LED Replacements for Fluorescent Tubes

Since high brightness LED technology has reached efficiency levels comparable with those of fluorescent lamps, many retrofit products have appeared on the market designed to replace the popular 4 foot fluorescent tube. Due to the directional nature of LEDs a 32W T8 replacement product can produce a similar light intensity measured at floor level consuming less than 20W thereby offering significant energy savings over fluorescent. **Peter B. Green, LED Group Manager, International Rectifier, El Segundo, USA**

Fluorescent tubes have been and continue to be used in vast numbers worldwide. These offer much greater efficiency in terms of lumens (light output) per watt (electrical power) than incandescent light bulbs. The most widely used linear fluorescent tube is the 4 foot long 32W T8 tube. These are used in offices, hospitals, schools and homes in light fixtures often containing two or more tubes. In the past electro-mechanical starters and iron cored magnetic ballast inductors have been used as an inexpensive means of ignition and current limitation enabling several years of tube life. More recently high frequency electronic ballasts have been introduced that offer increased efficiency, extended lamp life and improved line power factor and harmonics.

Magnetic ballasts used with fluorescent lamps will be phased out by government legislation in many countries over the next few years. This will force the market to use more the expensive electronic ballasts where the payback will be in reduced replacement costs as well as lower emissions and less waste. Used fluorescent tubes, many of which contain toxic mercury are generally dumped in landfills contributing to long term environmental damage.

Alternatives to fluorescent lamps

Although there are several different approaches to the design of LED replacement tubes, these all currently cost more than a fluorescent alternative even when the fluorescent lamp is combined with an electronic ballast. This is due to the much higher cost of LEDs, which is expected to reduce significantly in the coming years.

The market for LED light sources in general lighting is still at an early stage and it is expected be several years before use of fluorescent tubes declines significantly. LED tube replacement sales are still modest, being sold only to early adopters at this time.

The different approaches used in LED tube design can be broken down into two main categories; those with external drivers and those with internal drivers. The external driver approach is based on the fluorescent concept where a single external LED driver runs one or more LED tubes which contain a string or array of LEDs with little or no additional electronics. This approach makes a lot of sense in terms or optimizing performance and minimizing costs however it seems the market may be going more towards the internal driver approach. The reason for this is most likely because it makes retrofitting of existing fluorescent fixtures more straightforward. The contractor simply needs to remove existing fluorescent control gear and wire the lamp end caps directly to the AC line rather than having to mount and wire up a new LED driver module as well. Figure 1 shows a fluorescent fixture fitted with LED tubes.

The internal driver approach however requires that all the electronics be housed within the confines of the LED tube, which creates many restrictions on components sizes and form factors, particularly for inductors. It is also more difficult to incorporate smart features such as 0-10V or DALI controlled dimming as used in architectural lighting control systems. Many of these products are non-dimmable or rely on inefficient triac based phase cut dimming approaches not normally preferred for office lighting.

External LED driver

Going back briefly to describe the external driver type system, the LED driver can comfortably include any dimming and smart features required. These might include fault protection, power factor and THD optimization and even lamp life monitoring.

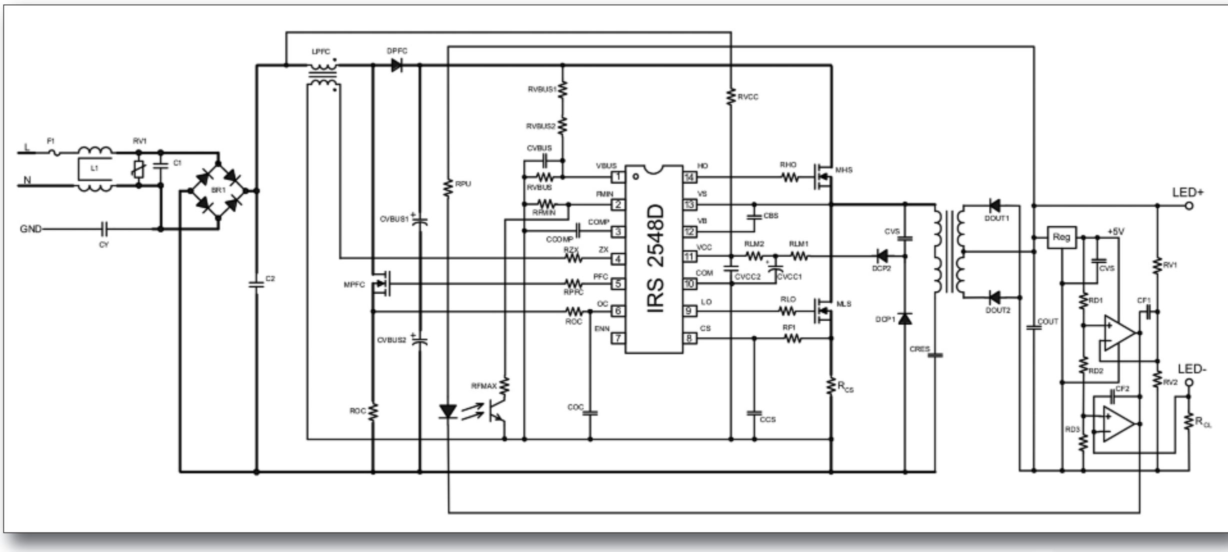
An external LED driver could consist of a single stage Flyback converter delivering a regulated output current to one or more lamps. Such a driver can operate over a wide line voltage input range while providing a high power factor and low THD. Multi stage designs consisting of a PFC boost front end followed by an isolated back end regulating stage offer even better efficiency and controllability. The back end stage could be a Flyback or resonant converter if galvanic isolation is required. In non-isolated systems a Buck regulator could be used provided some form of safety interlock is built into the light fixture to avoid potential electric shock. Figure 2 shows a multi stage LED driver example schematic.

