Keywords: standby power, energy efficient, budget power, microampere, computers, notebook, set-top box, battery life, remote air conditioning, environmental impact, voltage reference, quiescent, bandgap

APPLICATION NOTE 4427

Demonstrating Green Technology with Apples, Oranges, Lemons, and Limes

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Abstract: Green initiatives bring home the issue of wasting standby power. Through reducing their usage of standby power, U.S. households can save an average of $100 per year.[1] Battery life in portable devices is important, but this application note shows that power-saving appliances in our homes are also critical to reduce environmental waste. Maxim is taking the lead in energy-efficient integrated circuits, and this document lists examples of Maxim parts used to reduce power in appliances, computers, and set-top boxes.

Jim Henson's creation, Kermit the Frog says, "It's not easy being green." We concur that saving energy is difficult, but very necessary. Smart circuit designers and progressive companies are meeting consumer's expectations in this aspect. And the smallest details are critical: power efficiency is one measured in microamperes (µAs), one-millionth of an ampere. For comparison, a 60W incandescent light bulb draws 0.5A. That is 500,000µA.

Why is it necessary to measure so precisely? Because it is the sum of all currents that count and like any budget, one must reduce every cost, no matter how small. Obviously in a battery-powered device, customers are sensitive about battery life. Not so obviously, plug-in appliances also have a cost associated with just being plugged in. When a device is "off", but displays a power indicator while waiting for a remote command, button, or timer, it is consuming standby power.

What is the cost of standby power? That 60W bulb can cost $14.65* a month if it runs 24/7. An appliance that draws 1W in standby power can cost $0.25 without doing any practical work. Walk around a typical home and count the appliances, TVs, radios, stereos, computers, garage-door openers, microwave ovens, washing machines, dryers, forced air heaters, and lawn sprinklers. Then add the battery chargers. You can easily have 20 devices on standby power, and most draw more than just 1W.

That is the good news. The bad news is that a cable TV box can draw 80W while in operation and 79W while in standby (costing $19.53 and $19.30, respectively). A satellite DVR box can consume 120W while in operation or standby, so just add $29.30 to your monthly subscription rate.

This is relevant not only as a monthly cost; as a citizen of Earth, we must be conscious of our environmental impact. As circuit designers, we can choose carefully, and thankfully low-energy parts are not necessarily more expensive. In fact, because newer parts are made with smaller geometry IC processes, they tend to be more efficient. Furthermore, Maxim circuit designers have long taken the lead in designing with energy efficiency in mind.

Table 1 illustrates ICs that can be used to reduce power costs in household appliances, computers, and set-top boxes. Today both designers and consumers have choices; we all can influence our Earth's future by the little things we do each day.

Table 1. Examples of Maxim's Power-Efficient ICs

Part	Description	Current Consumption
MAX5052	Current-mode PWM controller for isolated/nonisolated power supplies; ideal for universal input (rectified 85VAC to 265VAC)	Operates on 1.4mA, Starts with 45µA
MAX669	PWM power-supply controller at medium and heavy loads; Idle Mode™ pulses only as needed at light loads	Quiescent 220µA
DS2786	Fuel gauge that accurately reports battery capacity from standard Li+ battery packs	Operates on 50µA, Standby sleep 1µA
DS80C320/DS80C323	Microcontrollers; 80C31, 80C32, and 8051 compatible; fast for power saving	Stop, bandgap on 50µA, Stop, bandgap off 1µA
DS80CH11	System energy manager; 8051-compatible core; key scanning; battery and power management; 2-wire serial I/O ports and 88 parallel pins; 8-channel 10-bit ADC; 4-channel, 8-bit PWM for LCD contrast and brightness	IDLE mode = 10mA, STOP mode = 1µA
DS2432	Security EEPROM; 64-bit secret; SHA-1 engine; unique identity 64-bit laser number	EEPROM write 500µA, Standby at 5µA
DS1340	Real-time clock and trickle charger with backup power switching	Operates on 800µA
MAX894L/MAX895L	High-side P-channel, MOSFET, load-isolation power switches	Switches on at 16µA, Switches off at 0.1µA
MAX7306/MAX7307	Serial-interfaced peripherals with 4 I/O ports; LED	Standby at

