Using the Performance and Reliability Advantages of Zero Crossing

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Zero-crossing detectors are used to synchronize switching with the AC wavelength or to extract the timing signal. By using zero crossing techniques, high inrush currents can be avoided.

There are many different approaches to detecting the zero-crossing point: both traditional and novel methods are well-documented. However, most approaches rely on a circuit such as that shown in Figure 1. A device like this detects the transition of the AC mains signal waveform between positive and negative. It then produces a narrow pulse that coincides exactly with the zero voltage condition.

![Figure 1 Basic 50/60 Hz zero-crossing detector [1]](image)

Aside from variations on the theme of Fig 1, alternative approaches include using an exclusive OR gate, a comparator circuit or even a differential line receiver. Each has its merits in particular applications, particularly at higher frequencies (such as audio applications). However, in the domestic appliance market, the traditional approach has the advantages of lower cost and high reliability.

This approach does, however, have one major shortcoming: regardless of the exact design of the zero-crossing detector, inevitably a number of energy-consuming passive devices will be required – at least a pair each of resistors and capacitors. And while this has not always been a major issue, the evolution of international legislation and the market’s insatiable desire for greener appliances are conspiring against the traditional zero-crossing circuit.

The major legislation in question is the European Commission ErP Ecodesign Directive, and specifically ErP Lot 6, which applies to standby and off-mode power consumption in domestic appliances. The standard dictates that the maximum allowable off-mode power consumption for any domestic appliance is just 0.5 W. Therefore any losses from anything as peripheral as a zero-crossing circuit are (to say the least) unfortunate.
However, ErP Lot 6 is just the tip of the iceberg. Such is the public interest in green appliances that manufacturers are playing a game of one-upmanship in which standby power consumption is becoming billed as a key performance indicator. So any source of power saving is welcome.

Enter CAPZero™

Power Integrations’ CAPZero IC was originally conceived as a means of improving the efficiency of EMI filters. In this application, the device is connected in series with the resistors within the filter circuit, and only becomes active when the AC power is removed. So in the CAPZero off-state (when the AC power is connected), it blocks power losses through the discharge resistors. And in the CAPZero on-state (when the AC supply is turned off), it switches on the resistors and permits the discharge of the capacitance from the filter within the required time frame, as required by safety standards.

In this way, a CAPZero device allows designers to use higher values of X capacitors, while complying with safety agency approvals for sub-1 s discharge of the X capacitors. What’s more, the CAPZero IC is self-powered from the AC line, and has a power consumption of less than 5 mW at 230 VAC.

Interestingly, International Standard IEC 62301 on household electrical appliances, which embodies the requirements of ErP Lot 6 among other standards, rounds down any standby power consumption below 5 mW to zero. This makes the CAPZero-based solution lossless.

However, with just a few external components, a CAPZero IC can also function as a zero-crossing detector. But unlike the traditional designs of zero-crossing detectors, it does not require a stack of resistors for the high-voltage divider. As these resistors are the major source of losses in traditional zero-crossing designs, the CAPZero zero-crossing detector is effectively lossless as it runs from the CAPZero supply current.

The exact circuitry for a CAPZero-based zero-crossing detector will depend on the nature of the system, and will vary between isolated and non-isolated appliances. Figure 2 takes as an example a non-isolated circuit using neutral as the system ground, and illustrates the savings in component count that are enabled by the CAPZero solution.

The operation of the zero-crossing circuit in Figure 2 is both simple and elegant. When \( V_{NL} \) is positive, the current supplied to the CAPZero device flows through voltage regulator VR1 from anode to cathode. This produces sufficient gate voltage to fully enhance Q1, which will pull down the zero-cross input of the system microcontroller.

In the second half of the AC supply cycle, when \( V_{NL} \) is negative, CAPZero's supply current flows through the voltage regulator in the opposite direction. This produces a negative gate voltage at Q1, turning the device off, and thereby releasing the zero-cross input of the system microcontroller.

Figure 2. CAPZero-based zero-crossing detector in a negative output voltage, non-isolated system. [2]
As can be seen from the waveforms in Figure 2, the logic transitions coincide exactly with the zero-crossing points.

To further improve system efficiency, it is the same CAPZero device that forms part of the EMI filter within the appliance that is used for AC line voltage zero-crossing detection when an AC voltage is present. (On the basis that it is only used as an X capacitor discharge circuit when the AC supply is removed).

The zero-crossing detection circuit can also act as a loss-of-AC detector, which can be used to provide a time stamp for system settings and memory to be backed up before power is lost. It can also extend to AC fault detection for conditions such as temporary line dropouts and load short-circuits that might cause the temporary loss of AC input.

Today’s appliance manufacturers are driven by seemingly conflicting mandates to reduce power consumption, reduce costs and yet maintain or improve reliability. Using a single CAPZero device to reduce power consumption, cut component count and improve reliability through efficient zero crossing detection ticks all the boxes.

References
