System Overview

It is ironic that the challenge in designing line-power applications is not high voltages or dangerous currents. Rather, it is the process of creating a simple, efficient power supply for low-voltage components. Often, delivering a minimal 50 mw to the control section can dissipate over 2 – 3 watts in the power supply. This added heat dissipation both increases the cost of the power supply and introduces significant heating in the case. That is why it is important, when designing low-cost line-powered control applications, to utilize every possible power-saving feature and technique.

Microcontroller

Reducing power in a design starts with the selection of the microcontroller. While older CMOS microcontrollers claim to be low power, only a new low-power microcontroller designed for battery operation can provide effective power management. These new microcontrollers have features that can significantly reduce their current consumption in a design, including:

1. Newer low-power microcontrollers have been optimized specifically for lower current consumption, so they consume less current than older CMOS microcontrollers.
2. Newer microcontrollers have low-frequency clock options, which further reduce their current consumption.
3. Newer microcontrollers can run at lower voltages, which also reduces their current consumption.
4. Sleep modes in the new microcontrollers cut current consumption dramatically.

All of these new features are, in fact, common in the new families of microcontrollers designed for battery operation. A good example of this new low-power mentality is the nanoWatt Technology microcontrollers from Microchip. They have been specifically designed to reduce current consumption either through reduced operating current or by creating clock and shutdown schemes. Just these four capabilities drop the 1 – 2 mA current draw of an older CMOS microcontroller to less than 18 μA by using a newer low-power nanoWatt Technology microcontroller at 3V with a 32 kHz clock, while spending at least 50 percent of its time asleep.

One thing to note -- most significant reductions are achieved through the use of the 32 kHz clock and placing the microcontroller in its sleep mode for 50 percent of the time it is operating. The question is often asked, “Are these restrictions limiting on the design?”
The answer is no, not really. A typical line-powered application operates around the timing of the 60 Hz power-line frequency. Operating a typical microcontroller on a 32 kHz clock still gives it over 136 instruction cycles per cycle of the 60 Hz power. This is an eternity if the microcontroller is only tasked with firing a TRIAC at an appropriate delay from the 60 Hz zero crossing. The only other timing-critical requirement on the microcontroller is the user interface and even this function operates in the range of 10s to 100s of milliseconds. As a result, there are few, if any, tight timing requirements that require either a fast clock or a large number of instruction cycles.

However, if the microcontroller does require a burst of speed, the variable clock structure is typically under software control. This means the microcontroller can tailor its clock to its current activity. If it is monitoring buttons and waiting for the zero cross, it can run at a power-saving 32 kHz clock frequency. If it needs to perform a complex floating-point calculation, then it simply increases the clock to a higher frequency until the operation is complete and returns the clock back to the low-power frequency. This self control of its clock frequency puts it in charge of its own current consumption and allows it to adapt to any and all conditions that may arise.

TRIAC Drive

TRIACs are a common choice for switching AC power, due to their latching nature and bi-directional switching capability. Unfortunately, most designers forget what the latching nature of a TRIAC means for a design. Because a TRIAC is latched on once it conducts more than its minimal hold current, the bias current to the TRIAC gate can be discontinued, saving considerable current. In fact, a 3 mA bias pulse, 300 µS wide, on the gate of a sensitive gate TRIAC is all that is required to turn on the TRIAC for the full half cycle of the waveform. This means the 3 mA current pulse, averaged over the 60 Hz half cycle, is actually equivalent to a continuous draw of less than 100 µA. So, a narrow pulse drive on the TRIAC can save almost 96 percent (the current traditionally used to control a TRIAC).

The User Interface

Older designs typically use low-current LEDs for indicators in their user interface. However, LEDs can draw up to 1 - 5 mA per LED. In a design trying to conserve microamps, this not good. The solution is to once again turn to low-power microcontrollers. Specifically, microcontrollers designed with on-chip LCD drivers.

