

# CCFL INVERTERS IN VEHICULAR ENVIRONMENTS

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## Abstract

*Various CCFL (Cold Cathode Fluorescent Lamp) inverter performance aspects will be addressed as they relate to the challenges of backlighting in a vehicular environment. These are to include wide range dimming and control techniques, simple ambient light sensing methods and thermal management of the CCFL's through the use of luminance feedback. Additionally, the electrical and thermally abusive environment encountered in these applications will be discussed as it relates to reliability and long term stability of the backlight system.*

## 1. Introduction

With the emergence of Flat Panel displays in vehicular applications, the performance of the CCFL backlight and inverter as a system becomes more critical. Many factors need to be considered in the development of a successful CCFL backlight product. Once the display is chosen, the designer will need to make intelligent decisions in two main areas:

1. Backlight architecture
2. Inverter features

## 2. Backlight Architecture

A limited discussion of the CCFL backlight architecture will be provided, since the primary focus of this paper is with regard to the inverter. It is important, however, to touch on some key factors that dictate the type of backlight required. These requirements will in turn drive the inverter requirements. Typical application specifications might include:

- Sunlight Readability

- Low light Readability
- Touchscreen
- Extreme hot and/or cold temperature operation
- CCFL Replacement/Serviceability
- High Shock & Vibration

While this list is by no means all-inclusive, these features will immediately begin to drive the backlight architecture in terms of the type and number of lamps, along with possible mounting and packaging techniques.

The type of LCD chosen may preclude certain backlight architectures. With some LCD types, edge lighting utilizing a light guide is the only option, while other displays may only support direct back-lighting methods. The key is to determine which approach will be the easiest to implement and provide the desired performance. There are advantages of each approach with regard to packaging and wiring, which affect manufacturability. Also, each approach has some unique electrical properties that can be exploited to improve dimming or temperature performance.

Other components found within the backlight assembly would include:

- “U”, “L”, or Straight CCFL's
- Active heaters for the CCFL's
- Passive/Active cooling for the CCFL's
- CCFL inter-connection schemes
- Brightness enhancement filters/films

As the designer begins to get a handle on the options available, the tradeoffs will begin to become clear. What may not be so clear is the contribution that key inverter features can make to extend and improve the backlight performance.

As previously mentioned, this paper will focus on the characteristics of the Inverter, and how it can enhance the viewability of the display, as well as contribute to the overall reliability of the backlight. Simply stated, the objective of the inverter is to drive the CCFL's over an intensity range consistent with the needs of the application.

### 3. Inverter Basics

The two most important parameters that the inverter must always satisfy when driving CCFL's are:

1. Starting Voltage
2. Nominal Lamp Current

As simple as the concepts of these two requirements are, they are the two parameters that continue to be overlooked far too often. The problem exists because there is a delayed time function associated with both. Inadequate starting voltage problems may not show up until the lamps become old and/or cold. One would think testing during the design phase should ferret out problems, but even the most conscientious designer cannot always anticipate the performance variations the CCFL's will exhibit over time.

It is true that most lamp manufacturers specify worst case starting voltage at end of life, but how accurate are these values? It is also important to realize that these values are specified at the lamp. Any distance between the inverter and the lamps will result in partial loss of starting voltage. Also, environmental conditions of high humidity will tend to rob the lamps of the full starting voltage developed at the inverter outputs.

The message is, don't skimp on starting voltage. Because generation of high voltage by the inverter is one of the most stressful elements to the inverter (short of heat), many designs try to minimize this risk by providing marginal starting voltage levels.

During development, testing for optimal starting voltage with various aged lamps under cold conditions while using the actual inverter is the best design practice to follow. After obtaining test data under these conditions, additional margin should also be considered.

