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# Meeting The Standby Power Specification In LED TVs With A Single Power Supply

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Despite all the efforts to add new features to LED TVs, the average selling price continues to drop, forcing TV manufacturers to squeeze out as much of the electronics cost as possible. That includes the power supply block. This is one of the reasons why LED TVs have stopped using a dedicated standby power supply to fulfill the increasingly stringent criteria for standby power consumption.

Fortunately, the improved efficiency of today's power converters under light loads has helped designers to remove this extra power supply, reducing the size and cost of the overall function. Supporting this trend, the TVs' signal processing circuitry has experienced reductions in its power consumption in standby mode. However, new features such as Internet-connected TV are driving this standby power back up, creating new challenges.

If improving light-load efficiency is relatively straightforward for a flyback converter used for limited power (< 100 W) in up to 42-in. screen size TVs, this task becomes much more complex for resonant LLC converters used for higher output power. This article is intended to help switched-mode power supply (SMPS) designers get the best possible overall performance when they have to design an LED TV with a single SMPS that still matches standby requirements.

After a brief discussion on LED TV power supply requirements, including both electrical and safety demands, the article describes improvements to the flyback and LCC power supply architectures that reduce standby power consumption. These improvements are implemented in several power supply controllers from ON Semiconductor and the application of these controllers in LED TV power supplies is discussed in detail.

## Power Supply Requirements in Active (On) Mode

Before delving into the subject of standby mode operation, it is worth looking at the nominal power (on mode) that defines the overall SMPS architecture. This single SMPS has to provide energy to the two main functions of the LED TV:

- The signal processing and audio amplifiers are now commonly powered by a 13-V supply, used directly by the full bridge class D audio amplifier (providing ~ 2 x 10 W at 8 Ω) and by multiple dc-dc buck converters providing regulated 5 V, 3.3 V and any other voltage required by the signal processing.
- The LED backlight now requires higher voltage than the previous 24 V to reduce size and cost of downstream converters. This voltage, between 80 V and 300 V, supplies either a boost or buck LED driver for the single (or dual) LED string present in most of the LED TVs.

The power ratio between the two outputs is almost constant across the range of TV sizes with ~ 1/3 for the 13-V signal & audio block and ~ 2/3 for the high-voltage backlight. The 13-V supply is always regulated by the primary-side controller avoiding any variation due to audio modulation and/or LED backlight low-frequency PWM dimming.

The LEDs' downstream converter regulates the LEDs' current and manages input-voltage variations on the 80- to 300-V rail. The primary-side controller limits the overall power delivered to secondary side to ~120% of the requested power avoiding any hiccup but is able to stop in case power is over the limit after a given time defined by a fixed timer.

The first challenge to be addressed by designers is meeting the requirements for safety tests and circuit protection. When the 13-V is shorted to ground just after the rectifier diode), the extremely low impedance allows primary protection to be immediately activated, avoiding severe damage to parts within safety standards requirements.

 

However, the same test should be done anywhere on this supply line and particularly on the signal processing module (after long cable and copper traces) and when the LED backlight is off. In that case, the total 120% of power should be available on the single 13-V supply before any switch off of the primary-side controller.

This test will most likely result in extremely high currents flowing through all the elements of the 13-V line such as the transformer, diode and PCB traces. This current can be more than four times the maximum on-mode current, resulting in overheating and possibly destroying parts not in line with safety standards. To avoid such a catastrophic failure, components have to be oversized, which will negatively impact the BOM cost.

However, the use of a secondary-side current controller solves this issue in a more elegant way, avoiding overcurrent on the 13-V supply, improving the safety protection without oversizing of components. The fully integrated CC/CV (constant current and constant voltage) NCP4328 controller from ON Semiconductor, is specially designed for such functions. This controller replaces the existing TL431, allowing an overall cost reduction by eliminating the need for oversized diodes and a large, low-profile heatsink, which would increase the overall PCB surface.

Thanks to this TSOP-5 IC device, the current delivered on the 13-V output is controlled such that it never exceeds the defined value. While this solution—the combination of the NCP4328 secondary-side controller with a primary-side controller—is not yet commonly used with flyback converters (<100 W), it simplifies the critical safety tests and provides an overall design simplification with a total solution cost reduction.

The standby mode can now be the focal point but to simplify, we will focus on two architectures:

- Flyback without PFC (< 100 W)
- LLC with PFC (> 100 W).

## *Below 100 W: The Flyback Solution*

Today's flyback converters (PWM fixed frequency or quasi-resonant) easily support light load/standby mode when designed with frequency foldback and skip mode, allowing good output-voltage regulation despite extremely low output power. However, to stay below the power consumption mandate (<300 mW at 230 V) and still deliver enough power to support new high-level features, it is necessary to improve the overall efficiency versus classical designs.

