89-3 | Diodes | BCX5510TA |
| 2 | Q7, Q11 | MMBT3906LT1G | Transistor, -40V, 0.2A | SOT-23 | Onsemi | MMBT3906LT1G |
| 3 | Q2, Q13, Q10 | 2N7002MTF | N-channel MOSFET, 60V, 115mA | SOT-23 | Faichild | 2N7002MTF |
| 3 | R52, R67, R104 | 0 | Film resistor, 1% | 1206 | Yageo | RC1206FR-070RL |
| 6 | R1, R3, R5, R16, R17, R18 | 3.3M | Film resistor, 1% | 1206 | Yageo | RC1206FR-073M3L |
| 1 | R11 | 5.1K | Film resistor, 1% | 1206 | Yageo | RL1206FR-075K1L |

## EVHR1204-S-00A BILL OF MATERIALS (*continued*)

| Qty | Ref | Value | Description | Package | Manufacturer | Manufacturer P/N |
|---|---|---|---|---|---|---|
| 3 | R9, R12, R19 | 100m | Film resistor, 1% | 2512 | Yageo | RL2512FK-070R1L |
| 12 | R40, R41, R64, R79, R66, R65, R70, R60, R107, R108, R109, R22 | 10K | Film resistor, 1% | 0603 | Yageo | RC0603FR-0710KL |
| 10 | R14, R42, R46, R63, R68, R71, R75, R97, R8, R61 | NS | | | | |
| 2 | R15, R20 | 31.6K | Film resistor, 1% | 0603 | Yageo | RC0603FR-0731K6L |
| 15 | R13, R45, R51, R81, R86, R97, R98, R99, R110, R84, R62, R57, R58, R86, R80 | 100K | Film resistor, 1% | 0603 | Yageo | RC0603FR-07100KL |
| 1 | R24 | 47K | Film resistor, 1% | 0603 | Yageo | RC0603FR-0747KL |
| 1 | R23 | 357 | Film resistor, 1% | 1206 | Yageo | RC1206FR-07357RL |
| 3 | R27, R34,R74 | 2K | Film resistor, 1% | 0805 | Yageo | RC0805FR-072KL |
| 1 | R29 | 20K | Film resistor, 1% | 0805 | Yageo | RC0805FR-0720KL |
| 4 | R30, R31, R32, R78 | 20K | Film resistor, 1% | 0603 | Yageo | RC0603FR-0720KL |
| 1 | R36 | 15.8K | Film resistor, 1% | 0603 | Yageo | RC0603FR-0715K8L |
| 1 | R37 | 5.1K | Film resistor, 1% | 0603 | Yageo | RC0603FR-075K1L |
| 1 | R38 | 2K | Film resistor, 1% | 0603 | Yageo | RC0603FR-072KL |
| 1 | R39 | 16.9K | Film resistor, 1% | 0603 | Yageo | RC0603FR-0716K9L |
| 1 | R87 | 220 | Film resistor, 1% | 0603 | Yageo | RC0603FR-07220RL |
| 3 | R2, R43, R48 | 10 | Film resistor, 1% | 0805 | Yageo | RC0805FR-0710RL |
| 1 | R21 | 20 | Film resistor, 1% | 1206 | Yageo | RL1206FR-0720RL |
| 1 | R4 | 4.99 | Film resistor, 1% | 0805 | Yageo | RC0805FR-074R99L |
| 1 | R44 | 820K | Film resistor, 1% | 0603 | Yageo | RC0603FR-07820KL |
| 1 | R47 | 50 | Film resistor, 1% | 0603 | Yageo | RC0603FR-0750RL |
| 2 | R54, R55 | 200 | Film resistor, 1% | 0603 | Yageo | RC0603FR-07200RL |
| 1 | R56 | 51 | Film resistor, 1% | 0603 | Yageo | RC0603FR-0751RL |
| 1 | R69 | 100 | Film resistor, 1% | 0603 | Yageo | RC0603FR-07100RL |
| 4 | R59, R7, R102, R10 | 0 | Film resistor, 1% | 0603 | Yageo | RC0603FR-07oRL |

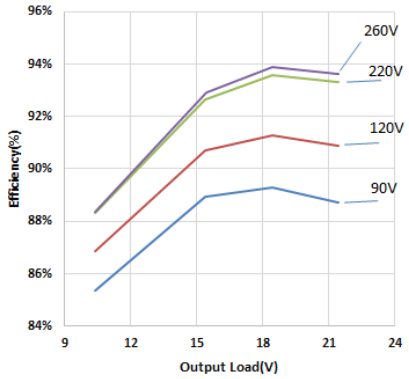
## EVHR1204-S-00A BILL OF MATERIALS*(continued)*

| Qty | Ref | Value | Description | Package | Manufacturer | Manufacturer P/N |
|---|---|---|---|---|---|---|
| 2 | R101 | 1K | Film resistor, 1% | 0603 | Yageo | RC0603FR-071KL |
| 4 | R6, R92, R72, R91 | 10 | Film resistor, 1% | 1206 | Yageo | RL1206FR-0710RL |
| 1 | R73 | 1.5K | Film resistor, 1% | 0603 | Yageo | RC0603FR-071K5L |
| 1 | R76 | 1.2K | Film resistor, 1% | 0805 | Yageo | RC0805FR-071K2L |
| 1 | R82 | 47K | Film resistor, 1% | 0603 | Yageo | RC0603FR-0747KL |
| 1 | R83 | 76.8K | Film resistor, 1% | 0603 | Yageo | RC0603FR-0776K8L |
| 1 | R103 | 150K | Film resistor, 1% | 1206 | Yageo | RL1206FR-076K8L |
| 1 | R85 | 10K | Film resistor, 1% | 0805 | Yageo | RC0805FR-0710KL |
| 2 | R88, R89 | 6m | Film resistor, 1% | 2512 | 旺诠 | LR2515-22R006F4 |
| 2 | R94, R96 | 3 | Film resistor, 1% | 0805 | Yageo | RC0805FR-073RL |
| 1 | R105 | 33K | Film resistor, 1% | 0603 | Yageo | RC0603FR-0733KL |
| 1 | R106 | 12K | Film resistor, 1% | 0603 | Yageo | RC0603FR-0712KL |
| 1 | RT1 | 5 | Thermal resistor | DIP | 江苏兴顺 | 5D2-10 |
| 2 | RY1,RY2 | OJE-SS-112HMF | Electric relay | DIP | TYCO | OJE-SS-112HMF |
| 1 | T1 | 316uH | Transformer, Lp = 316uH N1:N2:N3:N4:N5 = 22:2:2:3:3, PQ3230 | DIP | Emei | FX0537 |
| 1 | T2 | 778uH | Transformer, Lp = 778uH N1:N2:N3 = 95:30:14, EPC13 | DIP | Emei | |
| 1 | U1 | HR1204 | PFC + LLC combo controller | SOIC-28 | MPS | HR1204GY-0001-Z |
| 1 | U2 | MP6924 | SR controller | SOIC-8 | MPS | MP6924AGS-Z |
| 2 | U4, U8 | PC817C | Photocoupler, 1-channel | DIP | Sharp | PC817C |
| 1 | U5 | LM358 | Dual Operational Amplifiers | SOIC-8 | TI | LM358ADR |
| 1 | U3 | TL431 | Shunt regulator, $V_{REF}$ = 2.5V | SOT-23 | TI | TL431AIDBZR |
| 1 | U6 | MP8801 | Linear regulator | SOT-23 | MPS | MP8801DJ-3.3-LF-Z |
| 1 | U7 | MP020A | Flyback controller | SOIC8-7A | MPS | MP020A-5GS |
| 2 | VAR1, VAR2 | 471KD14 | MOV | DIP | TKS | TVR14471KS42Y |
| 1 | HS1 | | Heatsink for BRIDGE | DIP | | |
| 1 | HS2 | | Heatsink for PFC rectifier DIODE | DIP | | |
| 1 | HS3 | | Heatsink for LLC primary MOSFETs | DIP | | |
| 1 | HS4 | | Heatsink for SR MOSFETs | DIP | | |