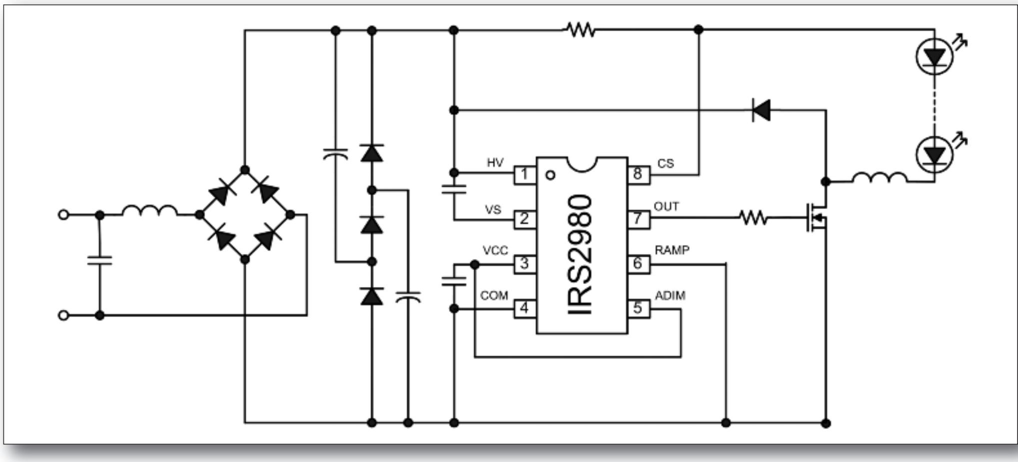
Since there is less restriction on size and form factor combined with the fact that better efficiency and heat transfer from the circuitry is possible, the external LED driver approach should offer better reliability.

Internal LED driver

Out of the several products on the market taken apart and examined several cheaper products contained nothing more that low current standard white LEDs with a very simple current limiting circuit containing a

Figure 1: A fluorescent fixture fitted with LED tubes





ABOVE Figure 2: Multi stage LED driver example schematic

LEFT Figure 3: Buck circuit with passive valley fill

bridge rectifier, a resistor, and a few capacitors. This type of product though cheap does not offer high efficiency, has a low power factor and high harmonics. The low power LEDs used are better suited for indication rather than illumination and in any case are being driven with high peak currents, all of which is likely to contribute to reduced operating life.

Of the tubes containing an active power converter, most are based on a simple Buck regulator using a passive "valley fill" PFC correction circuit. This would seem to be an adequate low cost approach to making a non-dimmable tube replacement. Power factor of 0.9 can be accomplished with line current THD at around 50%. This would meet US Department of Energy (DOE) Energy Star requirements for commercial lighting. Products using this type of system often use peak current regulation, which is sufficient to compensate against variations in LED output voltage but may not be adequate in providing current control over a wide AC line input range. For this reason some LED tube replacements may be limited to 100-120VAC line operation or 220 to 240VAC line operation.

Hysteretic average current regulation is used in the latest generation of Buck LED controller ICs such as the recently launched IRS2980. This method is able to provide tight current control over a wide input range. Figure 3 shows a Buck circuit with passive valley fill.

