# 200 W power supply based on STNRG011 digital combo controller for LED TV

## Introduction

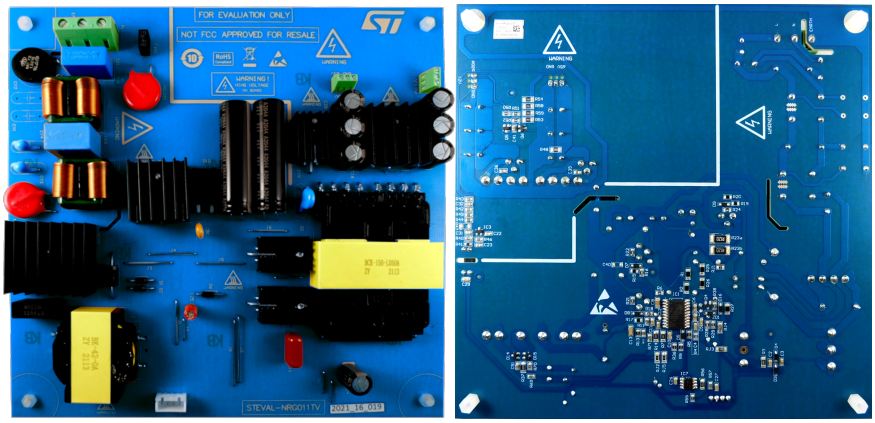
The STEVAL-NRG011TV evaluation board main characteristics are described herein.

The board features 200 W, wide input range, power-factor correction and is designed for flat LED TVs and industrial power supplies with very low power consumption under light load without a standby supply.

Thanks to a very low consumption at no load, no auxiliary supply is needed.

The design is based on the STNRG011 IC digital combo controller for two stages: a transition mode PFC pre-regulator and an LLC HB resonant converter.

**Figure 1. STEVAL-NRG011TV evaluation board (top and bottom views)**



# 1 Specifications

**Table 1. Target specifications**

| Parameter | Value |
|---|---|
| Input mains range | 90 ~264 $V_{ac}$, frequency 45~65 Hz |
| Output voltage | 12 V/4 A, 65 V/2.3 A, continuous operation |
| Full load efficiency | > 91% at 115/230 $V_{ac}$ |
| No load mains consumption | < 120 mW |
| Standby power (at 250 mW) | < 450 mW |
| Ripple and noise | < 1% under all load conditions at 115/230 $V_{ac}$ |
| Mains harmonics | According to EN61000-3-2 Class-D and JEITA-MITI, Class-D |
| EMI | According to EN55022 Class-B（NA） |
| Dimensions | 185 x 185 mm, height < 20 mm |
| PCB | Single layer, 35µm, CEM-1 |

# 2 Circuit description

The STNRG011 application architecture consists of two stages: a front-end PFC pre-regulator based on a transition mode boost PFC controller and an LLC resonant half-bridge converter. The STEVAL-NRG011TV provides:

- a 12 V regulated output voltage to supply the MCU and audio system applications to meet the most stringent efficiency and standby regulations;
- a 65 V output voltage for LED back lighting. An external boost can be added for a constant current control for LED back lighting strings.

The evaluation board exploits a full digital implementation using the STNRG011 IC embedded firmware and software and allows great flexibility through a complete set of parameters stored in its non-volatile memory for the application configuration and fine tuning.

# 3 Functional check

## 3.1 Startup

**Figure 2. PFC startup sequence at 90 $V_{ac}$ full load**

- Ch1 - PFC inductor current
- Ch2 - Main voltage
- Ch3 - VCC
- Ch4 - PFC Vbulk

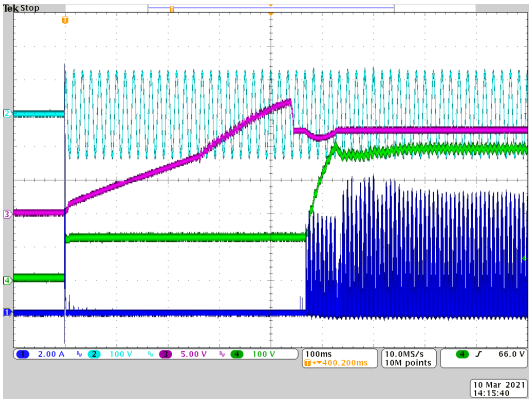



**Figure 3. PFC startup sequence at 90 $V_{ac}$ full load (zoom)**

- Ch1 - PFC inductor current
- Ch2 - Main voltage
- Ch3 - VCC
- Ch4 - PFC Vbulk

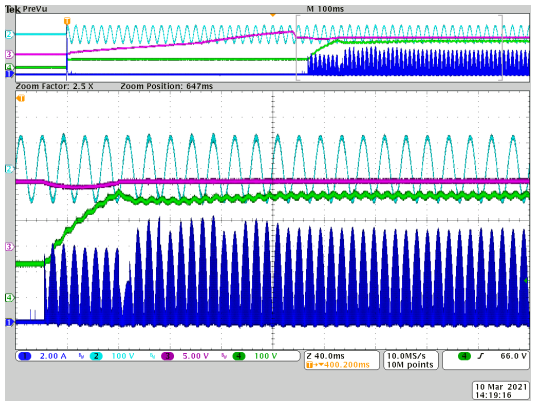



**Figure 4. LLC startup sequence at 90 $V_{ac}$ full load**

- Ch1 - LLC resonant tank current
- Ch2 - Vout_12V
- Ch3 - VCC
- Ch4 - PFC Vbulk

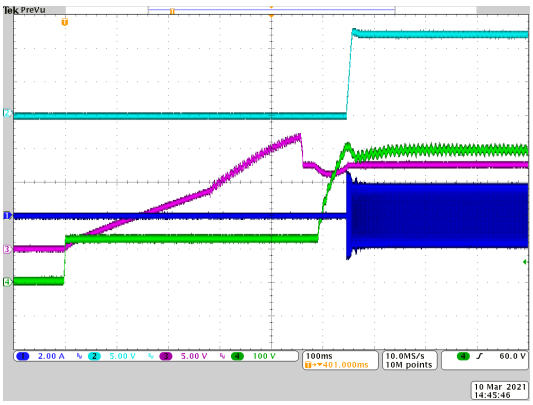
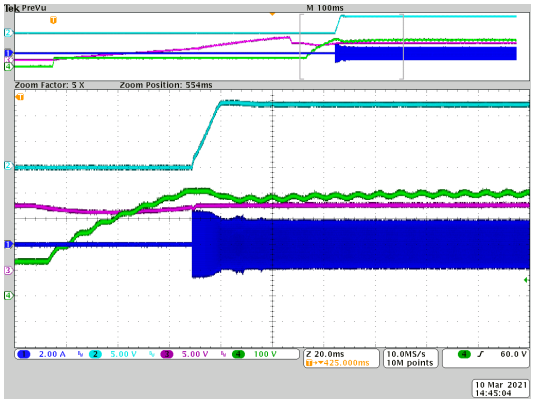



**Figure 5. LLC startup sequence at 90 $V_{ac}$ full load (zoom)**

- Ch1 - LLC resonant tank current
- Ch2 - Vout_12V
- Ch3 - VCC
- Ch4 - PFC Vbulk




## 3.2 LLC safety startup sequence

During startup, HVG and LVG duty cycle are not 50%-50%. This startup mechanism avoids MOSFET hard switching.

**Figure 6. LLC safety startup at 90 $V_{ac}$ full load**

- Ch1 - LLC resonant tank current
- Ch2 - High side MOSFET Vgs
- Ch3 - Low side MOSFET Vgs
- Ch4 - Low side MOSFET Vds

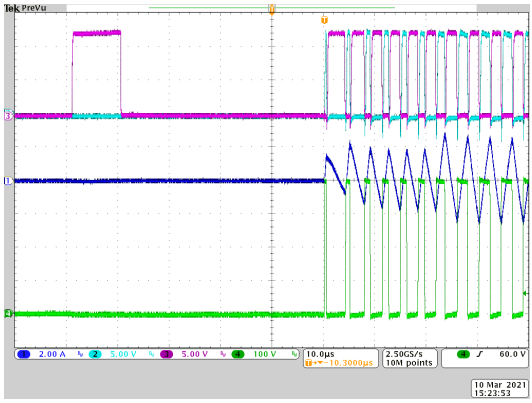
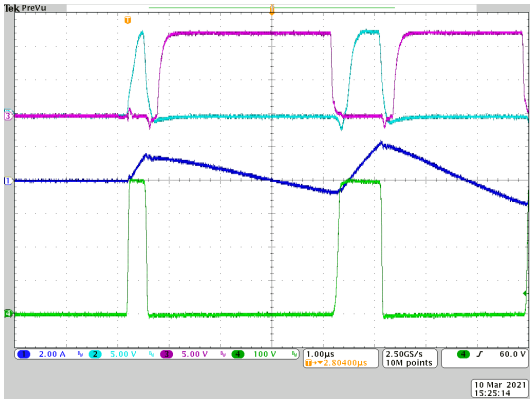


**Figure 7. LLC safety startup at 90 $V_{ac}$ full load (zoom)**

- Ch1 - LLC resonant tank current
- Ch2 - High side MOSFET Vgs
- Ch3 - Low side MOSFET Vgs
- Ch4 - Low side MOSFET Vds

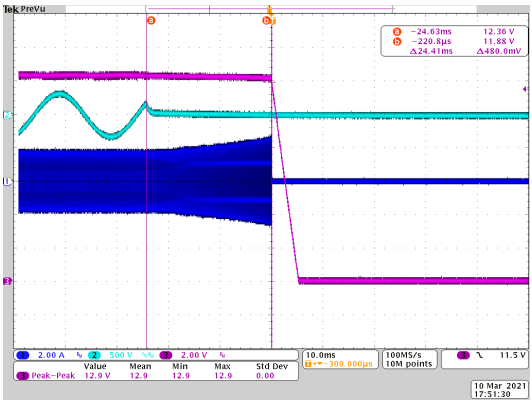


## 3.3 Hold up time

The figure below shows a hold up time > 20 ms at 230 $V_{ac}$ under full load condition.

**Figure 8. Hold up time at 230 $V_{ac}$/50 Hz full load**

- Ch1 - LLC resonant tank current
- Ch2 - Main voltage
- Ch3 - Vout_12V
- Ch4 - PFC Vbulk



## 3.4 Ripple and noise

The figures below show ripple and noise under full load and standby load conditions. For all measurements, the ripple and noise are below 1%.

