# AN1440
# APPLICATION NOTE

# 80W POWER-FACTOR-CORRECTED AC-DC ADAPTER WITH STANDBY USING THE L6561 AND THE L5991A

**by C. Adragna**

*This note describes an 80 W, wide-range mains, power-factor-corrected AC-DC adapter. Its electrical specification is tailored on a typical hi-end portable computer power adapter. The peculiarity of this design is its extremely low no-load input consumption (<1 W).*

*The architecture is based on a two-stage approach: a front-end PFC pre-regulator based on the L6561 TM PFC controller and a back-end DC-DC converter in flyback topology that makes use of the L5991A PWM controller. The Standby function of the L5991A, which reduces the switching frequency of the DC-DC converter upon recognition of a light load, is also used to turn off the PFC stage to make it possible meeting the severe no-load consumption requirement.*

## Design Specification

The design of an 80W power-factor-corrected AC-DC adapter suitable for hi-end portable computer and the evaluation results of a prototype are here described.
Table 1 shows the electrical specification of the application, table 2 provides the BOM and tables 3 and 4 list magnetics' spec. The electrical schematic is illustrated in figure 1 and the PCB layout in figure 2.

**Table 1. 80W AC-DC adapter with PFC and Standby: electrical specification**

| | |
|---|---|
| Input Voltage Range ($V_{in}$) | 90 to 265 Vac |
| Mains Frequency ($f_L$) | 50/60 Hz |
| Holdup time | 20 ms |
| Maximum Output Power ($P_{outmax}$) | 80 W |
| Output | $V_{out}$ = 18 Vdc ± 2%<br>$I_{out}$= 0 to 4.5 A<br>$V_{ripple}$ = 1% |
| Line and Load regulation | < 1% |
| Switching Frequency (Flyback, @ $P_{out}$ = 80 W) | 65 kHz |
| Switching Frequency (Flyback, @ $P_{out}$ = 0 W) | 22 kHz |
| PFC Minimum Switching Frequency (@ $P_{out}$ = 80 W) | 35 kHz |
| PFC Output Voltage | 400 Vdc ± 5% |
| PFC Output Voltage ripple (@$f_L$ = 50 Hz, full load) | <20 V pk-pk |
| PFC Output Overvoltage threshold | 440 Vdc |
| Overall Efficiency (@ $P_{out}$ = 80 W, $V_{in}$ = 90÷265 Vac) | $\eta > 75\%$ |
| Maximum No-load Input Power | < 1 W |
| Low-frequency harmonic contents | EN 61000-3-2, class D compliant |
| Conducted EMI | EN 55022, class B compliant |

To meet the requirement on low-frequency emission, active power factor correction will be used, resulting in a two-stage architecture: a front-end PFC pre-regulator, using boost topology, followed by a cascaded DC-DC converter. As to the PFC stage, the power rating suggests the use of TM operation, and then the L6561 [1] will be used as the controller. The cascaded DC-DC converter will use flyback topology: the high input voltage (400V, output of the PFC stage) and the relatively high output voltage make this topology the most attractive for this application.
A special requirement concerns the no-load consumption from the mains: less than 1 W. Especially in a two-stage system, this is a tough job. Special design care needs to be taken, from both the system and the selection of the PWM controller point of view.

