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Low-Wattage Energy Efficient Power Supplies Got Their Start In White Goods

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The first energy efficient low-wattage power supplies were developed for the white goods appliance industry. The semiconductor companies developed simple pulse-width-modulator (PWM) control ICs targeting white goods applications. These ICs were also used by the cell phone charger manufacturers in building chargers for NiCd, and NMH batteries. In more recent times, Li-ion batteries, became the main battery of choice for cell phones and the chargers developed for these batteries often use the same types of ICs.

Since these cell phone chargers are also constantly plugged in, they draw power and dissipate energy in the standby mode. Over time, the United States Department of Energy (DoE) and the California Energy Commission (CEC) have developed standards and regulations for battery chargers and external power supplies. However, the story of how these chargers and their efficiency regulations developed and even the origins of the regulatory agencies is rooted in the history of the appliance industry.

This article recaps how the process for developing energy efficient low-wattage power supplies began with the energy systems used in refrigerators back in the 1970s. Besides giving some insight into how low-power energy efficient power supplies developed, this article will help to explain how appliances became energy efficient. It also discusses why there are no efficiency standards specifically for the power supplies used in white goods.

The Impact Of White Goods

There are many home appliances under the broad heading of white goods. These include refrigerators, dishwashers, clothes washers, clothes dryers, cooking ranges (gas and electric), microwave ovens, and water softeners. These appliances are always connected to the mains or ac power. Since they are constantly plugged-in, they are always “on”. However, for a large amount of time in a 24-hour or a 7-day period they are in the standby mode. Power consumption in the standby mode could be as low as 0.1 W or as high as 20 W, depending on the appliance and its age.

For this reason both the United States Department of Energy (DoE) and the California Energy Commission (CEC) have made regulations to reduce the standby electrical energy usage. These regulations have caused manufacturers to design more energy-efficient appliances. There are rebate programs from the utilities (for example, ComEd in the Chicago area) that give consumers a $50.00 rebate when purchasing a new energy efficient refrigerator.

In the 1970s after the OPEC oil embargo, the U.S. Congress started to investigate the uses of energy both oil and electric (see references 1-3). At the same time, California created its own department of energy.[4]

Major Users Of Energy

The investigations looked into what were the largest users of electrical energy. There were three major areas that used large amounts. They discovered that approximately 50% of the electrical energy was used by motors and about 30% of the total energy was used by lighting. In homes, the largest consumer of electrical energy was the refrigerator.

Refrigerators

The refrigerator was the first white goods appliance to be regulated in terms of energy usage. The first ruling was to allow only “Frost Free Refrigerators” to be manufactured after a specific dated. At the time this rule was made there were Frost Free Freezers on the market, and data was available to show they used less electrical energy.

Here’s why. When frost builds up ice on the cooling coils, the ice buildup is a thermal insulator preventing the coils from cooling the air inside the box. As a result, the compressor runs constantly using electrical energy. To eliminate this ice buildup, an automatic defrost cycle was added to the refrigerators.

In simplistic terms this caused the refrigerators to be redesigned with a timer. The first timers and controller were set to defrost approximately every four hours. Mechanical timers were replaced by electronic timers using low-power energy-efficient microcontrollers and/or microprocessors, which required a power supply. Besides the defrost cycle, the use of aluminum wire in the motor winding was prohibited to improve motor efficiency.

Some of earliest controllers used a 60-Hz transformer power supply, while others used a capacitive drop power supply (see Figs. 1 and 2). In applying these circuits, care must be taken since these have connections to the ac line. The current is limited as follows.

In a half-wave capacitor drop supply, the dc output current in milliamps is limited to 10 times the value of C1 in microfarads. For example, a C1 of 1 µF capacitance produces 10 mAdc of supply current. The rule is doubled in a full-wave capacitor drop supply where a 1-uF value of C1 produces 20 mAdc of supply current. In these circuits zener diode Z1 is the regulator. A 5.6-V zener is used in the half-wave circuit to generate 5.0 Vdc. In the case of the full-wave circuit, a 5.0-V zener will generate 5.0 Vdc.

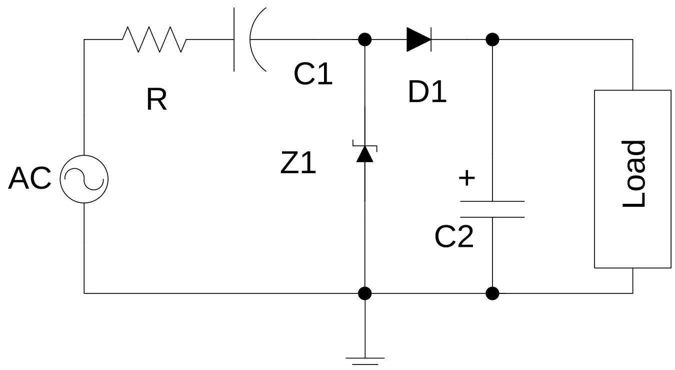

Fig. 1. Half-wave capacitor drop supply.