**Figure 9. Ripple and noise at 230 $V_{ac}$/50 Hz full load (1 of 2)**

- Ch1 - LLC resonant tank current
- Ch2 - PFC Vbulk ripple
- Ch3 - Vout 12 V ripple

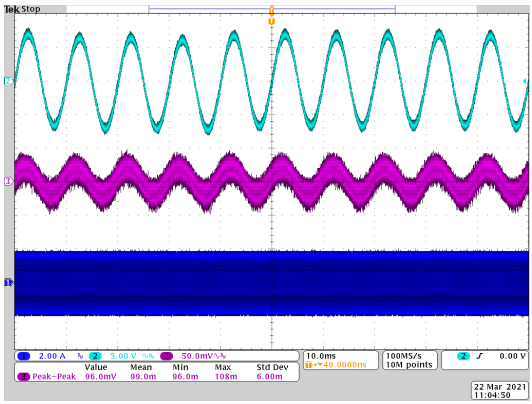



**Figure 10. Ripple and noise at 230 $V_{ac}$/50 Hz full load (2 of 2)**

- Ch1 - LLC resonant tank current
- Ch2 - PFC Vbulk ripple
- Ch3 - Vout 12 V ripple

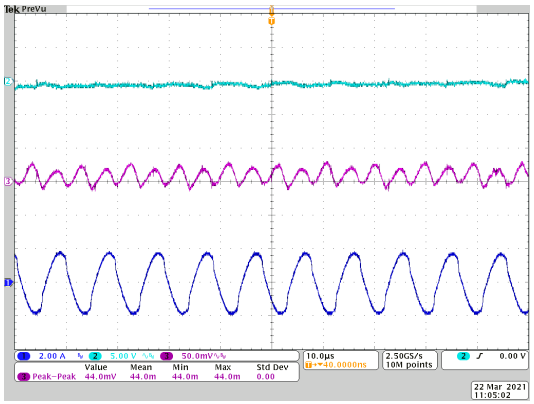



**Figure 11. Ripple and noise at 115 $V_{ac}$/60 Hz full load (1 of 2)**

- Ch1 - LLC resonant tank current
- Ch2 - PFC Vbulk
- Ch3 - Vout_ 12 V

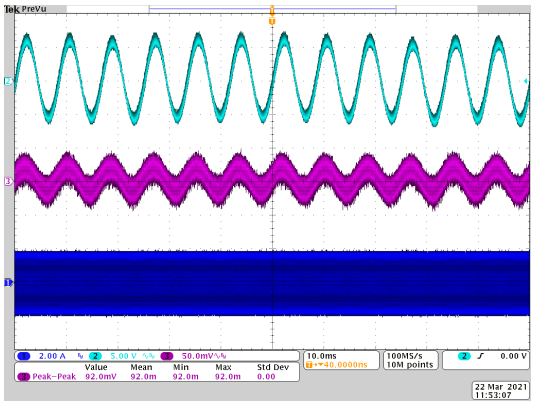



**Figure 12. Ripple and noise at 115 $V_{ac}$/60 Hz full load (2 of 2)**

- Ch1 - LLC resonant tank current
- Ch2 - PFC Vbulk
- Ch3 - Vout_12 V

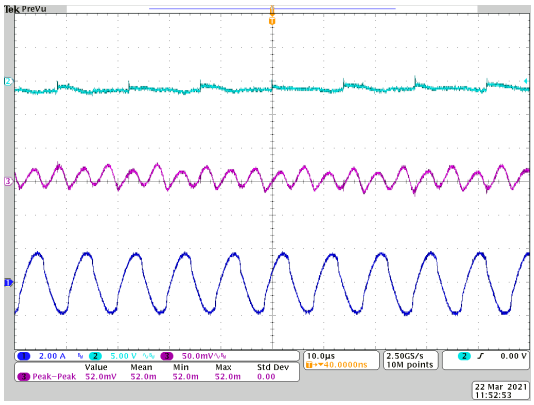


**Figure 13. Ripple and noise at 230 $V_{ac}$/50 Hz standby load - 12 V/16 mA (1 of 2)**

- Ch1 - LLC resonant tank current
- Ch3 - Vout 12 V

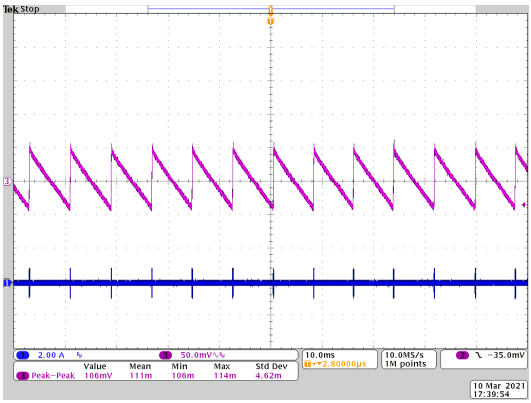
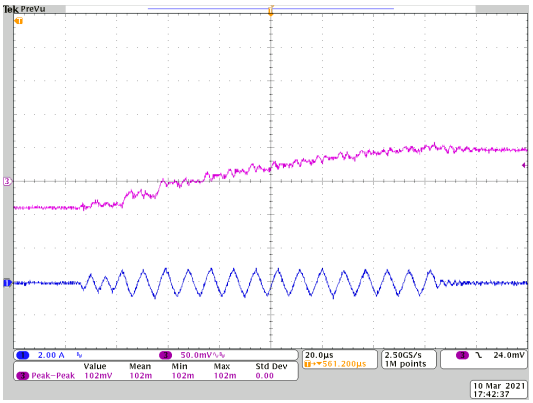


**Figure 14. Ripple and noise at 230 $V_{ac}$/50 Hz standby load - 12 V/16 mA (2 of 2)**

- Ch1 - LLC resonant tank current
- Ch3 - Vout 12 V ripple



## 3.5 Dynamic load

This section shows dynamic load performance. Figure 15 shows output 12 V channel with 1.5 A - 4 A 10 ms-10 ms 1 A/µs dynamic load and back light channel with full load (2.3 A). Back light channel average output voltage is 63.9 V.

Figure 16 shows output 12 V channel with 1.5 A - 4 A 10 ms-10 ms 1 A/µs dynamic load and back light channel with no load. Back light channel average output voltage is 90.3 V.

**Figure 15. 1.5 A - 4 A 10 ms-10 ms 1 A/µs - Back light 2.3 A load (full load)**

- Ch1 - LLC resonant tank current
- Ch3 - Vout 12 V
- Ch4 - Vout 65 V

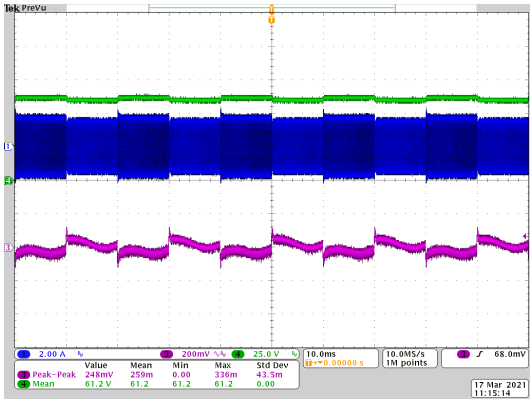
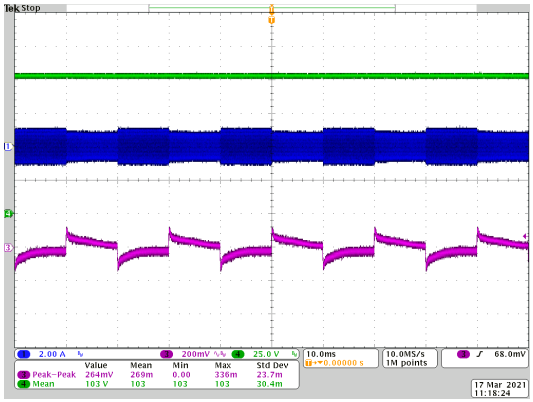


**Figure 16. 1.5 A - 4 A 10 ms-10 ms 1 A/µs - Back light no load**

- Ch1 - LLC resonant tank current
- Ch3 - Vout 12 V
- Ch4 - Vout 65 V



## 3.6 Output overvoltage protection

This section shows output overvoltage protection (OVP) performance. The below test has been performed after removing R43 to let feedback system enter open loop status.

**Figure 17. OVP - Full load condition**

- Ch1 - Vout_63 V
- Ch3 - Vout_12 V
- Ch4 - LLC AUX pin

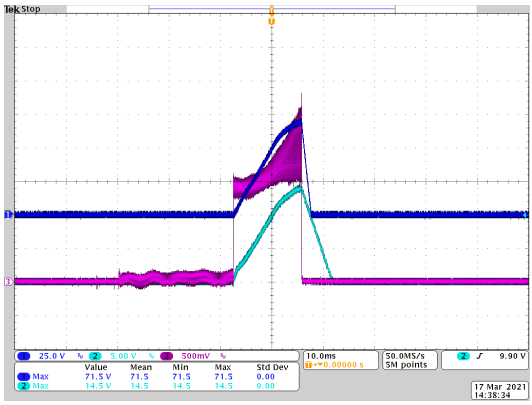
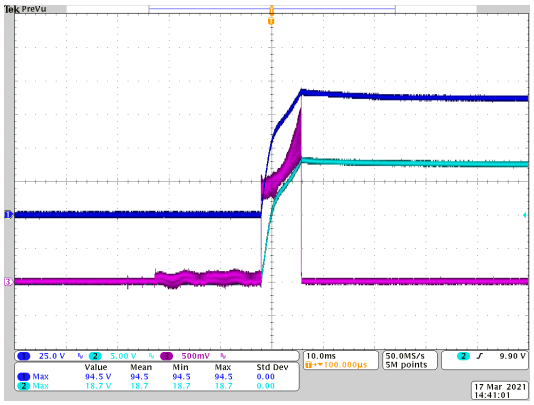



**Figure 18. OVP - No load condition**

- Ch1 - Vout_63 V
- Ch3 - Vout_12 V
- Ch4 - LLC AUX pin




## 3.7 Short output circuits

This section shows short output circuit LLC behaviors. Figure 19 shows the waveform when short output circuits and LLC keep working in ZVS. Figure 20 shows the system auto-restart performance: once the output circuit short disappears, the power supply auto-restarts again.

**Figure 19. Short output circuits - ZVS**

- Ch1 - LLC resonant tank current
- Ch2 - High side MOSFET Vgs
- Ch3 - Low side MOSFET Vgs
- Ch4 - Low side MOSFET Vds

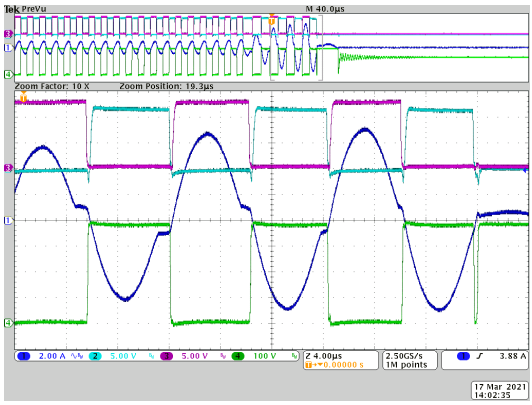
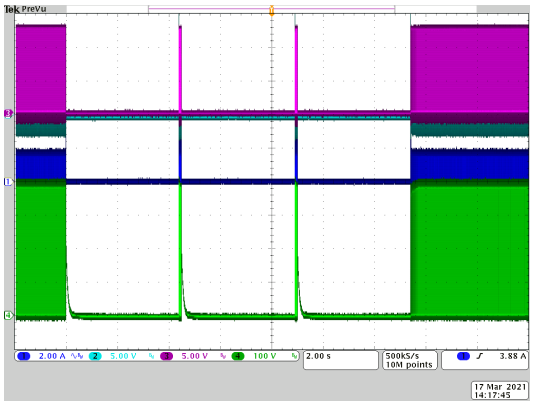



**Figure 20. Short output circuits - auto-restart**

- Ch1 - LLC resonant tank current
- Ch2 - High side MOSFET Vgs
- Ch3 - Low side MOSFET Vgs
- Ch4 - Low side MOSFET Vds



# 4 Acoustic noise check

The STEVAL-NRG011TV evaluation board has been tested for acoustic noise sound pressure level (SPL): 12 V output with 16 mA for standby load and 65 V backlighting without load. The microphone has been placed at 10 cm of distance from the board.

