AX-CAP™ Technology

Shao-Chun Huang

Abstract: This paper presents one of Fairchild Semiconductor’s mWSaver™ technologies, the AX-CAP™ discharge function, to offer best-in-class minimum power consumptions in no-load and light-load condition to meet 2013 ENERGY STAR and ErP specifications. This innovative technology can minimize power losses in the EMI filter stage by eliminating the X-cap discharge resistors, while still meeting UL1950 safety requirements.

I. INTRODUCTION

In recent years, power-saving has been the focus of electrical appliances, particularly in the area of standby power consumption. To minimize power consumption and meet the latest ENERGY STAR specifications and 2013 ErP Standby Power Regulation (less than 0.5W consumption with 0.25W load for ATX power and LCD TV power), Fairchild has developed several innovative technologies to enhance power-saving performance in no-load and light-load conditions.

One of the major losses is caused by the paralleled discharge resistors to X-capacitor belonging to EMI filter, as shown in Fig. 1. The resistors are used for safety regulations, such as UL1950 and IEC61010-1, which require a capacitor to discharge to a safe level within a given time after a power supply is unplugged from the power outlet.

UL1950: voltage across a capacitance greater than 0.1 µF must decay to 37% of the AC input peak voltage in one second for type-A equipment and 10 seconds for type-B equipment.

IEC61010-1: The pins should not be hazardous (live) at 5 seconds after disconnection from the supply.

The discharge resistor must comply with Equation (1) to meet the discharge time within one second. The power loss of discharge resistor paralleled with X-cap shows in Equation (2):

$$\tau_{DIS} = C_X \times R_{DIS} \leq 1s$$  \hspace{1cm} (1)

$$P_{Loss} = \frac{V_{AC\ (RMS)}^2}{R_{DIS}}$$  \hspace{1cm} (2)

Table 1 shows the relationship between different rated power systems and the power dissipation of the discharge resistor. As the power level increases, the EMI filter capacitor tends to increase and, therefore, requires a smaller discharge resistor to maintain the same discharge time. This typically results in more power dissipation in high-power applications. Power dissipation in the discharge resistor is one of the major causes of standby power consumption in high-power applications.

<table>
<thead>
<tr>
<th>Effective X-CAP</th>
<th>Typical Rated Output Power</th>
<th>Discharge Resistor</th>
<th>Power Dissipation in Discharge Resistor at 240VAC for f_{DIS}=1s</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 nF</td>
<td>20–50 W</td>
<td>4 MΩ</td>
<td>14.4 mW</td>
</tr>
<tr>
<td>500 nF</td>
<td>50W–100 W</td>
<td>2 MΩ</td>
<td>28.8 mW</td>
</tr>
<tr>
<td>1 µF</td>
<td>100W–200 W</td>
<td>1 MΩ</td>
<td>57.6 mW</td>
</tr>
<tr>
<td>2 µF</td>
<td>200W–400 W</td>
<td>500 kΩ</td>
<td>115.2 mW</td>
</tr>
<tr>
<td>4 µF</td>
<td>400W–800 W</td>
<td>250 kΩ</td>
<td>230.4 mW</td>
</tr>
<tr>
<td>8 µF</td>
<td>800W–1,600 W</td>
<td>125 kΩ</td>
<td>460.8 mW</td>
</tr>
</tbody>
</table>

The innovative AX-CAP™ discharge method, a proprietary mWSaver™ technology of Fairchild Semiconductor, was developed to eliminate X-cap discharge resistors, while meeting safety requirements.
II. PROPOSED SOLUTION

The EMI filter in the front end of the switched mode power supply typically includes a capacitor across the AC line connector, as shown in Fig. 2. Safety regulations, such as UL1950 and IEC61010-1, require the capacitor to be discharged to a safe level within a given time after the power supply is unplugged from the power outlet. Typically, a discharge resistor across the capacitor is used to ensure the capacitor is discharged, which introduces power loss of the power supply. Fairchild’s innovative AX-CAP™ technology in the FPS™ (Fairchild Power Switch) FSB-series intelligently discharges the filter capacitor only when the power supply is unplugged from the power outlet. Since the AX-CAP discharge circuit is disabled in normal operation, the power loss in the EMI filter can be virtually removed.

