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The LCD TVs Standby Power Consumption Reduction

Prepared by: Stanislav Raska
App. Lab. ON Semiconductor Roznov p.R.

Nowadays, many electrical appliances (e.g. computers, audiovisual or white electronics) uses a standby mode of its switched power supplies, but not all of them fulfill the GreenPoint™ statements.

According to the GreenPoint requirements the total power consumption of those appliances in a standby mode should be kept under 1.0 W with 0.5 W efficient load.

The presented method reduces the standby power consumption of LCD-TV-SMPS unit. The reduction is achieved through a slight modification of the power supply unit. The main advantages of the presented solution are the fulfillment of the GreenPoint requirements and the final low cost of the modification.

The reduction of the standby power consumption of LCD TV is described on article of realized 220 W TV converter, although it is generally applicable in any other power supply units that consists of power factor corrector, resonant switcher or more and standby supply unit.

A typical block schema of the TVs power supply unit (PSU) is shown on Figure 1.

A major power loss of the standby supply unit (SSU) during the standby mode consists of the power consumption of all three resistance dividers: power factor corrector (PFC), resonant switcher (RS) and SSU divider.

Another no negligible power loss ($0 \div 100$ mW) is made by the variable leakage consumption of bulk capacitors. The typical leakage consumption of the bulk capacitors individually varies according to its quality. To maintain the transparency of the article and to keep the elegance of the calculations the leakage consumption of bulk capacitors is not further considered.

The last but not least power consumer remains the SSU itself.

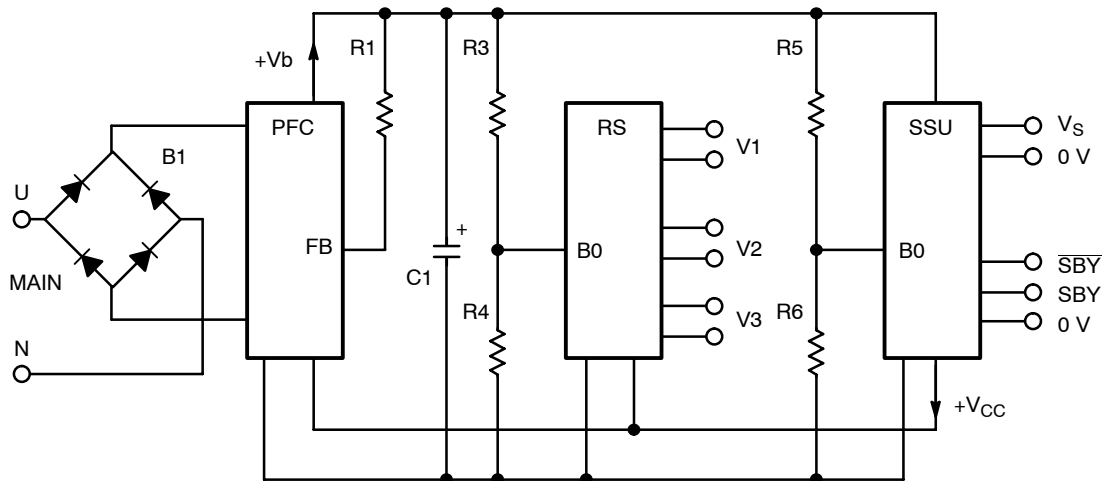


Figure 1. The Block Diagram of Standard LCD TVs PSU

The Power Consumption of Resistance Dividers in SSU (See Figures 1 and 6)

The power consumption of 3 MΩ resistance divider R5/R6 of brownout (BO) SSU is considerably low (cca 47 mW @ 265 Vac) and cannot be easily decreased. Moreover the SSU operates also in standby mode.

The Power Consumption of Resistance Dividers in PFC and RS (See Figures 1 and 2)

The power consumption of PFC/FB feedback resistor R1 1.92 MΩ is 73 mW @ 265 Vac and the power consumption

of RS/BO resistance divider R3/R4 1.17 MΩ is 125 mW @ 265 Vac. Thus the power dissipation on all three resistors makes 200 mW. The value of PFC/FB resistor R1 cannot be increased because it is used for a proportional conversion of the bulk voltage to PFC/FB input current. The resistance of RS/BO divider R3/R4 cannot be increased due to the internal input current hysteresis.