**Figure 21. Acoustic noise test setup**

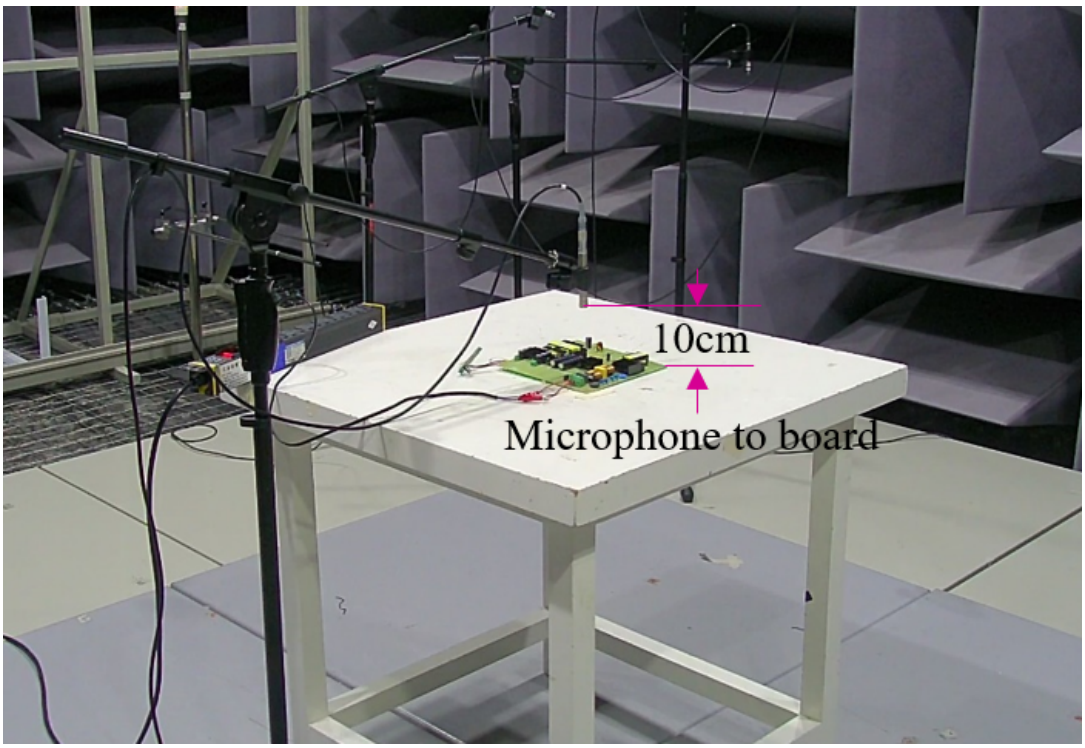
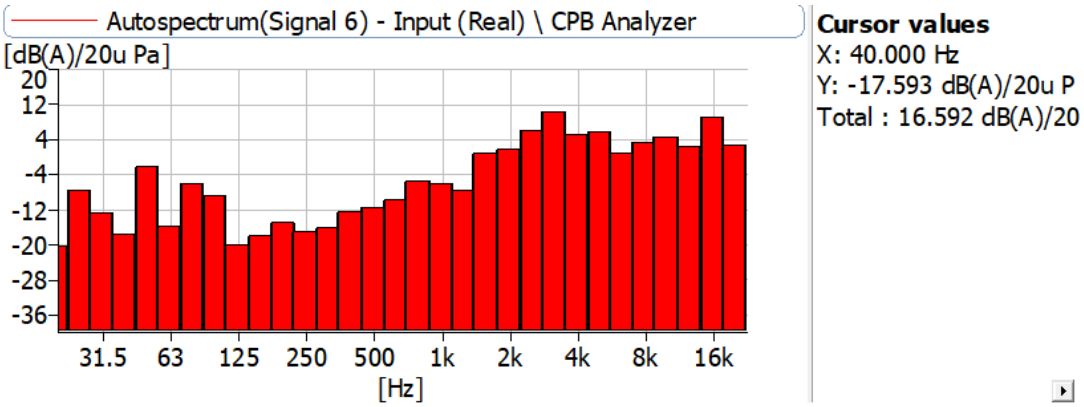



**Figure 22. Acoustic noise SPL test results**




## 4.1 Mains voltage and current

Figure 23 shows PF and iTHD performance at 115 $V_{AC}$/60 Hz. Figure 24 shows PF and iTHD performance at 230 $V_{AC}$/50 Hz.

**Figure 23. Mains voltage and current waveforms at 115 $V_{ac}$/60 Hz - full load**

- PF = 0.999
- iTHD = 1.7%
- Ch1 - Main voltage
- Ch2 - PFC choke current
- Ch4 - Main current

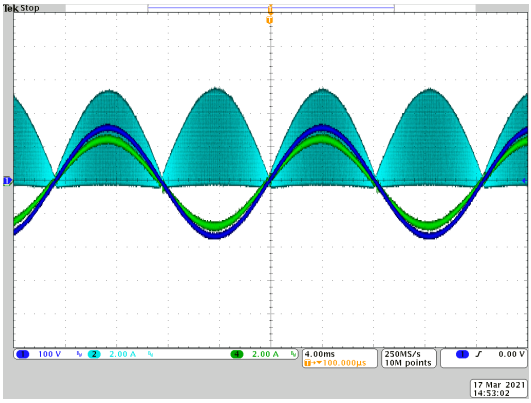
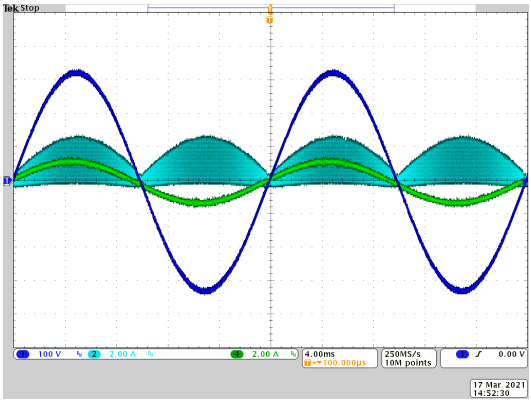



**Figure 24. Mains voltage and current waveforms at 230 $V_{ac}$/50 Hz - full load**

- PF = 0.992
- iTHD = 1.4%
- Ch1 - Main voltage
- Ch2 - PFC choke current
- Ch4 - Main current




*Note: The above test results are based on the equipment listed in the following table*

| Test equipment | Manufacturer/Model |
|---|---|
| AC source | KIKUSUI/PCR500L |
| Power meter | YOKOGAWA/WT310 |
| Electronic load | Chroma/63103/63108/6314 |
| Oscilloscope | Tektronix/DPO 4054 |
| Differential probe | Tektronix/P5205A |
| Current probe | Tektronix/TCP0020 |
| Voltage probe | Tektronix/P6139A |

# 5 Efficiency measurements

## 5.1 Overall efficiency

The table below shows the overall efficiency, measured at different mains voltage. The full load efficiency is 90.44% at 115 $V_{ac}$ and 92.27% at 230 $V_{ac}$. The below test results are PS/ON short or kept low level.

**Table 2. Overall efficiency at different input voltages**

| 90 $V_{ac}$ | 12 V | | 65 V | | Pout | Pin | Eff. |
|---|---|---|---|---|---|---|---|
| Load | Vout(V) | Iout(A) | Vout(V) | Iout(A) | (W) | (W) | (%) |
| 10% | 12.286 | 0.405 | 63.47 | 0.24 | 20.209 | 24.13 | 83.75% |
| 25% | 12.3 | 0.999 | 63.57 | 0.585 | 49.476 | 56.04 | 88.29% |
| 50% | 12.285 | 1.9998 | 63.32 | 1.185 | 99.58 | 110.85 | 89.83% |
| 75% | 12.3 | 2.999 | 63.28 | 1.682 | 143.325 | 159.28 | 89.98% |
| 100% | 12.285 | 3.982 | 62.74 | 2.3843 | 198.51 | 223.31 | 88.89% |
| Average (25, 50, 75, 100) = 89.25% | | | | | | | |
| **115 $V_{ac}$** | **12 V** | | **65 V** | | **Pout** | **Pin** | **Eff.** |
| Load | Vout(V) | Iout(A) | Vout(V) | Iout(A) | (W) | (W) | (%) |
| 10% | 12.285 | 0.401 | 63.46 | 0.24 | 20.157 | 23.95 | 84.16% |
| 25% | 12.3 | 0.999 | 63.42 | 0.585 | 49.388 | 55.44 | 89.08% |
| 50% | 12.286 | 1.998 | 63.17 | 1.185 | 99.404 | 109.55 | 90.74% |
| 75% | 12.298 | 2.999 | 63.28 | 1.682 | 143.319 | 157.18 | 91.18% |
| 100% | 12.282 | 3.982 | 62.75 | 2.3843 | 198.522 | 218.76 | 90.75% |
| Average (25, 50, 75, 100) = 90.44% | | | | | | | |
| **230 $V_{ac}$** | **12 V** | | **65 V** | | **Pout** | **Pin** | **Eff.** |
| Load | Vout(V) | Iout(A) | Vout(V) | Iout(A) | (W) | (W) | (%) |
| 10% | 12.285 | 0.401 | 63.45 | 0.24 | 20.154 | 23.51 | 85.73% |
| 25% | 12.3 | 0.999 | 63.55 | 0.585 | 49.464 | 54.56 | 90.66% |
| 50% | 12.294 | 1.998 | 63.28 | 1.185 | 99.55 | 107.91 | 92.25% |
| 75% | 12.293 | 2.999 | 63.25 | 1.682 | 143.253 | 153.92 | 93.07% |
| 100% | 12.292 | 3.982 | 62.86 | 2.3843 | 198.824 | 213.61 | 93.08% |
| Average (25, 50, 75, 100) = 92.27% | | | | | | | |
| **264 $V_{ac}$** | **12 V** | | **65 V** | | **Pout** | **Pin** | **Eff.** |
| Load | Vout(V) | Iout(A) | Vout(V) | Iout(A) | (W) | (W) | (%) |
| 10% | 12.285 | 0.401 | 63.44 | 0.24 | 20.152 | 22.74 | 88.62% |
| 25% | 12.3 | 0.999 | 63.56 | 0.585 | 49.47 | 54.02 | 91.58% |
| 50% | 12.294 | 1.998 | 63.28 | 1.185 | 99.55 | 107.46 | 92.64% |
| 75% | 12.274 | 2.999 | 63.25 | 1.682 | 143.196 | 153.88 | 93.06% |
| 100% | 12.272 | 3.982 | 62.68 | 2.3843 | 198.315 | 212.92 | 93.14% |
| Average (25, 50, 75, 100) = 92.60% | | | | | | | |

The figures below show the average efficiency calculated according to ENERGY STAR 2.0 criteria.