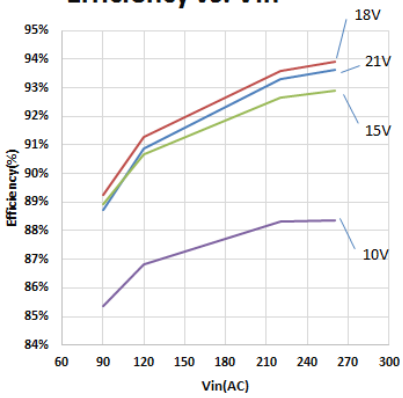
# EVB TEST RESULTS

**Performance waveforms are tested on the evaluation board.**
**$V_{IN\_AC}$ = 90V to 265V, $V_{OUT}$ = 21V, $I_{OUT}$ = 18A, $P_{OUT}$ = 400W**

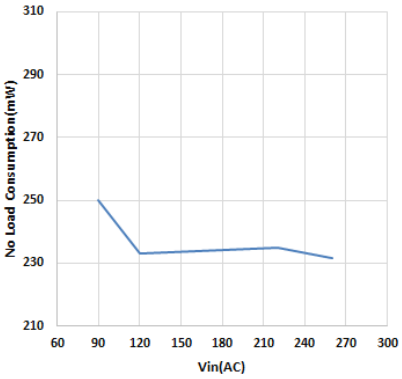
### Efficiency vs. Load



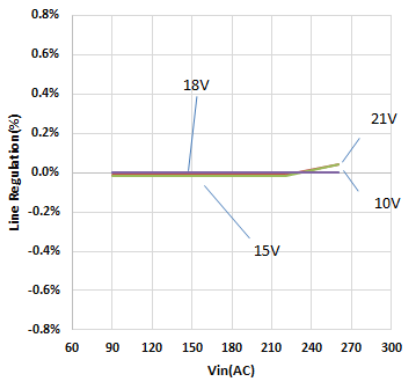

### Efficiency vs. Vin



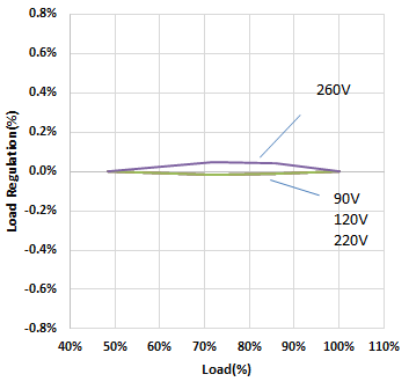

### No Load Consumption



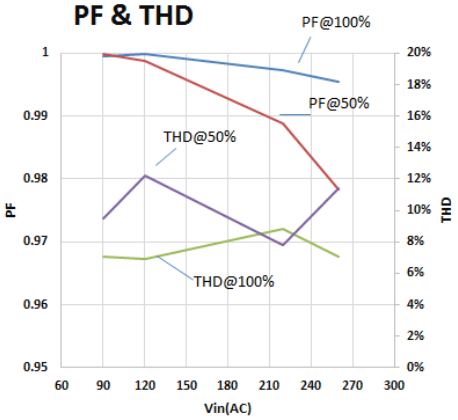

### Line Regulation




### Load Regulation

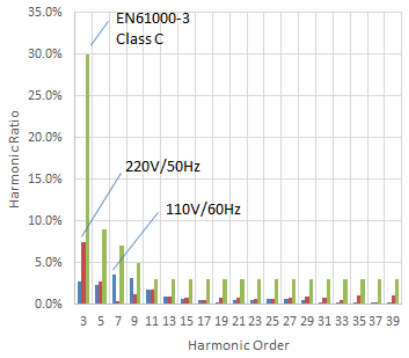



### PF & THD

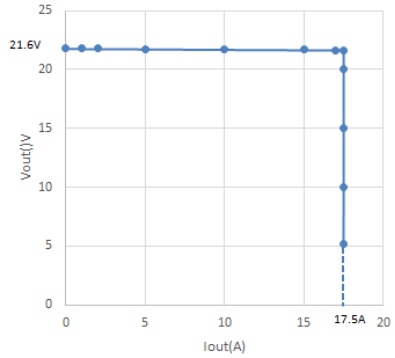



### HARMONIC

Vin=110VAC/60Hz&220V/50Hz,Full Load



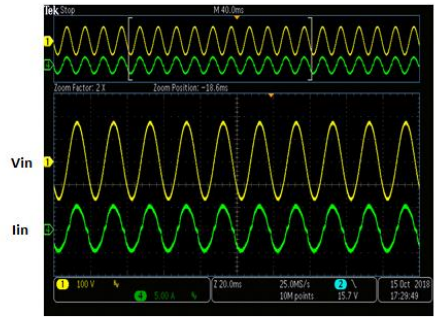

### CC/CV



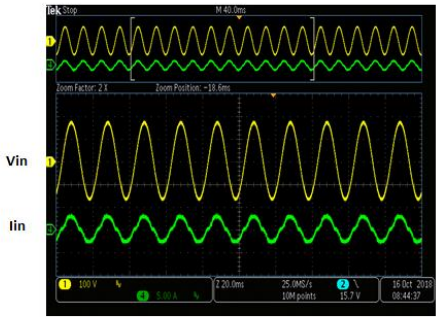
## EVB TEST RESULTS *(continued)*

**Performance waveforms are tested on the evaluation board.**
**$V_{IN\_AC}$ = 90V to 265V, $V_{OUT}$ = 21V, $I_{OUT}$ = 18A, $P_{OUT}$ = 400W, CV Load**

