High-end control using an easy to implement CCFL Inverter technology

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Abstract: *This paper will illustrate how CCFL backlights can be precisely controlled using an inverter technology than can accept a wide range of input control stimuli. Analog, Digital, Ambient Light, Luminance Feedback & Temperature are but a few of the control input methods that will be discussed.*

Introduction

When choosing a CCFL (Cold cathode fluorescent) inverter, the designer in most cases is concerned with selecting **an inverter** that will properly drive the LCD Panel/Backlight. Starting or Strike Voltage, Operating or Sustaining Voltage range and Output Current, along with the inverters input voltage range, comprise the main design parameter decisions. The inverter manufacturer generally dictates basic inverter control signals such as Enable and Intensity Level. Very little thought is given to any other control formats, and to be sure, many designs may not require design heroics when it comes to CCFL inverter control.

That being said, a growing number of new applications and/or requirements would benefit greatly from wider latitude of control methods. Many designers in even fairly mundane applications, are needing to pre-process generated analog levels to be compatible with video controller cards having an OSD (On screen display) of CCFL intensity levels. Simple push button control and serial control are methods that are native in the digital world. Most customer applications reside in the digital world but typically additional hardware is required to control the analog interface of most inverters.

Inverter behavior, as a result of ambient light levels or the luminance from the CCFL's themselves are also becoming desirous and in some applications required. Temperature also as an input that can be processed by the inverter has many benefits that can greatly improve the reliability and functionality of a system.

It will be shown how **an inverter** technology capable of processing one or more of the aforementioned input control stimuli, yields a simpler, higher performance and lower cost system.

Analog Control

In earlier times when giants walked the earth a simple knob controlling intensity of a device was all that was needed. It had several advantages including the fact that it returned to the last intensity setting upon power-up! Certainly basic knob based/potentiometer controlled intensity designs will remain and for some applications are the most ergonomic. Consider however, the desire for intensity control of the backlight via the OSD menu. The Wiz-Bang controller card company may output an intensity signal of 0V(off) to +5V(full intensity) while the Gee-Wiz controller card company uses, lets say +2.5V(off) and +0.5V(full intensity). Add to this the polarity of enable (active high vs. active low) and the inverter and/or controller card signals are incompatible. The designer is now faced with doing the necessary level/polarity conversions and is forced to add hardware on his application board or some form of interface board. Assuming the controller card is higher on the food chain than the inverter, another option is to find a different inverter that meets all of the primary CCFL drive parameters and hopefully is compatible with the controller card.

The best option however, is having **an inverter** that allows the designer to select the control levels/polarity as well as the CCFL drive parameters. Variation on this theme would be **an inverter** that allows you, via the use of a separate "mode control " pin, the ability to select from a number a various intensity control formats. Other modes that could be selected might include Linear vs. Logarithmic brightness response of the backlight as a function of intensity control changes.

For some applications, the easiest way to produce a varying dc level is to integrate a variable PWM signal via a simple RC filter. The PWM signal is commonly brought over from the applications micro. The voltage range possible in this case is dependent upon duty-cycle range and the voltage swing from high to low**. An inverter** that could accommodate variability of signal levels due to different processors, native operating voltage levels and voltage swing of the port pin would allow this simple interface to be most effective and economical.

Digital Control

Perhaps the simplest form of digital intensity control is the up/down push button. To incorporate push button control in an application and use most inverters available today, the designer must convert the simple push button signals to a varying analog level. One typical solution is to add a digital potentiometer IC that converts the pushbutton signals to changing analog levels. Here again, **an inverter** that comes equipped with up and down active low inputs would support direct connection to the buttons and eliminate any additional interface circuitry. Additional characteristics could also include a unique inverter response when both buttons are pressed simultaneously and/or predetermined intensity settings upon power-up.

The epitome of digital control would be **an inverter** that could respond to simple serial control. A single receive input that might operate at say 9600 Baud and accept a control and data byte would allow for maximum control of the inverter for just about any application. Standardized serial interfaces such as SPI or I^2C would provide additional reliability and familiarity for many designers. For most applications, the inverter needs only to operate in listen mode and respond to intensity control commands. In a more featured inverter design however, bi-directional communication capability would allow the inverter to respond back. Useful status information such as the health of the CCFL(s) along with the temperature of the inverter and/or backlight is but a few of the examples of what data the inverter could provide.