Figure 25. **Overall efficiency vs. output power**

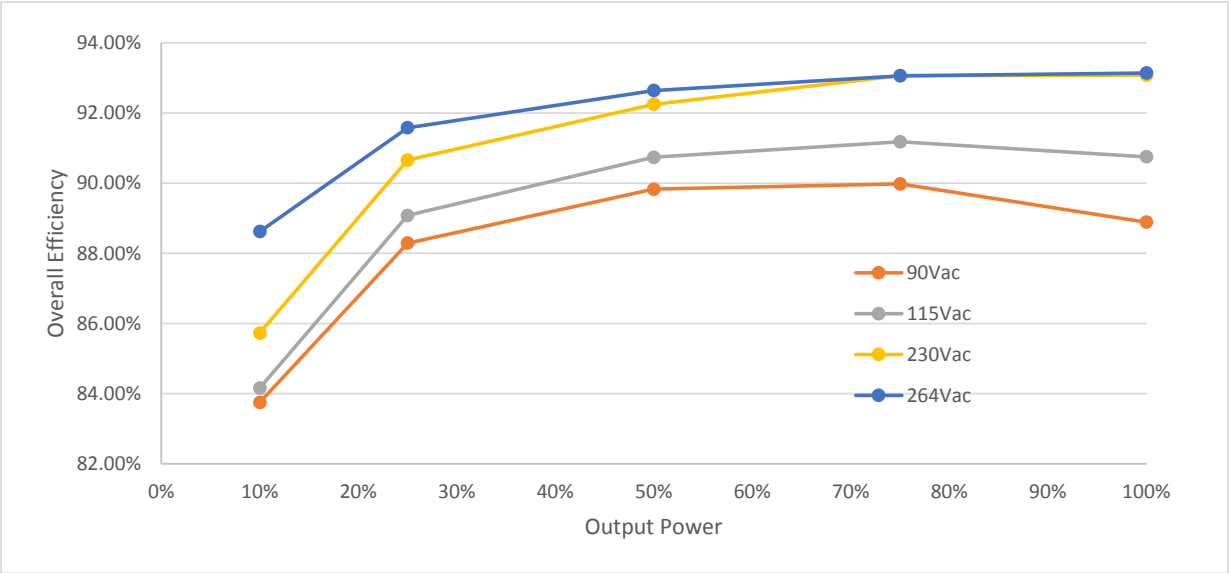
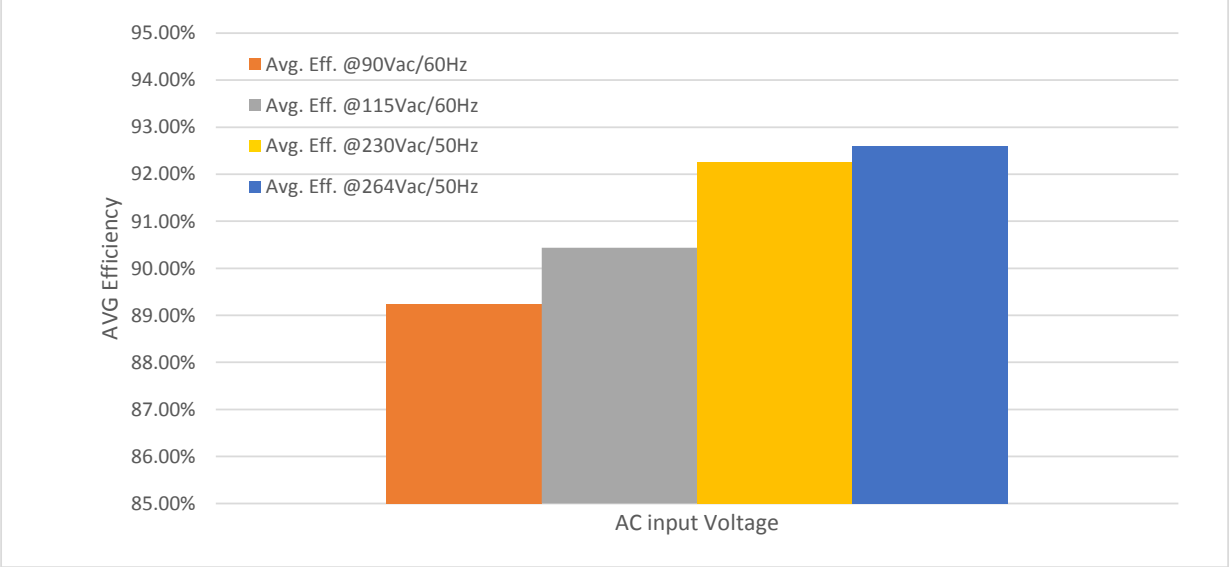



Figure 26. **Overall efficiency vs. input voltage**




## 5.2 Standby power efficiency

The below tables and figure show standby power efficiency measured at 115 $V_{ac}$ and 230 $V_{ac}$ mains voltage. Each measurement point is kept for about 1 minute. Test results are PS/ON open or kept high level.

Table 3. **No load consumption and light load efficiency at 115 $V_{ac}$**

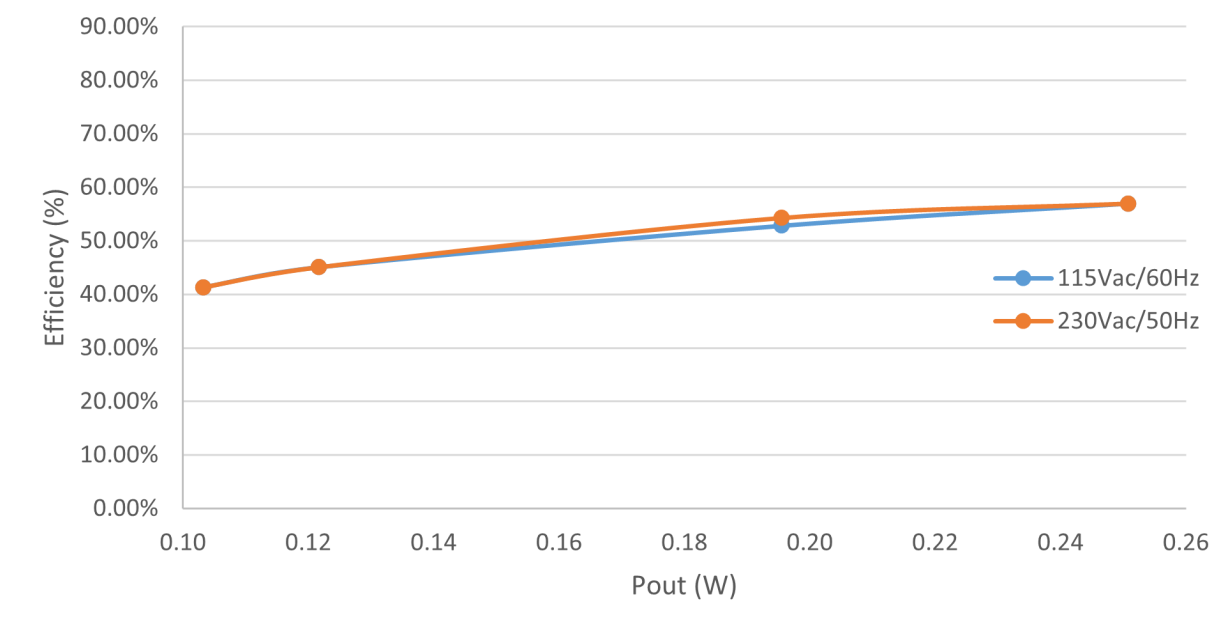
| 115 $V_{ac}$/60 Hz | | | | | | | |
|---|---|---|---|---|---|---|---|
| 12 V | 12 V | | 65 V | | Pout | Pin | Eff. |
| Iout | Vout(V) | Iout(A) | Vout(V) | Iout(A) | (W) | (W) | (%) |
| 0mA | 12.29 | | 65.3 | | | 0.12 | |
| 8mA | 12.291 | 0.0084 | 69.9 | | 0.10 | 0.25 | 41.30% |

| 115 $V_{ac}$/60 Hz | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10mA | 12.29 | 0.0099 | 70.2 | | 0.12 | 0.27 | 45.06% |
| 15mA | 12.291 | 0.0159 | 72.8 | | 0.20 | 0.37 | 52.82% |
| 20mA | 12.291 | 0.0204 | 74.6 | | 0.25 | 0.44 | 56.99% |

**Table 4.** **No load consumption and light load efficiency at 230 $V_{ac}$**

| 230 $V_{ac}$/50 Hz | | | | | | | |
|---|---|---|---|---|---|---|---|
| 12 V | 12 V | | 65 V | | Pout | Pin | Eff. |
| Iout | Vout(V) | Iout(A) | Vout(V) | Iout(A) | (W) | (W) | (%) |
| 0mA | 12.294 | | 65.3 | | | 0.12 | |
| 8mA | 12.294 | 0.0084 | 69.9 | | 0.10 | 0.25 | 41.31% |
| 10mA | 12.292 | 0.0099 | 70.3 | | 0.12 | 0.27 | 45.07% |
| 15mA | 12.291 | 0.0159 | 72.9 | | 0.20 | 0.36 | 54.29% |
| 20mA | 12.292 | 0.0204 | 74.6 | | 0.25 | 0.44 | 56.99% |

**Figure 27.** **Standby supply efficiency vs. light load output power**




## 5.3 Eco design requirements

**Table 5.** **EuP Lot 6 Tier 2 requirements for household and office equipment**

| Eup Lot 6 Tier 2 | Test results | | Limits | Status |
|---|---|---|---|---|
| | 115 $V_{ac}$/60 Hz | 230 $V_{ac}$/50 Hz | | |
| Avg. efficiency measured at 25, 50, 75, 100% | 90.44% | 92.27% | > 87% | PASS |
| Efficiency at 250 mW load | 56.99% | 56.99% | > 50% | |
| Efficiency at 100 mW load | 45.06% | 45.07% | > 33% | |

**Table 6. European CoC ver. 5 Tier 2 requirements for external power supplies**

| European CoC ver.5 Tier-2 for external power supplies | Test results | | Limits | Status |
|---|---|---|---|---|
| | 115 $V_{ac}$/60 Hz | 230 $V_{ac}$/50 Hz | | |
| Avg. efficiency measured at 25, 50, 75, 100% | 90.44% | 92.27% | > 89% | PASS |
| Efficiency at 10% load | 84.16% | 85.73% | > 79% | |
| No load input power (W) | 0.12 | 0.12 | < 0.15 W | |

# 6 Harmonic performance

This section shows harmonic performance according to EN61000-3-2 Class-D and JEITA-MITI Class-D, at 230 $V_{ac}$/50 Hz and 100 $V_{ac}$/50 Hz under full load condition and at 75 W of input power.

**Figure 28. Compliance with EN61000-3-2 at 230 $V_{ac}$/50 Hz - full load**

- THD = 1.4%
- PF = 0.992
- PIN = 219.7 W

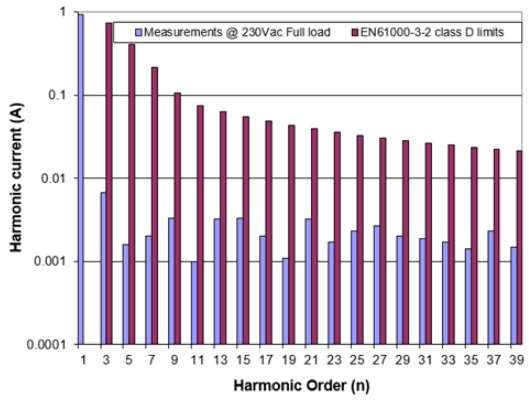



**Figure 29. Compliance with JEITA-MITI at 100 $V_{ac}$/50 Hz - full load**

- THD = 1.7%
- PF = 0.999
- PIN = 222.3 W

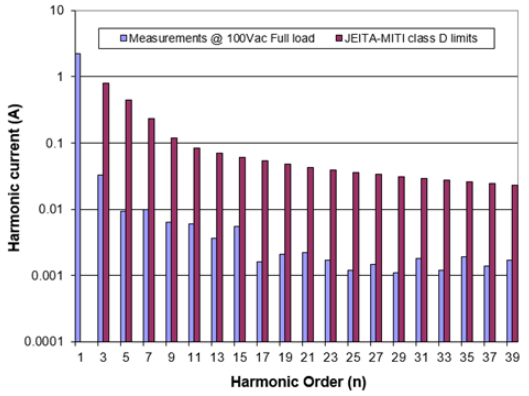



**Figure 30. Compliance with EN61000-3-2 at 230 $V_{ac}$/50 Hz - 74.3 W input power**

- THD = 10.3%
- PF = 0.934
- PIN = 74.3 W

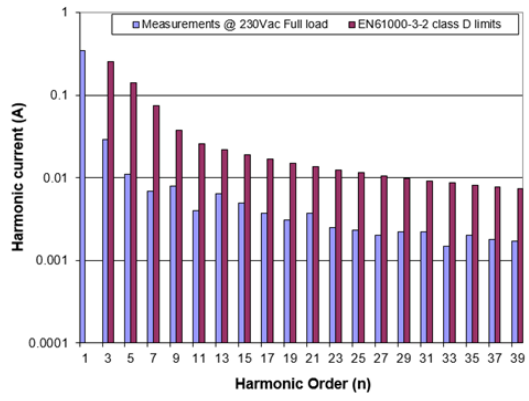
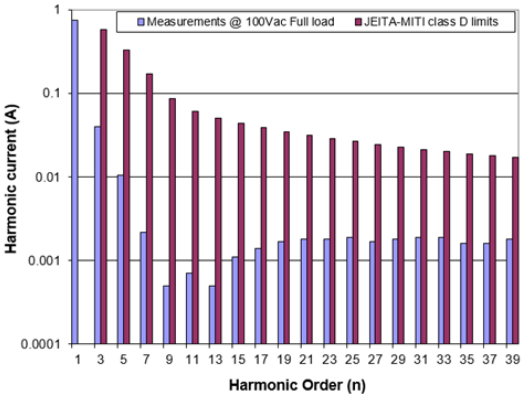



**Figure 31. Compliance with JEITA-MITI at 100 $V_{ac}$/50 Hz - 75 W input power**

- THD = 5.6%
- PF = 0.996
- PIN = 75 W



# 7 Thermal image

Figure 32 shows the full load thermal image at 115 $V_{ac}$/60 Hz input after letting the board run for 20 minutes without a fan. Figure 33 shows the full load thermal image at 115 $V_{ac}$/60 Hz input after letting the board run for 20 minutes without a fan.