**Input Voltage & Current**
Vin=120VAC, Vo=21V,Io=18A



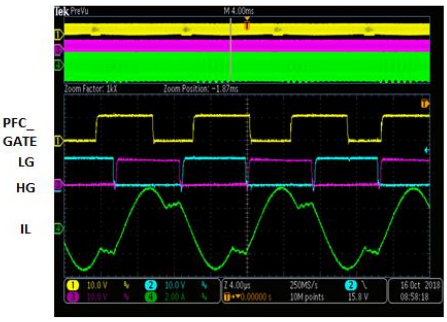

**Input Voltage & Current**
Vin=120VAC, Vo=10V,Io=18A



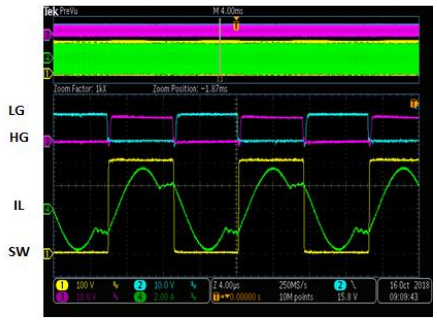

**Input Voltage & Current**
Vin=220VAC, Vo=21V,Io=18A


**Input Voltage & Current**
Vin=220VAC, Vo=10V,Io=18A

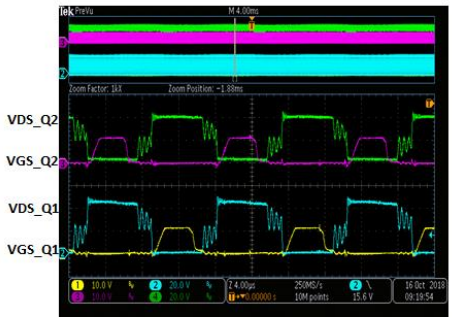

**Steady State**
Vin=120VAC, Vo=21V,Io=18A




**LLC Stage**
Vin=120VAC, Vo=21V,Io=18A




**SR Operation**
Vin=120VAC, Vo=21V,Io=18A

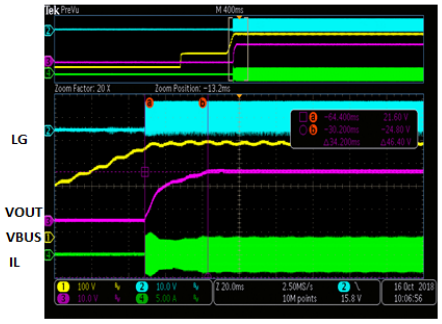


## EVB TEST RESULTS *(continued)*

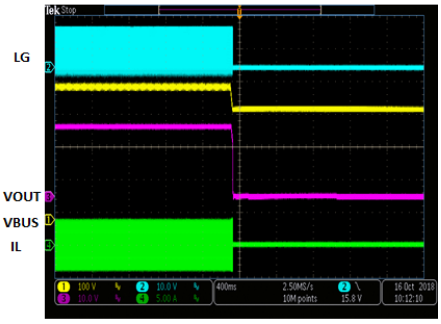
**Performance waveforms are tested on the evaluation board.**
**$V_{IN\_AC}$ = 90V to 265V, $V_{OUT}$ = 21V, $I_{OUT}$ = 18A, $P_{OUT}$ = 400W, CV Load**