	dim/blink together with key debounce	0.75µA
MAX4789, MAX4794	Switches to protect host devices; feature SDIO memory card	Operates on 80µA, Standby at 0.01µA
MAX2830	Wi-Fi® RF transceiver with PA and diversity Rx/Tx switch in a 7mm × 7mm package; designed for 802.11g/b applications	Receive 65mA, transmit 289mA (P_{OUT} = 15dBm), Shutdown 10µA
MAX9025–MAX9028	Comparators, some with 1.236V ±1% reference	With reference 1µA, Without reference 0.6µA
MAX8678	WLED charge pump with 1.1W audio amp; no output capacitors	LED 140µA, quiescent standby 0.1µA
MAX9723	Stereo DirectDrive® headphone amp with BassMax and volume	Standby 5µA
MAX9515	Video filter amp; autosenses signal and/or output coax load	Standby 5µA
MAX9503	Video filter amp; DirectDrive removes output capacitors	Standby 10nA
DS2714	NiMH battery charger, does not charge alkaline and lithium cells	500µA to 750µA

What does this have to do with apples, oranges, lemon, and limes? And how do these fruit demonstrate green technology? For a story to attract media attention, it needs a catchy headline. To demonstrate how little current is used by Maxim ICs, our parts can be powered by batteries made from apples, oranges, lemon, and limes. **Figure 1** shows such a circuit.

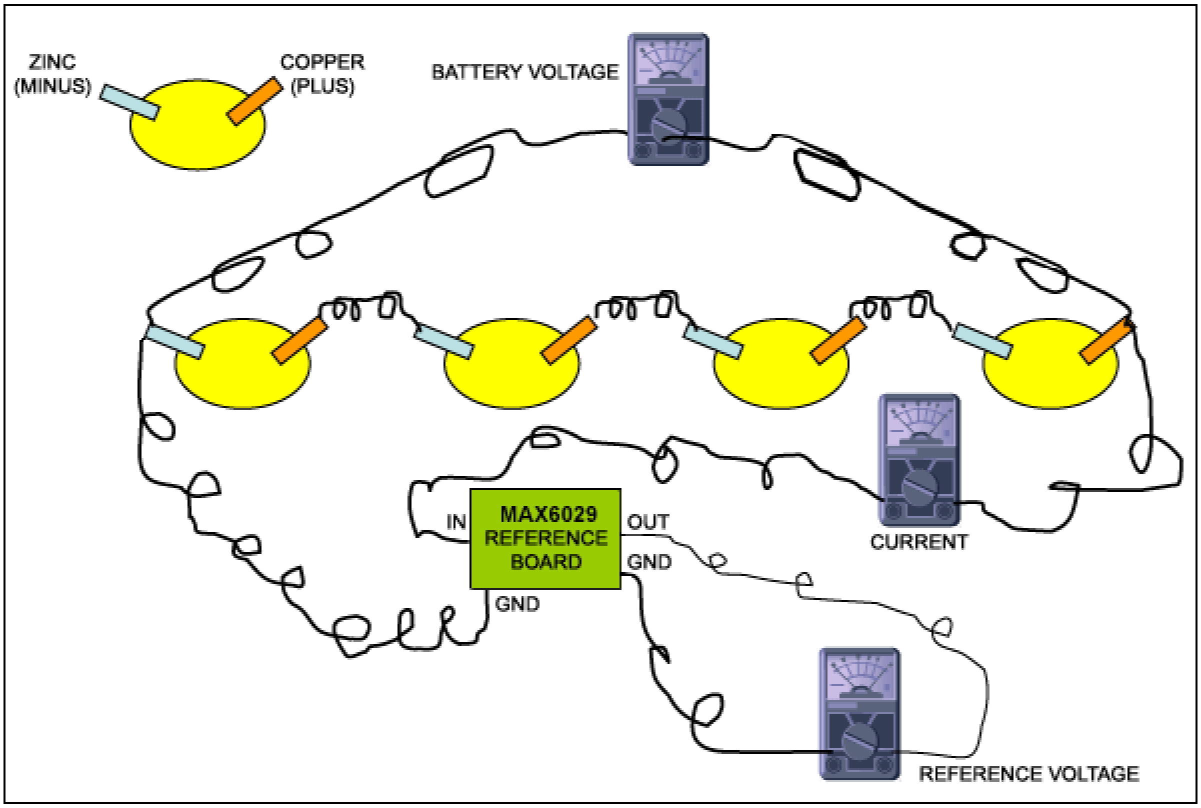

Figure 1. Lemon batteries running a voltage reference board.