**Figure 32. Thermal image at 115 $V_{ac}$/60 Hz - full load**

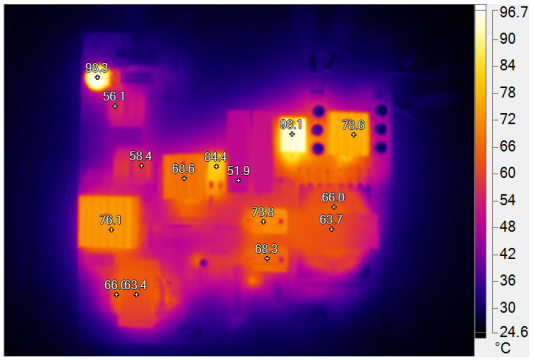
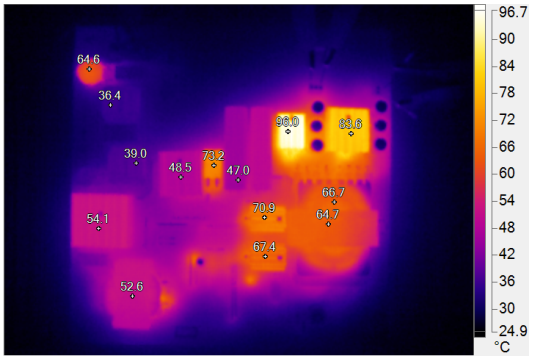



**Figure 33. Thermal image at 230 $V_{ac}$/50 Hz - full load**



# 8 Conducted emissions

The figures below show QP and AV measurements of the conducted emission noise at full load and nominal mains voltages. The limits shown in the diagrams are EN55022 Class-B compliant.

**Figure 34. Test at 115 $V_{ac}$/60 Hz - full load**

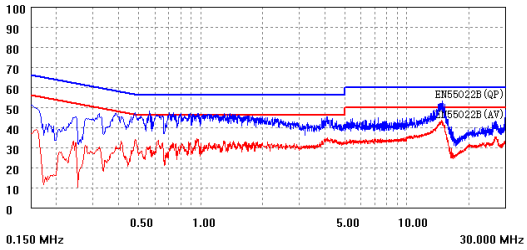
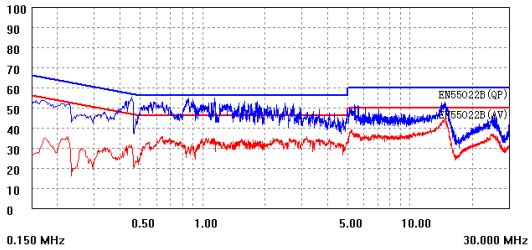



**Figure 35. Test at 230 $V_{ac}$/50 Hz - full load**



# 9 PFC coil

- Core type PQ3812, NH9
- Inductance: 240 µH ±7% at 100 KHz - 1 V
- Manufacturer: HAINING ZHENGYI ELECTRONIC, PN: BK-42-0A

**Figure 36. PFC coil pin-out**

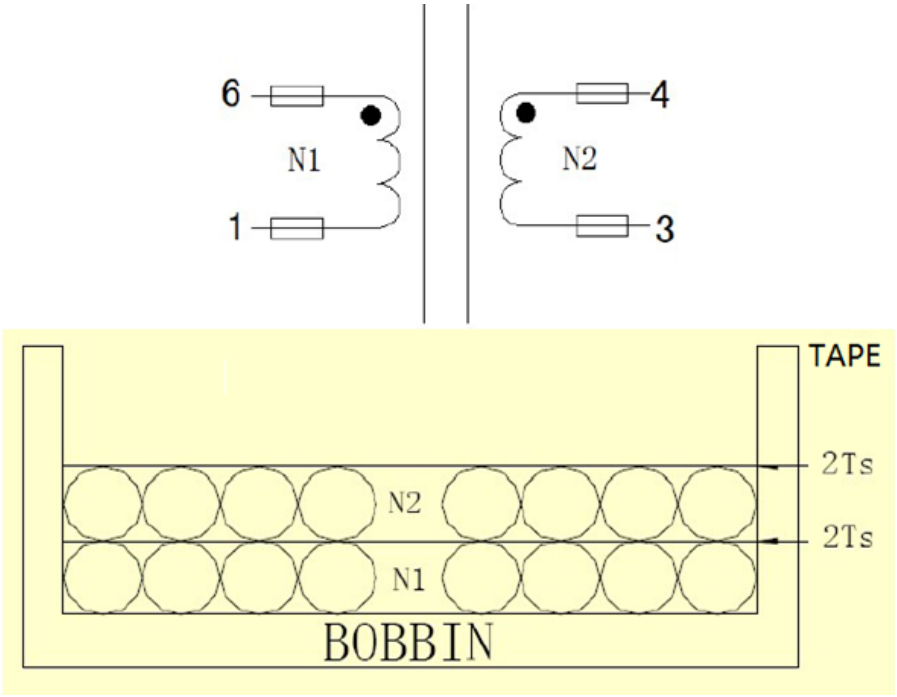
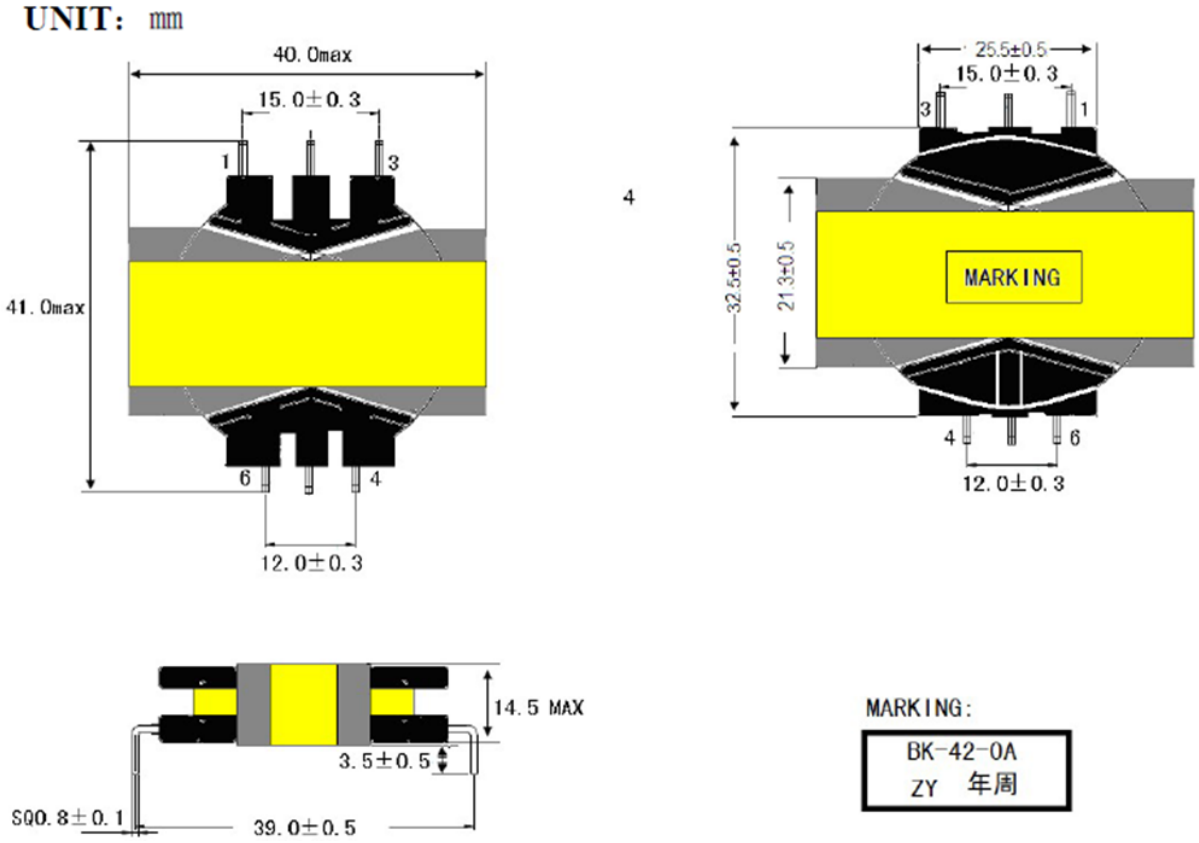



**Table 7. PFC coil winding data**

| F = 100 KHz V = 1.0 V at 25ºC | | | | |
|---|---|---|---|---|
| No. | Wire | Turns | Inductance | DCR (mΩ) |
| N1 (6-1) | 2UEW Φ0.10*50 | 40.5 Ts | 240µH±7% | 200 mΩ max. |
| N2 (4-3) | 2UEW Φ0.40 | 4.5 Ts | - | - |

Figure 37. **PFC coil overall drawing**



# 10 Transformer specifications

- Core type PQ3812, NH9
- Primary inductance: 500 µH ±7% at 100 KHz - 0.3 V
- Manufacturer: HAINING ZHENGYI ELECTRONIC, PN: BK-150-L050A