Nominal lamp current level certainly goes to the heart of the life and reliability of the backlight. The most conservative approach is to design the inverter to provide nominal lamp currents that fall within the ranges recommended by the lamp manufacturer. Although an inverter can fail in some ways that might cause excessive lamp current, higher than nominal current levels is usually the result of a brightness goal that forced the designer to push lamp currents beyond the lamp manufacturer specifications. If the chosen inverter design creates a trade off between higher lamp current levels and decreased lamp life, the designer should be prepared to make provisions for practical field lamp replacement during the life of the product.

Caution is the operative word, since not all overdrive situations may simply result in dim lamps over a shorter period of time. Pink lamps, burned out lamps and cracked lamps can be the result when the envelope on higher lamp current levels is pushed. It is also important to note that some inverter designs will also fail as a direct result of lamp failure.

### 4. Vehicle Power

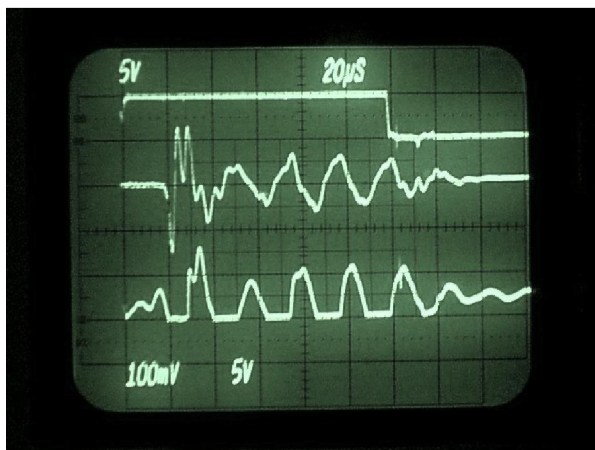
The automotive environment is not a nice clean and regulated +12V. Spikes and surges that can go as high as +80V coupled with normal operating voltage swings of +7V to +18V are typical. These instances or when a tow truck may jump start a vehicle with +24V (because of excessively long jumper cables), can terminate the life of a poorly designed inverter. Many inverter designs available, including those that promote their use in automotive applications, fall short in handling these vehicle power issues. The automotive industry is well aware of the electrical power environment in current generation vehicles, and over the years specifications have been developed that the designer should reference.

Often, traditional methods of noise suppression and filtering become impractical in large panel, high power sunlight readable designs. Inverter designs with a “front-end” topology that addresses these power issues can often be arrived at with much less expense and size. It has been this author’s experience that the circuitry and techniques necessary for support of desirable lamp control features also become the foundation for desirable protection features such as:

- Overvoltage protection
- Undervoltage protection
- Overheat protection
- Spike & surge protection

## 5. Dimming Range

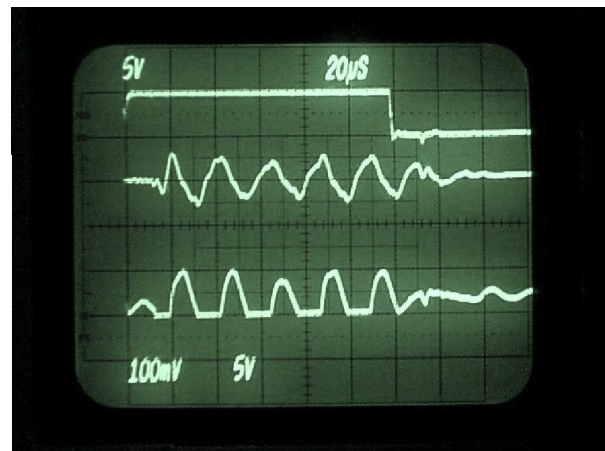
Wide range dimming is desirable when one considers bright, sunlit daytime viewing of the LCD versus low light or nighttime viewing. Since PWM dimming vs. amplitude dimming of the CCFL’s provides the best dynamic dimming range, this then becomes the method of choice. The basics of this method are simple but the proper execution relies on the careful consideration of the interaction between the CCFL backlight and inverter.



