From October 2009 *High Frequency Electronics*

Applying Engineering Knowledge to Everyday Life

Most engineers get questions from family and friends about technology—how it works, which one works best, is it really as good as they say, etc. Often, our technical knowledge provides useful information that is greatly appreciated. Most of us have been asked questions about digital TV transition, cell phone coverage problems and cable or satellite TV trouble. We hear about about computer and Internet problems, too—even if we are RF/microwave engineers.

Here is one example currently in the news: the savings achieved with compact fluorescent lamps (CFLs) and LED lighting instead of incandescent bulbs. There are a number of different light bulb sizes, and equivalent CFL or LED products, but for this exercise, let's compare a 60 watt incandescent bulb, a 15 watt CFL and an 8 watt LED light.

There are many published cost comparison tables, so we did our own calculation using an average of various published values for device cost, operating lifetime and electricity cost. The bottom line is:

Lifetime Cost (per 1000 hours)

Incandescent	CFL	LED
$4.25	$0.70	$0.76

The comparison shows a strong benefit for both CFL and LED technologies. LEDs are quite new and have not yet experienced much of the price reduction that comes from mass production. Assuming that LED cost will be lower in the future, it appears to be the eventual "winner" of this comparison.

There is More to the Story...

Let's make another comparison, one that is rarely seen in the general media—the effect of reduced heat output, which is the real difference between incandescent lighting and the alternatives of CFLs and LEDs.

We'll do two estimates, one for northern U.S. climate and one for southern U.S., since the heating and air conditioning needs are quite different. These two examples are sufficient to make a general comparison.

The premise is that the excess heat of lighting contributes to the heating, and must be replaced by other energy sources. During cooling, the excess heat is an additional load on air conditioning and adds to power consumption.

To simplify comparison, we'll assume that the cost of other heat sources is the same as electricity, and that air conditioning, as a more efficient heat pump technology, costs about half as much per watt. We'll also assume that 100% of the electricity consumed by the incandescent lamp is released as heat, either directly or when the light is absorbed.

Here are the usage assumptions:

- Northern U.S.: 6 months heating, 2 months cooling
- Southern U.S.: 4 months heating, 4 months cooling (other times equal heating/cooling, or neither)
- Lighting used 8 hours/day during heating season
- Lighting used 4 hours/day during cooling season

In the northern, U.S., 66.6% of the lighting's heat must be replaced by other sources:

$$\frac{[6 \text{ mo} \times 8 \text{ hr}] - [2 \text{ mo} \times 4 \text{ hr} \times 2 \text{ A/C eff}]}{[6 \text{ mo} \times 8 \text{ hr}] + [2 \text{ mo} \times 4 \text{ hr} \times 2 \text{ A/C eff}]} = 0.667$$

Using the numbers for the southern U.S., the factor is zero, an equal balance between replacement during heating, and removal during cooling. Thus, our first conclusion is that published comparisons of lighting costs are valid for this climate.

Although simplified, our calculation illustrates that the advantage to alternative lighting is less in areas where heating dominates cooling. Using our result for the northern U.S., two-thirds of the energy saved in lighting must be replaced during heating season. Thus, alternative lighting still has a cost advantage, but it is closer to 4:1 rather than the nearly 6:1 ratio of our lifetime cost comparison.

Lighting Quality: A Major Subjective Factor

Incandescent lighting looks best to nearly everyone because it is similar to sunlight—a wide range of wavelengths with a broad peak in the yellow.

The mercury vapor in CFLs creates a "blue" light that must be converted by secondary phospors, which are not yet able to match incandescents. In addition, poor cold weather performance and a slow warm-up time are considered negative attributes. CFLs' mercury content is major environmental concern as well.

LEDs are different in that they emit light in narrow wavelength bands. Various combinations of devices at different wavelengths can mimic typical "warm" to "cool" color temperatures, but the result is still considered unnatural by most people. Also, LED emission is in narrow beams, so their most common use is in spotlights until better methods are developed to provide more diffuse radiation.

Fortunately, development efforts to address the spectral and directional shortcomings of CFLs and LEDs are making good progress.