**Figure 38. Transformer pin-out**

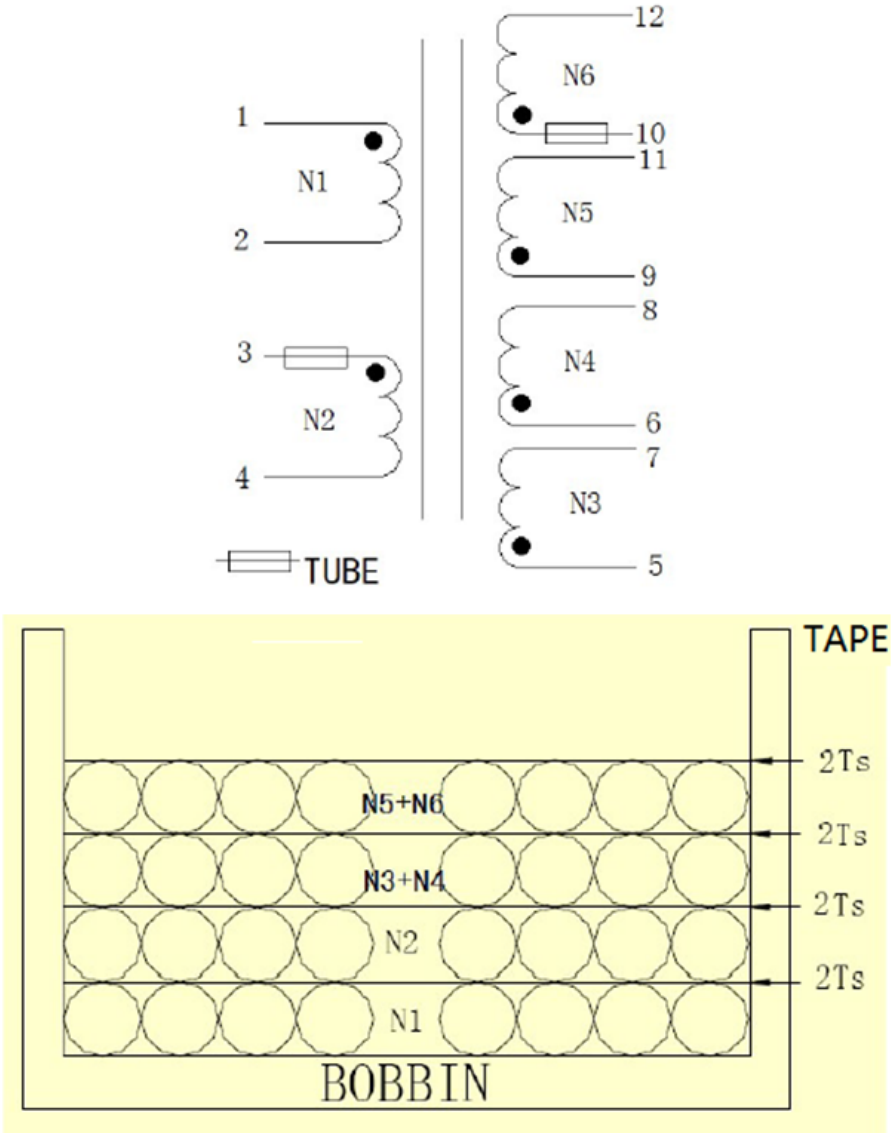
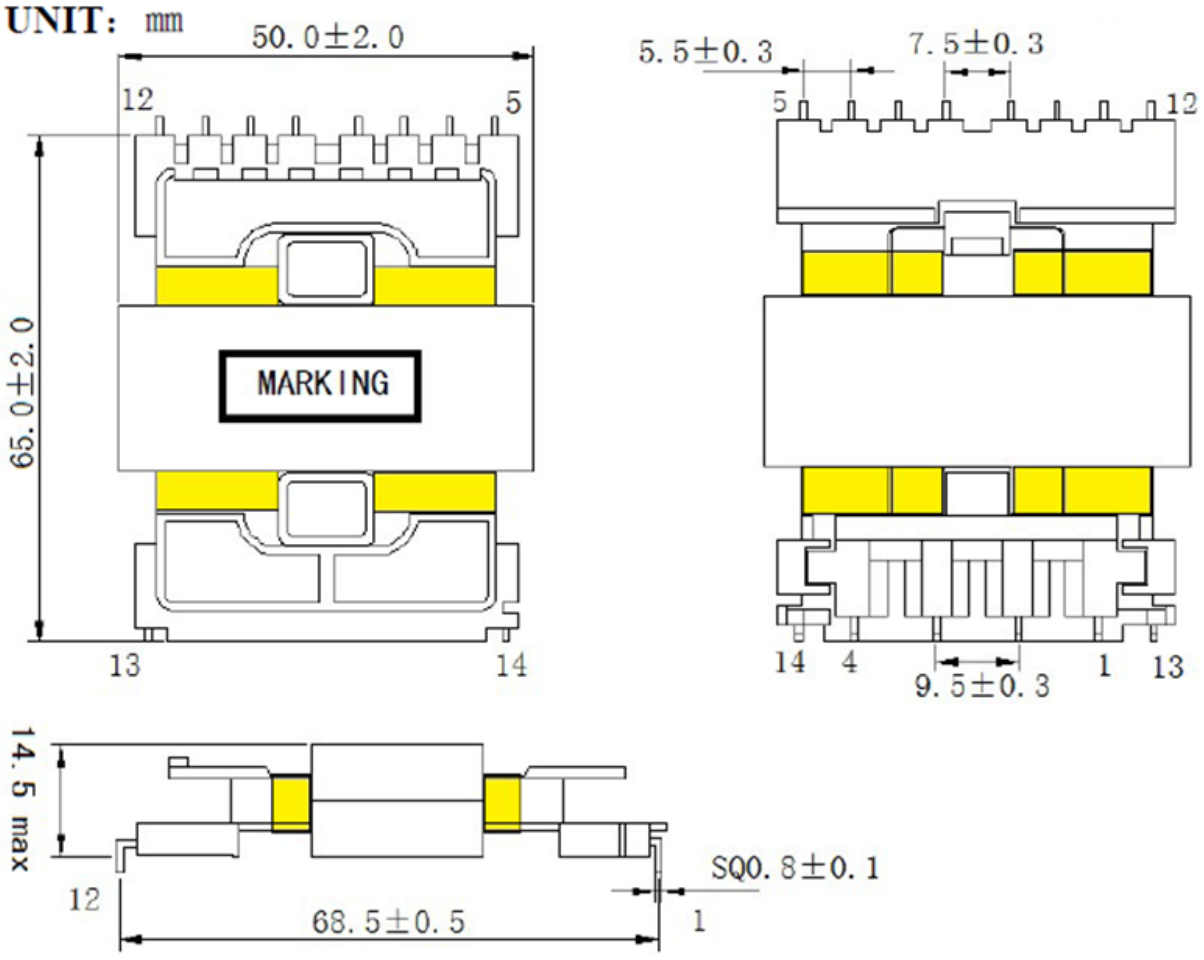


**Table 8. Transformer winding data**

| F = 100 KHz V = 0.3 V at 25°C | | | | | |
|---|---|---|---|---|---|
| No. | Wire | Turns | Inductance | | DCR (mΩ) |
| N1 (1-2) | 2UEW Φ0.10*40 | 34 Ts | 500 µH±7%<br>100 KHz - 0.3 V | 97 µH±7% (leakage)<br>1 KHz - 0.3 V | 175 mΩ max. |
| N2 (3-4) | ALTIW-B Φ0.20 | 3 Ts | - | | - |
| N3 (5-7) | USTC 0.10*50 | 2 Ts | - | | - |
| N4 (6-8) | USTC 0.10*50 | 2 Ts | - | | - |
| N5 (9-11) | USTC 0.10*40 | 10 Ts | - | | - |
| N6 (10-12) | USTC 0.10*40 | 10 Ts | - | | - |

**Figure 39. Transformer overall drawing**



# 11 NVM parameter configuration

**Table 9. NVM parameters**

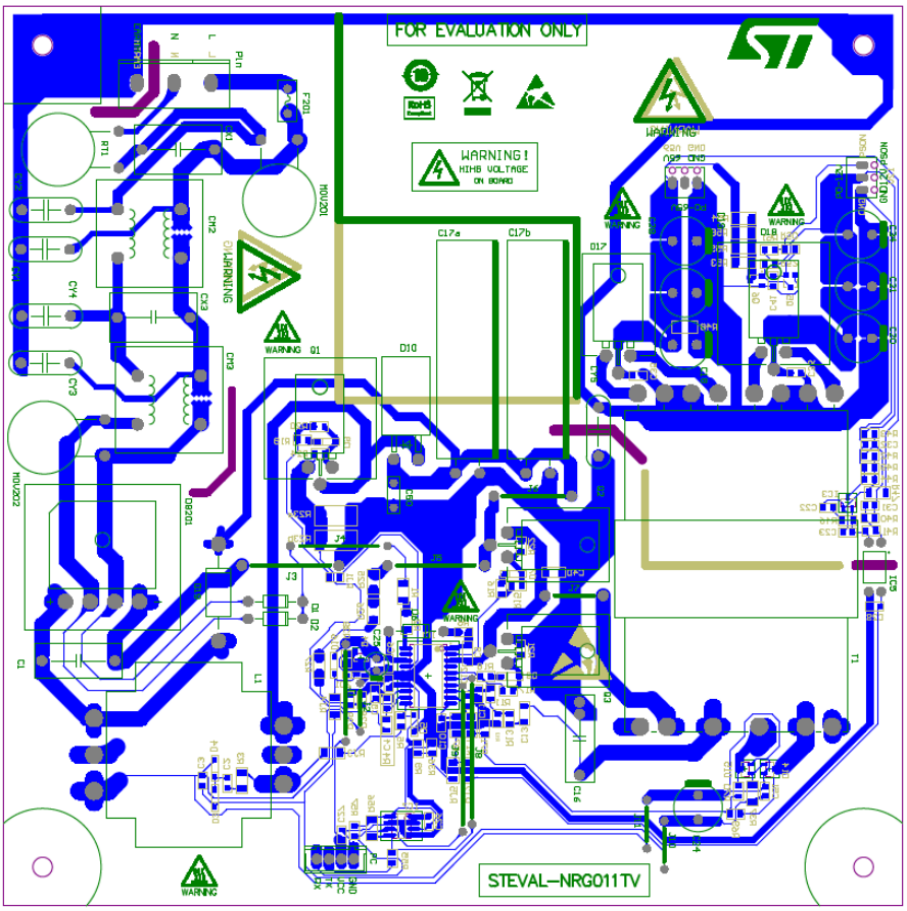
| # | Name | Value |
|---|---|---|
| 0 | Shutdown feature | 0 = Disabled |
| 1 | Patch upload from EEPROM | 0 = Disabled |
| 2 | ATE mode | 0 = Enabled |
| 3 | System monitoring | 0 = Enabled |
| 4 | $V_{AC}$ reading improvement | 1 = Enabled |
| 5 | Early Warning feature | 1 = Disabled |
| 6 | EW signal in burst mode | 1 = Normal |
| 7 | Non-latched faults timer | 3 = 4.37 s |
| 8 | Surge detection | 1 = Enabled |
| 9 | PFC OC2 detection | 1 = Enabled |
| 10 | Max. number of PFC OC2 | 1 (immediate) |
| 11 | PFC HW OVP detection | 1 = Enabled |
| 12 | LLC OC2 detection | 1 = Enabled |
| 13 | Max. number of LLC OC2 | 4 |
| 14 | LLC OVP detection | 0 = Enabled |
| 15 | Disconnection faults detection | 1 = Enabled |
| 16 | PFC OC2 behavior | 0 = Not Latched |
| 17 | PFC HW OVP behavior | 0 = Not Latched |
| 18 | PFC UVP behavior | 1 = Adaptive |
| 19 | LLC SS timeout behavior | 0 = Not Latched |
| 20 | LLC ACP behavior | 0 = Not Latched |
| 21 | LLC OC2 behavior | 0 = Not Latched |
| 22 | LLC OLP behavior | 0 = Not Latched |
| 23 | LLC OVP behavior | 1 = Latched |
| 24 | PFC Ki | 24 |
| 25 | PFC Kp | 64 |
| 26 | PFC boost exiting burst | 1 = Enabled |
| 27 | PFC MOSFET LEB | 22 = 366.7 ns |
| 28 | PFC THD improver base | 7 = 14mV |
| 29 | PFC THD improver gain | 7 |
| 30 | PFC maximum power | 15360 |
| 31 | PFC pss | 5120 |
| 32 | PFC pcc | 3218 |
| 33 | PFC Min Pin Vskip | 2176 |
| 34 | PFC Max Pin Vskip (delta) | 2560 |
| 35 | PFC Delta Pin Vskip | 352 |
| 36 | PFC maximum DCM power | 3072 |