Ambient Light Control

One of the most useful intensity control mechanism for CCFL backlights is **an inverter** that responds appropriately to ambient light. In most cases, the designer wants the backlight to be dimmer when the ambient light is low and brighter when the ambient light is high. For many applications tube life can be extended and when properly adjusted, the display image can be noticeably enhanced. When implementing this approach, many subtleties can make or break its usefulness. Performance issues related to the following aspects should be considered:

- Speed of intensity change from dark to light or visa versa.
- Ambient light vs. backlight intensity response
- Minimum and/or maximum intensity levels
- Manual offset or override control
- Ambient light sensor signal conditioning
- Calibration

Different applications may require a unique response speed to changes in ambient light. In addition, some may dictate a different dark to light rate of change vs. light to dark. Instantaneous changes in backlight intensity as a result of drastic changes in ambient light may not be desirable. In some applications the backlight intensity may not want to be changed in proportion to the changes in ambient light. Also, most applications require a minimum intensity level during very dark ambient conditions.

Some applications benefit from the operator taking control and manually increasing or decreasing the backlight intensity. Very often a blend (offset) of what the ambient light sensor indicates and the operator's personal taste results in a very favorable solution.

Most applications require nothing more that a simple CDS (Cadmium Sulfide) cell for the sensing of ambient light. Most CDS cells are accurate enough in the visible spectrum of light and require minimal support circuitry. Alternatively, new low-cost visible spectrum photodiodes are now available in packages as small as 1206 SMD. The accuracy and stability of a photodiode, while superior to a CDS cell, requires an op-amp front-end to do the current to voltage conversion. Here again, **an inverter** is the logical place for all this to be supported.

Finally, the system should provide a simple means of calibration to allow for light sensor tolerance and the physical position of the light sensor relative to the ambient light it must receive. Some more demanding applications may even require a response to a particular color temperature where careful attention to the ambient light sensor chosen is needed.

All in all when properly implemented, an application that makes use of ambient light control can enhance the overall display performance. There are times when it should be given the same attention that the LCD display and video controller card might receive.

Here again, **an inverter**, where the user need only connect the light sensor to the inverter makes this feature practical, cost effective and more likely to be successfully implemented.

Luminance Feedback Control

This method does for backlight intensity, what cruise control does for the speed of a car. For a given set point, the inverter continuously drives the backlight to the required intensity under varying conditions. Effects such as age and temperature are the typical contributors to variations in CCFL intensity. Luminance feedback control can be used in conjunction with any of the other control methods including ambient light sensing.

A light sensor, often a photodiode responsive to white light is placed within the backlight. The feedback signal from the photo diode is then used by the inverter to maintain the desired intensity of the backlight. Proper use of this signal allows for the following:

- Precise control of display intensity, typically +/-3%
- Compensates for the change of intensity as the CCFL's warm-up
- Provides quick warm-up of CCFL's depending upon inverter overhead drive capability.
- Compensates for the falloff of intensity as the CCFL's age
- Can be used to detect failed CCFL(s) and end-of-life

- Can be used to balance a multi-display application

When attempting to implement luminance feedback with a standard inverter, the designer must now consider how these aspects might be addressed:

- Placement of the luminance sensor
- Light sensor signal conditioning
- Dynamic range capability of the light sensor system
- Loop response time and stability issues
- Calibration
- Inverter overhead drive capability

The placement of the light sensor can present problems for some standard displays. If an inspection/optical window is present on the back of the display, this becomes an ideal place to locate the sensor. For custom backlights, a place can be designed that ideally presents an average sampling of the light produced within. At times when properly located, especially when using edge-lit backlights, allows the ability to detect the contribution of just one tube in a six or less lamp system. This can provide an additional benefit such as an error signal being generated by the inverter to the host in the event of a tube failure.

Proper photodiode signal conditioning and dynamic range capability is more critical when implementing luminance feedback Vs ambient light sensing. If wide range dimming is employed, very low light levels will require amplification of the photodiode signal. Conversely during high levels of intensity the gain must be reduced. As with any system that is closed loop, system stability and response must be taken into account.