**Figure 1. 80W AC-DC adapter with PFC and Standby: electrical schematic**

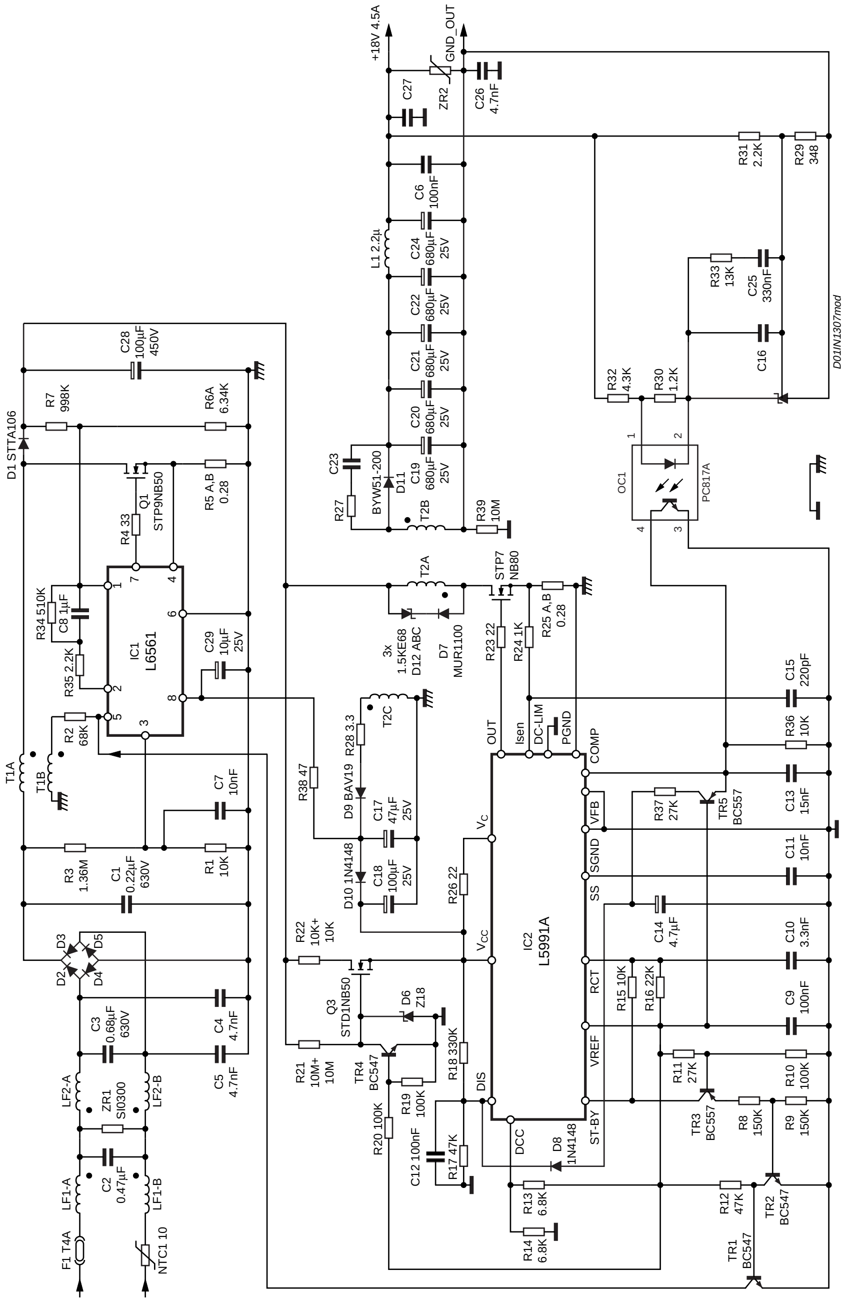


**Table 2. 80W AC-DC adapter with PFC and Standby: Bill Of Material**

| Symbol | Value | Note |
|---|---|---|
| R1, R15, R36 | 10 kΩ | |
| R2 | 68 kΩ | |
| R3A, R3B | 680 kΩ | |
| R4 | 33 Ω | |
| R5A, R5B, R25A, R25B | 0.56 Ω | 1W, metal film |
| R6A | 6.34 kΩ | Only R6A assembled. R6B is for Fine-Tuning |
| R7A, R7B | 499 kΩ | |
| R8, R9 | 150 kΩ | |
| R10, R19, R20 | 100 kΩ | |
| R11, R37 | 27 kΩ | |
| R12, R17 | 47 kΩ | |
| R13, R14 | 6.8 kΩ | |
| R16 | 20 kΩ | |
| R18 | 330 kΩ | |
| R21A, R21B | 10 MΩ | |
| R22A, R22B | 10 kΩ | ½ W |
| R23, R26 | 22 Ω | |
| R24 | 1 kΩ | |
| R27 | --- | Not assembled |
| R28 | 3.3 Ω | |
| R29 | 348 Ω | |
| R30 | 1.2 kΩ | |
| R31, R35 | 2.2 kΩ | |
| R32 | 4.3 kΩ | |
| R33 | 13 kΩ | |
| R34 | 510 kΩ | |
| R38 | 47 Ω | |
| R39 | 10 MΩ | ½ W, VR37 |
| C1 | 0.22 µF | 630V, polyester |
| C2 | 0.47 µF | 275 AVC, X2 |
| C3 | 0.68 µF | 630V, polyester |
| C4, C5, C26 | 4.7 nF | Ceramic, Y |
| C6 | 0.1 µF | Polyester |
| C7, C11 | 10 nF | |
| C8 | 1 µF | |
| C9, C12 | 100 nF | Ceramic |
| C10 | 3.3 nF | 5% |

**Table 2. 80W AC-DC adapter with PFC and Standby: Bill Of Material** (continued)

| Symbol | Value | Note |
|---|---|---|
| C13 | 15 nF | |
| C14 | 4.7 µF | 16 V, electrolytic |
| C15 | 220 pF | |
| C16, C23, C27 | --- | Not assembled |
| C17 | 47 µF | 25 V, electrolytic |
| C18 | 100 µF | 25 V, electrolytic |
| C19, C20, C21, C22, C24 | 680 µF | 25V Rubycon, ZL series |
| C25 | 330 nF | |
| C28 | 100 µF | 450 V, electrolytic, EPCOS B43502 |
| C29 | 10 µF | 25 V, electrolytic |
| D1 | STTA106 | 600 V / 1 A, Turboswitch, ST |
| D2, D3, D4, D5 | KBP208M | 800 V / 2 A Bridge recitifier, or equivalent |
| D6 | 1N5248B | 18V, ½ W Zener, or equivalent |
| D7 | MUR1100E | 1100 V / 1 A, Ultrafast |
| D8, D10 | 1N4148 | 75 V / 0.3 A p-n diode, or equivalent |
| D9 | BAV19 | 100 V / 0.25 A p-n diode, or equivalent |
| D11 | BYW51-200 | 200 V / 2x10 A Ultrafast, ST |
| D12A, D12B, D12C | 1.5KE68 | 1.5 kW / 68 V Transil, ST |
| L1 | ELC08D2R2E | 2.2 µH / 7.2A inductor, Panasonic, or equivalent |
| LF1 | B82732 | 15 mH / 1.1 A EPCOS |
| LF2 | B82734 | 47 mH / 1.3 A, EPCOS |
| TR1, TR2, TR4 | BC547 | Small-signal NPN |
| TR3, TR5 | BC557 | Small-signal PNP |
| Q1 | STP9NB50 | 500 V / 9A MOSFET, ST |
| Q2 | STP7NB80 | 800 V / 7A MOSFET, ST |
| Q3 | STD1NB50 | 500V / 1A MOSFET, ST |
| IC1 | L6561 | PFC TM controller, ST |
| IC2 | L5991A | PWM controller, ST |
| OC1 | PC817A | Optocoupler, SHARP |
| VR1 | TL431C | Programmable shunt regulator, ST |
| NTC1 | S236/10M | 10 Ω NTC |
| T1 | 473201A8 | PFC inductor (see table 3), OREGA |
| T2 | RDT13560 | Flyback transformer (see table 4), RD Elettronica |
| ZR1 | S14K300 | MOV, EPCOS, or equivalent |
| ZR2 | --- | Not assembled |
| F1 | T4A | 250V / 4A, ELU or equivalent |