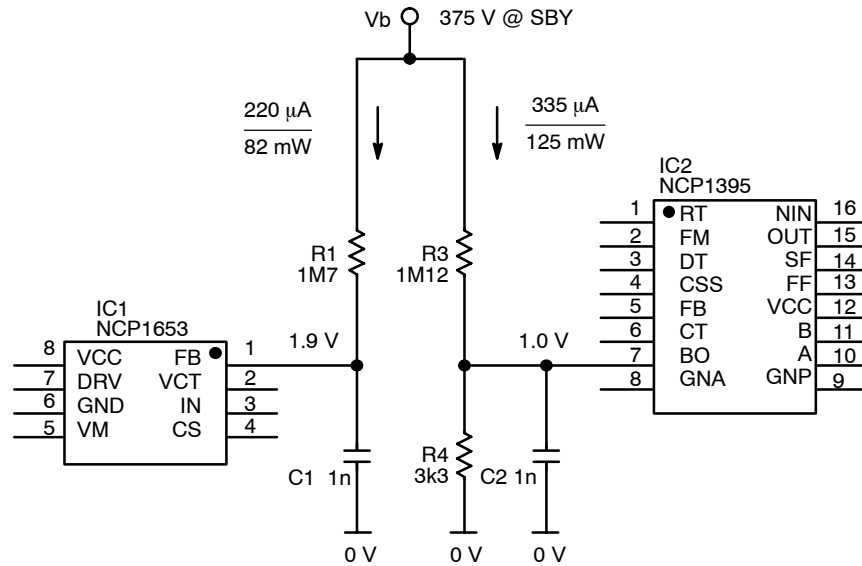


Figure 2. The Original Circuit of Resistor Bulk Voltage Sensing for PFC and RS

The Analysis of FB/PFC and BO/RS Inputs

The original circuit with bulk resistor dividers in FB/PFC and BO/RS inputs is shown in Figure 2.

The output voltage of PFC is regulated through a current feedback loop. The sensing current 100 ÷ 200 μA flowing through a resistor R1 produces voltage 1.5 ÷ 1.9 V on input FB. From the analysis of IC1 has this voltage evidently the same temperature dependency as the forward voltage of two diodes connected in series.

The brownout of RS is controlled through the bulk voltage level adjusted by the resistors R3/R4 divider to 1.0 V, with current hysteresis of ca 20 μA. The threshold level of BO/RS input is practically independent on temperature.

The Standby Power Consumption Reduction through the Voltage Follower

The circuit decreases the standby power consumption is shown in Figure 3. The main point of this circuit is a Q1 transistor connected as an emitter voltage follower. The transistor Q1 with R7/R8 divider in its base proportionally converts the bulk voltage to the emitter voltage. The divider

R3/R4 in Q1 emitter serves for RS, the resistor R1 serves for PFC. Whole the voltage follower is supplied by the board supply 15 Vdc.

The total resistance of R7/R8 resistor divider between 5 ÷ 10 MΩ is a compromise between the power consumption and accuracy. From the bulk voltage of 400 Vdc produces ca 13 Vdc on the base of transistor Q1. On the emitter of transistor Q1 is thus ca $V_e = 12.5$ Vdc. For this value we can simply specify the values of other resistors R1, R3, R4.

The value of resistor R4 is the same as original. The value of resistor R3 is chosen to assure ca 1.0 V on BO input. The value of resistor R1 is chosen to inject sensing current ca 200 μA to FB input. During practical evaluation should be required voltage values adjusted by resistors connected in series with resistors R1 and R3.

The values of capacitors C2, C3 are the same as original, to keep the same time constant.

During a standby mode PFC and RS do not operate by disabling of 15 Vdc board supply.

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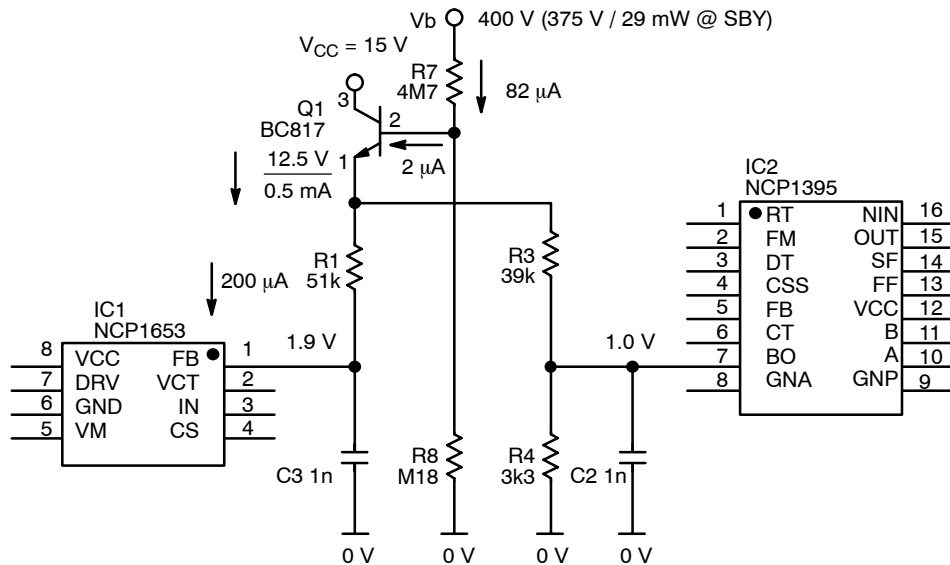