A first improvement is to change the output voltage regulation according to the TV mode. Although a 13-V output is required in the on mode, this voltage is far too high to supply the dc-dc buck providing the 3.3-V standby power. Reducing it down to about 50% of its nominal value offers several benefits. These include improved buck efficiency, reduced consumption of the secondary voltage regulation circuit, reduced consumption of the primary-side controller IC thanks to a lower $V_{CC}$, reduction in primary snubber power dissipation and a lower leakage current on the backlight supply.

The new fully integrated NCP4352 CC/CV "ECO Mode" controller from ON Semiconductor, allows (in addition to the functions performed by the NCP4328 CCCV) to have this dual-voltage regulation level with an automatic light load detection, changing the output voltage regulation from on to the standby mode through a deep-skip-mode detection. When the power is increasing again, the IC automatically forces the system back to on mode with the corresponding regulation level. When available, a "standby/on" control line can be added or even replace this automatic detection (Fig. 1.)

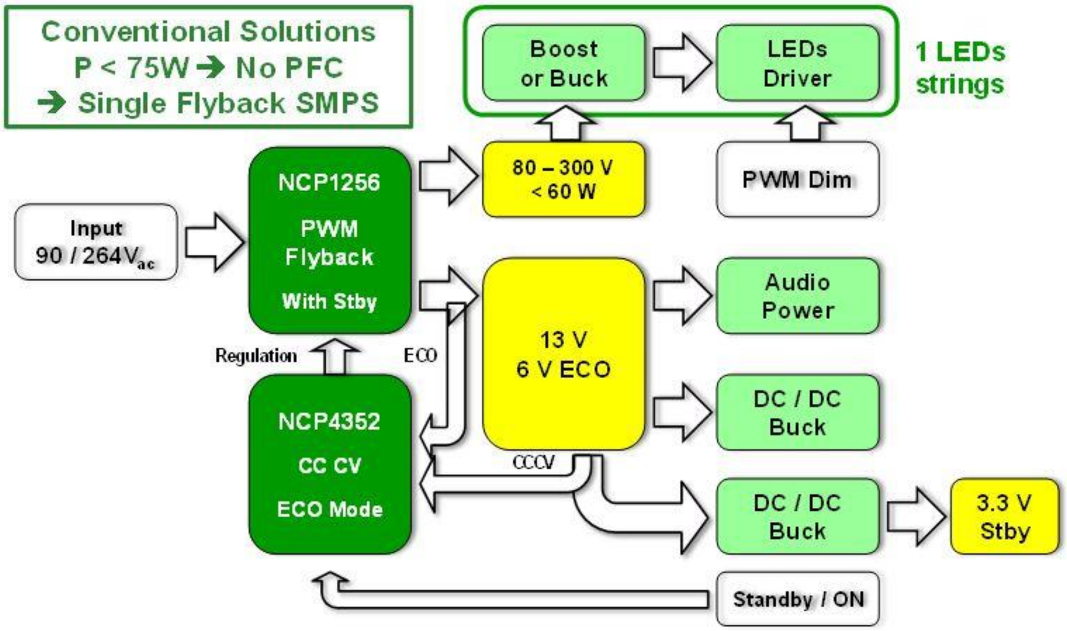


*Fig. 1. Single PWM flyback SMPS with ECO mode.*

The second possible improvement, to be done on the primary side, is related to the X2 capacitor discharge and startup resistors when the primary controller has no embedded high-voltage startup. To fulfill IEC-65 (or equivalent regulation), the X2 capacitors used in the EMI filters should be discharged in less than 1 s below 100 V to avoid the possibility of electrical shock to the TV user. To reduce overall solution cost and avoid larger common-mode coils, it is common to use larger X2 capacitors. This solves conducted EMI issues but it then becomes more critical to discharge these capacitors in the given time limit.

As an example, the discharge of two 330-nF capacitors will call for ~1.2-MΩ resistors, which will have a corresponding power dissipation of 44 mW at 230 V. These losses represent 15% of the 300-mW total power consumption budget (300-mW limit). Active X2 cap discharge solutions (like the NCP4810) have been developed to eliminate this power consumption. Active only after mains-off detection, the IC will very quickly discharge the X2 cap with almost no consumption when the mains are on.

While high-end flyback controllers in adaptor/charger applications have embedded high-voltage startup to reduce start-up time and avoid added consumption in standby, it is not yet common in TV applications which remain "always" in standby mode. Start-up time being less critical in TVs, it allows use of the X2 cap discharge resistances for primary controller start-up, avoiding additional consumption and allowing simple low-voltage controllers. Connected from each phase to $V_{CC}$, the two X2 cap discharge resistors will now have double function.

For some high-end applications, it could be interesting to have both HV startup and active X2 cap discharge features. The NCP1249 peak power PWM controller provides both functions for higher performance and integration.