This 3.6V battery is made of 4 lemon cells. Each cell produces 0.9V at approximately 100µA. The MAX6029 voltage reference produces a precise 2.5V while drawing a maximum of only 5.5µA. Figure 1 graphically demonstrates the tiny current draw of an IC.

The battery voltage is primarily determined by the chemistry between the copper and zinc. Many fruits and vegetables will operate as batteries. Apples, oranges, lemons, limes, grapefruit, and potatoes all produce voltages between 0.88V and 0.95V per cell. The color of the battery really makes no difference, but saying we are getting greener by using limes does make cute story.

It is estimated that 10% of household power consumption is lost to standby power.[2] The Energy Star® program, first created by the U.S. Environmental Protection Agency and the U.S. Department of Energy, estimates that there are 129 million households spending an average of $2200 each per year on electric power.[3] Putting the numbers together, households spend approximately $28.3 billion per year on standby power in the United States. That is a staggering number, considering it just allows us to become coach potatoes! If we just would get up and turn off a switch, we could save that money.

All of a sudden, green sounds pretty good when we realize our household can save $100 per year. Now that power efficiency is personal, we can redouble our environmental saving behavior. The Maxim website has live parametric tables that allow us to interactively select parts. We can pay attention to power consumption as we select the appropriate part for our circuit. Though a microampere is a tiny amount, when multiplied by the huge number of people in the world, it does make a difference.

*The residential retail price of electricity varies by location and over time. These prices were accurate for residential customers in Northern California at the time of this application note's posting.

Reference

[1]"What are energy vampires and what can I do about them?" ENERGY STAR, http://energystar.supportportal.com/link/portal/23002/23018/Article/21027/What-are-energy-vampires-and-what-can-I-do-about-them (accessed September 27, 2011).

[2]"Standby Power" in Wikipedia, The Free Encyclopedia, http://en.wikipedia.org/wiki/Standby_power (accessed September 27, 2011).

[3]"Where Does My Money Go?" ENERGY STAR, www.energystar.gov/index.cfm?c=products.pr_pie (accessed September 27, 2011).

Related Parts		
DS1340	I²C RTC with Trickle Charger	Free Samples
DS2432	1Kb Protected 1-Wire EEPROM with SHA-1 Engine	Free Samples
DS2714	Quad, Loose-Cell NiMH Charger	Free Samples
DS2786	Stand-Alone OCV-Based Fuel Gauge	Free Samples
DS80C320	High-Speed/Low-Power Microcontrollers	Free Samples
DS80C323	High-Speed/Low-Power Microcontrollers	Free Samples
DS80CH11	System Energy Manager	
MAX2830	2.4GHz to 2.5GHz 802.11g/b RF Transceiver with PA and Rx/Tx/Diversity Switch	
MAX4789	200mA/250mA/300mA Current-Limit Switches	Free Samples
MAX4794	200mA/250mA/300mA Current-Limit Switches	Free Samples
MAX5052	Current-Mode PWM Controllers with an Error Amplifier for Isolated/Nonisolated Power Supplies	Free Samples
MAX6029	Ultra-Low-Power Precision Series Voltage Reference	Free Samples
MAX669	1.8V to 28V Input, PWM Step-Up Controllers in µMAX	Free Samples
MAX7306	SMBus/I²C Interfaced 4-Port, Level-Translating GPIOs and LED Drivers	Free Samples
MAX7307	SMBus/I²C Interfaced 4-Port, Level-Translating GPIOs and LED Drivers	Free Samples

MAX8678	White LED Charge Pump with 1.1W Audio Amplifier	Free Samples
MAX894L	Dual, Current-Limited, High-Side P-Channel Switches with Thermal Shutdown	Free Samples
MAX895L	Dual, Current-Limited, High-Side P-Channel Switches with Thermal Shutdown	Free Samples
MAX9025	UCSP, 1.8V, Nanopower, Beyond-the-Rails Comparators With/Without Reference	
MAX9026	UCSP, 1.8V, Nanopower, Beyond-the-Rails Comparators With/Without Reference	Free Samples
MAX9028	UCSP, 1.8V, Nanopower, Beyond-the-Rails Comparators With/Without Reference	Free Samples
MAX9207	10-Bit Bus LVDS Serializers	Free Samples
MAX9503	DirectDrive® Video Amplifier with Reconstruction Filter	Free Samples
MAX9515	1mm x 1mm Video Filter Amplifier with Automatic Shutdown and 2V/V Gain	
MAX9723	Stereo DirectDrive® Headphone Amplifier with BassMax, Volume Control, and I²C	Free Samples

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