Figure 3. The Emitter Follower in a Bulk Voltage Sensing Circuit

The Temperature Compensation

The FB/PFC input voltage has the same temperature dependency as two diodes connected in series. The forward base-emitter voltage of Q1 has the same temperature dependency as forward voltage of one diode. Thus this temperature dependency is the same as of three diodes connected in series. Then a temperature change $\Delta T = 55^\circ\text{C}$ produces the bulk voltage change ΔV_{bpfc} equal to (Equation 1):

$$\Delta V_{\text{bpfc}} \cong \frac{V_b * 3 * \delta V_f / \delta T * \Delta T}{V_{\text{efb}}} = - \frac{400 * 3 * 0.002 * 55}{10.5} = \underline{\underline{-12.6 \text{ V}}} \text{ or } \pm 1.75\% \quad (\text{eq. 1})$$

The BO/RS input voltage has its temperature dependency derived only from Q1 forward base-emitter voltage. Therefore the BO threshold change recalculated at bulk voltage change ΔV_{brs} (Equation 2) is:

$$\Delta V_{\text{bprs}} \cong \frac{V_b * 31 * \delta V_f / \delta T * \Delta T}{V_e} = - \frac{400 * 1 * 0.002 * 55}{12.5} = \underline{\underline{-3.52 \text{ V}}} \text{ or } \pm 0.44\% \quad (\text{eq. 2})$$

ΔV_{bpfc} – Bulk voltage change (V)

ΔV_{brs} – Threshold bulk voltage change (V)

V_b – Bulk Voltage (V)

V_e – T1 Emitter Follower Voltage (V)

V_{efb} – Voltage between emitter of T1 and FB/PFC input (V)

$\delta V_f / \delta T$ – Forward voltage diode temperature dependency $-2.0 \text{ mV}/^\circ\text{C}$ (V)

ΔT – Temperature Change ($^\circ\text{C}$) $T = -10^\circ\text{C} \div 45^\circ\text{C}$

The uncompensated bulk voltage change ΔV_{bpfc} should be probably not acceptable. Figure 4. shows subsequently the temperature compensation of the bulk voltage change ΔV_{bpfc} with low-cost dual diode MMBD7000. The dual diode compensation distributes the residual one diode temperature dependency symmetrically between PFC and RS stages. The PFC bulk voltage temperature change in $T = -10^\circ\text{C} \div 45^\circ\text{C}$ is so three time lowered, $\Delta V_{\text{bpfc}} = -4.2 \text{ V}$. The recount RS threshold change of bulk voltage has previous value $\Delta V_{\text{brs}} = 3.5 \text{ V}$ but inverse sign.

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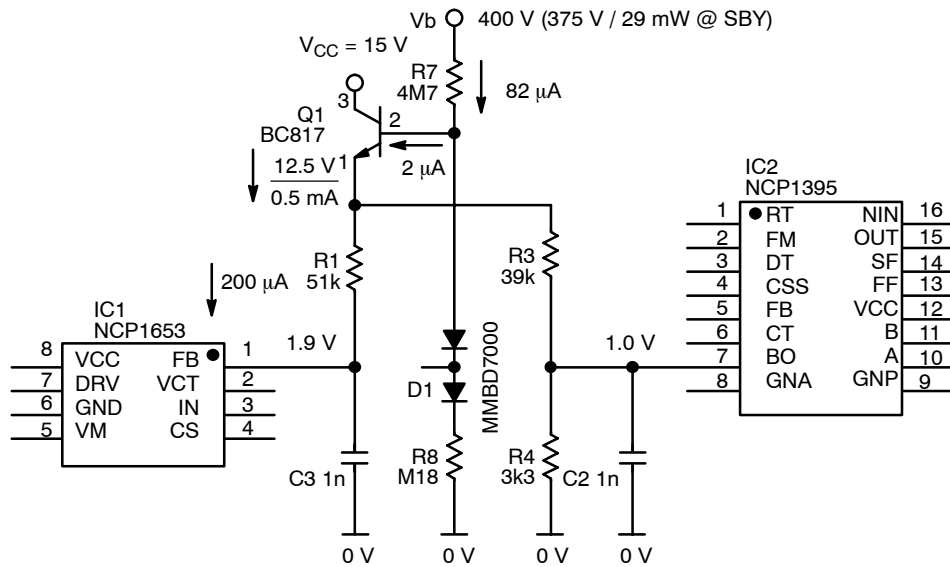


Figure 4. The Temperature Compensated Bulk Voltage Sensing Circuit

THE MEASURES OF TEMPERATURE COMPENSATED BULK VOLTAGE SENSING CIRCUIT

V_b Hysteresis

$$V_{bon} = 420 \text{ V} \quad V_{boff} = 375 \text{ V} \quad (\text{eq. 3})$$

The temperature dependence of V_{bon} , V_{boff} is negligible.