**Start-Up**
Vin=120VAC, Vo=21V,Io=18A

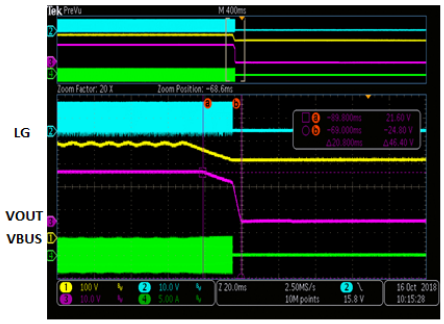

**Output Rise Time**
Vin=120VAC, Vo=21V,Io=18A



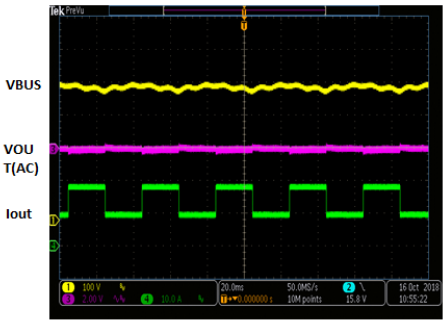

**Shutdown**
Vin=120VAC, Vo=21V,Io=18A



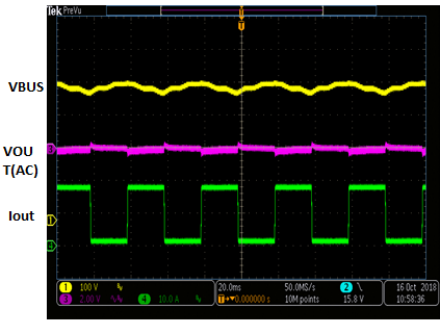

**Hold up time**
Vin=120VAC, Vo=21V,Io=18A




**Load Transient**
Vin=120VAC, 9A-18A

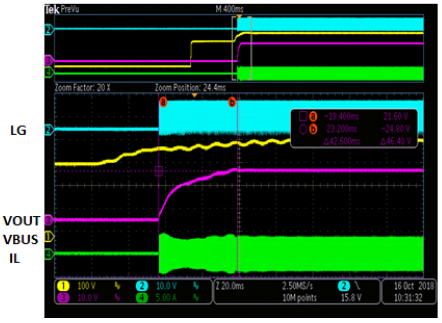



**Load Transient**
Vin=120VAC, 1A-18A

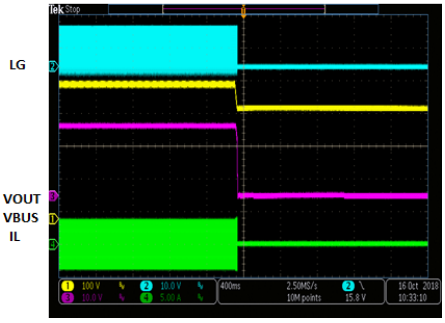



**Start-up**
Vin=220VAC, Vo=21V,Io=18A


**Output Rise time**
Vin=220VAC, Vo=21V,Io=18A



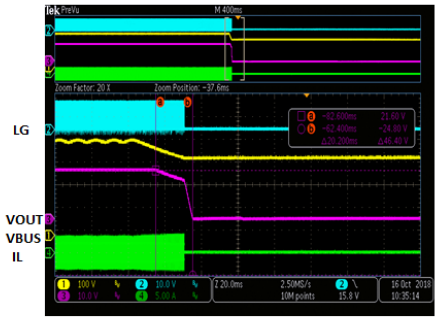

**Shutdown**
Vin=220VAC, Vo=21V,Io=18A



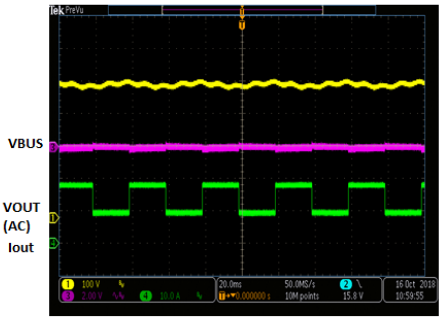
# EVB TEST RESULTS *(continued)*

**Performance waveforms are tested on the evaluation board.**
**$V_{IN\_AC}$ = 90V to 265V, $V_{OUT}$ = 21V, $I_{OUT}$ = 18A, $P_{OUT}$ = 400W, CV Load**

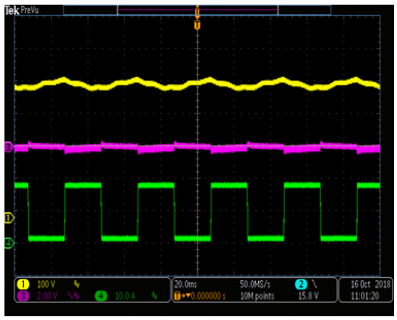
### Hold up time
Vin=220VAC, Vo=21V,Io=18A