The current consumption of the LCD driver typically only draws 30 – 40 µA, with an additional 100 – 200 µA to generate the bias voltages for the display. When compared to 1 – 5 mA for a single LED, the advantages of an LCD become clear. Not only does it draw less current, it also offers designers a flexible and user-friendly display. Because LCD drivers are also common in low-power applications, finding a chip with the combination of an LCD peripheral and low-power modes is not difficult. In fact, the PIC16F91X family has an LCD peripheral, includes Microchip’s nanoWatt Technology low-power features, and a wide selection of other peripherals as well.
A frequently cited drawback to LCD displays is that they have poor readability in low light. The answer is simple, add a backlight to increase the display contrast. One might ask, “Doesn’t that increase current consumption?” If an LED backlight is used, then the design would be back to a higher current consumption. However, using an electroluminescent (EL) backlight with an LCD display avoids this issue because EL panels can be driven directly from the 110 VAC supply with only a small current-limiting resistor. So, an EL backlight would have no impact on the low-voltage current consumption.

The other half of a user interface is the pushbutton inputs. Traditionally, this interface consists of one or more pushbuttons with individual resistor pullups that are tied to digital inputs on the microcontroller. While the current draw of the pullup resistors may seem too small an opportunity for improvement, low-power microcontrollers such as the PIC16F91X family can even help here with their ‘weak pullup’ feature. These internal weak-pullup resistors offer a comparable current source, without the cost of the external resistors. The weak pullups can also be enabled and disabled in software, which can be used to limit their current consumption to only those times when the microcontroller is actually reading the state of the pushbutton.

The Power Supply
At the start of this article, it was indicated that low-power microcontrollers significantly reduce current consumption, decrease power dissipation and reduce cost. This savings is compared against a traditional design using: a CMOS microcontroller, a TRIAC, two pushbuttons, and 6 LEDs. In this case, the current draw is approximately 10 mA: 3 mA for the TRIAC, 5 mA per LEDs (assuming only one is lit) and 2 mA for the microcontroller. To create this current at 5V, over 2.4 watts will have to be dissipated in the power supply.

\[ 2.4W = (110 \text{ VAC} - 5 \text{ VDC}) \times (10 \text{ mA} + 10 \text{ mA} + 3 \text{ mA}) \]

10 mA is the power-supply current during the positive half of the cycle, another 10 mA is to charge the bulk capacitor, which supplies current during the negative half cycle, and 3 mA is used to bias the zener diode.

Using the current reduction techniques discussed above, the current consumption for an equivalent design with a low-power microcontroller would be less than 400 µA: 100 µA average for the TRIAC, 240 µA for the LCD, and 18 µA for the microcontroller. To create this current, the power supply will only dissipate 140 mW. That is a reduction of 2.25 watts of power, compared to a traditional CMOS-microcontroller based design.

\[ 140 \text{ mW} = (110 \text{ VAC} - 3 \text{ VDC}) \times (400 \mu A + 400 \mu A + 500 \mu A) \]
Due to this lower dissipation, ¼ watt resistors can now be substituted for the 3 - 4 watt resistors in the traditional power supply. And, a lower-power zener diode can be used, (only a 500 µA bias). Finally, the bulk capacitance can be reduced to 1/7th the size of a traditional design. The end result is a cost savings, plus a design with a better display for easier use and improved customer appeal.

Conclusion
So, not only do low-power microcontrollers reduce the current requirements of an offline application, they can significantly improve the design by eliminating heat, reducing cost and improving appeal.

Microchip Featured Component Highlights
- PIC® Microcontrollers
  A broad family of low-power, Flash-based 8-bit microcontrollers with a range of nanoWatt Technology features for power reduction, including a lower operating current, clock-frequency controls, and a sleep mode. In addition, the weak pullups and LCD-display driver are available options in the PIC16F91X family of microcontrollers. Other peripherals including EEPROM data memory, Capture/Compare/PWM timer functions, 10-bit ADC modules, comparators and various hardware serial-communications peripherals. The combination of low-power features and a wealth of peripheral options gives the system designer the versatility to reduce system power consumption, increase reliability and performance, and minimize cost by eliminating external components.

Summary
This crossover of requirements is an unexpected benefit of the general proliferation of battery-powered electronics in our lives. Although microcontroller-based control is known for giving the designer the freedom in design, the feature set and low-power focus of battery operation also crosses well into the cost-sensitive nature of line-powered applications.

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