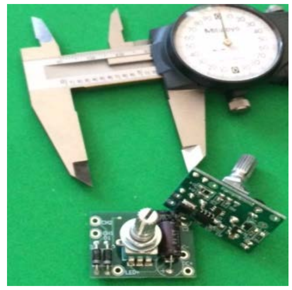
APPLICATION NOTE AN-101

Low Cost DB-100 Controller— A Breakthrough in Simplifying LED High-CRI, Dimmable, Variable-Color-Temperature Control

Controls 5 to 100 watts



DB-100

Some history

There has been awareness of differences in natural light (sunlight) and artificial light (such as fire) for centuries, even if the term "color temperature" was not used-- nor was there an ability to do much about it until about 60-70 years ago. Artists, centuries ago, knew to arrange their studios to always make best use of natural light—depending on the time of day and sky conditions.

When inexpensive photography and camera options spread to mass markets after WW-1, camera buffs learned to use "indoor" or "outdoor" film to compensate for the yellowish tint of candle light and indoor incandescent lighting or the bluish tint of outdoor overcast-sky lighting.

Solid state lighting—a game changer

The development of LED emitters of all colors and smaller point sources of light has opened up all kinds of possibilities. When the blue LED became commercially viable in the late 90's all the pieces fell into place.

All sources of white LED lighting employ one of two techniques:

1) ***Mixing of red, blue and green light, and occasionally amber, to create white light, sometimes with a tint toward blue or toward red i.e. warm white or cool white—known as "RGB" LED emitters.***
2) ***A blue emitter chip with a yellow phosphor coating in its light path-- The combination creates what is called "secondary emission" of white light. This is a process similar to that when a regular fluorescent tube generates UV light which reacts with an inside phosphor coating to create white light.***

It has long been known that mixing red, blue and green light can create white light. Sunlight, made up of all the colors of the rainbow, is the best example.

Figure 1 shows what happens on a surface when different colors of light are combined (All together they make white). Figure 2, in what is called the "subtractive process" is what we see on a surface by mixing colors of paint, crayons, etc (All together they make black). We will only concern ourselves with Figure 1.

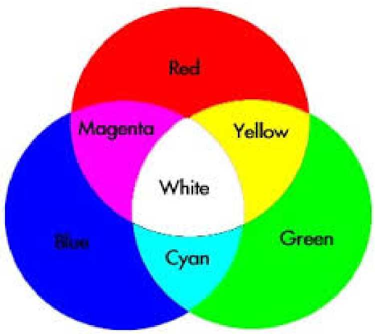


FIGURE 1

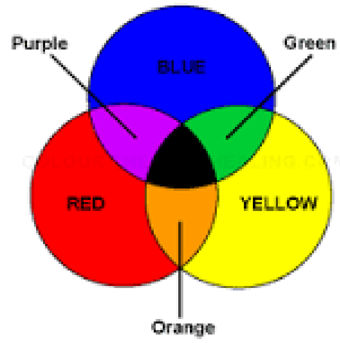


FIGURE 2

Only a few combinations are shown here but the variations are essentially infinite. Our eyes "mix" all those colors and give us a perception of white light and any combination of the individual rainbow colors.

Until about 2005, the spectral characteristics of blue-LED/yellow-phosphor types were so poor (generally "bluish") that RGB light sources were used only whenever incandescent equivalent light was needed in specialty markets. The RGB approach also facilitated the explosive growth in multicolored digital displays...even TV type displays... where it was possible to create an infinite number of color combinations, using standard digital circuits and pulse-width-modulation (PWM) to vary the amplitude of the individual chip colors.

Warm white, cool white...no problem. It meant that one could take that same methodology, perfected for displays, add very slight blue tint to the white light, shifting it higher in color temperature, making it more like the outdoor light might experience on a cloudy day. Similarly, one might add a reddish or yellowish tint so that the light is "warmer" and more like you would see at sunset on a clear day or what you would observe indoors with a room lighted by a regular incandescent lamp.

All this was just fine as long as white LEDs for general illumination had poor efficacy (i.e. less than 40-50 lumens per watt) high prices (over $1.00/watt) and a CRI (Color Rendering Index) less than 75. The CRI figure is a measure of how accurately a white LED replicates the "true" color of an object. For general task performance, CRI is of little importance. However, where color perception is important, such as in studio lighting (TV, motion pictures, photography) retail (fabrics, women's cosmetics) or museums (paintings, displays), a CRI over 90 is now considered a must.

While RGB lighting still dominates the display industry, phosphor-based white LED light is now dramatically more cost effective, has much higher lumens per watt, and is far simpler to use. A few things happened after about 2012 to move things along. Even CRI's over 90 are now available from a number of vendors, for CCTs from 2700K to 5600K, something just not possible a couple of years ago.

What all this means is that after 10-12 years of complaints that LED lighting could not faithfully replicate this or that color or this or that lighting condition, a properly selected LED product can now replicate virtually any incandescent or outdoor lighting condition.

These cost and performance advances have resulted in companies in all kinds of market areas introducing variable-CCT items —from novelty products for DIY consumers to serious high-end applications. Color temperature variability is now a serious marketing tool. In this context there are still impediments to more widespread use of such variable CCT.

A survey of variable- CCT offerings will invariably lead to two categories: a) novelty products and offerings which can be perceived as way overpriced unless one needs certain very specific "bells and whistles". The DB-100 is intended to faci8litate "more bang for the buck" performance and versatility found only in lighting products with double or triple the price.

The basics of CCT variability in phosphor-based white LEDs

All variable-CCT approaches using phosphor-based white LEDs start with the same idea. Two separate LED strings are used, one having high-CCT LEDs and the other, low-CCT LEDs.