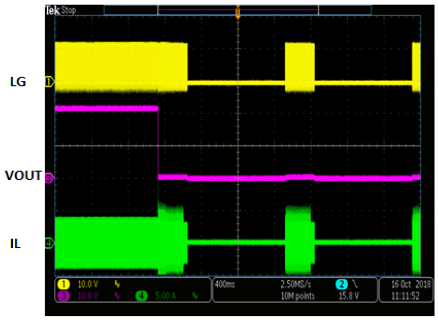

### Load Transient
Vin=220VAC, 9A-18A




### Load Transient
Vin=220VAC, 9A-18A

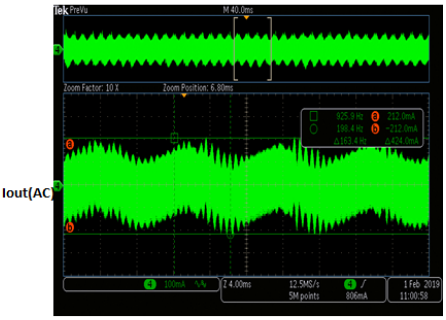



### SCP Entry
Vin=120VAC, Vo=21V,Io=18A



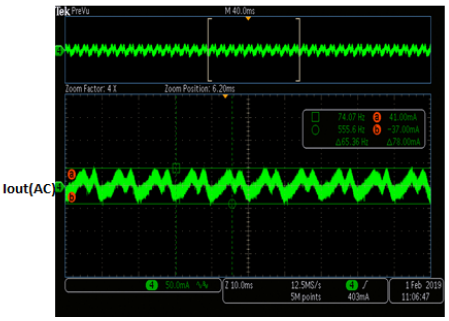

### SCP Recovery
Vin=120VAC, Vo=21V,Io=18A


### Output Current Ripple
Vin=120VAC, Vo=21V,Io=18A




### Output Current Ripple
Vin=120VAC, Vo=15V,Io=18A


### Output Current Ripple
Vin=120VAC, Vo=10V,Io=18A



# PRINTED CIRCUIT BOARD LAYOUT

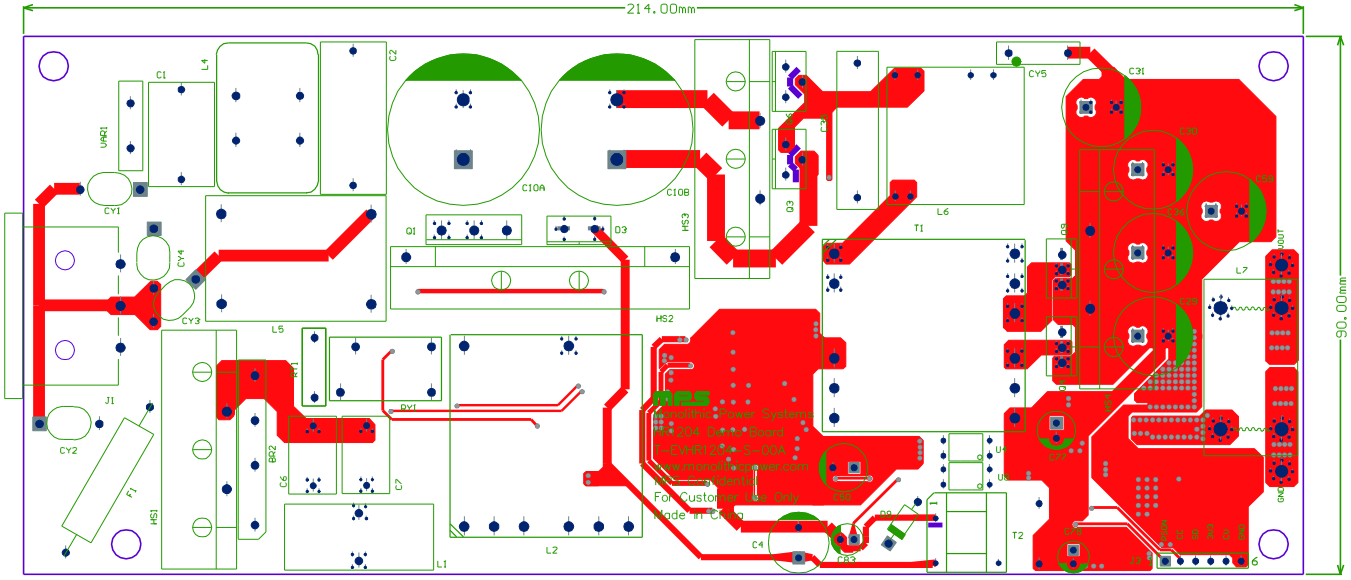



**Figure 1: Top Layer**

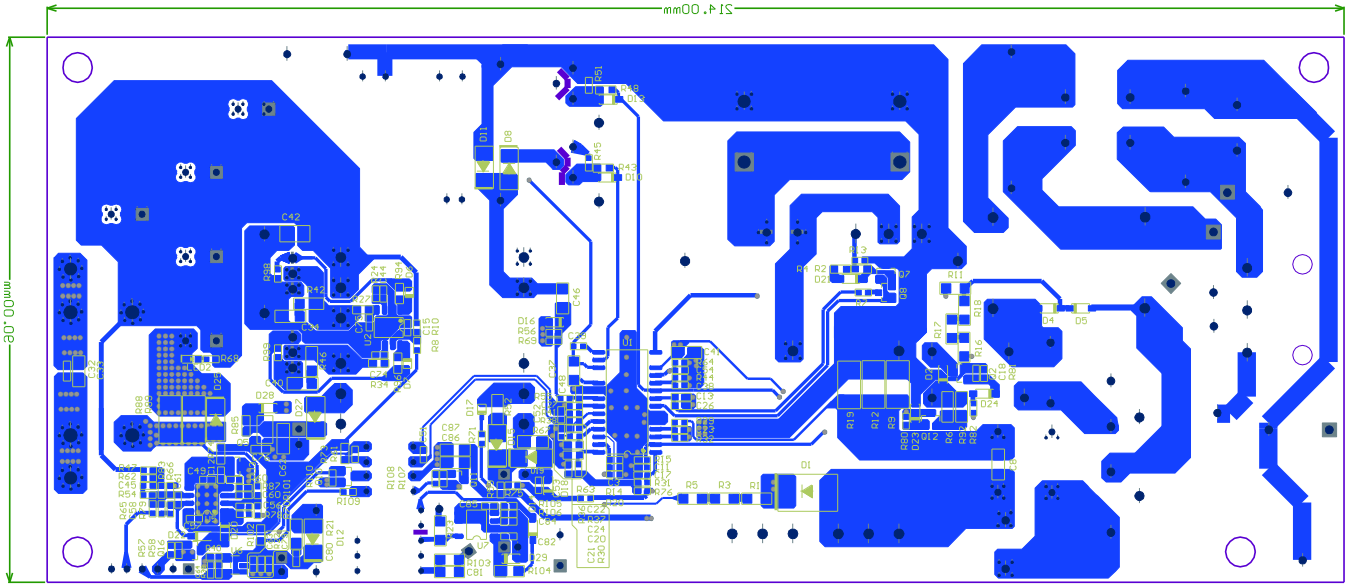



**Figure 2: Bottom Layer**

## SURGE TEST

Line-to-line 4kV and line-to-power earth 4kV surge testing was completed according to EN61000-4-5 Level 4.

The input voltage was set at $220V_{AC}$/50Hz. The output was loaded at full load, and operation was verified following each surge event (see Table 1).

**Table 1: Surge Test Results**

| Surge Level (V) | Input Voltage ($V_{AC}$) | Injection Location | Injection Phase (°) | Test Result (Pass/Fail) |
|---|---|---|---|---|
| 4000 | 220 | L to N | 90 | Pass |
| -4000 | 220 | L to N | 270 | Pass |
| 4000 | 220 | L to PE | 90 | Pass |
| -4000 | 220 | L to PE | 270 | Pass |
| 4000 | 220 | N to PE | 90 | Pass |
| -4000 | 220 | N to PE | 270 | Pass |

## CONDUCTED EMI TEST

Figure 3 shows the test with a $220V_{AC}$ input and full-load in L-line condition.

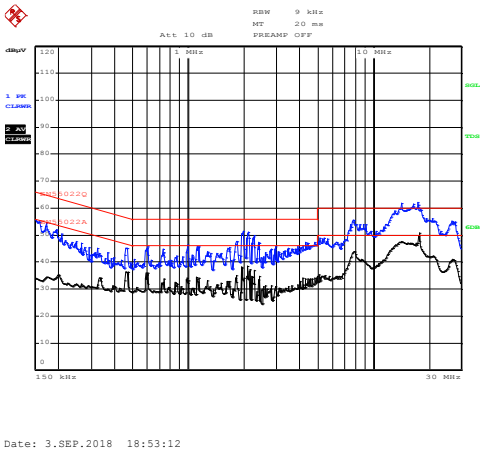



**Figure 3: $220V_{AC}$, 50Hz, Maximum Load, L-line, EN55022 Limits**

Figure 4 shows the test with a $220V_{AC}$ input and full-load in N-line condition.

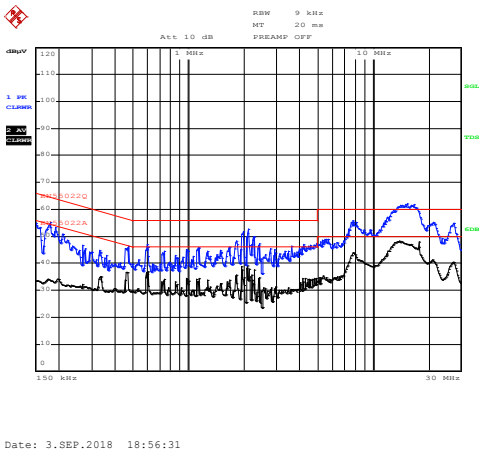
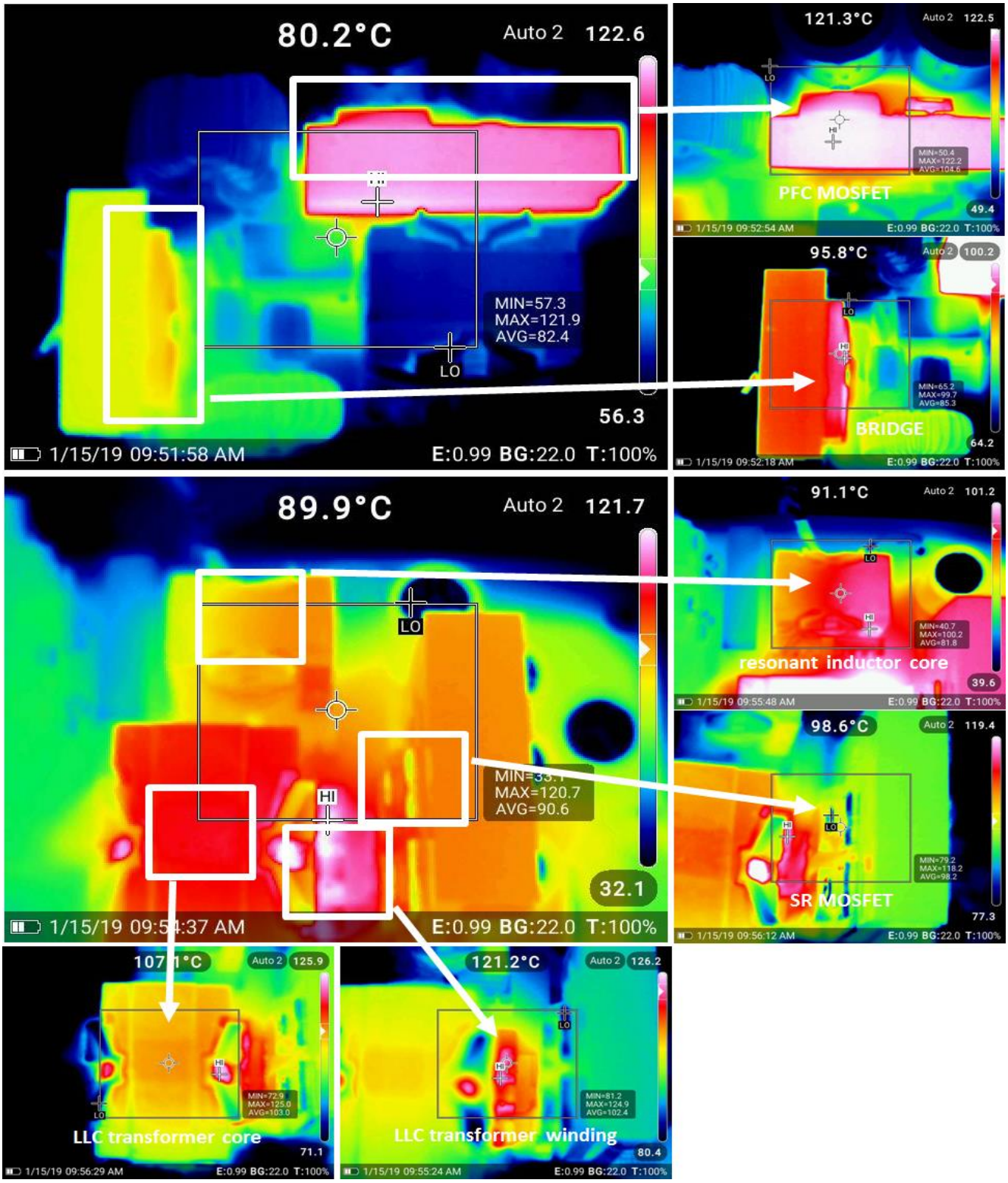