Notes: if not otherwise specified: all resistors are 1%, ¼ W, all capacitors may be plastic film or ceramic, 20% tolerance
Q1 is provided with a 25 °C/W heatsink, Q2 and D11 are provided with a 9.5°C/W heatsink

Table 3. 80W AC-DC adapter with PFC and Standby: PFC inductor spec (p.n. 473201A8)

| **Core** | B1ET2910A, B1 Material from THOMSON | | | | |
|---|---|---|---|---|---|
| **Bobbin** | Vertical mounting, 18 pins, slotted | | | | |
| **Air gap** | ≈ 1.25 mm on center leg for an inductance 2-7 of 430 µH | | | | |
| **Windings Spec & Build** | **Pin Start/End** | **Winding** | **Wire** | **Turns** | **Notes** |
| | 2/7 | Pri | 10 x AWG32 | 90 | |
| | 12/17 | Aux | AWG32 | 7 | |

Table 4. 80W AC-DC adapter with PFC and Standby: Flyback transformer spec (p.n. RDT13560)

| **Core** | E32/16/9, N67 Material or 3C85 or equivalent | | | | |
|---|---|---|---|---|---|
| **Bobbin** | Horizontal mounting, 14 pins | | | | |
| **Air gap** | ≈ 1 mm on center leg for an inductance 10-9 of 430 µH | | | | |
| **Leakage inductance** | < 10 µH (@ 65 kHz) measured between pins 10-9 with 3,5,12,13 shorted | | | | |
| **Windings Spec & Build** | **Pin Start/End** | **Winding** | **Wire** | **Turns** | **Notes** |
| | 10/1 | Pri1 | AWG26 | 28 | Innermost winding |
| | 3/5 | Sec | 4xAWG22 | 10 | Separated from the primary windings by a 3-layer polyester isolation |
| | 1/9 | Pri2 | AWG26 | 28 | Pin 1 will be cut for safety |
| | 12/13 | Aux | AWG32 | 8 | Evenly spaced, 2-layer isolation |

As to the PWM controller, the choice is the L5991A [2]: above all else, its Standby function makes this device particularly suitable for building a "highly-efficient" converter under no-load conditions.

From the overall system point of view, a fundamental point is:

- Under no-load conditions the PFC pre-regulator must be shut down.

Then the optimization effort for low light-load losses will be concentrated on the flyback converter. Based on the advice given in [3], the following design choices have been made:

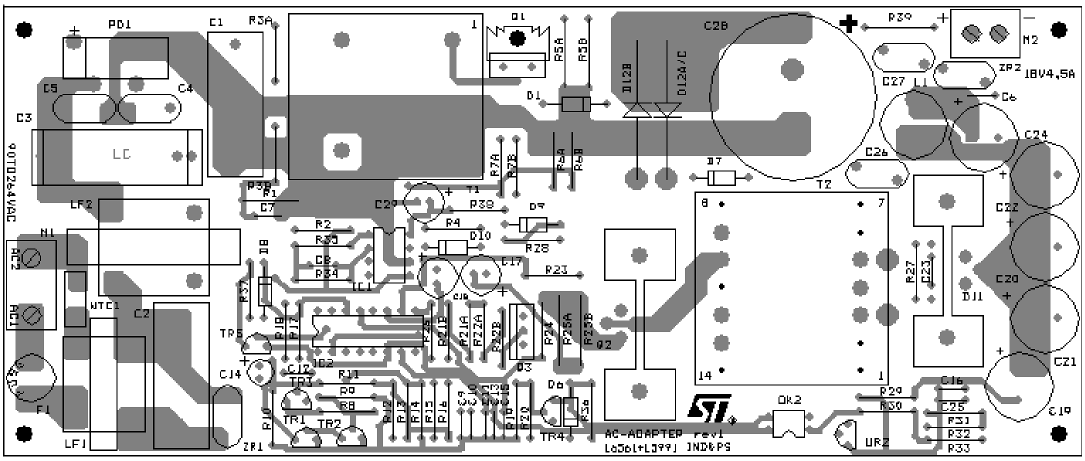
- Use of an active start-up circuit.
- Use of a Transil clamp to handle the leakage inductance spikes.

The critical point where maximum design effort needs to be put to optimize the performance is the design and the construction of the transformer. In particular the points to look at are:

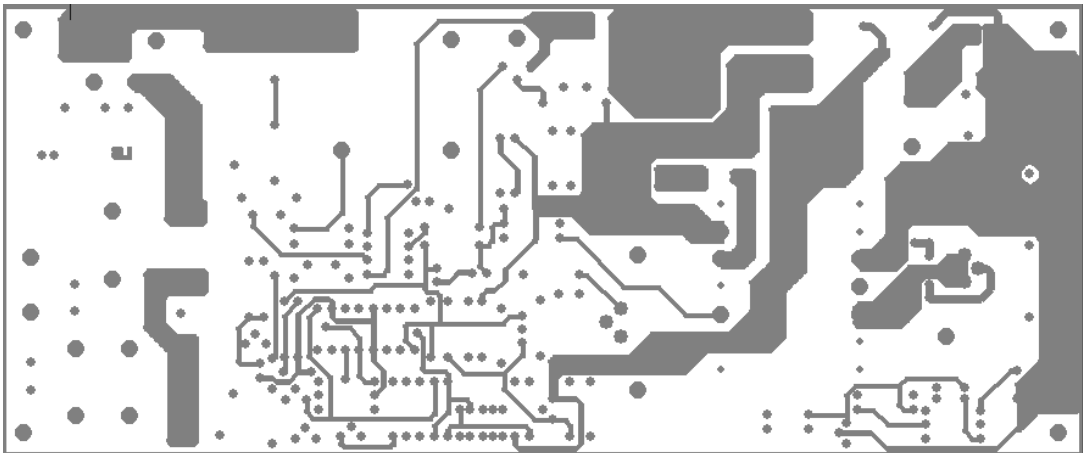
- The primary to-secondary leakage inductance, which must be as low as possible, to minimize the energy dissipated in the clamp circuit so as to make it possible the use of a Transil clamp.
- The intrawinding capacitance of the primary winding, which must be as low as possible, to minimize the capacitive losses of the MOSFET.
- The coupling between the secondary and the auxiliary winding, which must be as good as possible, to minimize the drop of the auxiliary voltage (used for supplying the controllers) as the converter's load goes to zero. This is very important, since a stable self-supply circuit avoids the use of dummy loads that would increase no-load consumption.

Figure 2. 80W AC-DC adapter with PFC and Standby: PCB layout (top view), 1:1.25 scale

top layer + silk



bottom layer



## Evaluation board description

The design of the PFC stage closely follows that of the L6561 demonstration board described in [4]. The main difference concerns the selection of the output capacitor, here imposed by the holdup requirement. Arbitrarily assuming a maximum drop of 20% for the output voltage after 20ms of line drop, the minimum capacitance needed is around 70µF, which requires the use of a 100µF capacitor to take its spread (±20%) into account too. With 100µF the low-frequency output ripple will always be <10 V, then well inside the spec.

As to the flyback stage, the switching frequency (65 kHz) has been selected not only trading off transformer's size against frequency-related losses, but also keeping an eye on EMI compliance, even if the effect of the PFC will be dominant in this respect. With this choice, the harmonics falling within the frequency range of interest to the EN55022 regulation (150 kHz - 30 MHz) will be from the third one onward.

The reflected voltage $V_R$ has been chosen equal to 100V. Lower values, do not give advantages in terms of MOSFET's voltage rating and, on the other hand, lead to too small values of duty cycle, thus increasing MOSFET's conduction losses. To provide enough room for the leakage inductance spike (so as to decrease clamp's losses and improve primary-to-secondary energy transfer) and considering the OVP threshold of the PFC stage, an 800V MOSFET (STP7NB80FI) will be used.

To get 100 V reflected voltage, the primary-to-secondary turn ratio is made 1:5.6, which generates a reverse voltage across the secondary rectifier that may approach 100V if the output of the PFC stage gets close to its OVP threshold. To have enough safety margin, a 200V ultrafast rectifier needs to be used. A BYW51-200 has been selected.

To stay within the required tolerance, the output voltage regulation is done with secondary feedback, using a typical arrangement TL431+optocoupler. An LC cell is used as a post-filter to minimize high-frequency output ripple, then the feedback signal is taken upstream the cell to avoid introducing an extra phase-shift that may affect loop stability significantly. By using a low-resistance choke, the degradation of the load regulation will be kept to a minimum.

There is a full coverage of anomalous operating conditions. Overload and short circuit are handled following the approach suggested in [5], resulting in a latched shutdown of the converter by means of L5991A's Disable function. R37 and C14 determine how much the shutdown is delayed. Additionally, thanks to the 2nd overcurrent level on the L5991A's current sense pin, also a short circuit directly across the secondary winding - or even D11 failing short - will be safely handled: either failure will cause an intermittent operation ("Hiccup" mode) with a low level of power throughput. Finally, in case the optocoupler fails or R31 opens, the Disable function of the L5991A will be invoked (via the divider R17-R18), thus causing a latched shutdown.

Two basic design choices have been done to meet the no-load consumption target. First, instead of the usual dropping resistor, the converter is started with a circuit comprising an active switch that is ON only during start-up and then is switched off as the converter starts operating. This circuit has been designed so as to provide a maximum wake-up time of 0.2s @ 90 Vac and a consumption of less than 10 mW @ 265 Vac when the circuit is off.

Second, the leakage inductance spikes are handled by a Transil clamp instead of an RCD clamp, thus saving the power $V_R^2/R$ that would be dissipated on the resistor during no-load conditions. This requires the transformer's leakage inductance to be as low as possible to limit full-load losses on the Transil. However, even with a transformer done to perfection, there is a limit to the leakage inductance reduction due to the need of fulfilling safety regulations. As a result, in the specific case, even with 1% leakage inductance the power dissipated in the Transil is so large that cannot be handled by a single device; therefore, three Transils (1.5KE68), series-connected, are used to share the loss.