Some products however, have gone beyond the Buck approach to use a single stage Flyback converter operating from an unsmoothed DC bus. This method requires more components in order to provide a higher power factor and lower THD. It seems that the market may be being driven by the introduction of new performance standards for LED lighting that mandate very high performance levels going beyond the requirements imposed on electronic ballasts used in fluorescent and other forms of lighting. Introduction of such strict standards with its added cost penalty is likely to slow down the adoption of LED lighting while fluorescent alternatives are available. Figure 4 shows a Flyback LED driver schematic.

Most of the products tested were not dimmable. Since triac based phase cut dimmers do not work with fluorescent tubes this form of dimming should not be necessary in LED tube replacements, however 0-10V dimming is widely used with electronic ballasts which so far has only been seen in external driver systems.

To further optimize energy usage it is also desirable to incorporate 0-10V or DALI dimming in the driver electronics. It would be more practical to incorporate this into an external driver system but internal driver systems offer easier retrofitting in non-dimming applications therefore both types are likely to continue being produced.

Retrofitting of existing fluorescent light fixtures with LED tubes makes a lot of environmental sense and since the number of fixtures already in existence runs into hundreds of millions the potential market for LED tube replacements is enormous.

Successful adoption on a large scale will depend on the future availability of very low cost high brightness LEDs in conjunction with low cost driver electronics. The LED driver whether housed within the tube or externally will need to provide the best possible efficiency and conform to reasonable standards for power factor and harmonics. Many LED drivers currently being sold are based on existing power supply and PFC control ICs. It is expected that the next generation of drivers will incorporate controllers designed specifically for the LED application with optimized functionality designed to conform to standards while at the same time keeping cost and component count to a minimum.

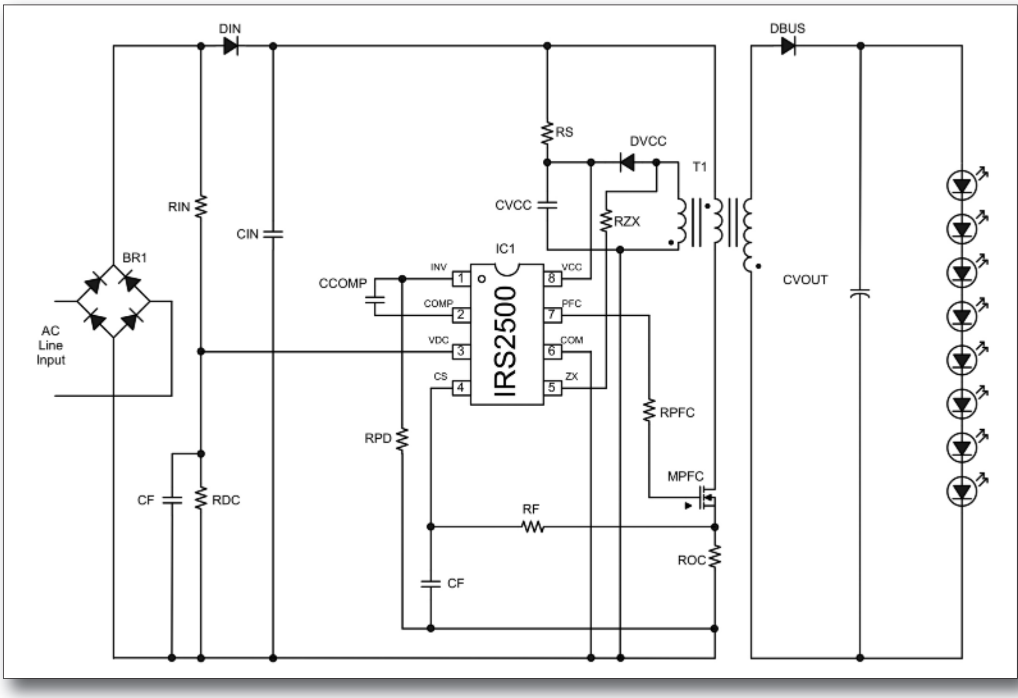


Figure 4: Flyback LED driver schematic

Conclusion

In conclusion the adoption of LED tube replacements saves energy and produces less waste, however the initial investment is high and the payback period can be up to 20 years. As LED technology continues to improve and mass production brings down the costs, the use of LEDs in general lighting applications will ramp up. This would be greatly aided by raising consciousness to the environmental impact from incandescent and fluorescent light sources. At this time the majority of consumers prefer to ignore environmental considerations in favor of reducing initial outlays as much as possible. There is also considerable political opposition to the introduction of new laws that outlaw inefficient light sources, largely supported by the fossil fuel lobby.