| # | Name | Value |
|---|---|---|
| 37 | PFC Min Tsw Vskip | 256 = 234 kHz |
| 38 | PFC Max Tsw Vskip | 1984 = 29 kHz |
| 39 | Skipping area threshold | 0 |
| 40 | PFC Vout target | 64 = 392.62 V |
| 41 | PFC Vout SS end (delta) | 8 = 3.79 V |
| 42 | PFC UVP threshold (delta) | 192 = 121.1 V |
| 43 | PFC SW OVP threshold (delta) | 2 = 20.35 V |
| 44 | LLC low frequency range | 1 = Disabled |
| 45 | LLC HVG first Ton | 16 = 266.7 ns |
| 46 | LLC LVG first TS | 48 = 700 ns (866.7 ns) |
| 47 | LLC dead time | 16 = 266.7 ns |
| 48 | LLC soft start speed | 2 = 16.6 ns (33.3 ns) |
| 49 | Minimum time shift | 60 = 625 ns (1250 ns) |
| 50 | Maximum time shift | 384 = 7.16 us (14.32 us) |
| 51 | LLC OLP threshold | 31 = 500 mV |
| 52 | LLC OLP timeout | 1 = 200 ms |
| 53 | ACP sensitivity | 1 = High |
| 54 | Hard ACP detection | 1 = Enabled |
| 55 | Soft ACP feature | 0 = Enabled |
| 56 | Soft ACP entering threshold | 14 = 233 ns (467 ns) |
| 57 | Soft ACP TS decrement | 3 = 200 ns (200 ns) |
| 58 | Maximum soft ACP occurrences | 1 = 16 |
| 59 | External burst mode | 0 = Disabled |
| 60 | BM enter for minimum TS | 1 = Enabled |
| 61 | Burst entering digital filtering | 0 = 270 us |
| 62 | LLC_FB burst entering thr | 110 = 268.6 mV - 350 ns (700 ns) |
| 63 | LLC_FB burst wake-up thr | 0 = 0.75 V - 2 us (4 us) |
| 64 | LLC_FB burst wake-up hyst | 1 = 10 mV |
| 65 | Min TS in burst mode | 0 = 1 us (4.2 us) |
| 66 | Min number of burst pulses | 17 |
| 67 | Max number of burst pulses (delta) | 0 |
| 68 | Min time between burst seq | 0 = 5.93 ms |
| 69 | Max time between burst seq (delta) | 64 = 4.97 ms |
| 70 | Minimum period to exit burst | 5 = 233 us |
| 71 | No-burst window width | 0 = 90 us |
| 72 | Surge comp digital filtering | 6 = 100 ns |
| 73 | PFC CS comp digital filtering | 0 = NO FILTERING |
| 74 | PFC CS comp hysteresis | 0 = 5 mV |
| 75 | PFC OC2 comp digital filtering | 8 = 133.3 ns |
| 76 | PFC OC1 comp digital filtering (delta) | 2 = 33.3 ns |
| 77 | PFC ZCD comp digital filtering | 2 = 33.3 ns |

| # | Name | Value |
|---|---|---|
| 78 | PFC ZCD comp falling thr | 0 = 0 mV |
| 79 | PFC ZCD comp rising thr | 1 = 110 mV (N/A for TH_F[3] = 200 mV) |
| 80 | PFC HW OVP comp digital filtering | 255 = 4.25 us |
| 81 | LLC OLP comp digital filtering | 1 = 16.7 ns |
| 82 | LLC OC2 comp digital filtering | 8 = 133.3 ns |
| 83 | LLC ZCD comp digital filtering | 3 = 50 ns |
| 84 | LLC ZCD comp hysteresis | 0 = 5 mV |
| 85 | LLC OVP comp digital filtering | 31 = 516.7 ns |

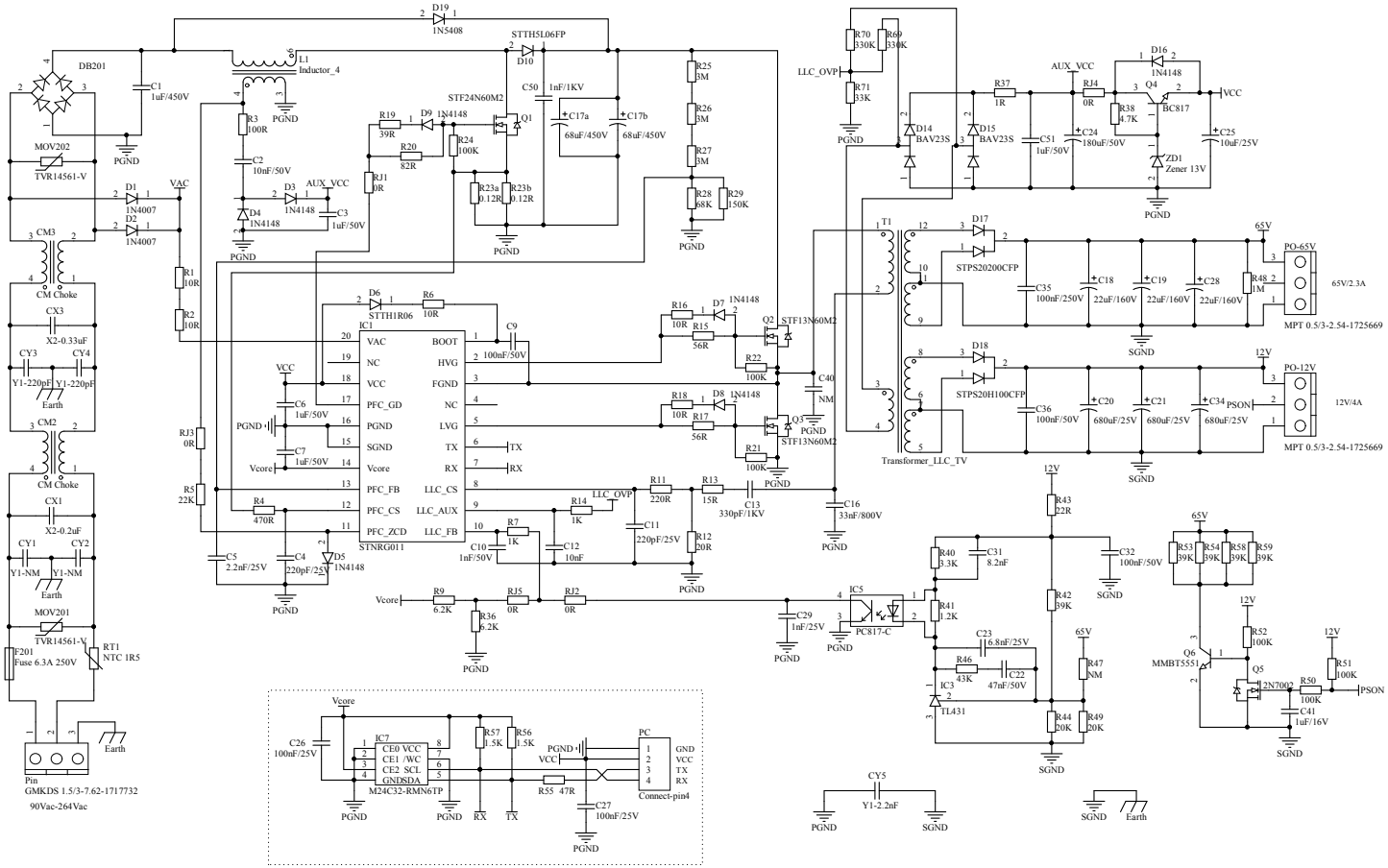
# 12 PCB layout

Figure 40. **STEVAL-NRG011TV layout - top view**



# 13 Schematic diagrams

Figure 41. **STEVAL-NRG011TV circuit schematic**



# 14 Bill of materials

Table 10. **STEVAL-NRG011TV bill of materials**

| Item | Q.ty | Ref. | Part/Value | Description | Manufacturer | Order code |
|---|---|---|---|---|---|---|
| 1 | 1 | C1 | 1uF/450V, C-BOX-7*18 | Capacitor | Panasonic | ECW-FE2W105K |
| 2 | 1 | C2 | 10nF/50V, C0805_wave soldering | Capacitor | Yageo | CC0805KRX7R9BB103 |
| 3 | 5 | C3, C6, C7, C51, C41 | 1uF/50V, C0805_wave soldering | Capacitors | Samsung | CL21B105KBFNNNE |
| 4 | 3 | C4, C11, C12 | 220pF/25V, C0805_Wave soldering | Capacitors | Samsung | CL21B221KBANNNC |
| 5 | 1 | C5 | 2.2nF/25V, C0805_Wave soldering | Capacitor | Samsung | CL21B222KBANNNC |
| 6 | 1 | C9 | 100nF X7R 25V 10%, 1206 | Capacitor | Walsin | 1206B104K250CT |
| 7 | 2 | C26, C27 | 100nF/25V, C0805_Wave soldering | Capacitors | Walsin | 0805B104K250 |
| 8 | 2 | C10, C29 | 1nF/50V, C0805_Wave soldering | Capacitors | Samsung | CL21B102KBANNNC |
| 9 | 1 | C13 | 330pF/1KV, C1206_wave soldering | Capacitor | Yageo | CC1206KKX7RCBB331 |
| 10 | 1 | C16 | 33nF/800V, C-BOX-6*18 | Capacitor | Panasonic | ECW-H8333HA |
| 11 | 2 | C17a, C17b | 68uF/450V, C-d12.5*45 | Capacitors | Rubycon | 450BXW68MEFR12.5X45 |
| 12 | 3 | C18, C19, C28 | 22uF/160V, C-D10 | Capacitors | Rubycon | 160LEX22MEFC10X12.5 |
| 13 | 3 | C20, C21, C34 | 560uF/25V, C-D10 | Capacitors | Rubycon | 25ZLQ560MEFC10X12.5 |
| 14 | 1 | C22 | 47nF/50V, C0805_Wave soldering | Capacitor | Walsin | 0805B473K500CT |
| 15 | 1 | C23 | 6.8nF/50V, C0805_wave soldering | Capacitor | Walsin | 0805B682K500CT |
| 16 | 1 | C24 | 150uF/50V, C-D10 | Capacitor | Rubycon | 50ZL150MEFC10X12.5 |
| 17 | 1 | C25 | 10uF/25V, C-D5 | Capacitor | Wurth | 860020472003 |
| 18 | 1 | C31 | 8.2nF/50V, C0805_wave soldering | Capacitor | Walsin | 0805B822K500CT |
| 19 | 1 | C32 | 100nF/50V, C0805_wave soldering | Capacitor | Yageo | CL21B104KBFNNNG |