More than with the case of ambient light sensing, some method of calibration must be made available. The general method is to set the intensity control or set point to a given brightness setting. Then, while measuring the intensity of the backlight or panel face, adjust a trimpot on the inverter until the desired intensity is reached. Other approaches that eliminate the need for a trimpot can be implemented however the basic procedure is the same.

The final key element required when implementing luminance feedback is the inverter overhead available to drive the backlight. Simply put, this is the output drive capability of the inverter over and above what is required for 100% intensity under nominal conditions. A 2 to 1 ratio would mean that **an inverter** solution nominally running 5mA per tube with new CCFL's at full intensity and fully warmed up, has the ability to drive the CCFL's during unique periods, say when the tubes are cold, to 10mA.

Figure #1 shows the difference during warm-up of a given backlight with and without luminance feedback. The Constant Luminance curve was achieved with **an inverter** that had a 2 to 1 overhead ratio vs. the Normal curve. Both curves meet after 5 minutes.

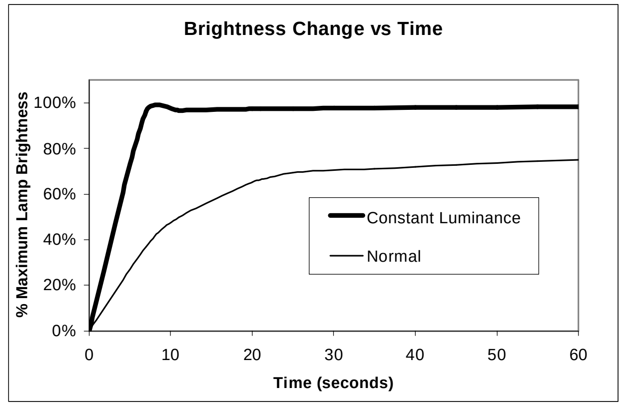

Figure 1. Comparison of CCFL intensity over time upon power-up. Normal & Constant Luminance modes.

The higher the ratio, the more horsepower is available so-to-speak, allowing the CCFL's to quickly get to the desired intensity and remain. Overhead ratios of even 1.25 to 1 provide enough useful punch for many applications. One must keep in mind that the application must be able to supply the additional amount of power that will be required by the CCFL's during periods of overdrive. Some designs have no overdrive capability at all. This is true because the application will be normally operated at less than 100% intensity where precise control of luminance is most important.

Whatever the case may be, proper execution of luminance feedback requires the designer be in control of many operational aspects. Once again, **an inverter** that has been designed to take into account the aspects mentioned, will allow the application to realize the full benefit of luminance feedback, without having the designer getting buried in all of the important subtleties.

Temperature Control

In many systems where multiple CCFL's are used, the backlight can produce a significant amount of heat. In sunlight readable systems, maximum brightness and direct sunlight are often mutually inclusive. To avoid over heating, a common method that does not involve active cooling is to simply throttle back the backlight. Many designers use one or two temperature sensors located within the application and desire gradual intensity action be taken to bring the system temperature back within acceptable limits.

On the opposite end of the temperature spectrum, cold temperature operation very often dictates not starting the CCFL's until they are artificially heated to a minimum acceptable level. In both of the cases illustrated, if **an inverter** was fed the temperature data from the sensor(s), the inverter itself could respond accordingly. Here again,

an inverter capable of accepting temperature inputs would simplify the designer's task.

Conclusion

Throughout this paper, continual reference has been made to **"an inverter"**. This in fact refers to an inverter technology that has already been developed and is in production at Applied Concepts Inc. By combining efficient transformer based converter design with a micro-controller based interface, all of the functionality described within this paper has been achieved on a variety of standard and custom inverter platforms. These integrated solutions have benefited our customers in the following ways:

- Quick time to market
- Simplification of customer circuitry
- Lower cost to implement and sustain
- Supports tailored solutions to customer specific requirements
- Application designer not defocused from his/her core competency
- Firmware control allows flexibility and supports empiricism for "tuning" of the application.

In conclusion when designing in your next inverter, consider the additional value and performance that an integrated inverter solution as described herein, can bring to your end application.