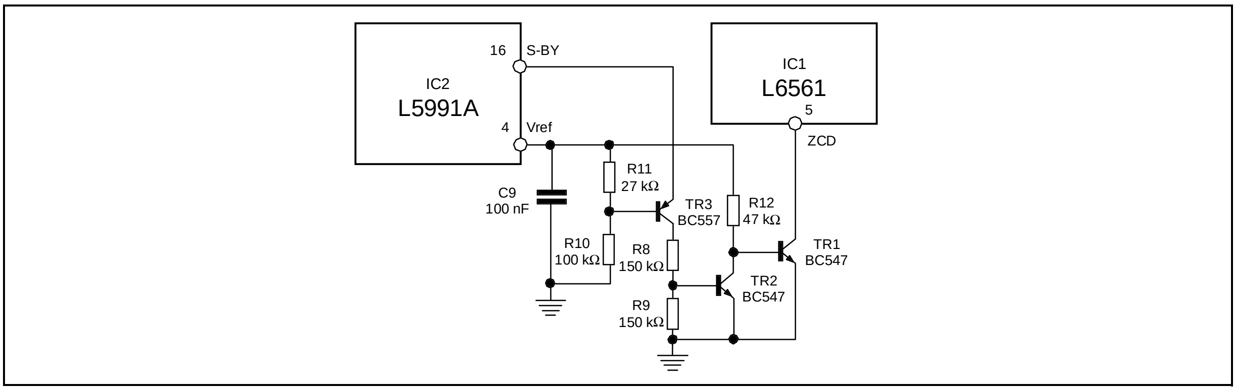
At this point, a number of design considerations are needed concerning how the two stages live together and interact. These will have a lot of implications, mainly on the power-on/power-off sequence and then on the self-supply system of the two IC's.

As previously said, a fundamental step to meet the no-load consumption requirement is to shut down the PFC stage under no-load conditions. Experiments show that a completely unloaded PFC stage, if well optimized, draws from the mains slightly more than 0.5 W at high line, hence leaving no practical room to the consumption of the flyback stage. Disabling the PFC stage is then a must.

On the other hand, power factor correction is required at nominal load, then it is of no use keeping the PFC stage active when the load is significantly lower. Hence it is possible to disable the PFC stage when the L5991A goes into Standby mode reducing the switching frequency of the flyback stage.

The Standby mode can be detected by looking at pin 16 (S-BY) of the L5991A: while during normal operation the voltage at pin 16 is 5V, during Standby mode the pin is floating, thus its voltage follows that at pin 2 (RCT) and swings from 1 to 3 V.

**Figure 3. 80W AC-DC adapter with PFC and Standby: L6561 ON/OFF via L5991A Standby mode**



The circuit shown in figure 3 interfaces the L5991A and the L6561 and illustrates how the S-BY pin signal can be used. When the L5591A goes into Standby, the base of TR3 (tied at about 4 V) is reverse-biased: TR3 is cut off and so is TR2. TR1 is then turned on and pulls L6561's pin 5 (ZCD) to ground, thus disabling the PFC controller. This solution is insensitive to temperature variations and parameter spread, does not alter the oscillator frequency and absorbs a negligible power during Standby mode.

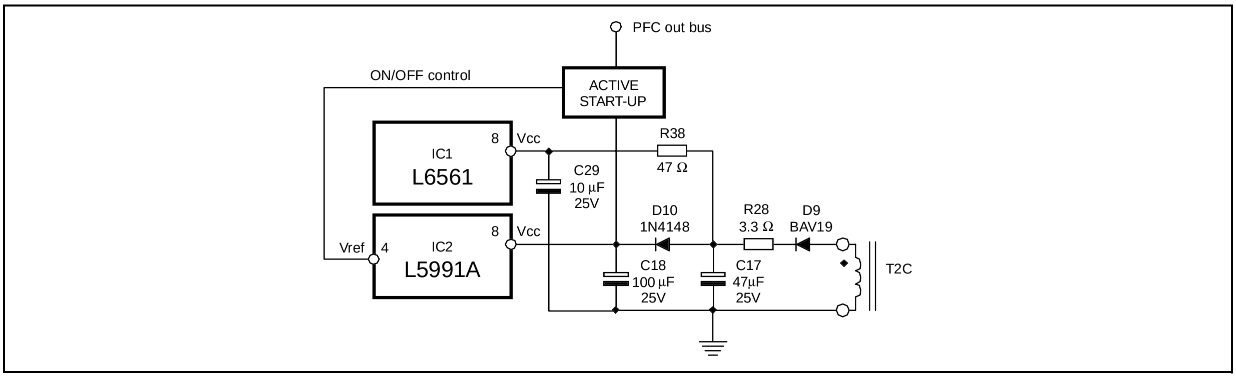
Special care is needed for the design of the self-supply circuit of both the L6561 and the L5991A. A solution with separate self-supply circuits has been discarded because the start-up sequence could not be definitely determined without using additional circuitry.

One more point to consider is that the supply voltage of the L6561 must be above its UVLO threshold at all times. Thus, when the L5991A goes from Standby mode back to normal mode following on a large load increase, it can start immediately to avoid any voltage dip on the converter's output.

Then, since the L6561 will be stopped during standby, the self-supply winding needs to be derived from the transformer of the flyback stage. The coupling of this winding with the secondary one is critical: because of not perfect coupling the voltage generated tends to increase at heavy load and to drop at light load. The tolerable change of this voltage is limited by the L6561: downward by its UVLO threshold (10.3 V) and upward by the internal zener on its Vcc pin (18 V). This is why the L5991A has been used instead of the L5991: the latter has a maximum UVLO threshold of 11V, which would narrow down the allowable Vcc range.

Using the flyback transformer to generate the self-supply requires the flyback stage to start first and the PFC pre-regulator to follow. The solution put to use is illustrated in figure 4.