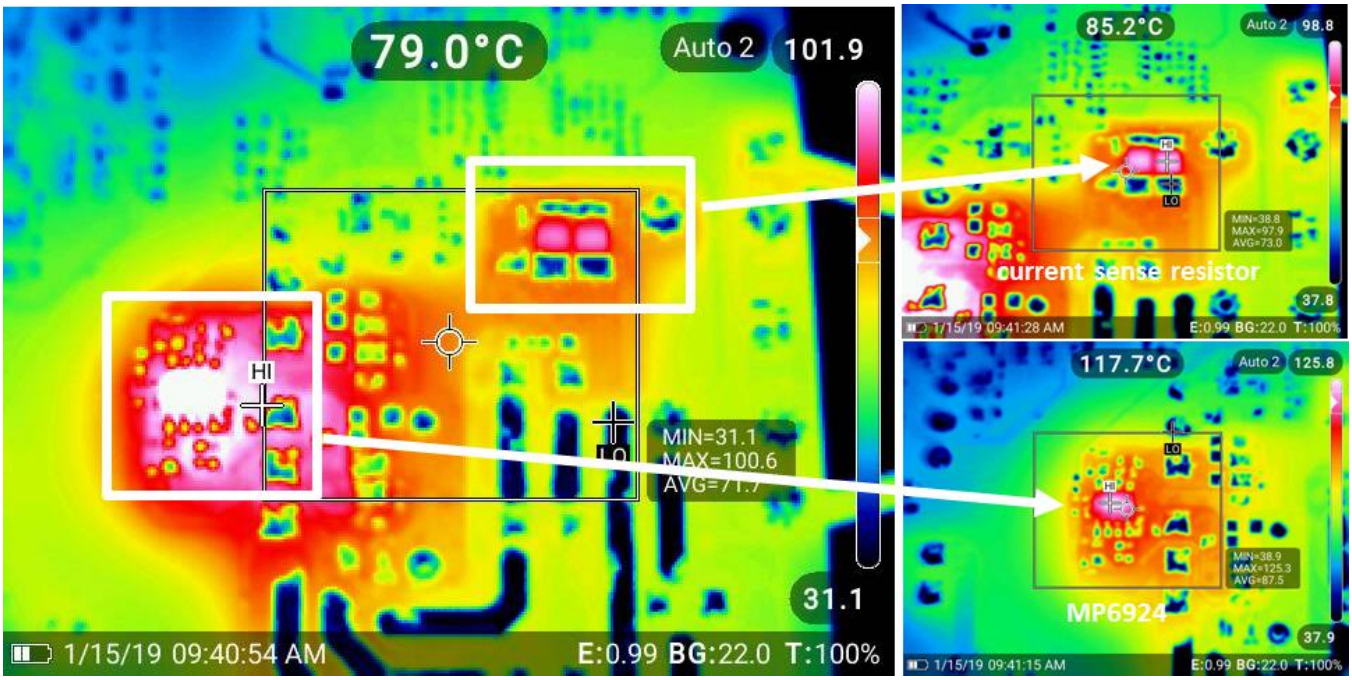

**Figure 4: $220V_{AC}$, 50Hz, Maximum Load, N-line, EN55022 Limits**

## THERMAL TEST

Figure 5 shows the test with 120$V_{AC}$ input and full-load condition. The PCB layout is with 2oz copper. The ambient temperature is 27°C without air flow.




**Top Layer**




**Bottom Layer**

**Figure 5: Temperature Chamber Test**

## QUICK START GUIDE

To quick start the EVB, follow the steps below.

1. Pre-set the power supply to $90V_{AC} \leq V_{IN} \leq 265V_{AC}$.
2. Turn the power supply off.
3. Connect the line and neutral terminals of the power supply output to the L and N ports. For three-wire input applications, connect the earth terminal to the earth port.
4. Connect the positive (+) load to VOUT.
5. Connect the negative (–) load to GND.
6. Turn the power supply on after making the connections.