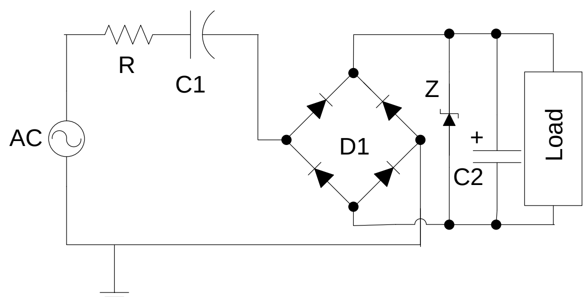

Fig 2. Full-wave capacitor drop supply.

The capacitor drop supplies have a number of issues including nonisolation, limited current, and power dissipation of the zener regulator. The 50/60-Hz stepdown isolation systems solve the isolation and power supply issues but waste power in the standby mode due to the hysteresis losses in steel laminations of the transformer.

To solve the excessive power loss in standby mode to meet the Energy Star and California Energy Commission regulations, semiconductor companies such as Power Integrations, STMicroelectronics, Fairchild Semiconductor, On Semiconductor and others created simple flyback controllers with internal power switches. These could operate either with optocouplers and second-side control or using primary-side control.

Although the requirements for energy efficiency in refrigerators motivated the development of these low-power power supplies, curiously there are no power supply efficiency standards or regulations for use in white goods. The appliances themselves are tested using what engineers refer to as a black box. The test is comparing the input to the output for efficiency. Please see the "2016 Appliance Efficiency Regulations"[5] from the California Energy Commission. This is a free regulation as are those from the DoE, and their appliance regulations and standards can also be found online.[6].

In addition, another group, the Appliance Standards Awareness Project, has a website[7] where it publishes its findings. Also please see the Electronic Code of Federal Regulations, which includes Appendix A to Subpart B of

Part 430 "Uniform Test Method for Measuring the Energy Consumption of Refrigerators, Refrigerator-Freezers, and Miscellaneous Refrigeration Products".[8] This is current with a October 4, 2018 date.

Improvements In Appliance Operation

As can be seen in Fig. 3, there have been many improvements in refrigerator efficiency. These include motor efficiency, compressor efficiency, insulation efficiencies, door seals, blend door improvements, circulating fan, etc. Many of these improvements have been carried over to other white goods.

However, with regard to the power supplies developed for use in refrigerator applications, there is no regulation for measuring the power supply efficiency. The best solution is to use the "no-load" or standby power published by the various semiconductor IC companies as starting point. This was discussed in a previous Safety & Compliance column on external power supplies.[9]