**Figure 4. 80W AC-DC adapter with PFC and Standby: self-supply circuit**



This system approach has a significant impact on the electrical design of the flyback stage. It will be designed for a steady-state Discontinuous Conduction Mode operation starting from a DC input of 400V, however the start-up phase cannot be neglected. The output voltage of the PFC stage takes some time to reach the final value (up to 80-90 ms at low line), thus a start-up @ 90 Vac input voltage, cold NTC and full load may require the flyback stage to work for some time with just the rectified mains, as if it were a not power-factor-corrected wide-range-mains converter. In the end, at least from the electrical point of view, the flyback will be treated as a wide-range-input system: then the inductance of the transformer and its $\Delta B$ swing, as well as the sense resistor will be selected consequently. Also the maximum duty cycle allowed will be fixed at 70% (whereas the steady-state value is around 15%). From the thermal point of view, however, there is no need to consider the start-up, thus MOSFET's' size, transformer's wire and clamp will be determined considering steady-state conditions.

### Board evaluation: getting started

The AC voltage, generated by an AC source ranging from 90 Vac to 265 Vac, will be applied to the input connector (M1, next to the bottom left-hand corner) and the load will be tied to connector M2, at the top right-hand corner). If desired, the board can be supplied also by a high-voltage DC source, in which case the PFC pre-regulator will work just as a standard boost converter. The most interesting points to analyze are those concerning the interaction between the PFC pre-regulator and the flyback stage occurring every time the L5991A passes from normal operation to Standby and vice versa because of a load change. Then, besides the usual points (MOSFET's drain voltage, current sense signal, etc.), it is worth probing the following ones:

- pin 2 (RCT), pin 6 (COMP) and pin 16 (S-BY) of the L5991A.
- pin 5 (ZCD) and pin 7 (GD) of the L6561.
- PFC pre-regulator's and flyback stage's output voltage (across C28 and C24 respectively).

To start the application board the input voltage has to be applied quickly. If the voltage is increased manually from zero, as prudent experimenter usually do with an unfamiliar unit, most probably the application board will not start: when the input voltage is low the converter works open-loop, then a slowly rising input voltage causes the "out of regulation" condition to last long. This will eventually trigger the overload protection circuit (TR5, R37, C14 and D8) that shuts off the L5991 and locks the system until the board is disconnected form the input source.

**Like in any offline circuit, extreme caution must be used when working with the application board because it contains dangerous and lethal potentials. The application must be tested with an isolation transformer connected between the AC mains and the input of the board to avoid any risk of electrical shock.**

### Board evaluation: bench results and significant waveforms

In the following tables the results of some bench evaluations are summarized. A number of waveforms showing the interaction between the two stages are presented for user's reference.

**Table 5. 80W AC-DC adapter with PFC and Standby: typical performance**

| Parameter | Value | Unit |
|---|---|---|
| Regulated Output Voltage (@ $V_{in}$ = 220 Vac, $I_{out}$ = 4.5A) | 18.056 | V |
| Line & Load Regulation ($V_{in}$ = 90 to 265 Vac, $I_{out}$ = 0 to 4.5 A) | 50 | mV |
| High-frequency Output Voltage Ripple (@ $V_{in}$ = 90 Vac, $I_{out}$ = 4.5A) | 20 | mV |
| Line-frequency Output Voltage Ripple (@ $V_{in}$ = 220 Vac, $f_L$ = 50 Hz, $I_{out}$ = 4.5A) | < 5 | mV |
| Output power for Normal-to-Standby mode transition (@ $V_{in}$ = 220 Vac) | 22.1 | W |
| Output power for Standby-to-Normal mode transition (@ $V_{in}$ = 220 Vac) | 28.1 | W |
| Minimum Full-load PFC Efficiency (@ $V_{in}$ = 90 Vac) | 87.5 | % |
| Full-load Flyback Efficiency (@ $V_{in}$ = 400 Vdc) | 86.7 | % |
| Minimum Full-load Total Efficiency (@ $V_{in}$ = 90 Vac) | 75.9 | % |
| Maximum No-load Input Power (@ $V_{in}$ = 265 Vac) | 0.9 | W |
| Typical Power Factor (@ $V_{in}$ = 220 Vac, $I_{out}$ = 4.5A) | 0.950 | - |
| Typical THD (@ $V_{in}$ = 220 Vac, $I_{out}$ = 4.5A) | 11.5 | % |

### Table 6. 80W AC-DC adapter with PFC and Standby: System Evaluation

| Vac [V] | | 90 | 110 | 135 | 175 | 220 | 265 |
|---|---|---|---|---|---|---|---|
| Iout [A] | 4.5 | η = 75.9 %<br>PF = 0.998<br>THD = 4.9 % | η = 79.2 %<br>PF = 0.998<br>THD = 3.5 % | η = 80.6 %<br>PF = 0.994<br>THD = 4.8 % | η = 82.0 %<br>PF = 0.979<br>THD = 8.6 % | η = 82.5 %<br>PF = 0.950<br>THD = 11.5 % | η = 82.9 %<br>PF = 0.916<br>THD = 12.5 % |
| | 2.25 | η = 79.1 %<br>PF = 0.997 | η = 80.7 %<br>PF = 0.992 | η = 81.2 %<br>PF = 0.982 | η = 81.7 %<br>PF = 0.951 | η = 81.7 %<br>PF = 0.900 | η = 81.8 %<br>PF = 0.832 |
| | 1.20 | η = 76.3 % | η = 78.4 % | η = 79.8 % | η = 81.2 % | η = 81.5 % | η = 81.5 % |

### Table 7. 80W AC-DC adapter with PFC and Standby: Load Regulation

| Iout [A] | 0 | 1.0 | 2.0 | 2.5 | 3.5 | 4.5 |
|---|---|---|---|---|---|---|
| Vout [V] | 18.104 | 18.088 | 18.080 | 18.076 | 18.066 | 18.056 |