## CONTACT INFORMATION

To request this evaluation board, please refer to your local sales office:
http://www.monolithicpower.com/Company/Contact-Us

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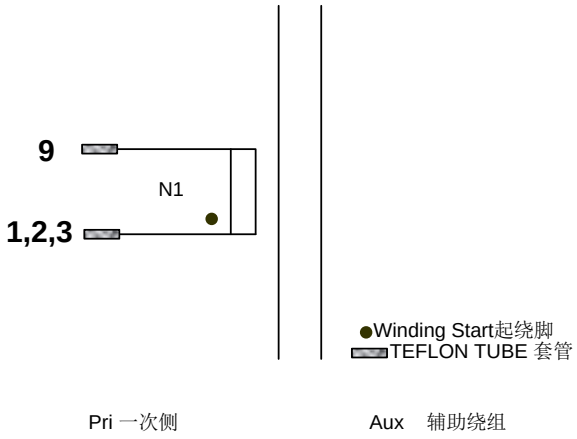
## REVISION HISTORY

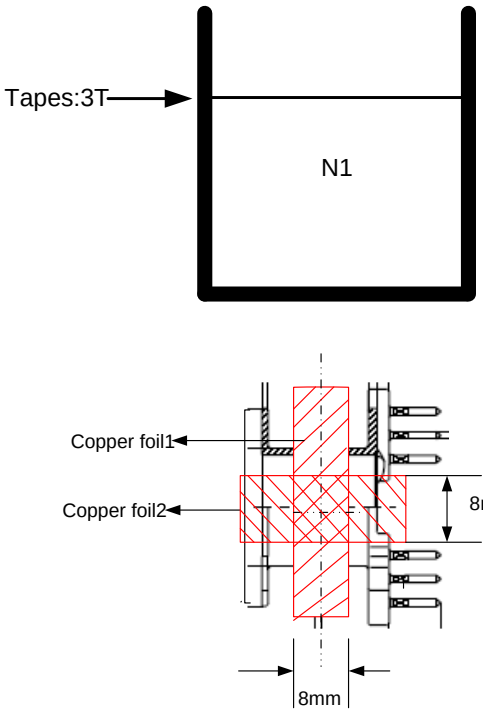
| Date | Author | Revision | Description & Changes | Reviewed |
|---|---|---|---|---|
| | | | | |
| | | | | |

# APPENDIX 1: PFC INDUCTOR SPECIFICATION

### Electrical Diagram



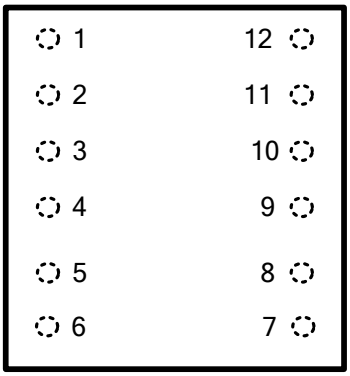

### Winding Diagram




**Note:** ***Core is wrapped with copper foils, as shown above. Connect the foils to pin 12 of the bobbin with wires.***

### Pin Definition of Bobbin

Pin out




View from the top

**Table 2: Electrical Characteristic**

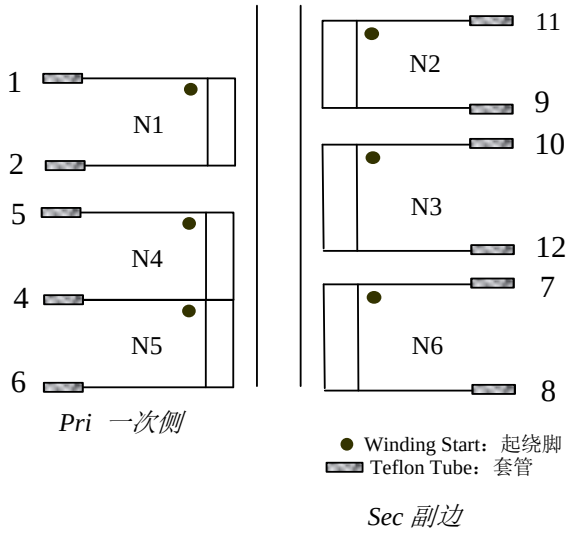
| Parameter | Condition | Value |
|---|---|---|
| Primary inductance | L (9-1,2,3) | 300μH ±10% |
| Core | | PQ3230 |
| Bobbin | | PQ3230 |
| Core material | | DMR40 or equivalent |
| Turn ratio | N1 | |

**Table 3: Winding Specification**

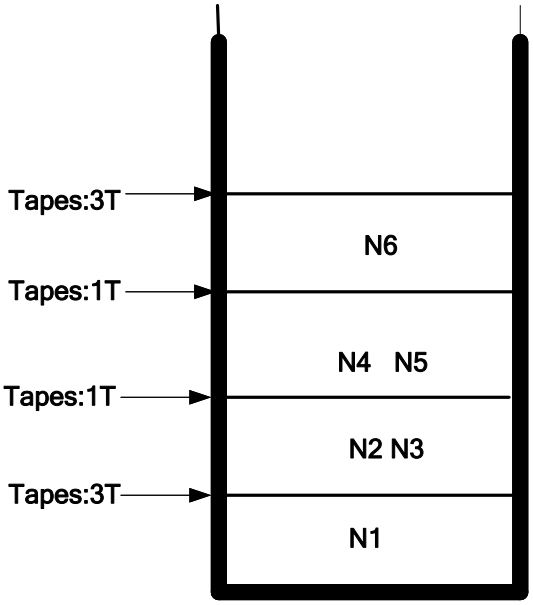
| Tape Turns | Winding No. | Margin Tapes | Start and End | Wire Diameter (mm) | Turns |
|---|---|---|---|---|---|
| 1 | N1 | | 9→1,2,3 | 0.1x100 | 50 |

# APPENDIX 2: LLC TRANSFORMER SPECIFICATION

### Electrical Diagram




### Winding Diagram




### Pin Definition of Bobbin

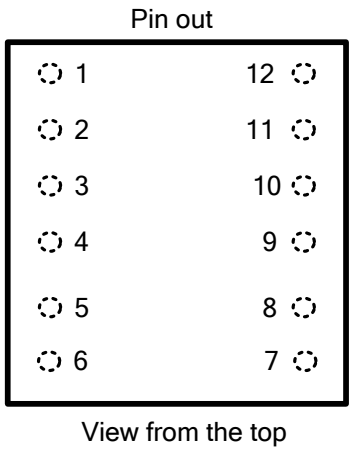



**Table 4: Electrical Characteristic**

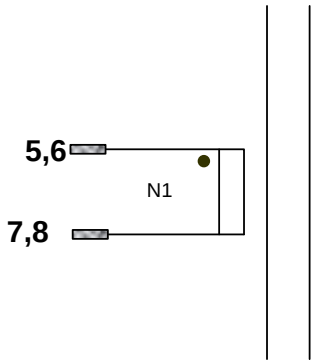
| Parameter | Condition | Value |
|---|---|---|
| Primary inductance | Lp (1-2) | 320uH ±5% |
| Core | | PQ3230 |
| Bobbin | | PQ3230 |
| Core material | | DMR44 or equivalent |
| Turn ratio | N1:N2:N3:N4:N5:N6 | 22:2:2:3:3:2 |