| Item | Q.ty | Ref. | Part/Value | Description | Manufacturer | Order code |
|---|---|---|---|---|---|---|
| 20 | 1 | C35 | 100nF/250V, C0805_wave soldering | Capacitor | TDK | C2012X7T2E104K125AA |
| 21 | 1 | C36 | 100nF/50V, C0805_wave soldering | Capacitor | Knowles Novacap | 0805B104K500NT |
| 22 | 1 | C40 | DNM | Capacitor (DNM) | - | - |
| 23 | 1 | C50 | 1nF/1KV, C-box-2.5*7.5 | Capacitor | Vishay | S102K29Y5PN63J5R |
| 24 | 2 | CM2, CM3 | CM-SQ1918-L | Choke | Zhengyi | LCL-008-A |
| 25 | 1 | CX1 | X2-0.33uF/305Vac, C-BOX-10*18 | Safety film capacitor | Epcos | B32922C3334K000 |
| 26 | 1 | CX3 | X2-0.56uF/305Vac, C-BOX-10*18 | Safety film capacitor | Epcos | B32922C3564K000 |
| 27 | 1 | CY1 | DNM | Capacitor (DNM) | - | - |
| 28 | 1 | CY2 | DNM | Capacitor (DNM) | - | - |
| 29 | 2 | CY3, CY4, | Y1-220pF, CY1 | Ceramic capacitor | Murata | DE1B3RA221KA4BQ01F |
| 30 | 1 | CY5 | Y1-2.2nF | Ceramic capacitor | Murata | DE1E3RA222MN4AQ01F |
| 31 | 2 | D1, D2 | 1N4007, DO-41 | Standard recovery rectifiers | ON Semiconductor | 1N4007G |
| 32 | 7 | D3, D4, D5, D7, D8, D9, D16 | 1N4148, SOD-123 | Small signal fast switching diodes | Vishay | 1N4148W-E3-08 |
| 33 | 1 | D6 | STTH1R06, DO-41 | 600 V, 1 A Turbo 2 ultra-fast diode | ST | STTH1R06 |
| 34 | 1 | D10 | STTH5L06FP, Diode-TO220 | 600 V, 5 A Turbo 2 ultra-fast diode | ST | STTH5L06FP |
| 35 | 2 | D14, D15 | BAV23S, SOT-23 | Surface mount high voltage dual switching diodes | Diodes Inc. | BAV23S-7-F |
| 36 | 1 | D18 | STPS20H100CFP, heat sink-21*15*11 | 100 V, 20 A dual power Schottky rectifier | ST | STPS20H100CFP |
| 37 | 1 | D17 | STPS20200CFP, Heat sink-23*25*16.5 | 200 V, 20 A dual power Schottky rectifier | ST | STPS20200CFP |
| 38 | 1 | D19 | 1N5408, DO-201 | Standard recovery diode | ON Semiconductor | 1N5408G |
| 39 | 1 | DB201 | GBU8K, 30*32*16.5mm | Heat-sink | Micro Commercial | GBU8K-BP |
| 40 | 1 | F201 | 6.3A 250V, Fuse-4*8 | Fuse | BEL FUSE | 0697A6300-01 |

| Item | Q.ty | Ref. | Part/Value | Description | Manufacturer | Order code |
|---|---|---|---|---|---|---|
| 41 | 1 | IC1 | STNRG011, SO20_M | Digital combo multi-mode PFC and time-shift LLC resonant controller | ST | STNRG011TR |
| 42 | 1 | IC3 | TL1431CL3T, SOT-23 | Adjustable voltage reference | ST | TL1431CL3T |
| 43 | 1 | IC5 | PC817C | Photocoupler | EVERLIGHT | EL817M(C)-FG |
| 44 | 1 | IC7 | M24C32-RMN6TP, SO8_M | 32 Kbit serial I2C bus EEPROM | ST | M24C32-RMN6TP |
| 45 | 3 | J1, J4, J5 | | Jumpers | Yageo | JPW-10-T-52- |
| 46 | 3 | J2, J10, J11 | | Jumpers | Yageo | JPW-10-T-52- |
| 47 | 1 | J3 | | Jumper | Yageo | JPW-10-T-52- |
| 48 | 1 | J6 | | Jumper | Yageo | JPW-10-T-52- |
| 49 | 1 | J7 | | Jumper | Yageo | JPW-10-T-52- |
| 50 | 2 | J8, J9 | | Jumper | Yageo | JPW-10-T-52- |
| 51 | 1 | L1 | | PFC Inductor | Zhengyi | BK-42-0A |
| 52 | 2 | MOV201, MOV202 | MOV, MOV-14561-TV | Varistors | Littelfuse | V385LA20AP |
| 53 | 1 | PC | Connect-pin4, P-4 | Connector | JST | B4B-XH-A(LF)(SN) |
| 54 | 1 | Pin | GMKDS 1.5/3-7.62-1717732, P-GMKDS 1.5/ 3-7.62-1717732 | PCB terminal block | Phoenix Contact | 1717732 |
| 55 | 2 | PO-85V,P O-12V | MPT 0.5/3-2.54-1725669, P-MPT 0.5/3-2.54-1725669 | PCB terminal blocks | Phoenix Contact | 1725669 |
| 56 | 1 | Q1 | STF24N60M2, Heat sink-23*25*16.5 | Power MOSFETs | ST | STF24N60DM2 |
| 57 | 2 | Q2, Q3 | STF13N60M2, heat sink-21*15*11 | Power MOSFETs | ST | STF13N60M2 |
| 58 | 1 | Q4 | BC817, SOT-23 | Small signal bipolar transistors | NXP | BC817,215 |
| 59 | 1 | Q5 | 2N7002, SOT-23 | N-Channel MOSFET | On Semi | 2N7002 |
| 60 | 1 | Q6 | MMBT5551, SOT-23 | Bipolar transistor | Diodes Inc. | MMBT5551-7-F |
| 61 | 2 | R1, R2 | 10R, R1206_Wave Soldering | Chip resistors | Vishay | CRCW120610R0FKEA |
| 62 | 1 | R3 | 100R, R1206_Wave Soldering | Resistor | TE Connectivity | CRG1206F100R |
| 63 | 1 | R4 | 470R, R0805_wave soldering | Resistor | Yageo | RC0805FR-07470RL |
| 64 | 1 | R5 | 22K, R0805_wave soldering | Resistor | Yageo | RT0805FRE0722K |

| Item | Q.ty | Ref. | Part/Value | Description | Manufacturer | Order code |
|---|---|---|---|---|---|---|
| 65 | 3 | R6, R16, R18 | 10R, R0805_wave soldering | Resistors | Vishay | CRCW080510R0FKEA |
| 66 | 2 | R7, R14 | 1K, R1206_Wave Soldering | Resistors | Vishay | CRG1206F1K0 |
| 67 | 2 | R9, R36 | 6.2K, R0805_wave soldering | Resistors | Vishay | CRCW08056K20FKEA |
| 68 | 1 | R11 | 220R, R0805_wave soldering | Resistor | Vishay | CRCW0805220RFKEA |
| 69 | 1 | R12 | 20R, R0805_wave soldering | Resistor | Panasonic | ERJ6ENF20R0V |
| 70 | 1 | R13 | 15R, R0805_wave soldering | Resistor | Vishay | CRCW080515R0FKEA |
| 71 | 2 | R15, R17 | 56R, R0805_wave soldering | Resistors | Vishay | CRCW080556R0FKEA |
| 72 | 1 | R19 | 39R, R0805_wave soldering | Resistor | Vishay | CRCW080539R0FKEA |
| 73 | 1 | R20 | 82R, R0805_wave soldering | Resistor | Vishay | CRCW080582R0FKEA |
| 74 | 6 | R21, R22, R24, R50, R51, R52 | 100K, R0805_wave soldering | Resistors | Yageo | RC0805FR-07100KL |
| 75 | 2 | R23a, R23b | 0.12Ω 1%, SMD-2512 | Resistors | Yageo | RL2512FK-070R12L |
| 76 | 3 | R25, R26, R27 | 3M, R1206_Wave Soldering | Resistors | Vishay | CRCW12063M00FKEA |
| 77 | 1 | R28 | 68K, R0805_wave soldering | Resistor | Yageo | RC0805FR-0768KL |
| 78 | 1 | R29 | 150K, R0805_wave soldering | Resistor | TE Connectivity | CRG0805F150K |
| 79 | 1 | R37 | 1R, R1206_Wave Soldering | Resistor | Vishay | CRCW12061R00FKEA |
| 80 | 1 | R38 | 4.7K, R0805_wave soldering | Resistor | Yageo | RC0805FR-074K7L |
| 81 | 1 | R40 | 3.3K, R0805_wave soldering | Resistor | Yageo | RC0805FR-073K3L |
| 82 | 1 | R41 | 1.2K, R0805_wave soldering | Resistor | Vishay | CRCW08051K20FKEA |
| 83 | 1 | R42 | 39K 0,125W 1%, R0805_wave soldering | Resistor | Yageo | RC0805FR-0739KL |
| 84 | 1 | R43 | 22R, R0805_wave soldering | Resistor | Yageo | RC0805FR-0722RL |
| 85 | 2 | R44, R49 | 20K, R0805_wave soldering | Resistors | Multicomp | MC01W0805120K |
| 86 | 1 | R46 | 43K, R0805_wave soldering | Resistor | Yageo | RC0805FR-0743KL |
| 87 | 1 | R47 | DNM | Resistors (DNM) | - | - |
| 88 | 1 | R48 | 220K, R1206_Wave Soldering | Resistor | Panasonic | ERJ-6ENF2203V |

| Item | Q.ty | Ref. | Part/Value | Description | Manufacturer | Order code |
|---|---|---|---|---|---|---|
| 89 | 4 | R53, R54, R58, R59 | 39K, R1206 | Resistors | TE Connectivity | CRG1206F39K |
| 90 | 1 | R55 | 47R, R0805_wave soldering | Resistor | TE connectivity | CRG0805F47R |
| 91 | 1 | R56 | 1.5K, R1206_Wave Soldering | Resistor | TE Connectivity | CRG1206F1K5 |
| 92 | 1 | R57 | 1.5K, R0805_wave soldering | Resistor | Bourns | CR0805-FX-1501GLF |
| 93 | 2 | R69, R70 | 330K, R0805_wave soldering | Resistors | Yageo | RC0805FR-07330KL |
| 94 | 1 | R71 | 33K, R0805_wave soldering | Resistor | Yageo | RC0805FR-0733K |
| 95 | 1 | RJ1 | 0R, R0805_wave soldering | Resistor | Yageo | RC0805JR-070RL |
| 96 | 2 | RJ2, RJ5 | 0R, R1206_Wave Soldering | Resistors | Yageo | RC1206JR-070RL |
| 97 | 2 | RJ3, RJ4 | 47R, R1206_Wave Soldering | Resistors | Yageo | RC1206FR-0747RL |
| 98 | 1 | RT1 | NTC, MOV-14561-TV | Thermistor | Semitec | 1.5D2-15LD |
| 99 | 1 | T1 | Transformer_LLC_TV | Tansformer | Zhengyi | BCK-150-L050A |
| 100 | 1 | ZD1 | 13V, SOD-123 | Zener diode | On Semi | MMSZ13T1G |
| 101 | 1 | DB201 | | Heat-sink | Taobao | 35733140685 |
| 102 | 2 | D18, Q1 | | Heat-sinks | Taobao | 35733272389 |
| 103 | 3 | Q2, Q3, D17 | | Heat-sinks | Taobao | 42088561488 |

# Appendix A References

The following reference resources are freely available for download at www.st.com.

- STNRG011 datasheet - Digital combo multi-mode PFC and time-shift LLC resonant controller
- AN5118 - 12 V – 150 W power supply based on STNRG011 digital combo and SRK2001 adaptive synchronous rectifier controller
- AN5119 - How to design an application from draft with STNRG011
- UM2340 - STNRG011 NVM parameters description
- UM2342 - Getting started with the STEVAL-PCC020V1: USB to I²C UART interface board and associated GUI for STNRG products
- STF13N60M2 datasheet - N-channel 600 V, 0.35 Ω typ., 11 A MDmesh II Plus™ low Qg Power MOSFETs in TO-220FP and I2PAKFP packages
- STF24N60M2 datasheet - N-channel 600 V, 0.168 Ω typ., 18 A MDmesh II Plus™ low Qg Power MOSFETs in TO-220FP, I2PAKFP and TO-3PF packages
- STTH1R06 datasheet - Turbo 2 ultrafast high voltage rectifier
- STPS10H200CFP datasheet - High voltage power Schottky rectifier
- STPS20200CFP datasheet - High voltage power Schottky rectifier
- AN2761 - Solution for designing a transition mode PFC pre-regular with the L6562A
- AN2450 - LLC resonant half-bridge converter design guideline
- AN2644 - An introduction to LLC resonant half-bridge converter

# Revision history

Table 11. **Document revision history**

| Date | Version | Changes |
|---|---|---|
| 11-May-2021 | 1 | Initial release. |
| 14-Jun-2021 | 2 | Minor text changes. |

# Contents

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