Each string can consist of SMD or through-hole LEDs-- or can be a single or two-string COB type. For example, one string might be 2700K and the other 5600K. Typically, each string is driven from a separate dimmable, constant-current drive as in Figure 3.

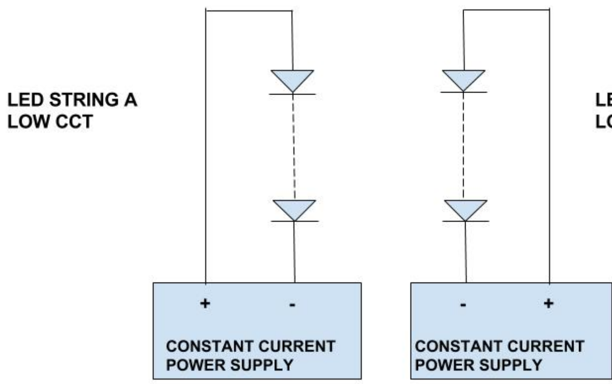


FIGURE 3

By dimming one or the other, we can change the relative proportion of "warm" light to that of the "cool" light. Consequently, we can vary the final color temperature of the light at the target surface, some distance away, from 2700K to 5600K—and even from below 2000K to 10,000K if we choose the right LEDs).

If we start out with one LED string of 2700K and the second string of 5700K, we can vary between the two limits. In whatever scheme is used, an objective is to have the total power to the pair of strings remain the same. This is to ensure so that the brightness remains "approximately" the same across the CCT range, unless we purposely dim the total output.

Note: The concept of LED color temperature variants is often discussed in relation to what is called a "Planckian locus" (also known as black-body locus). In simple terms this means that a piece of metal, like the filament in an incandescent lamp, when heated, will start to glow with a dim red and as it is heated more and more will smoothly transition from red , to reddish white, to white, to bluish white. Along the way, it will be emitting light wavelengths which replicates all the wavelength of sunlight. In other words, sunlight and incandescent lamps are the only sources of light which are said to be able to accurately reproduce all colors. All "electronic" sources of light do their best to equal them. These days, the difference can be inconsequential.

With relatively complex RGB LED systems, such complete wavelength "purity" can be maintained. However, CCT's with the phosphor based white LEDs used for most LED lighting today, will have some variations in

spectrum amplitude from warm white to cool white. That is, some wavelengths will be more dominant than others. Such absence of wavelength evenness, especially with LEDs having high CRI(Color Rendering Index) is generally imperceptible to the human eye and typically only detectable with scientific instruments.

The Internet, especially Wikipedia, describes some of these things in much more detail.

How The DB-100 works

With the tiny, plug-and-play DB-100 controller, a second LED driver (i.e. LED power supply) is unnecessary and no software or remote-wireless setup issues exist. The selective dimming of either of two strings is achieved with virtually any single standard driver. This is done by using a microprocessor to independently dim, via pulse-width modulation, each the two strings in a way which alters the relative average current in each string while yet maintaining constant total power and brightness.

Employing a microprocessor, the proprietary approach allows a very wide range of CCT control, while yet maintaining a high, constant-PWM frequency—above 2 KHz. This eliminates the undesired visual effects which can occur in video and motion picture lighting when a PWM frequency is too close to power-line frequency or frame rates.

Asides from the basic CCT variability, the DB-100 allows control with a simple integral potentiometer. Up to 100 watts can be controlled (LED string voltages to 50 volts and currents to 4 amps) with the power limit set by the chosen constant-current LED driver.

FIGURE 4

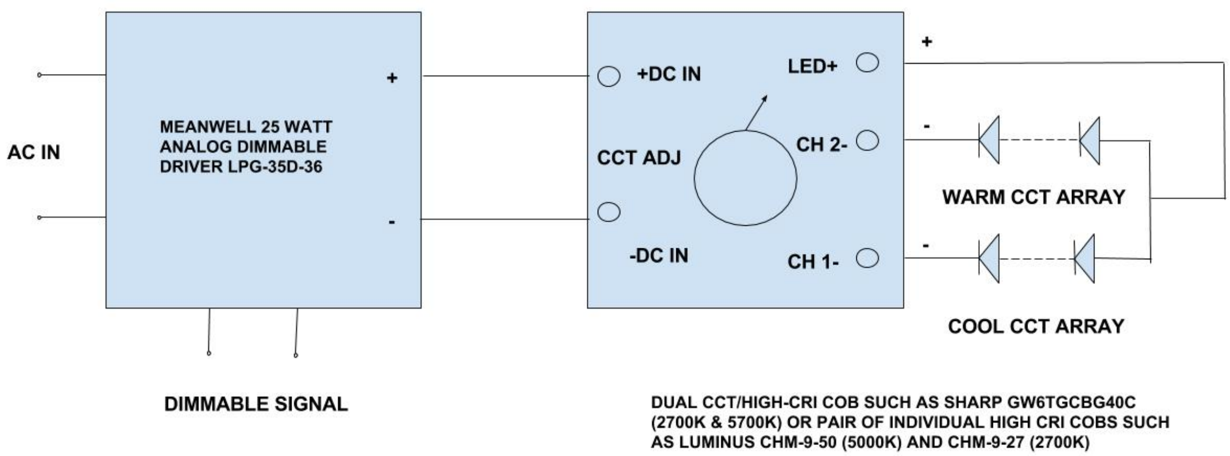


Figure 4 shows a block diagram of a typical configuration using an off-the-shelf driver (analog dimmable by either a 100K pot or 0-10V signal) and either of two attractive LED COB options.