In short, for a single flyback solution, the secondary-side ECO Mode CC/CV controller offers both stronger safety levels and better standby performance. The primary-side control can then be implemented using any of these combinations:

- A low-voltage controller such as the NCP1256 with startup resistors and X2 cap discharge combined
- A high-voltage startup controller such as the NCP1239 with passive or active X2 cap discharge

 

- A high-end controller such as the NCP1249 with both HV startup and active X2 cap discharge with added peak power excursion and off-mode capability.

### *Above 100 W: LLC With PFC*

Having discussed the low-to-medium power flyback applications, we will now consider the higher power applications using both PFC and LLC SMPS and still supporting the standby mode. As in the previous flyback implementation, the power ratio between the 13-V signal processing output and the backlight supply (now up to one-fourth and three-fourths, respectively) is asking for added CC/CV functions to address the safety concerns and avoid oversized components and a large heat sink. However, while the ECO mode looks to be a good solution for flyback SMPS, different solutions will be required to address the LLC behavior.

In a flyback converter, the overall energy stored in the system will be transferred to the secondary side and used to supply the signal processing circuitry. If there are some advantages in reducing the skip mode frequency, they are mainly related to the impact of the soft start used for each skip cycle with limited impact on the overall performance of the flyback.

But with LLC converters, the resonant capacitor has to be charged for correct operation and this charging energy will not be transferred to the secondary side (it's lost in power dissipation). During skip mode, the resonant capacitor being charged at the beginning of the cycle and then discharged at the end will have a direct impact on standby power consumption. To minimize the impact of resonant capacitor energy losses, the LLC converter should operate with a skip-mode frequency as low as possible.

The ECO mode works with a limited/classical skip mode ripple on the output capacitor asking for large output capacitors to achieve extremely low skip-mode frequency in an LLC configuration. This will increase both size and cost. The alternative solution is to work with a much larger and controlled output voltage swing in standby mode thanks to the dc-dc buck capability to regulate with a wide input supply voltage range.

The fully integrated CCCV SOIC-8 IC "OFF Mode" NCP4354/55 from ON Semiconductor makes it possible to have this large output voltage swing between two voltage levels with an automatic light-load detection, changing the voltage regulation from on to off mode through a deep skip-mode detection. When the power is increasing again, the IC will automatically force the system back to the on mode with the corresponding nominal regulated voltage level.

When available, a "standby/on" control line can be added to force the regulation to this high level and secure the startup despite the fact that the off mode IC has been designed to support strong load transients. There are two types of "off mode" IC but we do recommend using the "active on" type (NCP4355) as it provides the best performance for a limited cost increase (it adds one optocoupler) versus the NCP4354 "active off" type. The block diagram in Fig. 2 shows a typical implementation.

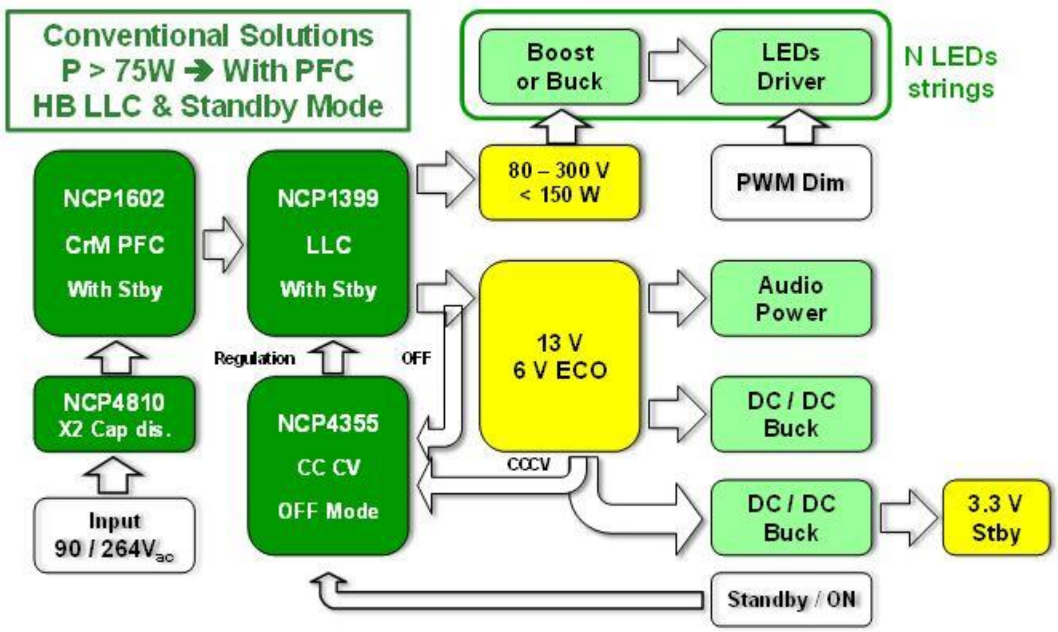


*Fig. 2. Single LLC SMPS with off mode and PFC.*

During the off mode, power supply consumption is linked to the voltage swing and can easily be tuned via the output capacitors. Higher performance simply requires larger capacitors using the same concept and design.