### Table 8. 80W AC-DC adapter with PFC and Standby: Light-load Input Power (@ Pout = 0.5 W)

| VAC [V] | 90 | 110 | 135 | 175 | 220 | 265 |
|---|---|---|---|---|---|---|
| Pin [W] | 1.0 | 1.0 | 1.0 | 1.1 | 1.3 | 1.4 |

### Table 9. 80W AC-DC adapter with PFC and Standby: No-load Input Power

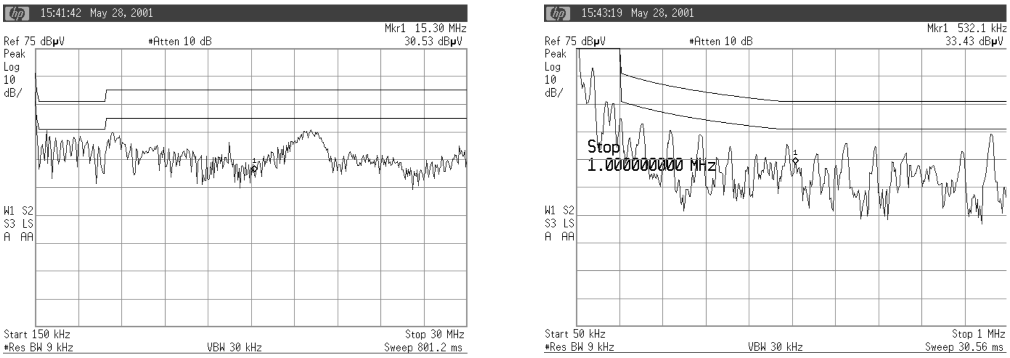
| VAC [V] | 90 | 110 | 135 | 175 | 220 | 265 |
|---|---|---|---|---|---|---|
| Pin [W] | 0.4 | 0.5 | 0.5 | 0.6 | 0.7 | 0.9 |

### Table 10. 80W AC-DC adapter with PFC and Standby: Typical Wake-up Time

| VAC [V] | 90 | 110 | 135 | 175 | 220 | 265 |
|---|---|---|---|---|---|---|
| TWAKE [s] | 0.15 | 0.12 | 0.10 | 0.07 | 0.06 | 0.05 |