The Temperature Dependence of the Bulk Voltage V_b

$T(^{\circ}\text{C})$	-10	0	25	45
$V_b(\text{V})$	389.5	389	386.7	385.2

$$\Delta V_b = -4.3 \text{ V or } \pm 0.54\%$$

The Dynamic Behavior of the Modified PSU

To maintain the original dynamics of PSU the original time constants and topology of both PFC and RS has to be preserved. The On/Off tests and load tests proved that the dynamics of PSU remained the same.

The Complementary Standby Mode Switch

The scheme shown in Figure 5 keeps stable board voltage of the power supply during the operating mode and ensures zero power consumption during the standby mode.

The SBP/SBN inputs are designed to switch-on and switch-off the PSU. The specific SBP/SBN input can be selected according to the external logic signals.

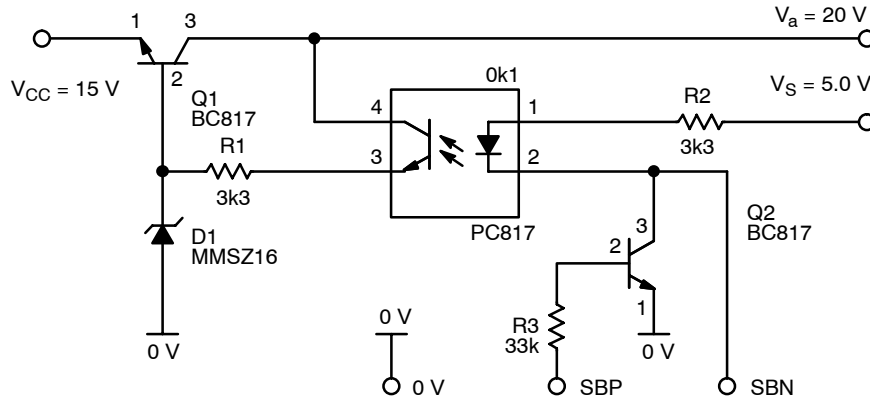


Figure 5. The Complementary Standby Switch and Board V_{CC} Regulator

The Standby Supply Unit (SSU) Efficiency

The total power consumption of measured TV converter (supplied by 265 Vac main) in standby mode is 179 mW @ 0 W and 828 mW @ 0.5 W. The further diminishing of the standby power consumption of SSU is restricted by the total efficiency of the transformer and switcher used in SSU and the required low cost of the application.

When the SSU is in standby mode unloaded, the SSU switcher has to be operating strictly in a skip mode. This limits number of hard-switching of the SSU switcher and subsequently decreases the total power consumption of the SSU. The skip mode of the SSU switcher is achieved through the lower capacity C49 between R-C pins of the voltage reference device VR2 TL431. (See in Figure 6).

The SSU Power Consumption Measurement

The standby power consumption P_{sby} is being measured on TVs PSU as a product of DC bulk voltage V_b and corresponding current I_b :

V_b (V) AC/DC	90/120	120/170	150/212	230/325	265/375
I_b @ 500 mW (mA)	5.6	4.1	3.35	2.41	2.21
P_{sby} @ 500mW (mW)	672	697	710	780	828
I_b @ 0mW (mA)	0.48	0.43	0.41	0.44	0.47
P_{sby} @ 0mW (mW)	58	82	87	143	179

The auxiliary voltage V_{aux} is being measured on variable output loads P_o in a standby (SBY) and operates (on) mode of the SSU:

P_o (W)	0	0,5	10
V_{aux} (V) SBY	18	20	23.7
V_{aux} (V) on (@18 mA)	17.8	18.7	2


Conclusion

The presented solution describes the “easy to make” modification of the power supply unit that diminishes the former maximal standby power consumption of the standby power supply unit (>1.1 W) by more than 200 mW to final achieved value 828 mW.

To maintain the high quality and the total low-cost of the application the ON Semiconductor devices were implemented.

This improves the total efficiency of the power supply unit in a standby mode such, that it with reserve fulfils the GreenPoint statements.

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