![AX-CAP™ Circuit Connection of FSB-Series](image)

Fig. 2. AX-CAP™ Circuit Connection of FSB-Series

In Fig. 3, when pulling out the plug, the AC voltage \( V_{AC} \) on X-cap discharges slowly by HV pin sampling. FSB-series samples the HV pin to detect the state of AC voltage on the X-cap connected as shown in Fig. 2. FSB-series sets a threshold voltage to check whether the AC voltage on X-cap continuously higher than this threshold level (about \( \frac{1}{2} V_{AC-Peak} \)) without any zero crossing for a debounce time. After meeting this condition, FSB-series enters a Discharge Mode that turns on the sampling switch. The voltage on the X-cap is discharged by the sampling path of the HV pin.

![Behavior of HV Pin as Unplugged from Power Outlet](image)

Fig. 3. Behavior of HV Pin as Unplugged from Power Outlet

III. WORST-CASE ANALYSIS

The discharge time after pulling out the plug can be calculated by Equations (3) and (4):

\[
V_{DIS-ST} = V_{CX} \cdot e^{-\frac{t_{AC-OFF}}{t_{S-CYCLE}}} \cdot e^{-\frac{t_{S-TIME}}{t_{S-CYCLE}}}
\]

\[
t_{DIS} = t_{AC-OFF} + R_{HV} \cdot C_{X} \cdot \ln \frac{V_{DIS-ST}}{V_{DIS-EN}}
\]

where:

- \( V_{DIS-ST} \): the voltage level of X-cap entering Discharge Mode;
- \( V_{DIS-EN} \): the voltage level of X-cap meeting safety requirements (37% of AC peak voltage);
- \( t_{AC-OFF} \): the debounce time of AX-CAP™ detecting line voltage;
- \( t_{S-TIME} \): HV pin sampling period; and
- \( t_{S-CYCLE} \): HV pin sampling rate.

The discharge time of FSB-series for worst-case \( V_{CX}=373 \text{ V} \) is calculated as shown in Table 2, such that \( V_{DIS-EN}=138 \text{ V} \). Here \( t_{AC-OFF} \) is 160 ms, \( t_{S-TIME} \) is 20 \( \mu \text{s} \), and \( t_{S-CYCLE} \) is 960 \( \mu \text{s} \). \( R_{HV} \) is determined by different AC input range; therefore, the worst case can be analyzed as shown in Fig. 4.

![Table 2](image)

**TABLE 2. WORST DISCHARGE TIME OF DIFFERENT X-CAP™ IN 264 V AC INPUT**

<table>
<thead>
<tr>
<th>X-cap (( \mu \text{F} ))</th>
<th>0.1</th>
<th>0.22</th>
<th>0.47</th>
<th>0.68</th>
<th>1</th>
<th>2.2</th>
<th>3.3</th>
<th>4.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Range (85VAC ~ 264VAC)</td>
<td>R(_{HV})=200 k( \Omega )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t_{DIS} ) (s)</td>
<td>0.18</td>
<td>0.20</td>
<td>0.25</td>
<td>0.29</td>
<td>0.36</td>
<td>0.59</td>
<td>0.81</td>
<td>1.09</td>
</tr>
<tr>
<td>High-Voltage Single Range (170VAC ~ 264VAC)</td>
<td>R(_{HV})=400 k( \Omega )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t_{DIS} ) (s)</td>
<td>0.20</td>
<td>0.24</td>
<td>0.34</td>
<td>0.43</td>
<td>0.55</td>
<td>1.03</td>
<td>1.47</td>
<td>2.03</td>
</tr>
</tbody>
</table>
IV. EXPERIMENTAL RESULT

A 16W / 5V standby power in 300W ATX power supply is tested to show the validity of proposed approach. Figure 5 shows the experimental result of using AX-CAP™ discharge method under the following conditions:

- X-CAP™: 0.47 µF
- RHV: 200 kΩ
- VIN: 264 V AC / 50 Hz
- Load: No load

By removing the discharge resistor which is 2 MΩ as X-cap is 0.47 µF for 300W power system, the power consumption can be saved up to 30mW.

V. CONCLUSION

The innovative AX-CAP™ discharge function is one of Fairchild Semiconductor’s mWSaver™ technologies which can improve the power saving performance more effectively in high power applications where relatively large EMI filter is required. It has been implemented in FSB-series to eliminate X-cap discharge resistor loss while still meeting UL1950 and IEC61010-1 safety requirements. With this benefit, AX-CAP technology can help customers design SMPS with low standby power consumption more easily.

REFERENCES


Shao Chun Huang received B.S. and M.S. degrees in electrical and control engineering from National Chiao Tung University, Hsinchu, Taiwan, in 2005 and 2007. Since 2008, he has been employed as an application engineer in the Power Conversion group at Fairchild Semiconductor Taiwan, where he is involved in high-power applications and Fairchild Power Switch (FPS™) families.