**Table 5: Winding Specification**

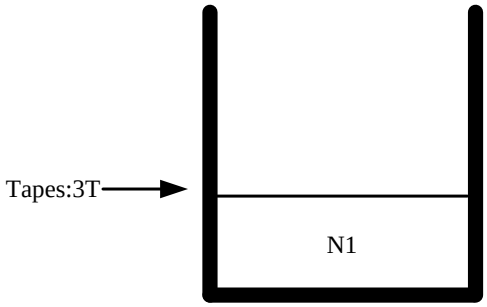
| Tape Turns | Winding No. | Margin Tapes | Start and End | Wire Diameter (mm) | Turns |
|---|---|---|---|---|---|
| 1 | N1 | | 1→2 | 0.1x50 | 22 |
| 3 | N2 | | 11→9 | Copper foil Thick=0.1mm | 2 |
| 1 | N3 | | 10→12 | Copper foil Thick=0.1mm | 2 |
| 1 | N4 | | 5→4 | 0.2TIW | 3 |
| 1 | N5 | | 4→6 | 0.2TIW | 3 |
| 3 | N6 | | 7→8 | 0.2TIW | 2 |

# APPENDIX 3: LLC RESONANT INDUCTOR SPECIFICATION

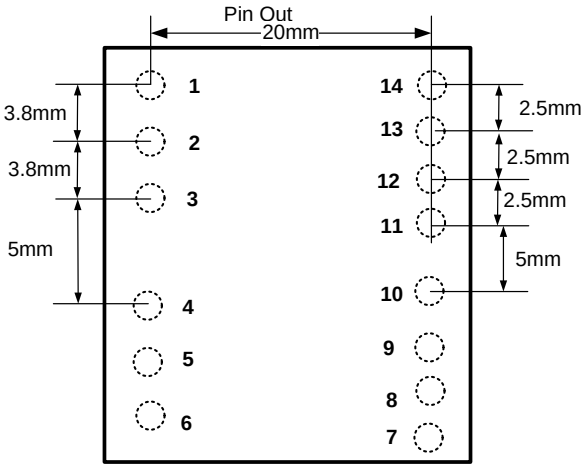
### Electrical Diagram

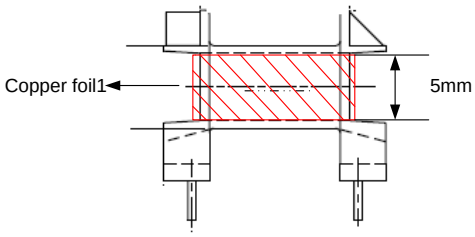



### Winding Diagram




### Pin Definition of Bobbin




**Note:** ***Core is wrapped with copper foil, as shown above. Connect the foils to pin 3 of the bobbin with wires.***

**Table 6: Electrical Characteristic**

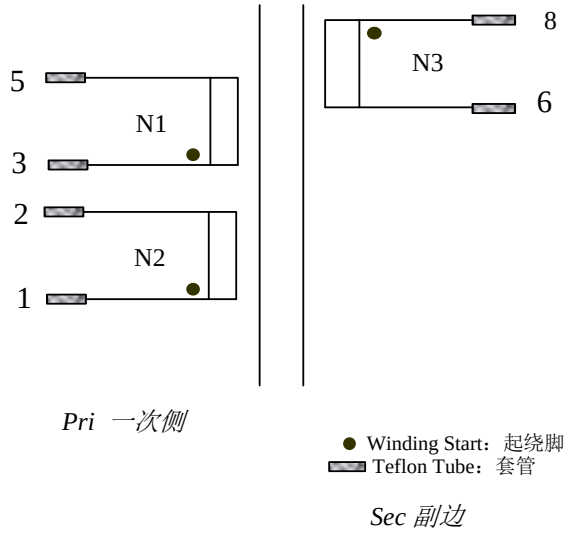
| Parameter | Condition | Value |
|---|---|---|
| Primary inductance | L (5,6-7,8) | 54μH ±5% |
| Core | | PQ2020 |
| Bobbin | | PQ2020 |
| Core material | | DMR40 or equivalent |
| Turn ratio | N1 | 22 |

**Table 7: Winding Specification**

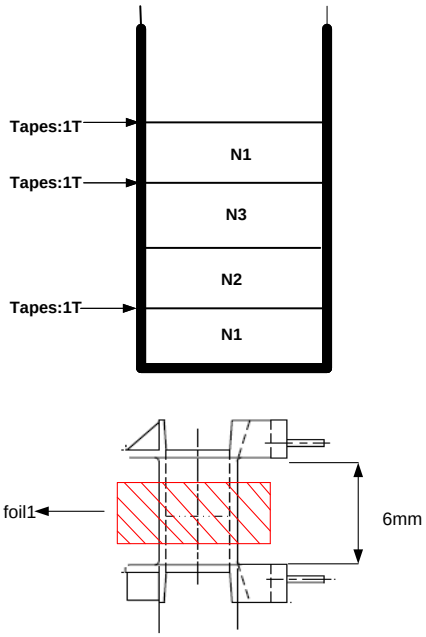
| Tape Turns | Winding No. | Margin Tapes | Start and End | Wire Diameter (mm) | Turns |
|---|---|---|---|---|---|
| 3 | N1 | | 5,6→7,8 | 0.1x50 | 22 |

# APPENDIX 4: FLYBACK TRANSFORMER SPECIFICATION

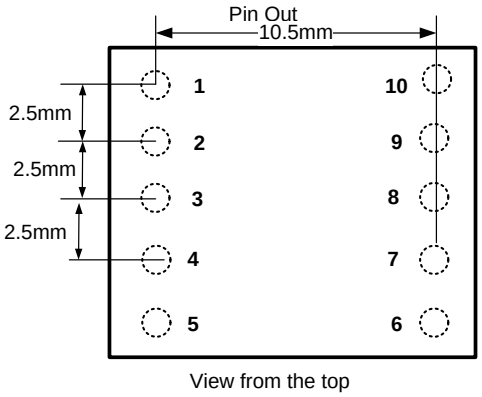
### Electrical Diagram




### Winding Diagram




### Pin Definition of Bobbin




View from the top

**Note:** ***Core is wrapped with copper foil, as shown above. Connect the foils to pin 2 of the bobbin with wires.***

**Table 6: Electrical Characteristic**

| Parameter | Condition | Value |
|---|---|---|
| Primary inductance | L (3-5) | 778μH ±5% |
| Core | | EPC13 |
| Bobbin | | EPC13 |
| Core material | | DMR40 or equivalent |
| Turn ratio | N1:N2:N3 | 95:30:14 |

**Table 7: Winding Specification**

| Tape Turns | Winding No. | Margin Tapes | Start and End | Wire Diameter (mm) | Turns |
|---|---|---|---|---|---|
| 1 | N1 | | 3→5 | 0.1 | 95 |
| 0 | N2 | | 1→2 | 0.2TIW | 30 |
| 1 | N3 | | 8→6 | 0.2TIW | 14 |

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