The off-mode secondary controller is also providing an on/off signal transferred to the primary side via an optocoupler to switch off the primary-side controller, thus minimizing the IC's consumption. The "active on" will avoid any signal and power consumption during all off times while the "active off" solution will force the off mode.

The primary side of the LCC should also be specially designed to support this low power/off mode. Thanks to the secondary control line and the new NCP1399 LLC controller capability through the REM pin, the controller is going into the off mode with extremely low consumption on the $V_{CC}$. This avoids a large $V_{CC}$ capacitor or high power consumption in a high-voltage startup supply despite the low skip-mode frequency. The low value of the $V_{CC}$ capacitor is also key to securing the fast LLC restart, avoiding an output voltage hiccup.

Some LLC converters have been designed with wide input-voltage range capability, suppressing the need for a PFC stage in standby mode. However, achieving this wide input range requires that the turns ratio of the main transformer be modified to provide enough energy on the secondary side at low mains supply voltages. This modification will impact the on mode or full-load efficiency.

But thanks to the PFC mode output, the NCP1399 can directly control the PFC $V_{CC}$ supply, allowing the PFC to be on only during the active phase of the LLC skip mode. You may use a small $V_{CC}$ PFC capacitor to avoid any start-up delay. This pin allows PFC regulation with an ~390-V supply and limits as much as possible both the LLC and PFC ICs' consumption. Finally, this output (with PFC $V_{CC}$ going down) also allows controlling low-power high-voltage MOSFETs to disconnect both PFC-feedback and PFC-brown out, further reducing the overall consumption when needed.

## Summary

Thanks to the light-load performance improvement, it is now possible to get the right standby performance without a dedicated standby SMPS. The secondary CC/CV controller elegantly solves safety issues and provides an "ECO mode" or "OFF mode" function, which is needed for very low standby power consumption.

 

While flyback converters can still use the conventional “ECO mode”, the LLC topology will take full advantage of the new “off mode” with large output voltage swing to keep a very low-frequency skip mode.

The added off-mode dedicated control line makes it possible to switch off all of the controllers (CC/CV + LLC + PFC) during the non-active phase of the skip mode to reduce the consumption as much as possible.

Designed to support the off mode, the NCP1399 LLC controller is managing this without extra parts while directly connected to the input supply for startup. With HV startup connected to the mains, the IC will stop quickly after mains turns off. This action will eliminate the usual delay in shutting off the 3.3-V standby power supply (typically a buck converter powered by the LLC SMPS), when the TV is unplugged.

Usually, the standby power supply remains operational because of energy stored in the large primary bulk capacitor. The main effect of the standby power supply staying on is that the red LED indicator, which tells the user the TV is in standby mode, remains lit even after the TV is unplugged—something consumers don’t like.

The overall system with NCP1602 PFC, NCP1399 LLC and NCP4355 CC/CV off mode has been designed as a “combo solution” providing a high-performance solution with very well controlled transition phases, a high level of integration and a high degree of flexibility to cope with any of the latest TV platforms.

This solution, implemented and tested on a 150-W application, can provide up to 150 mW on the output with less than 300 mW of power consumption at an input voltage of 230 Vac. Finally, an NCP4810 active X2 capacitors discharge circuit could be added to further reduce the standby consumption and provide higher flexibility with possibly larger X2 capacitors.

### About The Author

*Jean-Paul Louvel currently serves as TV system application manager at ON Semiconductor. Jean-Paul joined ON Semiconductor in March 2007 as a senior system application engineer, working on overall power system solutions. After the development of the LIPS solution for CCFL backlight and a specific solution for very high supply voltage in E-metering applications, he now works on new solutions for reduced standby power consumption and new LED TV backlight supplied directly from a primary-side regulated current flyback converter. Previously, he worked as a power lab manager for more than 20 years in television power development with Thomson Multimedia. This was based in Germany and Jean-Paul holds over 40 patents within the power conversion domain. Jean-Paul currently holds six issued U.S. patents pertinent to control techniques with ON Semiconductor, with three others that are still pending.*

For further reading on power conversion in TV applications, see the How2Power Design Guide, select the Advanced Search option, and select “Consumer and Entertainment” in the “Application” category. Also, see the links for “AC-DC power supplies” (under “Power Supply Function”) and “Flyback” and “Half-bridge” (under “Topology.”)