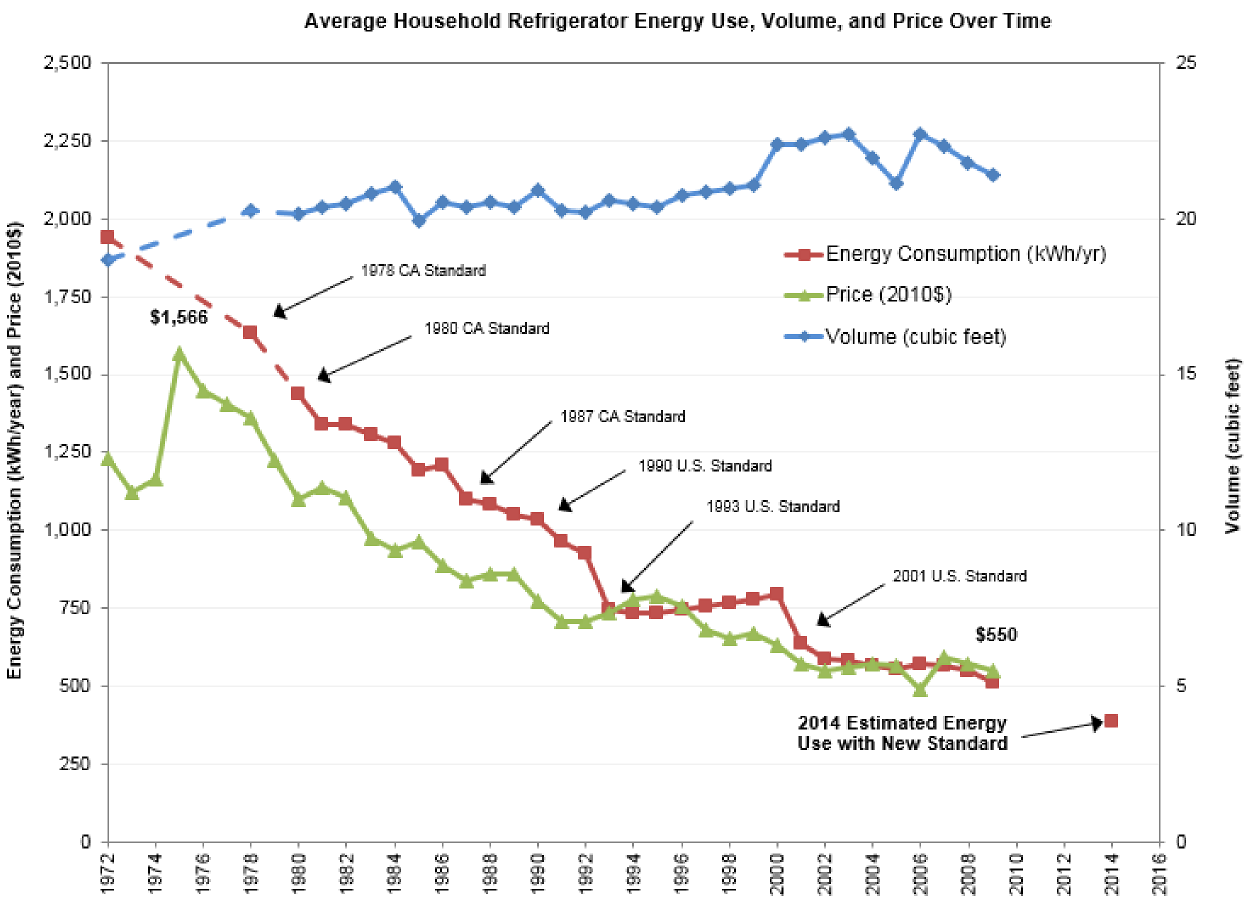

Fig. 3. Energy consumption of refrigerators over the years.[10]

Dishwashers

The home appliance with the next highest energy consumption is the dishwasher. There is a front panel controller that houses the appliance microprocessor controller. The controller drives relays for the pump and the heater. The amount of energy used by the heater to heat the water and to sanitize the dishes is high. In the standby mode with only a single LED, the amount of energy used is very low.

The power supply for the controller is usually a low-power unit with dc output. In contrast, the high-power current, which is ac current, is controlled by relays and solid-state switches and is used in powering these functions:

1. Motor for the pump
2. Heater

3. Water solenoid valve.

Water Softeners

Like the refrigerator, the water softener operates infrequently depending on the settings. The unit turns on and off various valves and solenoids. There may be a display which may use a small amount of electrical energy. If the unit recycles every three days, it is in the standby mode using less than 1.0 W of energy.

Clothes Washers

The controller is in the standby mode.

Power Supplies For White Good Appliances

To elaborate on what was said in the discussion on refrigerators, there are no known efficiency regulations specifically written for the internal power supplies used in consumer white goods. All the efficiency standards test the appliance product as a whole. Moreover, the standby energy of the power supply is not the cause of a high electric bill. It's the motors, pumps, compressors and heaters that consume the major amounts of energy.

The various semiconductor companies who manufacture ICs for charging cell phones, tablets and other similar products provide data sheets and applications notes for obtaining very low power. Some of these are as low as 10 mW (0.010 W) in the standby open-circuit mode. In practice, a power supply for these white good consumer products should be less than 0.1 W.

References

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About The Authors

Kevin Parmenter is an IEEE Senior Member and has over 20 years of experience in the electronics and semiconductor industry. Kevin was recently vice president of applications engineering in the U.S.A. for Excelsys, an Advanced Energy company. Previously, Kevin has served as director of Advanced Technical Marketing for Digital Power Products at Exar, and led global product applications engineering and new product definition for Freescale Semiconductors AMPD - Analog, Mixed Signal and Power Division based in Tempe, Arizona.

Prior to that, he worked for Fairchild Semiconductor in the Americas as senior director of field applications engineering and held various technical and management positions with increasing responsibility at ON Semiconductor and in the Motorola Semiconductor Products Sector. Kevin also led an applications engineering team for the start-up Primarion where he worked on high-speed electro-optical communications and digital power supply semiconductors.

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For many years, he worked as a field applications engineer (FAE) for Motorola Semiconductor, On Semiconductor, Cirrus Logic, and Active Semiconductor, assisting customers in using semiconductors. He published numerous application notes and conference papers at a variety of conferences: APEC, ECCE, IAS, and PCIM. Topics included power factor correction, lighting, and automotive applications. As an FAE, he traveled internationally giving switch-mode power supply seminars in Australia, Hong Kong, Taiwan, Korea, Japan, Mexico, and Canada.

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For further reading on power supply-related safety and compliance issues, see How2Power's special section on Power Supply Safety and Compliance.