**Figure 2. Improper match of inverter to backlight – Low level dimming will not be dependable.**

A complete understanding of the backlight characteristics is imperative if consistent performance is hoped to be achieved. To the inexperienced, a system design goal may be considered achieved because it meets the required dimming performance at the development stage. Odds are, a troublesome product will result without a thorough understanding of the dynamics of the CCFL’s as they age, the potential variation of parasitics within the backlight assembly from lot to lot, and varying stability factors that may be inherent in the design of the inverter.

Figure 2 & Figure 3 demonstrate differences in the response of an improperly matched and a properly matched inverter to backlight. The top waveform is the “on-time” of the PWM cycle running at 98Hz. The second waveform is the lamp current, and the third waveform is one end of the transformer primary. The differences in the response of the two lamp currents would amount to a noticeable flicker at the lower intensity settings of the display in Figure 2, versus a stable, well controlled light output of the display in Figure 3.



**Figure 3. Correct match of inverter to backlight – Low level dimming will be stable.**

For more traditional applications that do not involve the rigors of a vehicular environment, these concerns may seem misplaced. Even experienced designers of CCFL backlit products may be lulled into a false sense of security because their experience has never revealed the need to contend with these seemingly arcane issues.

## 6. Temperature Management

Temperature management is crucial, not only in extending the life of the CCFL's, but also its influence on the performance of the system under adverse conditions. In an ideally designed backlight system, the "thermal mass" of the backlight assembly should be low. The goal is to control the temperature of the CCFL's as easily as possible. A combination of self-heating and artificial heating of the CCFL's during cold temperature operation should not have to fight a design laden with excessive heatsinking. Conversely, cooling of the CCFL's during high temperature extremes cannot occur effectively if proper attention is not paid to airflow and/or conductive cooling characteristics.

Utilizing an input from a temperature sensor, the CCFL's intensity and hence their temperature (and that of the LCD) can be controlled. In the simplest case, when sensing an overheat condition within the unit, the inverter can begin a controlled foldback on the power to the CCFL's.

Conversely, under cold temperature conditions, temperature sensing can also support the rapid warm-up of the CCFL's. When sensing a predetermined range of cold temperatures within the unit, the inverter can carefully over-drive the CCFL's and bring them up to temperature and hence intensity quicker.

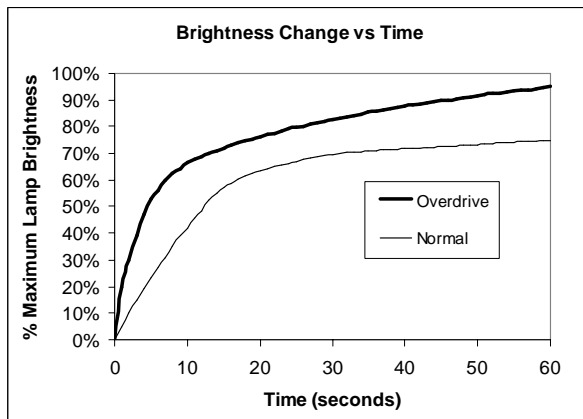


Figure 4. Comparison of CCFL intensity over time upon power-up. Normal & Overdrive modes.

Temperature and time provide a very useful and reliable determinant for the duration the inverter is in the over-drive mode. NOTE: Overdriving is not a substitute for supplemental heating to insure the lamps are at a minimum specified operating temperature.

## 7. Constant Luminance

Constant luminance or brightness regulation has several merits when applied in a vehicular environment. Variations in brightness intensity due to the effects of aging or temperature are dramatically reduced or eliminated by implementing this feature. Constant luminance control begins with sampling the backlight intensity via a light sensor, typically a photodiode. By properly applying this feedback signal, the inverter can vary the drive level to the CCFL's and thus hold the selected intensity level.