### Figure 5. 80W AC-DC adapter with PFC and Standby: conducted EMI @ Vin = 110 Vac, Pout = 80 W

Peak detection

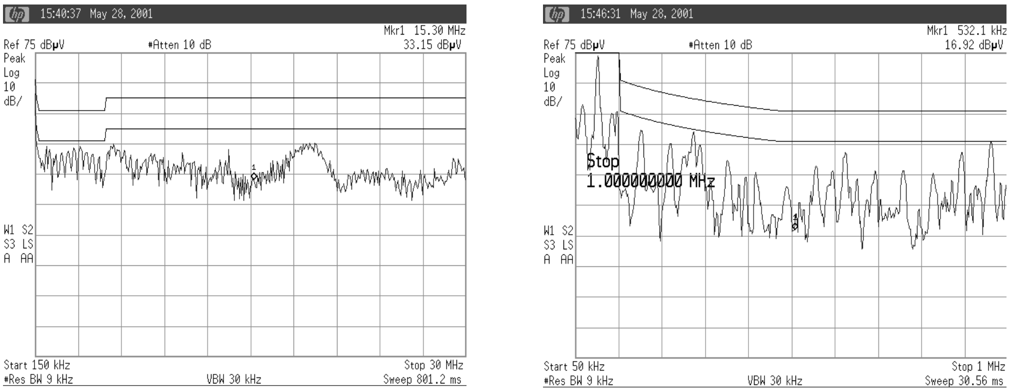


150 kHz - 30 MHz

Detail: 50 kHz - 1 MHz

## Figure 6. 80W AC-DC adapter with PFC and Standby: conducted EMI @ Vin = 220 Vac, Pout = 80 W

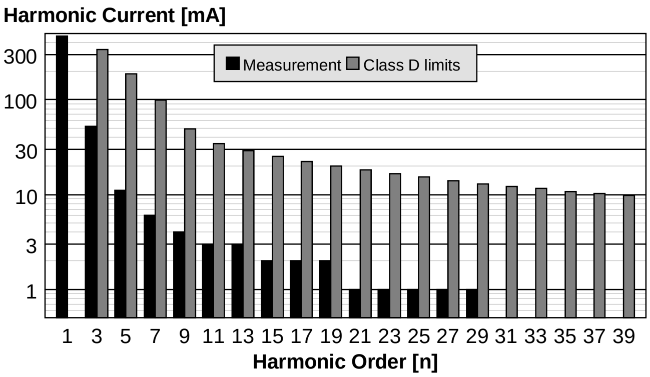
Peak detection



150 kHz - 30 MHz

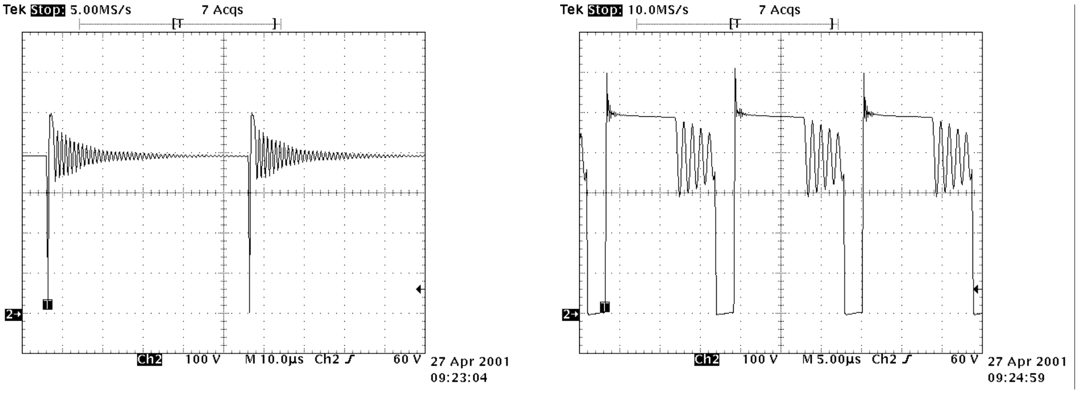
Detail: 50 kHz - 1 MHz

## Figure 7. 80W AC-DC adapter with PFC and Standby: Low-frequency Harmonic Contents



Vin = 220 Vac, 50 Hz; Pout = 80 W THD = 11.5% PF = 0.950

## Figure 8. 80W AC-DC adapter with PFC and Standby: Q2 drain at a) no-load, b) full-load



a)

b)

Figure 9. 80W AC-DC adapter with PFC and Standby: Load transient 0.1↔4.5 A @ Vin = 90 Vac (1)

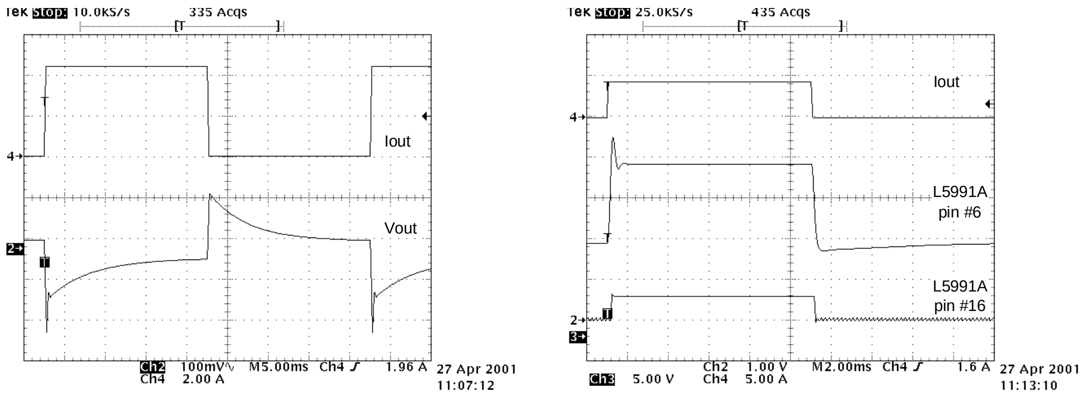


Figure 10. 80W AC-DC adapter with PFC and Standby: Load transient 0.1↔4.5 A @ Vin = 90 Vac (2)

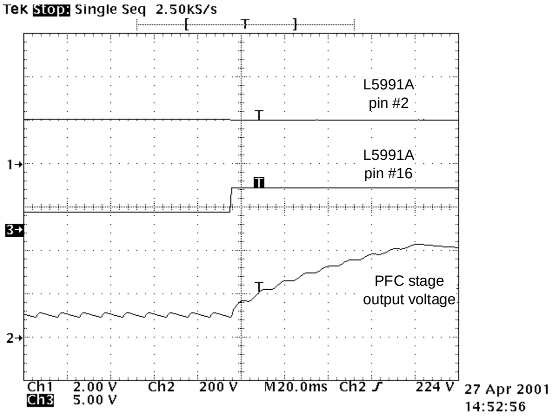
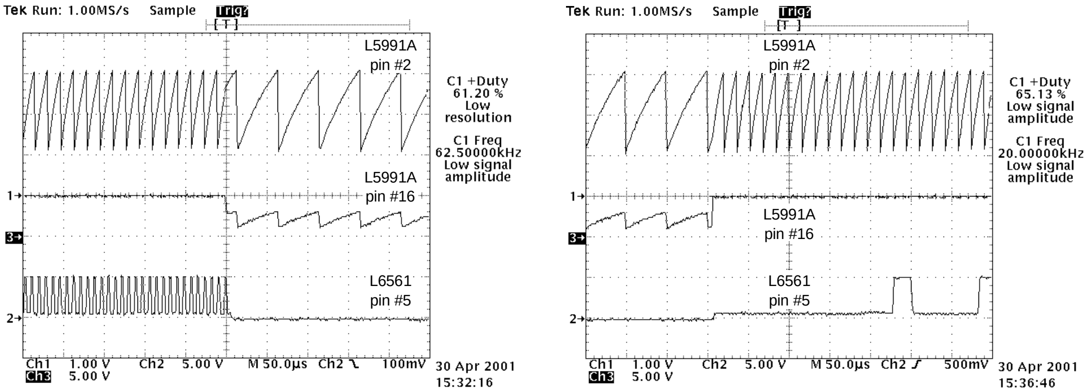


Figure 11. 80W AC-DC adapter with PFC and Standby: Load transient 0.1↔4.5 A @ Vin = 90 Vac (3)



PFC stage turn-off

PFC stage turn-on

## ACKNOWLEDGMENTS

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## REFERENCES

[1] "L6561 Power Factor Corrector" Datasheet

[2] "L5991/A Primary Controller with Standby" Datasheet

[3] "Minimize Power Losses of Lightly Loaded Flyback Converters with the L5991 PWM Controller" (AN1049)

[4] "L6561, Enhanced Transition Mode Power Factor Corrector" (AN966)

[5] "How to Handle Short Circuit Conditions with ST's Advanced PWM Controllers" (AN1215)

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