When utilizing the constant luminance method of lamp control, it is important to design the proper amount of "overhead" (the additional amount of CCFL drive capability vs. what is normally needed with new lamps). The inverter will utilize this overhead area in response to the CCFL's gradual aging, and the inverter will provide more output power to maintain the selected intensity point until a maximum is reached which corresponds to end of life. Additionally, when this maximum point is reached, an "end-of-life" signal could be provided.

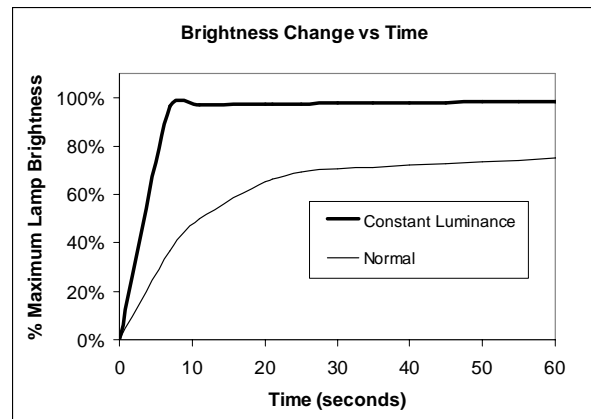


Figure 5. Comparison of CCFL intensity over time upon power-up. Normal & Constant Luminance modes.

From a cold-start point of view, constant luminance regulation inherently provides the quickest warm-up time function by applying full overhead power until lamp intensity reaches the desired setting. This method has the advantage of performing consistently under varying conditions of temperature and brightness settings.

## **8. Ambient Light Sensing**

Ambient light sensing is another method of control that automatically adjusts the intensity level of the CCFL's under varying ambient light conditions. This can be quite useful, since many users of display devices traditionally do not use the optimal brightness setting under all situations. This feature has the added benefit of extending the life of the CCFL's simply by reducing their intensity during lower ambient light level conditions.

Concerns that a totally automatic intensity control may not be optimum under all situations can be alleviated by providing a blend of ambient light sense control with manual override control. Response time of the resulting backlight intensity to changing light conditions can also be factored into the design, and would be dependent upon the application.

## **9. Shock, Vibration, Heat & Cold**

Shock, vibration, heat & cold are the environmental realities the inverter and backlight system will encounter in vehicular applications. Unfortunately, many designs do not take this into account seriously enough.

Components with high mass need to be secured satisfactorily to prevent lead fatigue and breakage over time.

Input and output connectors need to be carefully chosen, not only for their current carrying or voltage sustaining capability, but also for their ability to provide a reliable connection over time. In addition, temperature and humidity variations that can occur in a vehicle will lead to a faulty connection if the proper connectors and pin metallurgy are not chosen. Due to the constant current output nature of most CCFL inverters, a faulty connection that develops at the output will

ultimately lead to arcing and heat, ending in destruction of the connector.

Another area that is often overlooked is contamination of the high voltage areas by dust or dirt. Potentially high airborne pollution applications such as construction equipment, farm equipment or forklift trucks, to name a few, are susceptible to contamination. Coupled with high humidity environments, a conductive surface film can develop, again leading to arcing problems and failure. A favored design choice would be a totally enclosed system, provided that thermal management issues can be met via conductive cooling techniques.

## **10. Conclusions**

While vehicular display system designers face many challenges, there are practical, cost effective solutions available to meet these challenges. The inverter features previously discussed may appear to some to be unjustifiably expensive or impractical, but this author's experience has found quite the opposite to be true.

The value placed on a properly designed inverter will only serve to enhance the performance of the flat panel display. It should not be surprising that the engineering effort spent selecting the inverter solution can be greater than that selecting the display itself.

To designers of vehicular display products focusing on the more weighty development issues relating to the core application, the inverter may be seen as low on the food chain of components within the system. The inverter is, however, a key staple to the overall health of the backlight and therefore the flat panel display's performance.